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7–11 December 2015

Reykjavik, Iceland

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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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Executive summary

The third meeting of Working Group on Integrated Ecosystem Assessments for the Norwegian Sea (WGINOR) was held in Reykjavik, Iceland, 7–11 December 2015 and was chaired by Geir Huse (Norway) and Guðmundur J. Óskarsson (Iceland). The total number of participants was 15, representing Norway (8), Iceland (5) the Faroese (1), and Greenland (1). The objective of the meeting was to develop further and finalize the work developed over the initial two meetings and represented by the ToRs.

For the initial integrated assessment of Norwegian Sea (ToR a) it was decided to use a fairly straightforward three step operational approach consisting of: 1. Data assembly, 2. Data analysis, 3. Interpretation. Hence, relevant time-series of ecological, environmental, biological and fishery related variables were compiled, described and analysed (ToR b). The temperature of the Norwegian Sea is currently slightly above the normal and has had a downward trend in recent years after a peak in 2007. The biomass of mesozooplankton had a downward trend during 2003–2009, followed by an increasing trend in the subsequent period. In 2015, there was a reduction in the zooplankton level compared to 2014. The length-at-age of herring has been increasing in the last years and is negatively related to stock density. For mackerel on the other hand, there was a strong decreasing trend in length-at-age since 2007, in coherence with a strong density-dependent growth in the stock. A multivariate analysis was performed on all the time-series collected during the recent three years. The principal component analysis shows a shift in the first principal component from high values before 1995 and a sharp decline until 2010. The causes for these changes are not fully understood, but they are related to changes in the overall circulation. The work in WGINOR indicates that the Norwegian Sea ecosystem alternates between bottom up and top down forcing. Number of relevant publications in this field, both by WGINOR members and others, have appeared during the last three years and are addressed in the WGINOR report adequately.

Around fivefold increase in beaked redfish biomass in Norwegian Sea has taken place in the last 20 years. The breeding populations of kittiwake, Atlantic puffin, and guillemot in seabird colonies along the Norwegian coast has declined since monitoring started in 1980, while the causes are not completely known. The potentially large biomass of mesopelagic fauna (fish, cephalopods, shrimps, and jellyfish) remains unassessed. Regarding the status of marine mammals, the abundance of hooded seals in the Greenland Sea area, which feed to some extent in the Norwegian Sea, has been at low level following a major decline until 1980s. Similar, abundance of large baleen whales has not recovered to the pre-commercial whaling period, even if recent surveys suggest changes in either abundance or distribution.

Multispecies model (Enac-model) using a Management Strategy Evaluation (MSE) approach was used to study potential multispecies management of the three dominant pelagic fish stocks in the Norwegian Sea (ToR c). The main conclusions were that density-dependent growth can increase the simulated Spawning-Stock Biomass (SSB) and the Total Allowable Catch (TAC), and the results should be considered in relation to potential multispecies management of the stocks. Also, the observed intraguild predation among the stocks needs to be considered because following precautionary approach for one stock can have negative effects on other stocks.

As a part of estimating absolute abundance of zooplankton and pelagic fish (ToR d), the highly relevant time-series of mesozooplankton abundance indices in Norwegian Sea and adjoining waters for the period 1995–2015 were reconstructed. Absolute es-

timation of pelagic fish and macrozooplankton requires more attention in the coming years.

Over these three years various gaps in sampling requirements for integrated assessment have been recognized and listed (ToR e). While some of them have been addressed others still applies.

Finally, an initial draft of Ecosystem Overview for the Norwegian Sea was prepared by following the Workshop on Ecosystem Overviews (WKECOVER) criterion (ToR f). It can be found separately in Appendix 5 of this report.

1 Administrative details

Working Group name
Working group on integrated assessment of the Norwegian Sea (WGINOR)

Year of Appointment
2012

Reporting year within current cycle (1, 2 or 3)
3

Chairs
Guðmundur J. Óskarsson, Iceland
Geir Huse, Norway

Meeting venue
Marine Research Institute, Reykjavik, Iceland

Meeting dates

7–11 December 2015

2 Summary of work plan

Year 1	Focus will be on forming the group and start to work on developing an approach to integrated assessment for the Norwegian Sea based on reviewing the work of other groups and literature studies. Further work will be undertaken to perfom an integrated assessment for the Norwegian Sea and to perform simulations based on the current status of the ecosystem. Work on absolute estimates for the key ecosystem components will be develop based on tagging data and catch based summer surveys. Prepare intial draft of the Ecosystem Overview for the Norwegian Sea.
Year 2	The integrated approach will be developed further and the integrated assessment will be updated. Aleternative multispecies advice will be developed for the Norwegian Spring-spawning herring, mackerel and blue whiting based on the multispecies model and presented in report. Work on absolute estimates for the key ecosystem components will be continued. Initiation of work on developing sampling requirements.
Year 3	The integrated assessment will be updated with the available information and along with updated simulations. Work on absolute estimates for the key ecosystem components and sampling requirements will be reported.

3 Opening of the meeting and adoption of the agenda

The meeting started with a welcome by Gudmundur J. Oskarsson (GJÓ) who gave an overview of the agenda and provided an overview of housekeeping for the meeting. The rest of Day 1 was focused on presentations on survey information and specific studies relevant to WGINOR. Presentations were continued on Day 2 followed by a distribution of the work among the working group participants. The rest of the meeting included working in groups and with occasional plenary presentations and discussions. The agenda is provided in Annex 1.

4 Description of terms of reference a–f

ToR	Description
a	Develop an operational approach to integrated assessment of the Norwegian Sea
b	Perform up to date integrated assessment for the Norwegian Sea ecosystem
c	Utilize multispecies and ecosystem models to investigate effects of single and multispecies harvest control rules on fishing yield and ecosystem state for the purpose of developing ecosystem based advice
d	Develop absolute abundance estimates of zooplankton and pelagic fish
e	Develop sampling requirements for integrated assessment of the Norwegian Sea
f	Consider the WKECOVER report (ICES 2013d) and draft sections 1, 2, and 3 of an initial Ecosystem Overview for the Norwegian Sea.

A more detailed description of the ToRs is as follows:

Term of Reference a)

There are a range of different approaches to performing integrated ecosystem assessments. We will develop an approach for the WGINOR that is based on the state-of-the-art. This will be done with input from the other regaional seas and based on the developments at the Workshop on Benchmarking Integrated Ecosystem Assessments (WKBEMIA) in November 2012.

Term of Reference b)

There have been international fish-plankton centred surveys in the Norwegian Sea in May and since the mid 1990s. In the most recent years these surveys have transitioned into ecosystem surveys that caputure most of the key components of the ecosystem. These datasets are a firm foundation for undertaking integrated assessment of ecosystem status in the Norwegaian Sea which is yet to be done. A fairly recent book on the Norwegian Sea ecosystem is a good starting point for the assessment.

Term of Reference c)

At present a multispecies fisheries model and an end to end ecosystem model are being set up for the Norwegian Sea. These models are ideal for investigating the effects of existing single species and alternative multispecies harvest control rules on the ecosystem structure and functioning. Although there is some petroleum exploration in the outskirts of the Norwegian Sea, fishing by far represents the most important antropognic impact on this ecosystem. The model analyses will be an integrated part of the assessment.

Term of Reference d)

In traditional single-stock assessment it is not required to have an absolute abundance estimate. However, when addressing multispecies interactions and carrying capacities of different trophic levels in ecosystems it becomes important to establish absolute abundance levels for the different components in order to quantify the combined effect of consumption and flows between the different trophic levels. WGINOR will therefore put an effort on providing estimates for absolute abundace of the key components in the Norwegian Sea ecosystem. This work will be based on tagging data and catch based summer surveys.

Term of Reference e)

The survey and sampling strategy should be closely related to the integrated assessment. ToR e) will be devoted to developing an overview of sampling requirements for integrated ecosystem assessment. This list will be developed in dialogue with the Working Group of International Pelagic Surveys (WGIPS) and the final spesification will be reported to this group, which has competance on survey sampling strategy.

Term of Reference f)

The ecosystem overview is required by ACOM to help provide ecosystem input to the assessment working groups, it will also be used to head up the advice.

Sections 1, 2, and 3 of the WKECOVER overview template relate to:

1) the description of the management area (mostly a map and very little text, we create the map in the ICES secretariat);
2) the key main drivers that impact advice in the ecosystem;
3) the activities and pressures in the region.

5 Operationalizing integrated assessment of the Norwegian Sea (Tor a)

In relation to ToR a) on development of an operational approach to integrated assessment of the Norwegian Sea, the group had some discussion at the 2013 meeting of which approaches to choose for doing the integrated assessment of the Norwegian Sea. The different approaches in the other ICES regional seas groups were reviewed as well as the recommendations from WKBEMIA. It was decided to initially use a fairly straightforward three step approach consisting of: 1. Data assembly, 2. Data analysis, 3. Interpretation. More detailed consideration of the different approaches available will be done in the coming years. IEA is an important step in ecosystem approach, but there are several other steps as well as outlined in Figure 5.1. This cycle contains many of the same elements as the socalled Levin cycle (Levin *et al.,* 2009), that NOAA uses in the US. However, it is simpler schematically and more in line with the way that stock assessments are applied in the management cycle of harvested stocks. In the first year the focus was on getting an overview on which data are available on the different ecosystem components and presenting the status. In the following two next meetings we will put more emphasis on developing the integrated assessment approach and perform multivariate analyses.

Regarding the objectives for the ecosystem, it was agreed to adopt high level statements for the overall objetive for the Norwegian Sea ecosystem. In addition it was agreed to only take into account specific objectives for the ecosystem elements strongly affected by human impact and thus, where management of human action could be expected to have a direct impact on ecosystem components. For the Norwegian Sea, fisheries are the main pressure therefore only objectives for the harvested fish stocks were considered. These were the standard F_{MSY} objectives used by ICES for the respective stocks. Also alternative ecosystem based harvest strategies and objectives were investigated under ToR c), "Objectives from the Norwegian management plan".

Objectives for the protection and sustainable use of the Norwegian Sea in the Norwegian ecosystem-based management plan (Ottersen *et al.,* 2011) for the Norwegian Sea are multiple. Here are only the goals for management of biological, geological, and landscape diversity (Box 1). A problem in the follow up work of the management plan is to get data that can be used to evaluate whether these goals are met or not. A set of indicators has been established, but they do not provide the necessary information. It should be evaluated whether an integrated assessment can provide useful information for the management plan. Integrated Assessment (IA) may be particularly useful for some of the goals in the Norwegian management. In future we will also investigate the suitability of additional objectives for example related to zooplankton abundance or fish length-at-age, which can be related to the high level goals given in the management plan (Box 1).

Box 1. *From Norwegian ecosystem-based management plan for the Norwegian Sea - the goals for management of biological, geological and landscape diversity.*

Overall goal

Management of the Norwegian Sea will ensure that diversity at ecosystem, habitat, species, and genetic levels, and the productivity of the ecosystem are maintained. Human activity in the area will not damage the structure, functioning or productivity of ecosystems.

Subgoal for particularly valuable and vulnerable areas and habitat types

- Activities in particularly valuable and vulnerable areas will be conducted in such a way that the ecological functioning and biodiversity of such areas are not threatened.
- Damage to marine habitats that are considered to be endangered or vulnerable will be avoided.
- In marine habitats that are particularly important for the structure, functioning and productivity of ecosystems, activities will be conducted in such a way that all ecological functions are maintained.

Subgoal for species management

- Naturally occurring species will exist in viable populations and genetic diversity will be maintained.
- Management of living marine resources will be based on the principles of sustainable harvesting.
- Species that are essential to the structure, functioning and productivity of ecosystems will be managed in such a way that they are able to maintain their role as key species in the ecosystem concerned.
- Populations of endangered and vulnerable species and species for which Norway has a special responsibility will be maintained or restored to viable levels. Unintentional negative pressures on such species as a result of activity in the Norwegian Sea will be avoided.
- The introduction of alien species through human activity will be avoided.

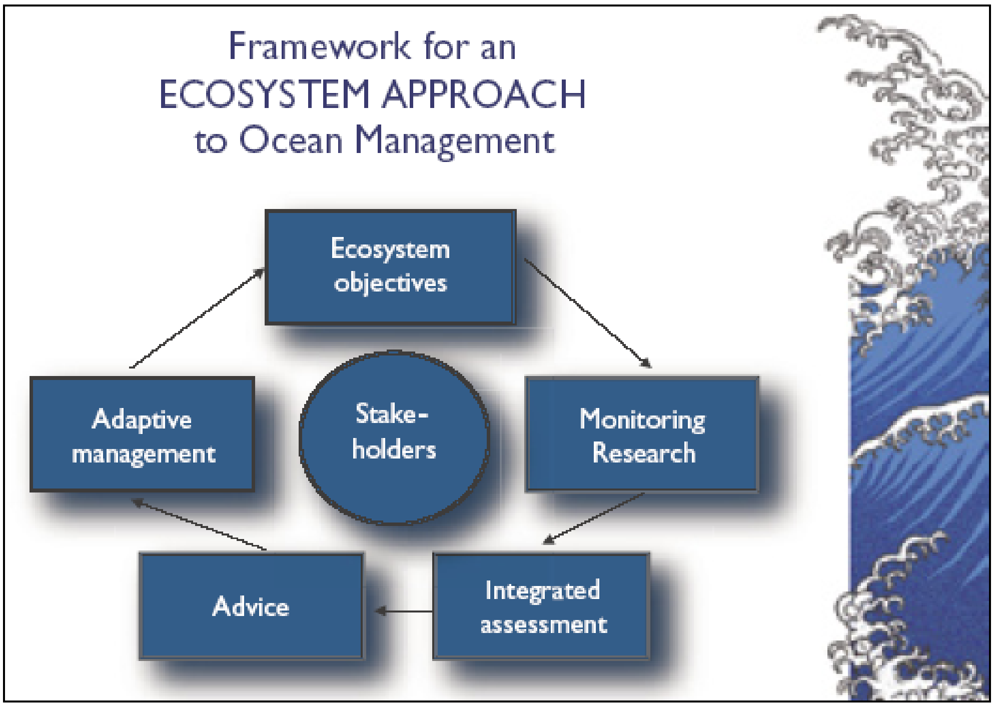


Figure 5.1. Steps in an ecosystem approach to ocean management (Anon., 2002).

6 An updated integrated assessment of the Norwegian Sea ecosystem (Tor b)

The approach taken in ToR b) on performing an up to date integrated assessment for the Norwegian Sea ecosystem was to go through the data for the different ecosystem components in the Norwegian Sea and assemble the most relevant dataseries available (Annex 3). This was done in a standardized way with an initial description of the ecosystem components, a description of the dataseries used, and brief justification for it, presentation of the data and the summary of present state and recent trends. A similar procedure was used for the pressure data. This treatment of the data was followed by some preliminary analyses and discussion of overall ecosystem status. Time did not allow for many analyses so this will have to be elaborated upon next year.

6.1 Climate and hydrography

The Norwegian Sea, the Greenland Sea, and the Iceland Sea comprise the Nordic Seas, which are separated from the rest of the North Atlantic by the Greenland–Scotland Ridge (Figure 6.1.1). The Norwegian Sea consists of two deep basins, the Norwegian Basin and the Lofoten Basin, and is separated from the Greenland Sea to the north by the Mohn Ridge. To the west, the basin slope forms the transition to the somewhat shallower Iceland Sea. The upper ocean of the Nordic Seas consists of warm and saline Atlantic water to the east, and cold and fresh Polar water from the Arctic to the west.

The Norwegian and Barents seas are transition zones for warm and saline waters on their way from the Atlantic to the Arctic Ocean. The Norwegian Atlantic Current (NwAC), the poleward extension of the Gulf Stream and the North Atlantic Current, acts as a conduit for warm and saline Atlantic Water from the North Atlantic to the Barents Sea and Arctic Ocean (Polyakov *et al.*, 2005). As Figure 6.1.1 shows, the North Atlantic Current splits into two branches in the eastern North Atlantic before entering the Norwegian Sea over the Iceland–Faeroe Ridge close to the east coast of Iceland, and through the Faeroe–Shetland Channel close to Shetland (Orvik and Niiler, 2002). The water then continues in two branches through the entire Norwegian Sea toward the Arctic Ocean (Orvik and Niiler, 2002). The western branch is a jet associated with the Arctic Front. It tends to feed the interior of the Norwegian Sea via several recirculation branches. The eastern branch, known as the Norwegian Atlantic Slope Current (NwASC), is an approximately 3500 km long, nearly barotropic shelf edge current flowing along the Norwegian shelf break, that tends to flow into the Barents Sea and Arctic Ocean. The NwASC is thus the major link between the North Atlantic, and the Barents Sea and Arctic Ocean.

The large-scale atmospheric circulation variations influence the currents and hydrographic conditions. Since the 1960s, changes in the large-scale wind pattern, principally the North Atlantic Oscillation (NAO), have resulted in a gradual change of the water mass distribution in the Nordic Seas. In particular, this is manifested by the development of a layer of Arctic intermediate waters, deriving from the Greenland and Iceland Seas, and spreading over the entire Norwegian Sea (Blindheim *et al.*, 2000). In the Norwegian Basin, it has resulted in an eastward shift of the Arctic front and, accordingly, an upper layer cooling in wide areas due to increased Arctic influence. Blindheim *et al.* (2000) also found that the westward extent of Atlantic water in the Norwegian Sea was less during the high phase of the North Atlantic Oscillation than during the low phase, with the difference between its broadest recorded extent in 1968 and its narrowest extent in 1993 exceeding 300 km. This implies that a stronger cyclonic atmospheric circulation pattern would move the surface waters to the east. This would decrease the area of Atlantic water and thus reduce ocean-to-air heat loss.

Dataseries

The selected indices chosen to resolve key aspects of the ocean variability of the Norwegian Sea are presented in Table A.1 in Annex 3.

The **North Atlantic Oscillation Winter Index** (Hurrell, 1995) to a large degree capture the strength of the westerlies in the Norwegian Sea. A positive NAO give a stronger Slope Current (Skagseth *et al.*, 2004), and an eastward contraction of the Atlantic Water extent (Blindheim *et al.*, 2000; Mork and Blindheim, 2000). Here the winter NAO index is used, i.e. the mean over the months December–March. The series span the period from 1864–2015.

Index from: *http://climatedataguide.ucar.edu/guidance/hurrell-north-atlantic-oscillation-nao-index-station-based*

The Sup-polar gyre index: Represents strength of the cyclonic circulation in the western North Atlantic. A weak gyre (positive gyre index) means a weaker and warmer gyre, and associated warmer and more saline Atlantic Water inflow to the Norwegian Sea (e.g. Hátún *et al.*, 2005). The Subpolar gyre SPG-index is taken as the leading EOF mode of annually low-pass filtered sea surface height data over the area lat: [45-64] deg N and lon [-56, 0] deg East. Data: Satellite sea surface height data updated at delay of less than one month. The series span annual values from 1993–2015.

Data from: *aviso.oceanobs.com*

East Greenland Current pressure differences: Atmospheric pressure differences along the East Greenland Current, representing the northerly wind, are found of main importance for the relative importance of Arctic Water in the Norwegian Sea (Blindheim *et al.*, 2000). Estimated using the NCEP/NCAR monthly gridded MSLP data. 1948–2015.

The mean sea level pressure differences are taken at:

1) Agmamaslik (65N, 37.4W) - Stykisholmur (65N,22.5W)
2) Scoresbysund (70N, 22W) - Jan Mayen (70N, 10W)
3) Danmarkshavn (77N, 20W) - Spitsbergen (78N, 15E)

Data from: *http://www.esrl.noaa.gov/psd/data/gridded/data.ncep.reanalysis.html*

The windstress curl in the Norwegian – Lofoten Basin: The area integrated windstress curl over the 2000 m depth contour defining these basins are the key forcing spinning up the cyclonic gyre circulation (Mork and Skagseth, 2005) with a clear winter amplification. The estimates are based on the NCEP/NCAR 6-hourly gridded windstress data taking the mean over the period December to March. 1948–2015.

Data from: *http://www.esrl.noaa.gov/psd/data/gridded/data.ncep.reanalysis.html*

Hydrography in Svinøy section: The property of the Atlantic Water that enters the Norwegian Sea is captured in the Svinøy section occupied about 4–6 times per year.

From these data we define indices for core temperature and salinity, and area of Atlantic water defined as S > 35 (Mork and Blindheim, 2000).

Index from: *www.imr.no*

Hydrography in the Langanes East section: The Arctic water in the East Icelandic Current east of Iceland is captured in the Langanes East section. Here we provide the mean over the upper 0–100 m from hydrographic stations 5 and 6. Period from 1950 to 2015.

Index from: *www.hafro.is/Sjora/*

East Icelandic Current index: The strength of the East Icelandic Current into the Southern Norwegian Sea is represented by the area in the southern Norwegian Sea occupied with water with S < 34.9 in the depth range 150–300 m based on the gridded annual hydrographic data during spring since from 1995 to present.

Data source: Hydrographic data from the PGNAPES cruises, ARGO and other data.

Relative heat content: The variability of the heat content in the Atlantic layer, above the sigma-t 27.9 kg/m^3, of the Norwegian and Lofoten Basins. All available hydrographic data during spring, 15 April–15 June, are used (Skagseth and Mork, 2012; Mork *et al.*, 2015).

Source: PGNAPES and ARGO, ++. Period: annually 1951 to present.

Habitat area of the main pelagic species: Based on the gridded annual hydrographic data during spring we estimate the suitable habitat area for a) Norwegian Spring-spawning Herring: T > 2, and depth range 25–100 m, b) Blue Whiting: T > 1, and depth range 150–400 m, and 3) Mackrel: T > 6, and depth range 10–100 m. In addition we estimate the relative heat content of the Atlantic layer in the Norwegian Sea approximated by the water above the sigma-t 27.9 surface (Skagseth and Mork, 2012; Mork *et al.*, 2015).

Source: PGNAPES and ARGO, ++. Period: annually 1995 to present

Table of the data is given in Table A.1 in Annex 3.

State and recent trends

Figure 6.1.2 shows the main defined climate series representing atmospheric and oceanographic variables with relevance for the Norwegian Sea. The NAO-index during the last 10 years show year-to-year variability but signals that extend over consecutive years appear not prominent compared to earlier periods. The wind conditions along the East Greenland Current have been remarkable stable over the since 2003, except for possibly 2014. Also, the windstress estimated gyre circulation index in the Norwegian-Lofoten basin has been rather stable from 2000 to 2013, but during 2014 and 2015 the cyclonic circulation has been stronger. The Subpolar gyre index show a decrease from the absolute maximum in 2013 (note convention that larger positive index means a weaker gyre and vice versa). The hydrographic conditions in the Svinøy section show that the transition toward warmer and more saline Atlantic water in 1995–2004 is at least partly connected to the change in the Subpolar gyre (SPG), but again indications of a decreasing trend during the last years. The temperature in the East Icelandic Current represented here by the Langanes-East section show a tendency of a warming from the 1990s to the 2000s. Following this water into the Norwegian Sea the signature of the East Icelandic Current was strong in the late 1990s, and with generally low values over the last 10 years. The Relative Heat content of the Atlantic layer in the Norwegian Sea has been after the absolute maximum in 2003. The habitat area for herring, blue whiting and mackerel in the Norwegian Sea show similar evolution and have increased from 1995 to a maximum in 2003–2004 and subsequently a slight decrease but still relative high values.

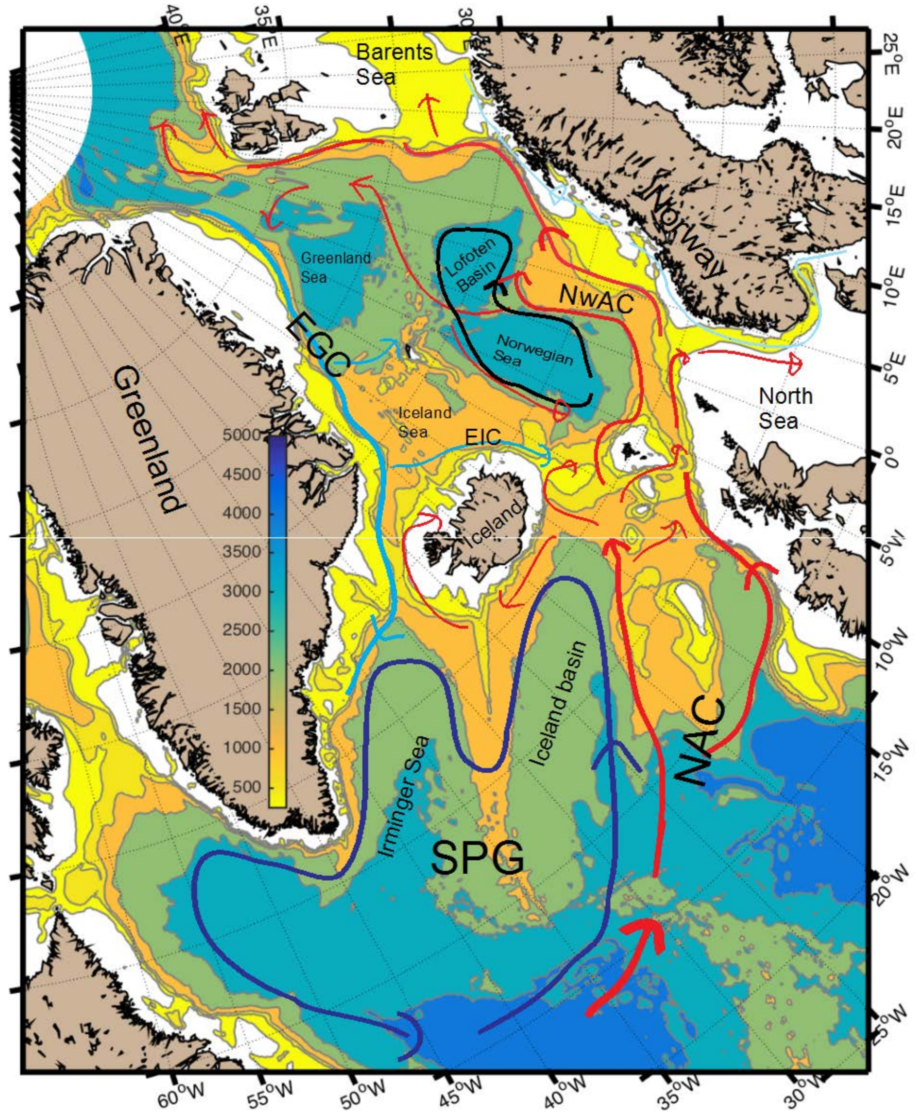


Figure 6.1.1 Schematic map of the investigation area including bottom depths in colors, the main ocean currents of Atlantic origin in red, cold/and or fresh currents in blue, and the deep cyclonic circulation of the Norwegian Sea-Lofoten Basin in black. Abreviations are: Subpolar gyre (SPG), North Atlantic Current (NAC), Norwegian Atlantic Current (NwAC), East Icelandic Current (EIC).

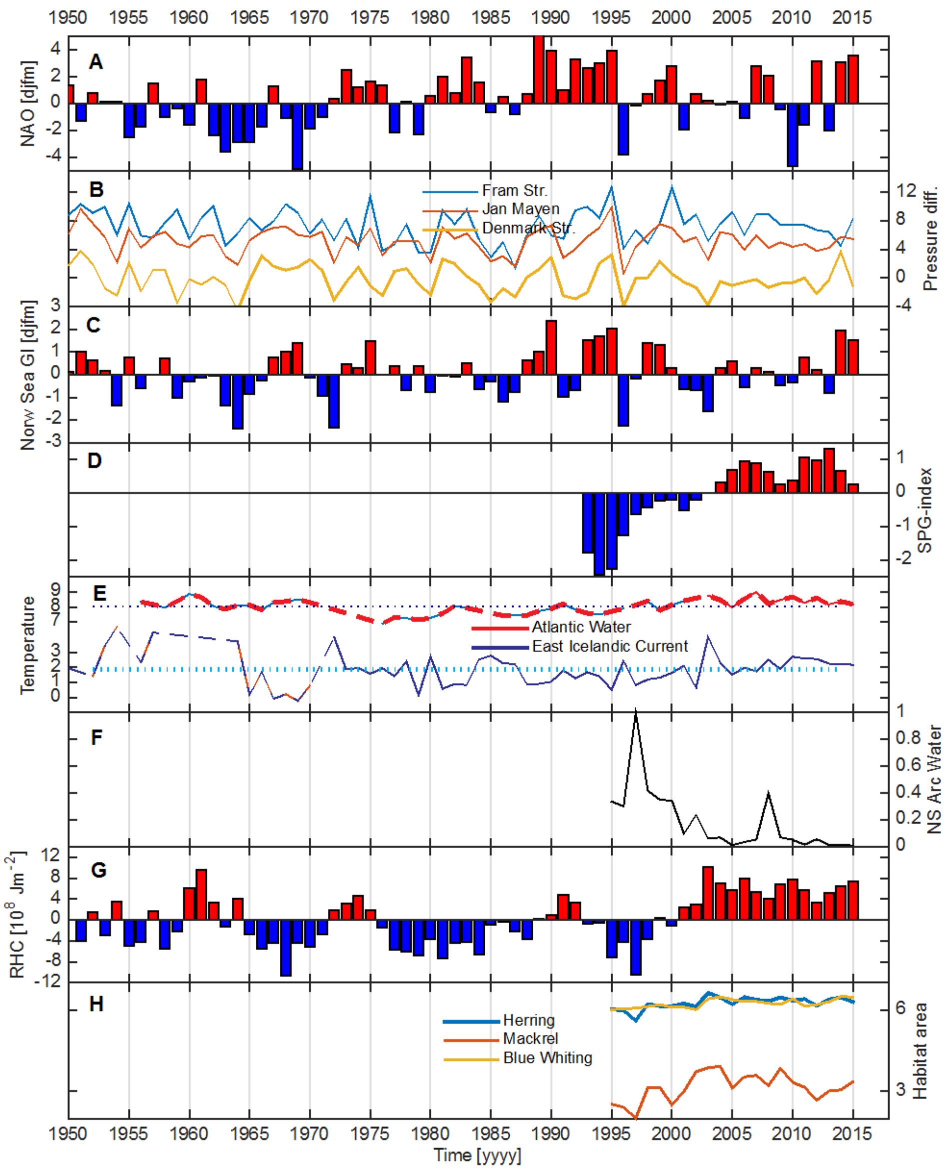


Figure 6.1.2 Climate series representing atmospheric and oceanographic variability of relevance for the Norwegian Sea. These includes *a)* the North Atlantic Oscillation index, *b)* mean sea level pressure differences along the East Greenland coast from Fram Strait to the Denmark Strait, *c)* a gyre circulation index of the Norwegian Sea based on the area average windstress curl within depths > 2000 m, *d)* the Subpolar Gyre index based on satellite sea surface height data, *e)* core temperature variability of the Atlantic inflow in Svinøy section and of the East Icelandic Current at the Langanes East section, *f)* an index of Arctic Water of salinity S < 34.9 in the southern Norwegian Sea, *g)* the relative heat content of the Atlantic layer in the Norwegian Sea, and *h)* habitat area for herring (T > 2°C, and depth 25–100 m), mackerel (T > 6°C and depth 10–100 m) and blue whiting (T > 1°C, and depth 150–400m).

6.2 Ocean chemistry

Nutrients such as nitrate, silicate, and phosphate in Atlantic Water masses typically peak early in spring (February–March) due to winter mixing processes. Therefore, we suggest that the data from this seasonal period are used for assessing the annual time-series (maximum values of the year). The high values observed in early spring are considered to represent, or be a proxy for, the potential for new phytoplankton production in the following months.

Dataseries

IMR holds a dataset representing depth-specific concentrations of various nutrients including nitrate, silicate, and phosphate for the Norwegian Sea. These data are collected by Norwegian vessels, generally from the early 1990s up to and including 2010. Nutrient collection and measurement is a standard procedure at most CTD stations, both during monitoring of transects (including Svinøy and Gimsøy sections) and on regional cruises. The data made available to WGINOR were extracted from the IMR databases with the spatial area between 58 and 90 °N and between -20 and 30 °E. Data for the years 2011–2013 are not yet available from the Chemistry Department, but will be provided to WGINOR when ready.

State and recent trends

Francisco Rey (2012) presented inter-annual variation in spring (~ March) silicate levels for various monitoring sections as well as Ocean Weather Station Mike (St. M) for the period 1990–2010. There is a trend of decreasing silicate concentrations in early spring (Figure 6.2.1). Rey also mentions decreases for nitrate, though much lower. WGINOR has access to the nutrient data, and is therefore in a position in look into other possible nutrient trends in the Norwegian Sea, including the years to come.

Declining silicate concentrations in the Norwegian and Barents Seas

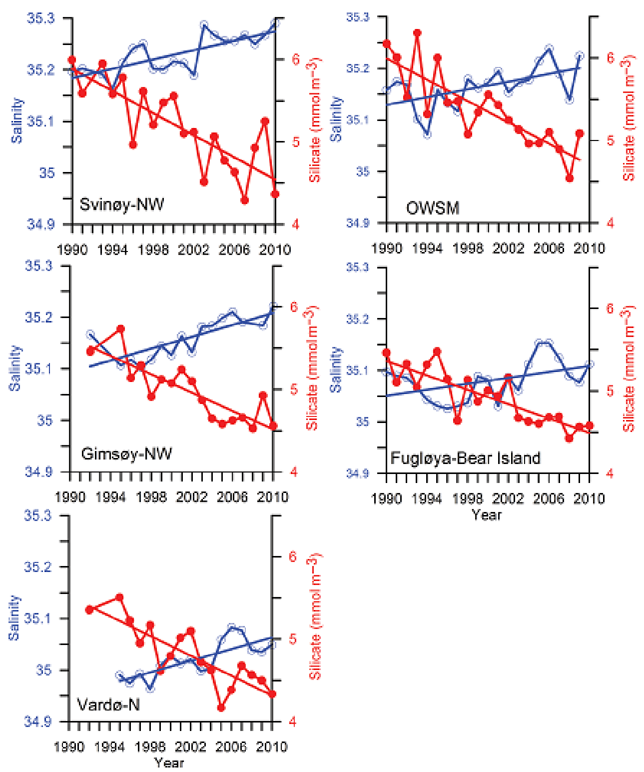


Figure 2. Time-series of salinity (open blue circles) and silicate (closed red circles) at different places in the Norwegian and Barents Seas. Locations of the sections are shown in Figure 1. Results of the regression analysis are shown in Table 1.

Figure 6.2.1. (Rey, 2012)

Ocean acidification

Regular monitoring of ocean acidification started in the Norwegian Sea in 2010. In addition, data from various research projects have been assembled, allowing for analyses of time-series going back to 1981.

Results from the monitoring show that there is large seasonal and spatial variation in pCO_2 and pH in the Norwegian Sea. Aragonite is an important carbonate material used by calcifying organism. Acidification of the oceans will cause saturation of aragonite to decrease, and degree of saturation of this mineral is therefore measured. Degree of saturation of aragonite decreases from the ocean surface, and at large depths undersaturation occurs. The depth where this happens is called the saturation horizon. Both degree of saturation of aragonite and the saturation horizon vary in time and space in the Norwegian Sea.

Analyses of time-series from 1981 to present have been done for the Lofoten and the Norwegian basins. During the last 30 years, pH has decreased significantly in most water layers in both basins. Average decrease is 0.11 pH units in the Norwegian basin and 0.07 units in the Lofoten basin. This is similar to the average global decrease since the start of the industrial revolution. During the last 30 years, the saturation horizon for aragonite has increased slightly in the Norwegian basin while no increase has been detected in the Lofoten basin.

In addition to uptake of CO_2 from the atmosphere, a number of other factors may affect pH and carbon systems in the ocean, such as temperature, salinity, and alkalinity. Analyses have therefore been performed to disentangle the influence of atmospheric CO_2. The results show that increased uptake of atmospheric CO_2 is the most important factor in the Norwegian Sea, explaining 50–90% of the changes in pH in the water.

6.3 Phytoplankton

WGINOR considers chlorophyll *a* to be the most useful measure for phytoplankton biomass available. This variable is measured on the cruises on a routine basis, while surface chlorophyll can also be interpreted by remote sensing (e.g. Vikebø *et al.*, 2012). Chlorophyll is an indirect measure of phytoplankton biomass. The timing of the chlorophyll spring peaks and maxima may differ between years and areas, thereby making it difficult to compare the results for different years based on cruise monitoring.

Dataseries

WGINOR has access to an IMR-dataset representing depth-specific concentrations of chlorophyll and phaeophytin for the Norwegian Sea area. These data are collected by Norwegian vessels, generally from the early 1990s up to and including 2010. The data extraction was made from the IMR databases with the spatial area restricted to within 58 and 90 °N and between -20 and 30 °E. Data for the years 2011–2013 are not yet available from the Chemistry Department, but will be delivered to the marine data department (NMD) when ready. Chlorophyll collection and measurement is standard procedure at most CTD stations, both on monitoring of transects (including Svinøy and Gimsøy sections) and on regional cruises.

State and recent trends

WGINOR needs to process available data to construct relevant time-series on chlorophyll. This is a necessary precursor for assessing possible trends in phytoplankton biomass, both between and within years. Due to inter-annual variation of both timing of the blooms and cruise periods, the maximum values and development of the phytoplankton community may prove difficult to assess. For next year, we plan to gather data from remote sensing of primary productivity and phytoplankton biomass (Vikebø *et al.*, 2012).

6.4 Zooplankton

Zooplankton plays an important role in the ecosystem by transferring energy from the phytoplankton to higher trophic levels. One of the most important zooplankton groups in the Norwegian Sea is the genus *Calanus*, both in numbers and biomass (Melle *et al.*, 2004). This genus displays strong seasonal vertical migrations as part of its life cycle. However, there are also many other important groups of zooplankton such as other copepods, krill, and amphipods (Melle *et al*., 2004; Skjoldal *et al.*, 2004).

Dataseries

WGINOR has identified three datasets that are particularly relevant to the integrated assessment. Two of the time-series/datasets are based on regional coverages, and represent May and July-August, respectively. The sampling is made by WP2 nets with 180–200 µm mesh size from 200 m (or bottom when shallower) to the surface. Each sample is as routine split in two parts, one used for taxonomic/stage processing and the other half for size-fractioned biomass measurements. Due to the time and cost-consuming taxonomic analysis, only selected samples are processed with respect to species and stage composition. In contrast, the biomass values are readily available for all samples. For some regional coverages, as well along the standard IMR monitoring transects, selected stations are also sampled with MOCNESS (Multiple Opening and Closing Net, with an Environmental Sensing System). Thus, the third dataset provides depth-stratified samples, in contrast to the WP2. Due to the comparatively much fewer samples, the MOCNESS data need to be aggregated in time and space. The MOCNESS may provide supplementary information to the WP2 because it is used to sample much deeper (typically up to 600–700 m in deep areas) than the 200 m lower sampling-depth used as a standard for the WP2 and provides quantitative information on macro zooplankton density.

1) May time-series. Zooplankton biomass from regional coverages from 1995 to present.

The ICES biomass dataset for May (Annex 6) is evaluated in more detail here. The total biomass of zooplankton for the uppermost 200 m across the whole coverage area the last three years are shown in Figures 6.4.1a, b, and c. Of these three years the biomass was highest in 2014 and lowest in 2015. The mean zooplankton biomass of the whole dataset (the years 1995–2015, Figure 6.4.2) was relatively higher than in recent years, but generally, the biomass showed highest values in the western part of the study area. To get a clearer picture of the regional difference, the total area were divided into 4 subareas 1) Southern Norwegian Sea, 2) Lofoten Basin, 3) w2w i.e. Jan Mayen to Iceland and 4) East of Iceland (Figure 6.4.2). The zooplankton data were interpolated using objective analysis utilizing a Gaussian correlation function (Gandin, 1963; Bretherton *et al.*, 1976). The first step was to calculate a mean spatial climatology using all available zooplankton data for a given period of the year. In this report two periods were investigated separately; May and July–August. The spatial influence radius for this step were set to 100 km. The next step was then to run the similar procedure for the individual years. Since the data are less for the individual years the influence radius were increased to 150 km. Outside this radius the solution converge toward the climatology. These annually gridded fields polygons are defined to extract area mean time-series. In the previous report area averaged time-series of zooplankton biomass were taken as the mean of the samples obtained within a specified area. It is expected that calculating the similar time-series based on the gridded fields would tend to give more smooth results, e.g. in the case of few data the solution would converge toward the long-term mean. Means of zooplankton biomass for each of these subareas as well as the whole area are shown in Figure 6.4.3 and Table 6.4.1. The means of zooplankton biomass for the periods representatives for higher amounts of zooplankton biomass (the years 1998–2002) and lower amounts (the years 2010–2015) are presented in Figures 6.4.4a and b, respectively.

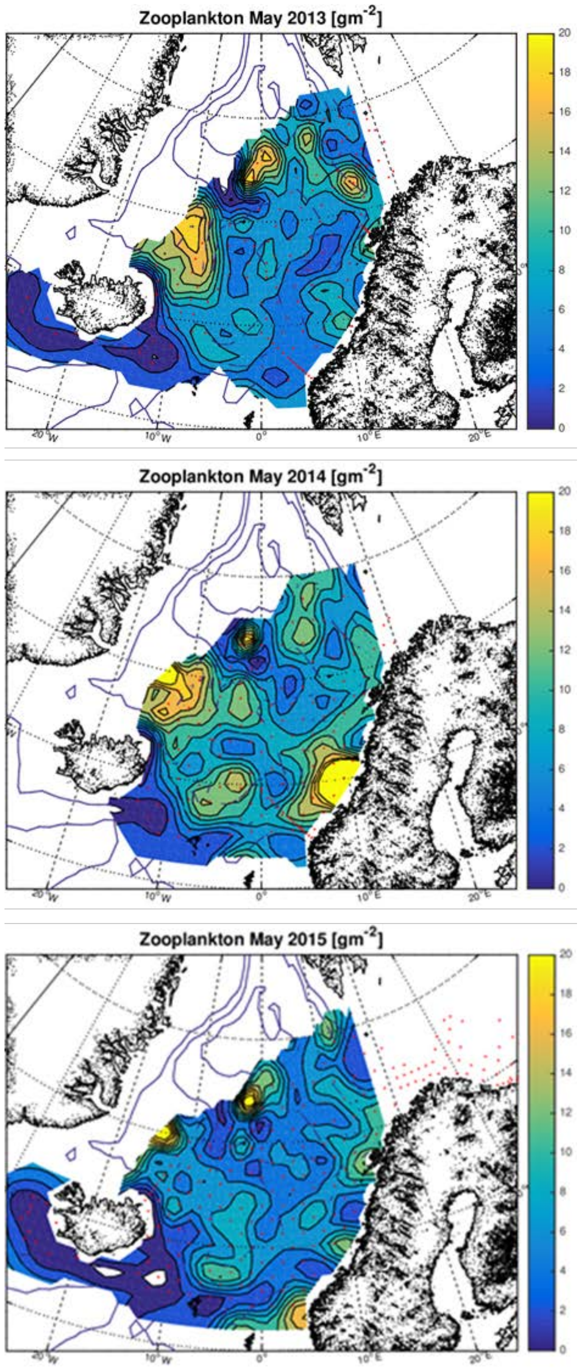


Figure 6.4.1 a, b, and c. Zooplankton biomass (g dw m^{-2}, WP2, 200–0 m) in the Norwegian Sea and surrounding waters in May a) the year 2013, b) the year 2014 and c) the year 2015.

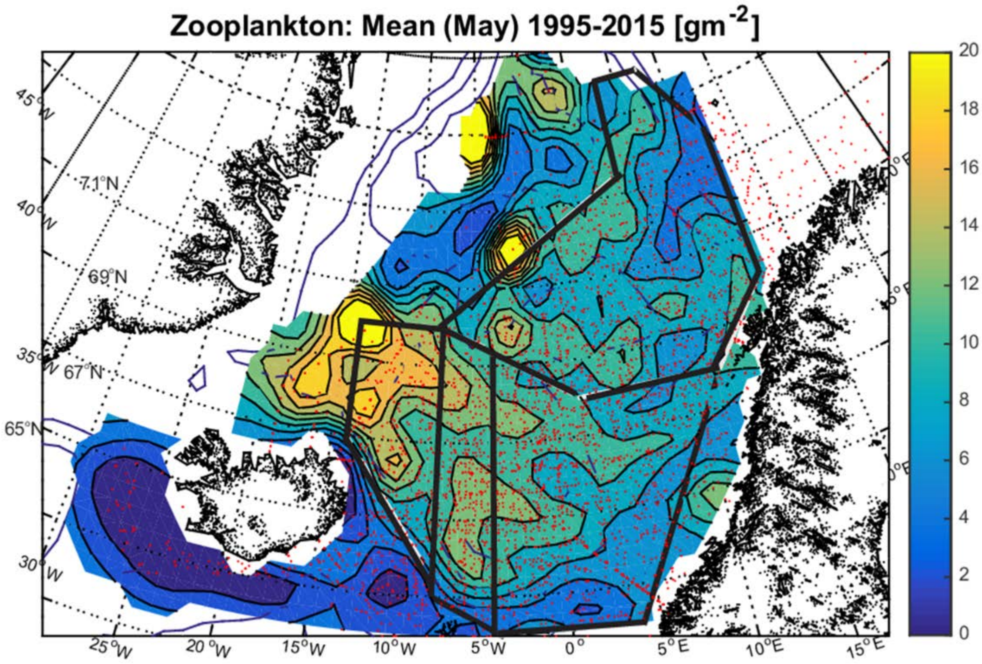


Figure 6.4.2. Means of zooplankton biomass (g dw m^{-2}, WP2, 200–0 m) in the Norwegian Sea and surrounding waters in May the years 1995–2015. The map shows the 4 subareas defined for further evaluations 1) Southern Norwegian Sea, 2) Lofoten Basin, 3) w2w i.e. Jan Mayen to Iceland and 4) East of Iceland

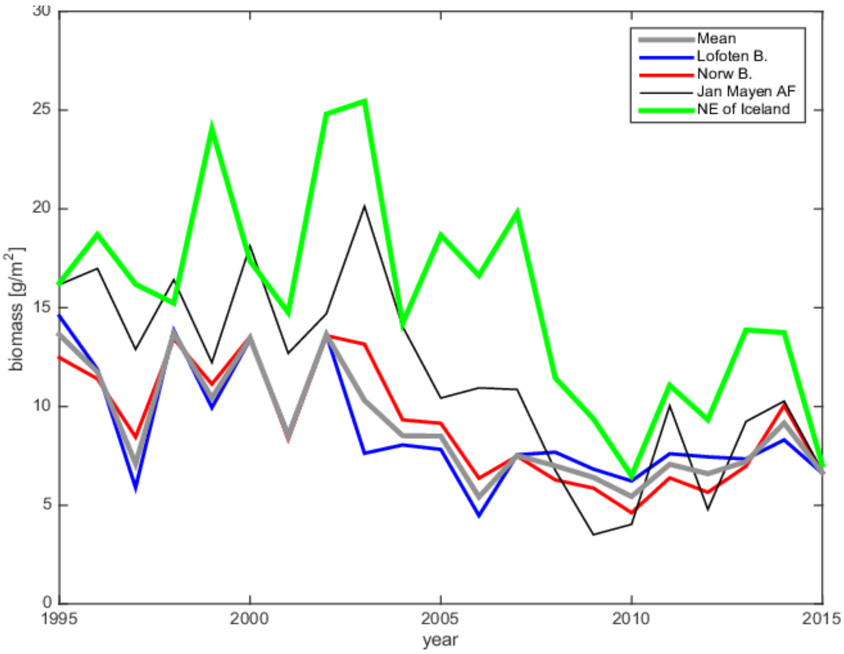
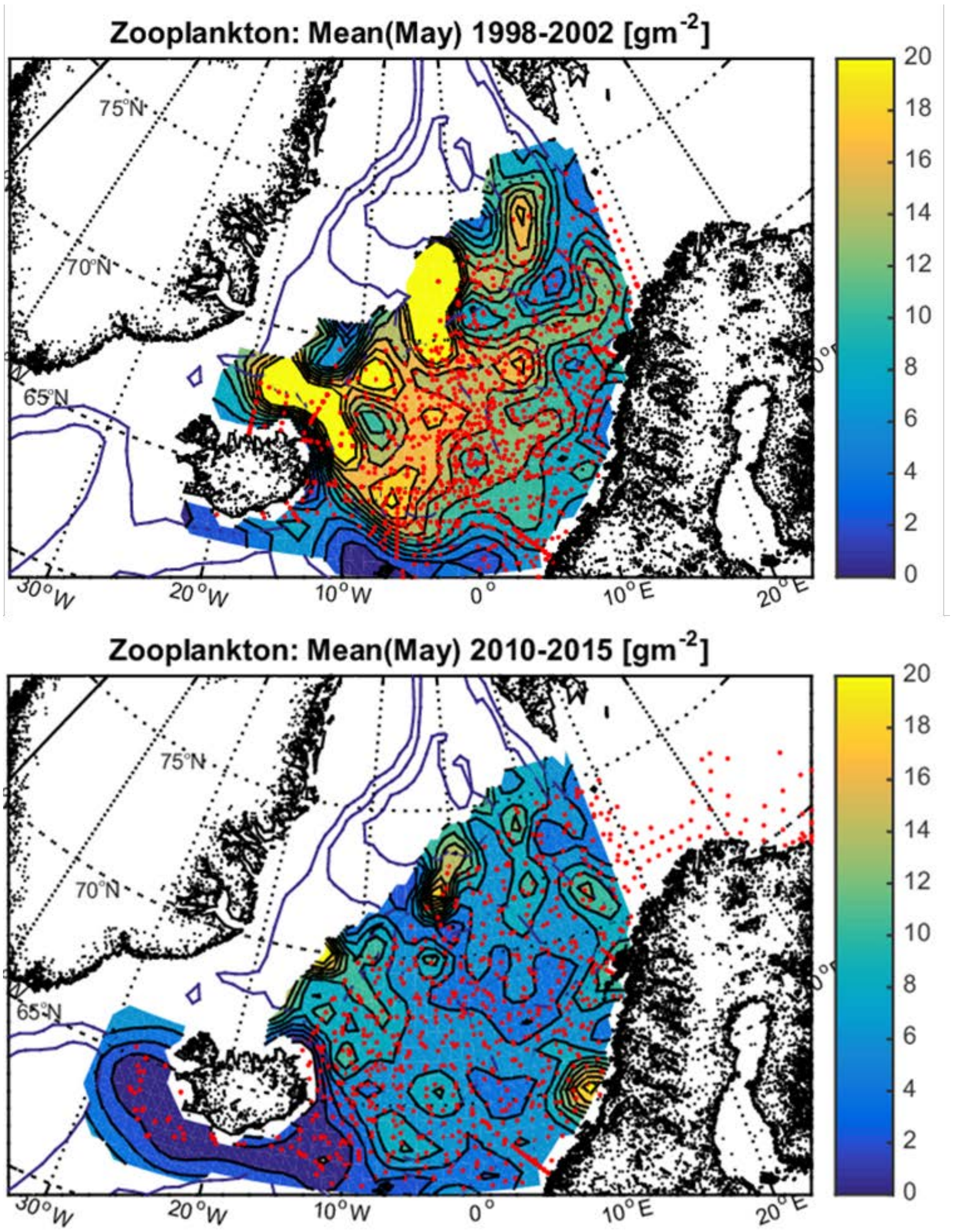


Figure 6.4.3. The annual mean dry weight of zooplankton biomass (g dw m^{-2}; WP2, 200–0 m) in the 4 subareas (defined in Figure 6.4.2) as well as their means the years 1995–2015.

Table 6.4.1. Zooplankton dry weights (g dw m^{-2}; WP2, 200–0 m) in May for the 4 subareas defined in Figure 6.4.2 and the estimated average for the total area covered years 1995–2015.

Year	Mean	Norwegian Sea	Lofoten Basin	West of 2°West	North of Iceland
1995	13.6	12.4740	14.5803	16.1643	**16.2400**
1996	11.7	11.3974	11.8751	16.9814	**18.7021**
1997	7.1	8.4480	5.8888	12.8883	**16.1836**
1998	13.7	13.4353	13.8498	16.4131	**15.2267**
1999	10.4	11.1296	9.9384	12.2186	**24.0394**
2000	13.5	13.5229	13.3970	18.1246	**17.3603**
2001	8.5	8.3447	8.5975	12.6884	**14.7555**
2002	13.6	13.5837	13.6322	14.6908	**24.7989**
2003	10.3	13.1497	7.6264	20.1299	**25.4496**
2004	8.5	9.3192	8.0491	14.0390	**14.2000**
2005	8.5	9.1463	7.8223	10.4225	**18.6671**
2006	5.4	6.3633	4.4715	10.9389	**16.6227**
2007	7.5	7.4821	7.5492	10.8582	**19.7923**
2008	7.0	6.2799	7.6818	6.7646	**11.4437**
2009	6.4	5.8649	6.8249	3.5058	**9.3735**
2010	5.4	4.6177	6.2256	4.0297	**6.4878**
2011	7.1	6.3839	7.6045	10.0303	**11.0656**
2012	6.6	5.6520	7.4465	4.7881	**9.3254**
2013	7.2	6.9708	7.3384	9.2358	**13.8678**
2014	9.2	10.0520	8.3063	10.2665	**13.7332**
2015	**6.7**	**6.6440**	**6.6221**	**6.7062**	**7.0432**



Figures 6.4.4 a and b. Means of zooplankton biomass (g dw m^{-2}; WP2, 200–0 m) in the Norwegian Sea and surrounding waters. Figure representative for a) higher amounts of zooplankton biomass (1998–2002) and figure representative for b) lower amounts of zooplankton biomass (2010–2015).

2) July-August time-series. Zooplankton biomass from regional coverages (horizontal) from 2009-2010 to present.

This may be the beginning of a time-series, but at present, there are only data back to 2009-2010. However, Norwegian data do exist for earlier years (before Iceland and the Faroese entered the arena, Annex 6). The total biomass of zooplankton for the uppermost 200 m across the whole coverage area the last three years are shown in Figures 6.4.5a, b, and c. By far the highest values were recorded in Faroese and Icelandic waters in 2013. But when considering just the defined subareas, the year 2014 had the highest mean values (Figure 6.4.6 and Table 6.4.2).

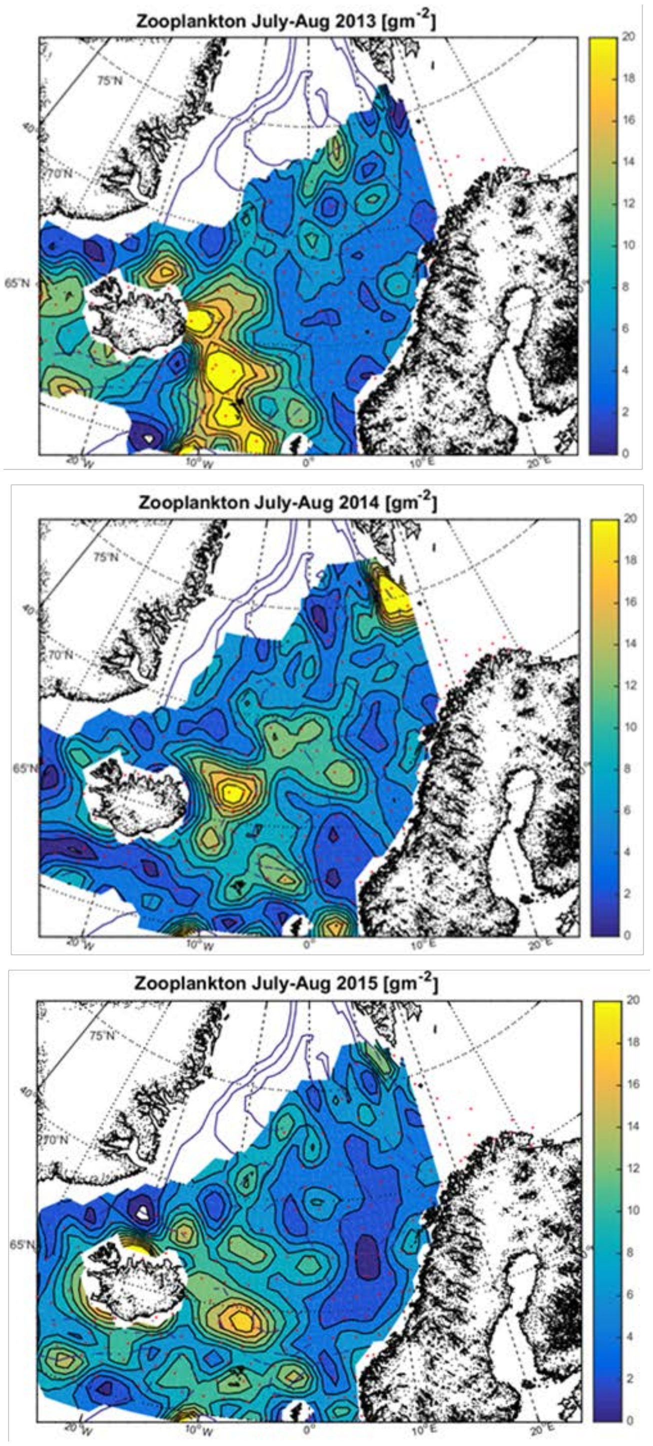


Figure 6.4.5 a, b, and c. Zooplankton biomass (g dw m^{-2}; WP2, 200–0 m) in the Norwegian Sea and surrounding waters in May a) in 2013, b) in 2014 and c) in 2015.

Figure 6.4.6. Annual mean dry weight of zooplankton biomass (g dw m^{-2}; WP2, 200–0 m) in July-August in the 4 subareas (defined in Figure 6.4.2) as well as their means the years 2006, 2009–2015.

Table 6.4.2. Zooplankton dry weights (g dw m^{-2}; WP2, 200–0 m) for the 4 subareas defined in Figure 6.4.2 and the estimated average for the total area covered for July-August the years 2006, 2009–2015.

Year	Mean	Norwegian Sea	Lofoten Basin	West of 2°W	NorthEast of Iceland
2006	**6.2**	7.1894	5.0966	9.7137	7.8091
2009	**4.8**	5.1697	4.4529	7.0047	6.1354
2010	**6.0**	5.6266	6.1724	8.4004	8.5863
2011	**5.1**	3.8231	6.2490	5.6295	6.4488
2012	**5.3**	5.0006	5.5274	6.8805	9.2026
2013	**6.8**	7.4583	6.1005	11.5536	11.0165
2014	**8.2**	8.2643	8.1658	10.9923	10.2594
2015	**6.3**	7.3615	5.1186	11.2475	9.6043

3) April, May, and June/August datasets. Zooplankton biomass from depth-stratified samples, from 1990 to present.

The MOCNESS is commonly used to get a profile of zooplankton down to 500 to 600 m. The 1-m^2 MOCNESS filters about 25 times as much water as the WP-2 Net, which is the standard net used to sample zooplankton in the upper 200 m. This is due to the larger opening (WP-2 is 0.25 m^2) and oblique vs. vertical towing. In an extensive zooplankton sampling gear intercomparison we have shown that the two nets give comparable results for mesozooplankton biomass (Skjoldal *et al.*, 2013). we report in this document the MOCNESS data, but we plan eventually to analyse combined MOCNESS and WP-2 datasets.

The zooplankton samples are collected and treated according to the standard IMR method, which is described in detail by Melle *et al.* (2004). The method involves splitting the sample in two halves, one for biomass determination and the other fixed with formaldehyde and stored for eventual analysis. The portion for biomass is screened successively through 2000, 1000 and 180 μm mesh screens, transferred to pre-weighed Al trays, dried and then weighed.

This method of determining zooplankton dry weight biomass in size fractions was used as the basic method in a comprehensive zooplankton gear intercomparison study carried out with two ships in Storfjorden at Møre in Norway, June 1993. The method was found to be robust and reproducible and associated with relatively low variance generated by the various steps (splitting, sieving, drying, weighing) of the procedure (Skjoldal *et al.*, 2013).

The MOCNESS is a multiple opening and closing net system with a 1 m^2 opening that is towed obliquely from the deepest layer at about 1.5 knot speed with nets successively opened and closed at predetermined depths by signals through a cable from the ship. The MOCNESS was used with nets of 180 or 200 μm mesh on most cruised but nets of 300 or 333 μm mesh were also used on some cruises. Below the Biomass in the southeast part of the Norwegian Sea is shown taken from the work region

Zooplankton biomass as g dry weight m^{-2} in the 0–200 m layer in the southeastern region are shown in Figure 6.4.7 for April (upper), May (middle), and June-August (lower panel). The biomass in April was about 6 g dw m^{-2} in the 1990s, and increased to about 10–12 g dw m^{-2} in the 2000s (*n* were 122, 50, 8, and 9 for the four periods). The biomass in May was about 10–11 g dw m^{-2} from 1991 to 2005, while being somewhat lower (about 8 and 6.5 g dw m^{-2}) in 2006–2010 and 2011–2013 (*n* were 17, 110, 33, 21, and 15 for the 5 periods). The biomass in June-August decreased from 10 g dw m^{-2} in 1991–1995 ($n = 80$) and 6 g dw m^{-2} in 1996–2000 ($n = 97$), to around 3 g dw m^{-2} during the 2000s (n = 15, 12, and 8).

In the June-August series there is a progression towards later sampling, with many June samples taken during the 1990s (38 and 21), and a shift to only August samples in the last years (Skjoldal and Bagøien, 2013). However, recalculating the data for July only did not change the trends much, with values still decreasing from about 8.5 g dw m^{-2} in 1991–1995 to about 3 g dw m^{-2} in the 2000s (Figure 6.4.7).

The biomass in the deeper layer between 200 and 500 m depth varied around about 5 g dw m^{-2} in April, May, and June-August (Figure 6.4.7). The biomass was lowest in the last three years (2011–2013) for the Series (3.7 g dw m^{-2}, n = 15), while it was similar to the previous periods for the June-August series (5.3 g dw m^{-2}, n = 21).

The size distribution of the zooplankton in the deeper layer differed from that in the upper layer by more dominance by larger forms. The largest fraction (> 2 mm) made up from about 50 to 70% of the total biomass in May, when the medium fraction constituted about 25–50% and the smallest fraction made up only about 5%. In June-August, the smaller fractions had increased in relative importance, with about 12–20% of the total biomass in the smallest and about 35–45% in the medium size fraction.

The sum of the biomass in the deeper (200–500 m) and upper (0–200 m) layers was typically 11–16 g dw m^{-2} in April and May and somewhat lower, 7–16 g dw m^{-2} (Figure 6.4.7). The lowest biomass values (7–9 g dw m^{-2}) were observed after 2000, reflecting the lower biomass in the upper 200 m.

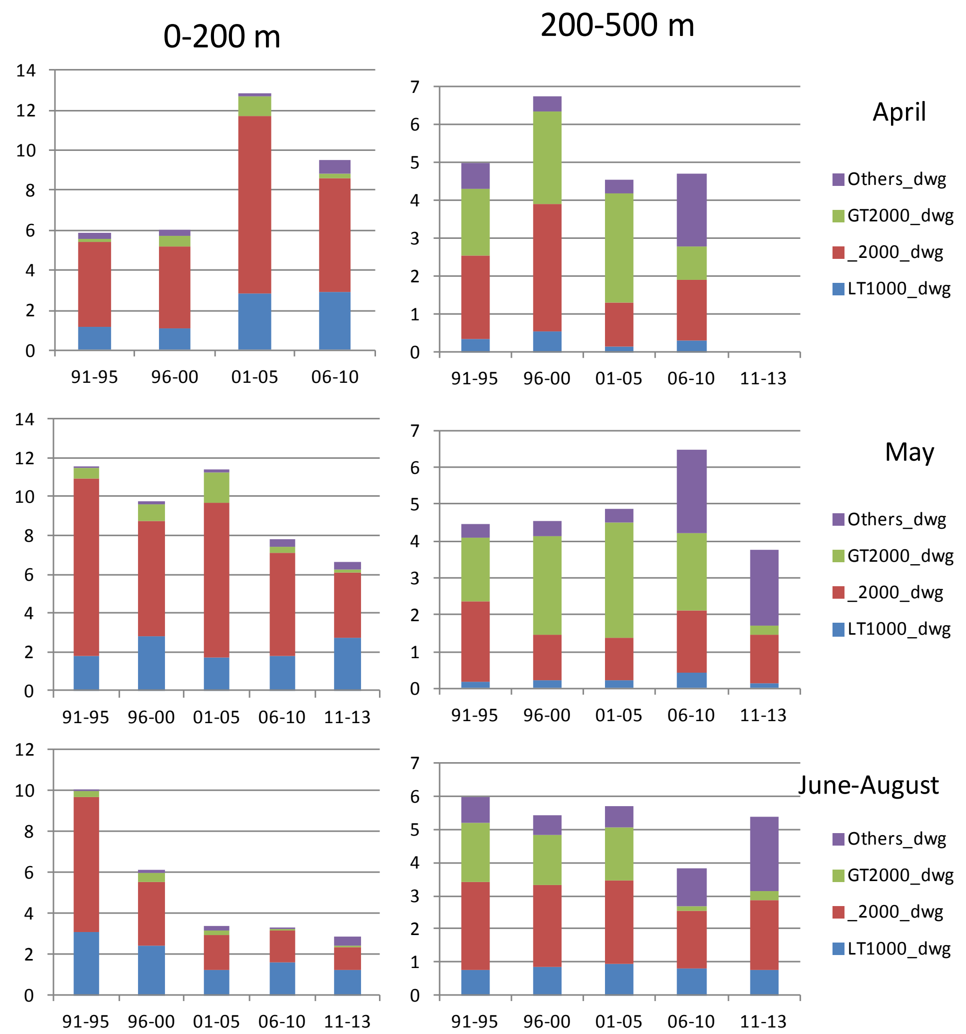


Figure 6.4.7. Zooplankton biomass (g dry weight m^{-2}) in size fractions (< 1 mm - blue; 1–2 mm -red; > 2 mm - green; others are taxa sorted from the > 2 mm fraction) in the 0–200 m (left column) and 200–500 m (right column) depth intervals in the southeastern region of the Norwegian Sea in April (upper), May (middle), and July-August (lower). Values are means over 5 years period from 1991 to 2010 plus the last 3 years (2011–2013).

State and recent trends

With respect to the time-series for the ICES coordinated May cruises presented above, the reported biomasses for the uppermost 200 m across the whole coverage area show a declining trend from the early 2000s, with the levels increasing since 2010 except for a decline again in 2015 (Figure 6.4.3). The trend is similar for summer (July-August) (note, much shorter time-series) the values were increasing from 2011 and dropping in 2015. For periods representative for higher zooplankton biomass (1998–2002; Figure 6.4.4a) there were generally higher values recorded over the whole surveyed area, with the highest values in the Jan-Mayen and North of Iceland subareas. While on the other hand in periods representative for lower zooplankton biomass (2010–2015; Figure 6.4.4b), similar (low) values were recorded over the whole study area. Of the 4 subareas, the area East of Iceland had the highest biomass followed by the Jan Mayen area, while Southern Norwegian Sea and Lofoten Basin have lower but similar values. In summer, the concentration were lower but as in spring the highest biomass were recorded East of Iceland and in the Jan Mayen area, and lower and very similar values in Southern Norwegian Sea and Lofoten Basin. The interannual changes in the amount of biomass are in line in all the subareas, except East of Iceland in May where there seems to be some kind of delay compared to the other areas (Figure 6.4.3). In May 2015, the estimated average for the total area covered was 6.7 g dry weight m^{-2}, as compared to the minimum level of 5.4 in 2006 and 2010 (Figure 6.4.3 and Table 6.4.1).

The MOCNESS data give the same picture for May, with a decreased biomass in recent years. The data indicates an increased biomass for April. It needs to be investigated whether this is caused by an earlier peak in the zooplankton succession, or there are other causes for this. The number of MOCNESS hauls is much lower in the last two periods so that also needs to be looked into (Skjoldal and Bagøien, 2013). For the May and July periods there is a marked decrease in later years for the upper 200 m, whereas for the 200–500 m depth the trends are less clear.

6.5 Pelagic fish

Norwegian spring-spawning herring

The Norwegian spring-spawning herring (*Clupea harengus*) is the largest herring stock in the world and is widely distributed and highly migratory throughout large parts of the Northeast Atlantic during its lifespan (based on Stock Annex provided in ICES, 2015a). This makes it an important component of the Norwegian Sea ecosystem. The herring spawns along the Norwegian west coast in February–April and the larvae drift north and northeast and distribute as 0–group in fjords along the Norwegian coast and in the Barents Sea, the latter being by far the most important juvenile area for the large year classes. With maturation, the young herrings start joining the adult feeding migration in the Norwegian Sea. The feeding migration starts just after spawning with the maximum feeding intensity and condition increase occurring from late May until early July. The feeding migration is in general length dependent, meaning that the largest and oldest fish perform longer and typically more western migrations than the younger ones. After the dispersed feeding migration, the herring concentrate in one or more wintering areas in September-October. These areas are unstable and since 1950 the stock has used at least six different wintering areas in different periods. Considering its life history, four time-series are considered important for integrated assessment purpose, (a) spawning-stock biomass, (b) recruitment index (number-at-age 0), (c) weight-at-age representing condition and feeding success, and (d) length-at-age representing growth rate.

Dataseries

The data on herring include spawning-stock biomass (SSB), recruitment, weights-at-age and lengths-at-age (Annex 3, Figure 6.5.1, and Figure 6.5.2). Recruitment and SSB represent the results of the analytical assessment of the stock by the ICES Working Group on widely distributes stocks (WGWIDE) in 2015 (ICES, 2015a) for the period 1988–2015 and an older VPA run for 1950–1987 (Toresen and Østvedt, 2000). The estimates derive from the VPA population model TASACS. The input data are both catch-at-age from the fishery and number-at-age from the various research surveys, where the IESNS survey in May get most weight (Annex 7). Thus, this series is representative for developments in stock size and recruitment in the stock. Weights-at-age are taken from the assessment input data in ICES (2015a). The data of length-at-age is retrieved from IMRs database. The sampled fish are either from regular surveys or from commercial catches, where a sample is sent to IMR for analyses. All individuals that are age-determined by using either scale or otoliths during the period 01.10.year$_x$ - 01.04.year$_{x+1}$ are included in the dataset. There are no restrictions on the area the fish are sampled from. Herring is not feeding and have therefore no individual growth in this period. Any change in weight in this period does not affect the dataset as only length measurements are retrieved. The fish that are sampled in the autumn year$_x$ are given age +1 to make them comparable to those sampled in spring year$_{x+1}$. For all individuals with the same age the mean length and standard deviation is calculated and the number of fish is counted. The dataset includes the consecutive years from 1981-1982 to 2014-2015. The length-at-age 6 is presented together with the standard error in Figure 6.5.2.

State and recent trends

Historically, the size of the stock has shown large variations and dependence on the irregular occurrence of very strong year classes (Figure 6.5.1). In the absence of strong year classes after 2004, the stock has declined since 2009 and is not expected to increase in the near future even when fishing according to the management plan.

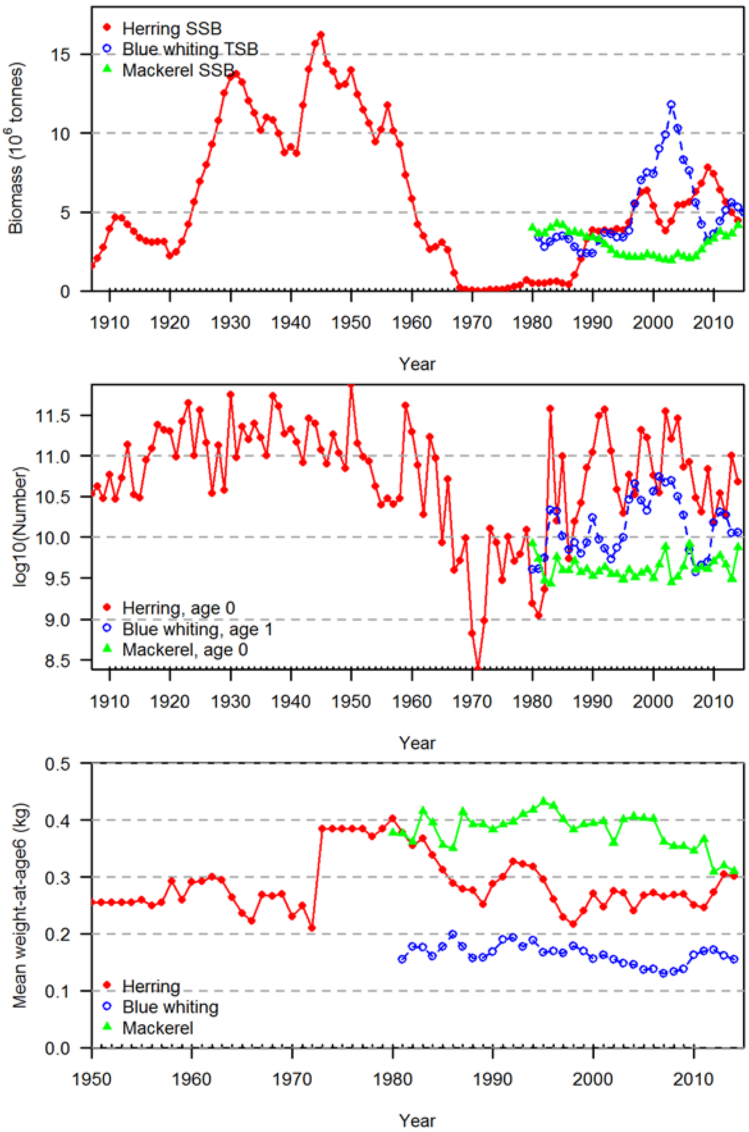


Figure 6.5.1. Historical development in SSB (a), recruitment (b), mean weight-at-age 6 (c), and age 8 (d) of Norwegian spring-spawning herring, blue whiting and mackerel in according to ICES assessment (ICES, 2012).

Blue whiting

Blue whiting (*Micromesistius poutassou*) is a highly migratory small pelagic gadoid that is widely distributed in the Eastern North Atlantic, from Svalbard to Morocco (based on Petitgas *et al.*, 2010 and Trenkel *et al.*, 2014). They mature at 2 to 4 years old, majority of the stock is < 10 years old and < 32 cm long. Their migration pattern is not well defined. We know mature individuals migrate between summer feeding grounds in the Norwegian Sea and adjoining waters to spawning grounds located from Porcupine Bank to the Hebrides shelf in March-April. Major nursing grounds are believed to be the Norwegian Sea and in the Bay of Biscay. The Norwegian Sea is an important feeding area for all life stages of blue whiting (Annex 8), therefore we consider its total biomass an important component of the Norwegian Sea ecosystem. Considering its life-history, four time-series are considered important for integrated assessment purpose, (a) total biomass, (b) recruitment index (number-at-age 0), (c) weight-at-age representing condition and feeding success, and (d) length-at-age representing growth rate.

Dataseries

The data on blue whiting include total-stock biomass (TSB), recruitment index (1-group), weight-at-age, and length-at-age (Annex 3, Figures 6.5.1a-d, and Figure 6.5.2). Recruitment and TSB represent the results of the analytical assessment of the stock by the ICES Working Group on widely distributes stocks (WGWIDE) in 2015 (ICES, 2015a). The estimates derive from the SAM model, where the input data are both catch-at-age from the fishery and number-at-age from the annual International Blue Whiting Spawning Stock (IBWSS) survey in March-April. Thus, this series is representative for developments in stock size and recruitment in the stock. The data of length-at-age is retrieved from IMRs database. Blue whiting samples are either from scientific surveys or from commercial catches. All aged individuals are from Q1 (1 January to 1 April), a period when they do not feed and somatic growth is assumed to be none existing. There are no restrictions on geographical location of samples. Any change in weight in this season doesn't affect the dataset (i.e. biomass) as only length measurements are retrieved. Mean length-at-age (±1 standard deviation) and number of individuals is reported. The dataset includes consecutive years from 1980 to 2014. The length-at-age-six is presented together with the standard error in Figure 6.5.1c.

State and recent trends

During the period from 1980 to 2014, estimated blue whiting TSB ranged from 2.8 to 11.7 million tonnes (ICES, 2015a). There is one major peak in abundance which occurred from 1998 to 2006 (abundance > 7 million tonnes) and a smaller one from 2012 to 2014 (abundance > 5 million tonnes; Figure 6.5.1b). The general trend in stock size fluctuation was a drastically increase from 3.4 million tonnes in the mid-1990s to 11.7 million tonnes in 2003, followed by a drastically declined to 3.2 million tonnes in 2009 (Figure 6.5.1b). TSB increased after 2009 to 5.5 million tonnes in 2013 but declined to ~ 4.5 million tonnes in 2015. Fluctuations in TSB are driven by variable recruitment, which ranges from 3.7 to 55.5 billions individuals, average 17.5 billions (Figure 6.5.1a). The recruitment improved from 2009 and on, and even if the estimates of the 2013 and 2014 year classes are uncertain, information from recent IBWSS survey, as well as IESNS survey in May indicate that they are strong. As a consequence, the total biomass and SSB started to increase again around 2012.

Northeast Atlantic mackerel

Northeast Atlantic mackerel is found in the area extending from the Iberian Peninsula in the south to the northern Norwegian Sea in the north, and Greenland in the west to western Baltic Sea in east (based on Stock Annex provided in ICES, 2014). The spawning occurs widely on the shelf from Biscay to the southern edge of the Norwegian Sea and into the North Sea during January to July. After spawning, mackerel generally migrate to Northern areas to feed in the Norwegian Sea, Irminger Sea, and the North Sea from June to October. The Norwegian Sea and adjacent waters have, since the mid-2000s been the main feeding ground of the stock and therefore important component of the ecosystem. Considering its life history, four time-series are considered important for integrated assessment purpose, (a) spawning-stock biomass, (b) recruitment index (number-at-age 0), (c) weight-at-age representing growth rate, condition and feeding success, and (d) length-at-age representing growth rate.

Dataseries

The data on mackerel include spawning-stock biomass (SSB), recruitment, weights-at-age and lengths-at-age (Annex 3; Figure 6.5.1). Recruitment and SSB represent the results of the analytical assessment of the stock by the ICES Working Group on widely distributes stocks (WGWIDE) in 2015 (ICES, 2015a). The assessment was performed using the state-space assessment model SAM, where the input data are catch-at-age from the fishery, SSB estimates from the triennial Mackerel Egg survey, recruitment time-series from the International Bottom Trawl Surveys (Jansen *et al.*, 2015), tag-recapture data and swept-area biomass estimations from the IESSNS survey July-August (ICES 2015c; Nøttestad *et al.*, 2015). The data of length-at-age is retrieved from IMRs database. The sampled fish are either from regular surveys or from commercial catches, where a sample is sent to IMR for analyses. All individuals that are age-determined by using otoliths during the period 01.10.$year_x$ -01.05.$year_{x+1}$, are included in the dataset. There are no restrictions on the area the fish are sampled from. The mackerel is not feeding during winter and is therefore assumed to have no substantial growth in this period. Any change in weight in this period doesn't affect the dataset as only length measurements are retrieved. The fish that are sampled in the autumn $year_x$ are given age +1 to make them comparable to those sampled in spring $year_{x+1}$. For all individuals with the same age the mean length and standard deviation is calculated and the number of fish is counted. The dataset includes the consecutive years from 1981-1982 to 2014-2015. The length-at-age six is presented together with the standard error in Figure 6.5.2.

State and recent trends

The spawning-stock biomass is estimated to have increase almost continuously from just below 2 million tonnes in the late 1990s and early 2000s to 4.2 million tonnes in 2014. The estimate for 2015 (supported only by the IESSNS data; ICES, 2015c) suggests a slight decline from 2014 to 2015. The recruitment time-series from the assessment shows a clear increasing trend since the late 1990s in which two very large year classes (2 to 3 times the average) are apparent (2002 and 2006). The 2011 year class appears to be large or the third largest since 1990 (ICES, 2015a; Figure 6.5.1b).

Trends in growth of the three pelagic fish stocks

There has been a downward trend in the length-at-age in herring over time as reported in (Huse *et al.*, 2012). Figure 6.5.2 shows that this trend seems to have been reversed in the recent two years. More recent analyses have shown that length-at-age (age 6) was negatively related to stock size (number-at-age 5–7 and SSB) indicating an intraspecific competition for resources (Homrum *et al.*, 2016). For mackerel on the other hand a downward trend was started in 2006 and has been maintained since (Figure 6.5.3.). The blue whiting showed a downward trend until 2007, but has since showed an upward trend with the strong reduction in the stock. The stock is increasing strongly at present so it will be interesting to see how this develops in the coming years. Two recent studies have suggested that density-dependence may be driving large parts of the variations in the growth of mackerel (Jansen and Burns, 2015; Ólafsdóttir *et al.*, 2015). Trenkel *et al.* (2015) suggests density-dependence (cohort size-at-age 1) has major effects on blue whiting whereas environmental factors (temperature and prey abundance) have minor effects.

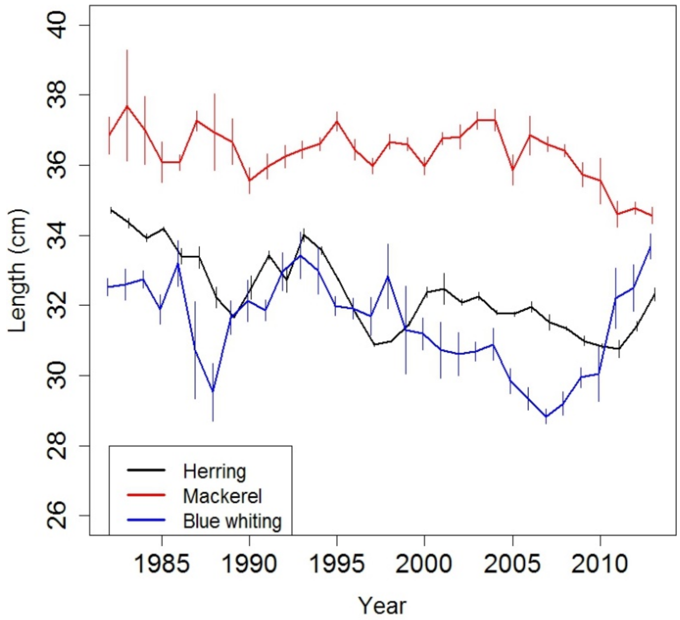


Figure 6.5.2. The length-at-age six years for herring, mackerel, and blue whiting.

Growth of Northeast Atlantic mackerel

A recent study on mackerel growth suggests their length/weight-at-age continually declined during the last decade (Figure 6.5.3; Ólafsdóttir *et al.*, 2015). In 2013, the average mackerel was 3.7 cm shorter and weighed 175 g less than the average individual in 2002. In the study, weight-at-length and length/weight-at-age were analysed for mature 3-year-old to 8-year-old mackerel (n = 26 084), collected annually in fall (September and October) at the end of the annual feeding season, from 1984 to 2013, in the northern North Sea. The age range represented 92% of mackerel stock size (age 3+). Individual's weight-at-length, demonstrating annual summer feeding success, continually declined during the last five years, whereas somatic growth of cohorts, from age 3- to 8-years old, continually declined for the last 11 of 25 cohorts investigated. Growth of the latest cohort was 34% of the maximum cohort growth recorded. Both weight-at-length and cohort growth were negatively affected by mackerel stock size and Norwegian spring-spawning herring stock size (weight-at-length: R^2 = 0.89; growth (length): R^2 = 0.68; growth (weight): R^2 = 0.78), while temperature was not significant. Conspecific density-dependence was most likely mediated via intensified competition associated with greater mackerel density. Negative effects of herring were likely mediated by exploitative competition for shared food resources rather than direct competition due to limited spatio-temporal overlap between mackerel and herring during the feeding season. Herrings begin their seasonal feeding migration at least a month before mackerel, therefore, herring consumption influences prey availability for the later arriving mackerel. Record of low mackerel growth and negative effects of mackerel and herring stock size suggest that the carrying capacity of the Norwegian Sea and adjacent areas for plankton feeding fish stocks has been reached. However, compounding effects of a less productive Norwegian Sea during the 30-year period cannot be excluded. Higher migration cost associated with feeding area expansion could have contributed to declining growth and weight-at-length observed in recent years.

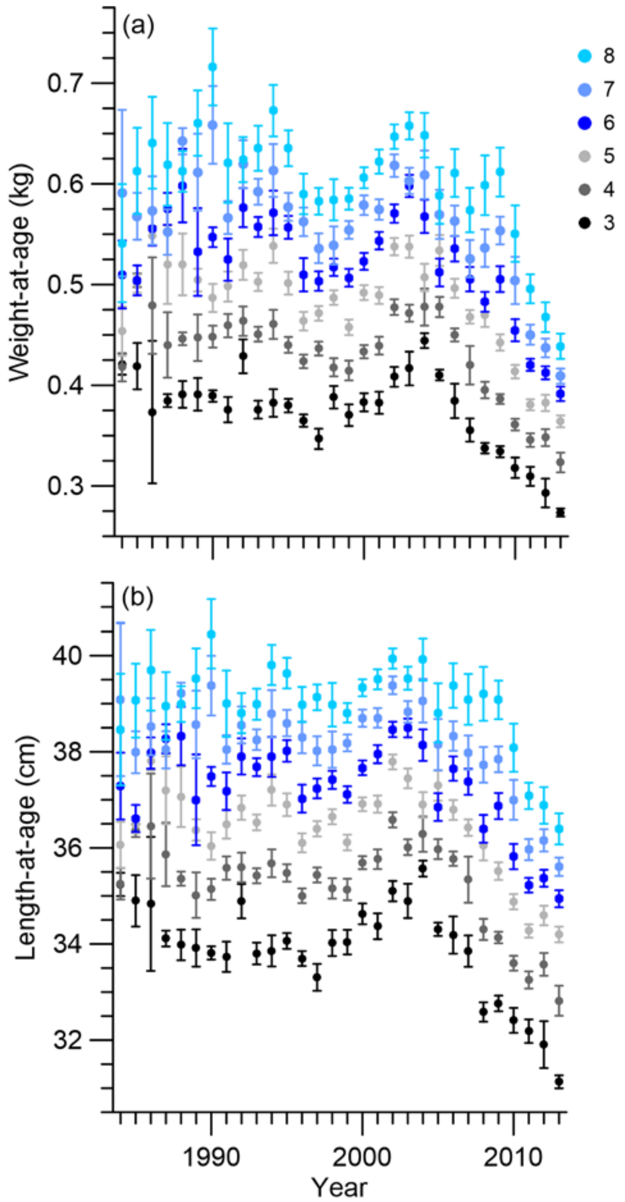


Figure 6.5.3. Mackerel annual average (± 95% CI) weight-at-age (W_a; a) and length-at-age (L_a; b) for 3- to 8-year-old individuals sampled in September and October from 1984 to 2013 (Ólafsdóttir *et al.*, 2015).

6.6 Mesopelagic fauna and other fish species

Mesopelagic fauna

Early estimates of global biomass of mesopelagic fish suggested a billion metric tonnes (Gjøsæter and Kawaguchi, 1980), but these were based on midwater trawling, which substantially underestimates biomass. Recent estimates are on the order of 10 billion metric tonnes i.e. hundred times more than present annual global fish landings (Lamhauge *et al.*, 2008, Irigoien *et al.*, 2014, FAO, 2014). On the top of this comes the biomass of animal groups other than fish in the mesopelagic zone. Uncertainty in mesopelagic fish biomass estimates remains colossal, but right or wrong, these suggest that a major component of the ocean ecosystems is not yet adequately studied and assessed. Few investigations of the mesopelagic fauna have been conducted in high latitudes compared with mid and tropical latitudes. To date, high latitude field studies have predominantly been conducted in fjords, but there remain considerable knowledge gaps regarding biomass of the mesopelagic fauna in Subarctic Seas.

Hydroacoustic data collected with echosounders during scientific surveys offer an opportunity to map the distribution of fauna from the Southern Norwegian Sea up to Svalbard and to study its vertical distribution and migrating behaviour. Six cruises conducted in recent years in the Norwegian Sea and to the west and north of Svalbard during summer, covering in total more than 7800 nautical miles, provide a first description of the distribution of mesopelagic fauna in the region (Figure 6.6.1) (Siegelman-Charbit and Planque, accepted). The acoustic energy recorded with the echosounders is generally greater in the mesopelagic than in the epipelagic layer (0–200 m). This is observed in all surveys analysed except for the northernmost latitude (Figure 6.6.2). The mean hydroacoustic energy in the epipelagic layer can be highly variable, and does not seem to follow any clear geographical pattern. On the other hand, the energy in the mesopelagic layer appears to decrease with increasing latitude. There was 3.4 times more acoustic energy recorded at low latitudes than at the highest. The measured acoustic energy in the Norwegian Sea suggests the presence of a dense layer of mesopelagic fauna known as the deep scattering layer (DSL). Although there was no appropriate sampling to estimate accurately species composition and abundance, the high levels of acoustic energy recorded suggest that the biomass in the mesopelagic layer may exceed that of the epipelagic layer, a pattern similar to what has been reported for tropical and subtropical regions. The depth of the deep scattering layer appears to vary in response to light, which confirms diel vertical migration as observed in other regions. This is in agreement with previously reported patterns for mesopelagic fish in the Norwegian Sea (Skjoldal, 2004) and Norwegian fjords (Balino and Aksnes, 1993; Kaartvedt *et al.*, 2008), and for other micronekton taxa in the Northeast Atlantic and for myctophid fish in western north Pacific. This has important implications for the functioning of the Norwegian Sea ecosystems as it suggests a strong coupling between the upper (epipelagic) layer of the ocean where most commercial fish species are harvested and the deeper (mesopelagic) layer where large biomass is suspected.

Aside from the major mesopelagic fish species frequently encountered in the Norwegian Sea such as *Maurolicus mülleri*, *Benthosema glaciale*, *Arctozenus risso* and *Argentina silus*, the biodiversity of this layer remains largely unknown and mesopelagic invertebrates such as some euphausiids, decapods, copepods, and gelatinous plankton could well represent a more important part of the biodiversity than it is commonly acknowledged. The cephalopod *Gonatus fabricii* is found from surface to 1500 m, but predominantly in the mesopelagic zone in the Norwegian sea of, and serves as an important food item for marine mammals (Bjørke, 2001) and fish. It is recorded to constitute at least 1.5 million tonnes in biomass by Bjørke and Gjøsæter (1998) in upper 30 m and 4.1 million tonnes by Dalpadado *et al.* (1998) based on trawling down to 600 m. Considerable knowledge gaps still remain, regarding trophic interactions within the mesopelagic layer as well as between the mesopelagic layer and shallower and deeper waters.

Progress in observation methodology gives new possibilities to examine the mesopelagic layer, and should be further explored (Kaartvedt *et al.*, 2008; Davison *et al.*, 2015).

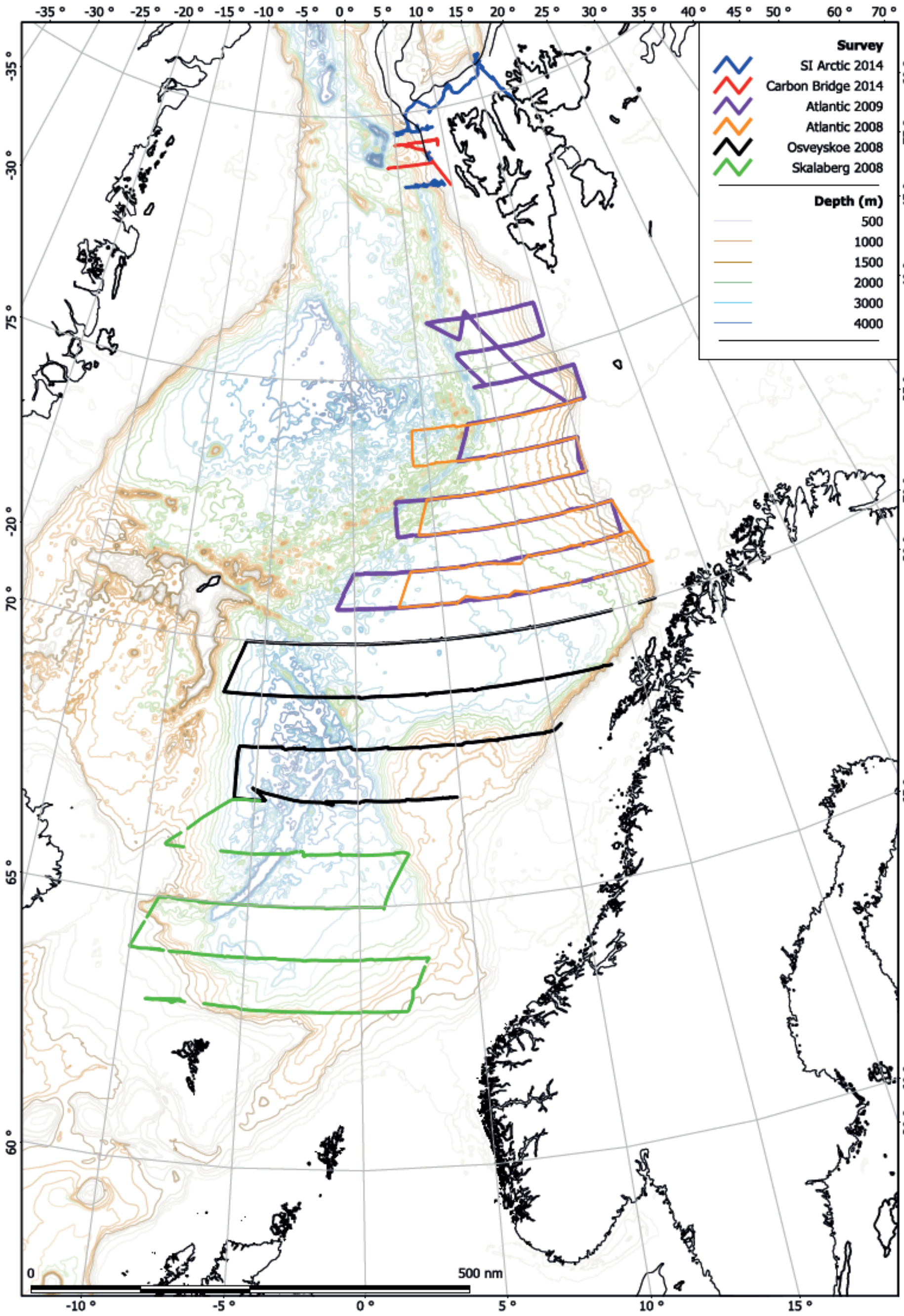
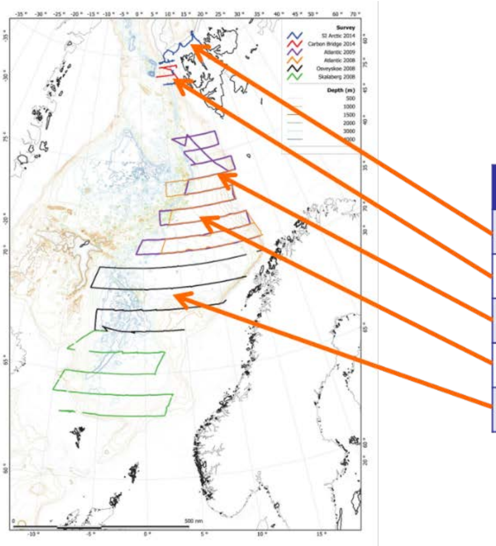


Figure 6.6.1. Hydroacoustic registering transects during six cruises in the Norwegian Sea and to the west and north of Svalbard during summer, between 2008 and 2014.



sA	epi	meso	m/e
Sl Arctic	170	66	0.4
Carbon bridge	18	61	3.4
Atlantic 09	71	140	2.0
Atlantic 08	116	133	1.2
Osveyskoe	87	215	2.5

Figure 6.6.2. Acoustic energy (SA) in the epipelagic and the mesopelagic zone by survey.

Deep-sea fish – Continental slope ecosystem

The continental slope around the Norwegian Sea constitutes a distinguished habitat for several benthic and fish species. Commercial fish species such as Greenland halibut (*Reinhardtius hippoglossoides*), beaked redfish (*Sebastes mentella*) and greater silver smelt (*Argentina silus*) are distributed along the slope from the Barents Sea to Greenland and there is connectivity between them. Although they are separated into different stocks one can assume that the deep-sea communities bear similarities along the slope, and it thus can be beneficial to include these species in an integrated assessment for the Norwegian Sea. Although the stock structure is not well known in all cases, there are considerable migrations between Barents Sea and Icelandic waters for Greenland halibut (Albert and Vollen, 2014). No annual survey covers the whole extent of the slopes, but several Nordic surveys do cover large part and provide data that may be sufficient for fish community studies (Figure 6.6.3) (ICES, 2010).

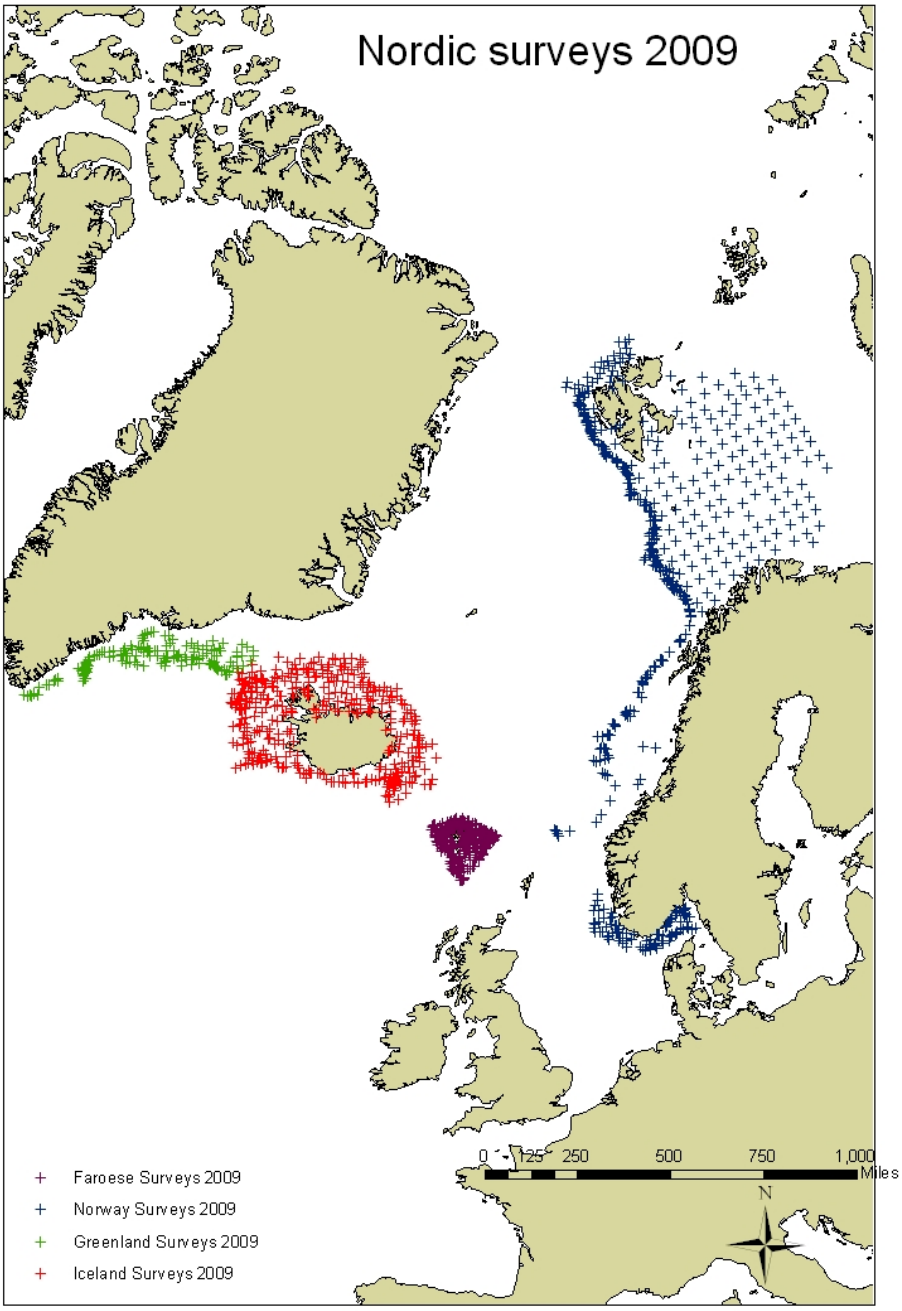


Figure 6.6.3. Survey coverage of the main Nordic Deep-water surveys (ICES, 2010).

Beaked Redfish

Adult individuals of beaked redfish (*Sebastes mentella*) are found scattered throughout the open waters of the Norwegian Sea (Bjelland and Holst, 2004). It is assumed to be a planktivore feeding on crustacean macrozooplankton (Bjelland and Holst, 2004). The biomass of redfish in the open Norwegian Sea during summer is estimated to at least ½ million tonnes and likely twice this amount or more (ICES, 2008; AGRED).

Dataseries

Spawning-stock biomass of beaked redfish is included (Annex 3; Figure 6.6.4). The SSB time-series was taken from the SCAA-assessment in ICES (2013a).

State and recent trends

The state of the stock is unknown, but the SSB appears to have been on a stable level in recent years (Figure 6.6.4).

Saithe

Large saithe (*Pollachius virens*) is probably a significant component of the pelagic complex in the Norwegian Sea as it is frequently caught in pelagic trawl hauls (Bjelland and Holst, 2004). However, the information regarding its feeding ecology in the Norwegian Sea is sparse, blue whiting (Kaartvedt *et al.*, 2005) and herring (Bjelland and Holst, 2004) seem to comprise an important part of the diet.

Dataseries

Stock biomass of saithe is included (Annex 3; Figure 6.6.4). Three saithe stocks were considered relevant to the Norwegian Sea ecosystem: (1) saithe in Subareas I and II (Northeast Arctic), (2) saithe in Division Vb (Faroe plateau) and (3) saithe in Subarea IV (North Sea), Division IIIa (Skagerrak), and Subarea VI (West of Scotland and Rockall), hereafter referred to as (1) Northeast arctic saithe, (2) Faroe saithe and (3) North Sea saithe. Migration from the shelf areas is more pronounced for large than for young saithe (Homrum *et al.*, 2013). To select “large saithe” from these stocks age groups with an average weight above 5 kg was somewhat arbitrary chosen. This corresponds to ages older than 8 years (9+) for Faroe and North Sea saithe and older than 9 years (10+) for Northeast arctic saithe. The biomasses of these components were obtained by multiplying the stocks weights at age with the corresponding estimated numbers-at-age. Data were taken from the latest ICES stock assessments (ICES, 2013a; 2013b; 2013c).

State and recent trends

All three saithe stocks are currently estimated at or slightly above B_{pa}, and all SSBs have been declining in recent years (Figure 6.6.4).

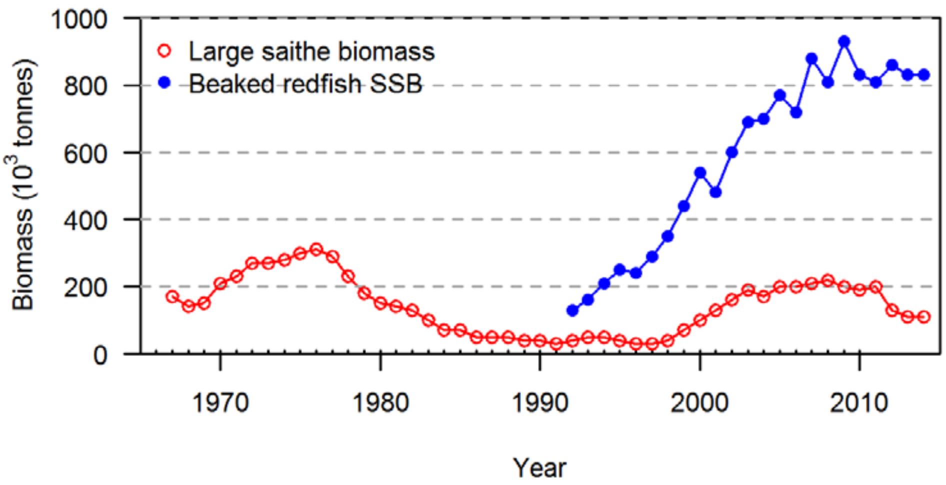


Figure 6.6.4. Historical development in biomass of beaked redfish and large saithe in the Norwegian Sea (see details in text).

Lumpsucker

Lumpsucker, or lumpfish (*Cyclopterus lumpus*), is apparently the most widely distributed species in the Norwegian Sea and adjacent waters. Results of the standardized surface trawl hauls in the July-August in Nordic Seas (IESSNS) show this clearly where it is caught in almost all of the predefined hauls (Figure 6.6.5; ICES 2015c). Lumpsucker is a pelagic species and preys on different kinds of gelatinous plankton, but also to some degree on crustaceans and small fish (Bjelland and Holst, 2004). It is only during spawning that, which takes place along the coasts in the North Atlantic, that lumpsucker is found near the bottom. Recent results on genetic structure of lumpsucker did not reveal a genetic difference in the Northeast Atlantic, indicating a single spawning group there (Pampoulie *et al.*, 2014). No estimation exists on stock size of lumpsucker in the region. Consequently, no time-series on state and trends were compiled for lumpsucker in Norwegian Sea, Furthermore, despite being widely distributed, their ecological role in the Norwegian Sea is considered to be small (Bjelland and Holst, 2004). The direct fishery for lumpsucker, which is mainly aimed for the roe, is generally managed on basis of bottom-trawl survey indices and/or catches (F-proxy). The main predators on lumpsucker are probably seals and some whale species.

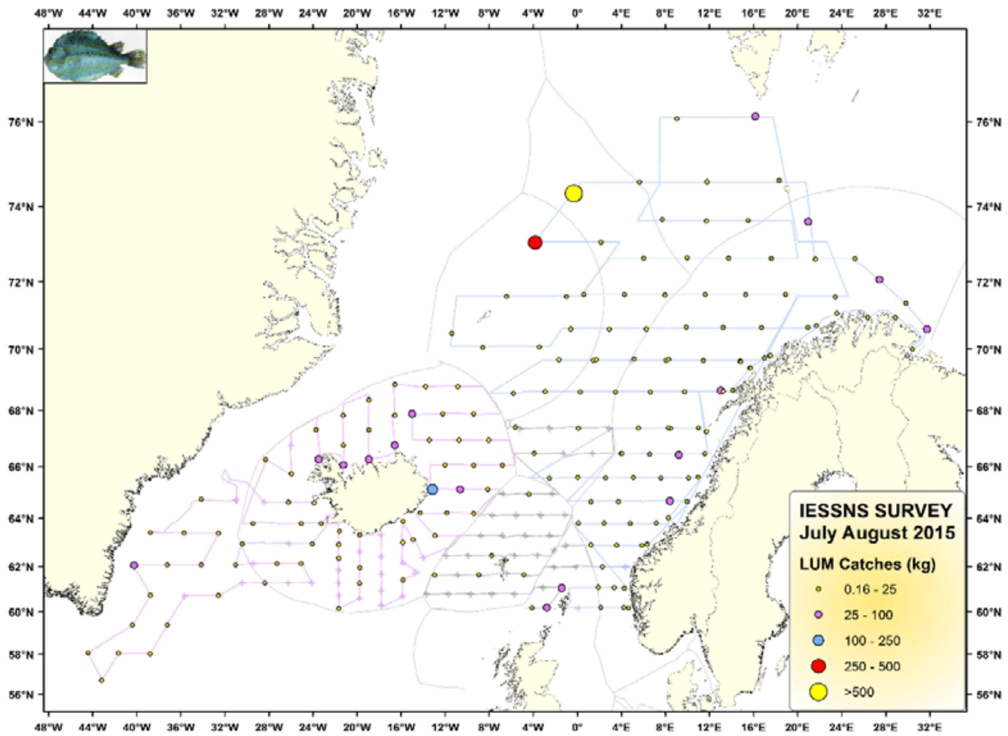


Figure 6.6.5. Lumpfish catches at surface trawl stations during the IESSNS survey in July and August 2015 (ICES, 2015c).

6.7 Marine mammals

Baleen whales are mainly present in the Norwegian Sea during summer while toothed whales are generally present year-round (Christensen *et al.*, 1992a). Hooded seals from the Greenland Sea breeding unit spend about 60% of their time on feeding excursions in the Norwegian Sea and adjacent continental slope areas (Folkow *et al.*, 1996).

The most commonly occurring baleen whale in the Norwegian Sea is the minke whale, followed by fin, and humpback whales. Stomach samples suggest a minke whale summer diet completely dominated by herring in the Norwegian Sea (Windsland *et al.,* 2007). Based on visual observations, pelagic fish are also likely the main prey of fin and humpback whales in the central Norwegian Sea (Nøttestad *et al.,* 2002). In more southern and northern areas, however, krill appears to be a more dominant prey for all three species (Ingebrigtsen, 1929; Sigurjonsson and Vikingson, 1997; Windsland *et al*., 2007).

Other pelagic feeding marine mammals in the Norwegian Sea area are killer whales, white beaked dolphins, harbour porpoises, grey seals, and harbour seals.

Due to their large biomass, sperm whales are the ecologically most important deep diving mammals in the Norwegian Sea. Stomach data from the Northeast Atlantic generally suggest a diet comprised by deep-water squid and mesopelagic fish, most notably lumpsucker (Martin and Clarke, 1986; Christensen *et al.,* 1992b). Other deep diving predators in the Norwegian Sea are hooded seals, northern bottlenose whales, and pilot whales, which are all thought to feed on a mixture of squid and fish.

Dataseries

Minke whales and Greenland Sea hooded seals are the only marine mammal species within the WGINOR core area, which are regularly monitored by dedicated surveys. The shipboard sightings surveys for minke whales in the Norwegian Sea is part of a six year monitoring cycle aiming to estimate the total summer abundance of minke whales in the Norwegian and Barents Seas as well as the area around Jan Mayen. Other marine mammal species encountered during these surveys are also recorded and it is believed that the surveys give reasonably reliable data on the summer occurrence of fin whales and humpback whales within the study area. Sperm whales are also sighted and recorded but so far no estimates have been corrected for the reduced sightability caused by the prolonged dives performed by this species. Correction factors from 1.5 to 9 have been reported in the literature (Gunnlaugsson *et al*., 2009; Sigurjonsson and Vikingsson, 1997). In their uncorrected form, however, the sperm whale estimates may serve as indicators of relative occurrence. No abundance estimates are derived for other species due to very small numbers of primary sightings (blue whales, sei whales, Northern bottlenose whales, harbour porpoises) or problems with estimation of group sizes (whitebeaked dolphins, whitesided dolphins, pilot whales, and killer whales).

Abundance is regularly estimated for harbour and grey seals along the Norwegian coast, but these species are so far considered to be outside the core area of WGINOR. Based on available satellite tracking data, harp seals are also generally expected to be distributed outside the WGINOR core area (Folkow *et al.,* 2004, Nordøy *et al.,* 2008).

Based on ecological relevance and data availability, the working group decided to limit its focus on marine mammals to minke whales, fin whales, humpback whales, sperm whales and hooded seals.

Table 6.7.1. Data availability on abundance of marine mammal species selected for inclusion in the work of WGINOR. All datasets are collected by the IMR.

Species	Abundance estimates
Fin whale	1987–89; 1995; 1996–2001; 2002–2007; 2008–2013
Humpbacks	1987–89; 1995; 1996–2001; 2002–2007; 2008–2013
Minke whales	1987–89; 1995; 1996–2001; 2002–2007; 2008–2013
Sperm whales	1987–89; 1995; 1996–2001; 2002–2007; 2008–2013
Hooded seals	1945–2013 (model estimates), 2005, 2007, 2012 (surveys)

State and recent trends

Table 6.7.1 shows the most recent published abundance estimate and estimated total biomass of the five selected species of marine mammals. Mean weights are taken from Dommasnes *et al.* (2000).

Table 6.7.2. Most recently published abundance estimates for focal marine mammal species and total estimated biomass. Sources: [1]Øien, 2009., [2]Bøthun *et al.*, 2008., [3]ICES, 2011., [4]Dommasnes *et al.*, 2000.

Species	period	Est. Abundance	Mean Weight (Kg)	Est. Total Biomass (tonnes)
Fin whales	1996–2001	6 409[1]	42 279[4]	270 966.1
Humpback whales	1996–2001	1 450[1]	31 782[4]	46 083.9
Minke Whales	2002–2007	44 445[2]	5 251[4]	233 128.1
Sperm Whales	1996–2001	6 207[1]	34 322[4]	213 842.0
Hooded seals	2007	91 000[3]	262[4]	23 842

For all species more recent data are available and are currently being analysed. These data will be made available to WGINOR as soon as possible.

Currently, no clear trends are known for the available dataseries of whale occurrence in the Norwegian Sea. Preliminary analyses of the most recent surveys may, however, suggest changes in either abundance or distribution (Nils Øien, pers. comm.). In a wider historical perspective it is, however, clear that the abundance of large baleen whales and sperm whales were reduced during the period of commercial whaling and have not recovered to previous levels. For hooded seals, catch based modelling shows a dramatic decline in abundance over the period 1945–1980 (see Figure 6.7.1). This decline is thought to be mainly catch-driven. The catches were significantly reduced from the early 1980s to 2006, but may nevertheless have been an important factor for the lack of recovery. Other factors such as possible changes in food availability and natural mortality can, however, also not be ruled out. Hooded seals have been completely protected since 2007.

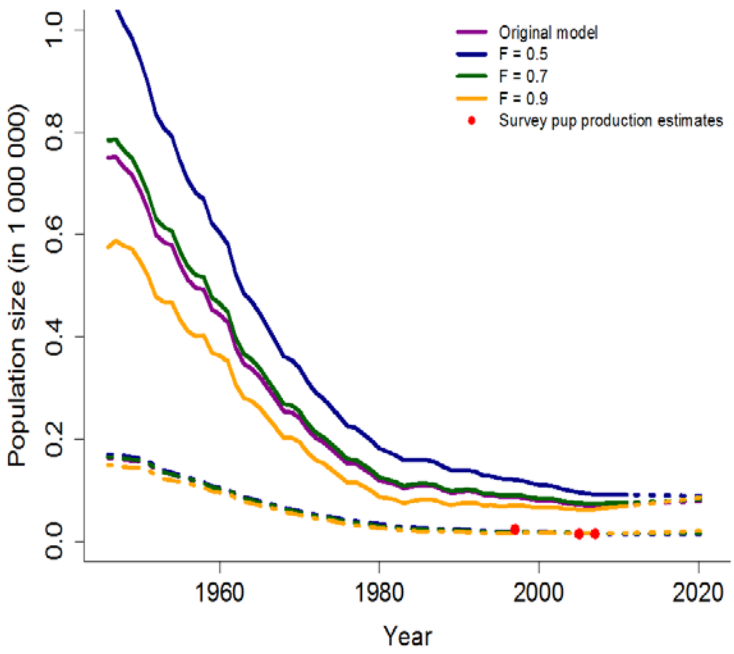


Figure 6.7.1. Modelled abundance of Greenland Sea hooded seals. F refers to different options for pregnancy rates. Currently a pregnancy rate of 0.7 is assumed for this population (from ICES, 2011).

6.8 Seabirds

Seabird species in the Norwegian Sea

Three species of seabirds feeding in the pelagic part of the ecosystem have been selected to be included in the analyses. These are black-legged kittiwake (*Rissa tridactyla*), Atlantic puffin (*Fratercula arctica*) and common guillemot/common murre (*Uria aalge*). The reason for selecting these species is that they feed in different parts of the pelagic ecosystem. The black-legged kittiwake obtains its food within the upper half meter of the sea surface layer in the form of (in the Norwegian Sea) first-year herring, sandeels, gadids, lanternfish, crustaceans, and pteropods. The common guillemot is a pelagic fish specialist, which typically feeds at depths down to 80 metres. Although the breeding adult may feed heavily on very small fish such as 0-group cod (Erikstad *et al.*, 2014), it feeds its chick (in the Norwegian Sea) sandeel, young saithe or herring brought back to the colony one by one. The Atlantic puffin typically feeds at depths down to 30 metres and brings loads of smaller fish to the chick, in the Norwegian Sea in particular first-year herring along with sandeel and gadids, but outside the breeding season, they also feed on crustaceans. Average total lifespan for birds that reach maturity is around 10–12 years for black-legged kittiwake, 25–30 years for common guillemot and 15–20 years for Atlantic puffin. Kittiwakes typically lay two (1–3) eggs, whereas the common guillemot and Atlantic puffin lay a single egg. Except for the breeding season, all three species spend their entire life at sea.

Population sizes

The total population size of seabirds breeding on the coasts of the Norwegian parts of the Norwegian Sea has recently been re-estimated based on the latest counts in all areas (Table 6.8.1, Anker-Nilssen *et al.*, 2015), which on the mainland were also adjusted for trends in numbers at the monitored colonies (Fauchald *et al.*, 2015). Insufficient data did not allow such calculations for northern fulmar and black guillemot, but we have subjectively adjusted the estimate for the former to account for some very apparent recent declines.

Table 6.8.1 Estimated population sizes (numbers of breeding pairs) of seabirds in the Norwegian parts of the Norwegian Sea in 2013, compared to the Norwegian and European totals (after Fauchald *et al.*, 2015, Anker-Nilssen *et al.*, 2015, adjusted for fulmar numbers (see text), European numbers are from Mitchell *et al.*, 2004).

Species	Mainland coast	Jan Mayen	Sum	Norway total (incl. Svalbard and Jan Mayen)	Europe total
Northern fulmar	< 1 000	> 170 000	**177 500**	± 1 000 000	3 000 000
European storm-petrel	> 1 000	0	**> 1 000**	< 10 000	690 000
Leach's storm-petrel	> 100	0	**> 100**	< 1 000	150 000
Northern gannet	3 600	0	**3 600**	5 700	300 000
Great cormorant	13 500	0	**13 500**	21 000	45 000
European shag	9 000	0	**9 000**	28 000	81 000
Common eider	41 000	< 100	**41 000**	104 000	2 000 000
King eider	0	0	**0**	500	500
Great skua	90	< 10	**100**	1 100	16 000
Arctic skua	< 1 000	< 10	**< 1 000**	3 000	17 500
Common tern	< 3 000	0	**< 3 000**	< 11 000	300 000
Arctic tern	20 000	< 1 000	**21 000**	< 40 000	750 000
Common gull	75 000	0	**75 000**	90 000	500 000
Lesser black-backed gull	6 500	< 10	**6 500**	28 000	180 000
Herring gull	42 000	< 10	**42 000**	72 000	850 000
Glaucous gull	0	> 200	**> 200**	4 000	21 500
Great black-backed gull	30 000	< 10	**30 000**	43 000	120 000
Black-legged kittiwake	44 000	< 10 000	**> 50 000**	340 000	2 500 000
Ivory gull	0	0	**0**	2 000	2 000
Common guillemot	2 600	< 1 000	**> 3 000**	150 000	2 900 000
Brünnich's guillemot	0	> 110 000	**> 110 000**	725 000	1 000 000
Razorbill	< 10 000	< 100	**< 10 000**	55 000	500 000
Little auk	0	< 100 000	**< 100 000**	± 1 000 000	> 1 000 000
Black guillemot	15 000	< 1000	**> 15 000**	55 000	200 000
Atlantic puffin	553 000	< 5 000	**< 558 000**	1 500 000	5 500 000
Total	870 000	400 000	**1 270 000**	5 500 000	23 000 000

Only for three species that are relatively sparse in numbers (northern gannet, lesser black-backed gull and great skua), the estimates are higher than the previous ones published by Anker-Nilssen and Lorentsen (2004) and Barrett *et al.* (2006). For many of the more abundant species, such as the Atlantic puffin, several gulls (including the black-legged kittiwake), common eider and the two cormorants, numbers have dropped substantially and mainly reflect substantial population declines in the last decade (see below).

Dataseries

Time-series of abundance of populations breeding along the Norwegian coast is assessed from their estimated total size in 2013 (Fauchald *et al.*, 2015) and relative changes in populations size in selected breeding colonies (Figure 3, performed through the SEAPOP programme). The main colonies monitored (key-sites) along the Norwegian Sea coastline of Norway are Runde (all species), Sklinna (all species), Røst (all species), Anda (black-legged kittiwake and Atlantic puffin), and Jan Mayen (common guillemot), but the latter time-series is still too short (initiated 2010-11) to allow valid trend estimation. Guillemots at Sklinna have not been included. This may be done, but will change the overall estimate very little. For common guillemots, no monitoring was done in the years 1984–1987, and index values have been estimated assuming a constant change between these years.

State and recent trends

Data for seabird population trends for this report were only available from the Norwegian coast, where most of the annual monitoring of the three focal species was initiated in 1979-1980.

Black-legged kittiwake

The breeding population of black-legged kittiwake in the Norwegian part of the Norwegian Sea has declined by 86% since monitoring started in 1980. Its outlook is grim, with many colonies risking going extinct within this century (Sandvik *et al.*, 2014).

Atlantic Puffin

For the Atlantic puffin the breeding population in the Norwegian part of the Norwegian Sea has declined by 72% since monitoring started in 1980.

Common guillemot

The breeding population Norwegian part of the Norwegian Sea has declined by as much as 99% since monitoring started in 1980 and the species is at high risk of extinction as a breeding species along the Norwegian mainland coast of the Norwegian Sea.

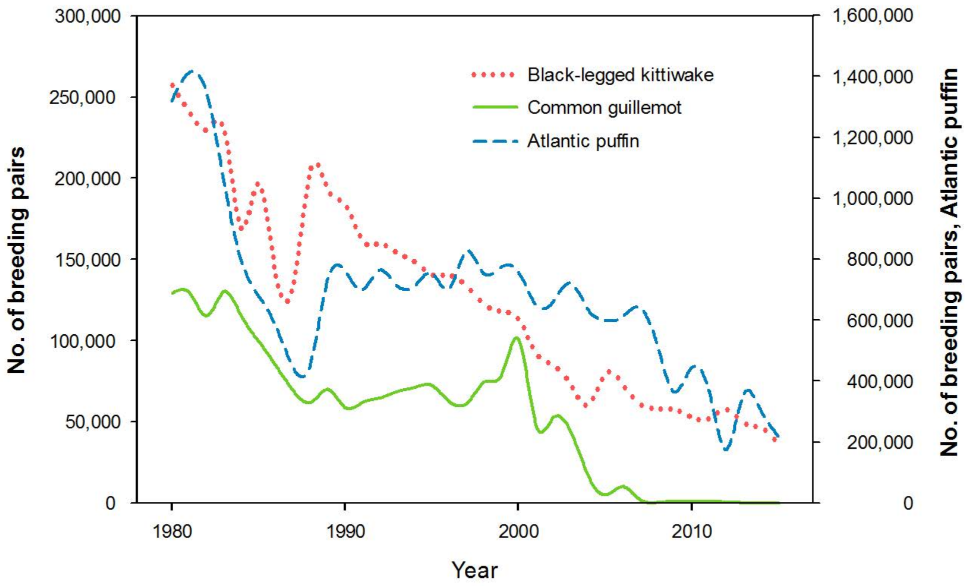


Figure 6.8.1. Development in the breeding populations of black-legged kittiwake, common guillemot and Atlantic puffin in the Norwegian part of the Norwegian Sea in the period 1980–2013.

The causes for the negative trends registered for breeding seabirds in the Norwegian Sea are not fully understood, but changes in food availability and climate play a major role. This has recently been clearly demonstrated by a study of the common guillemot in the Barents Sea (Mesquita *et al.*, 2015), which is also an important post-breeding area for many seabirds from the Norwegian Sea, including common guillemots (Lorentsen and May, 2012; Erikstad *et al.*, unpublished data), black-legged kittiwakes (Moe *et al.*, unpublished data) and Atlantic puffins (Anker-Nilssen and Aarvak, 2009a). At the SEAPOP key-sites on the Norwegian coast (i.e. Runde, Sklinna, Helgeland, Røst, and Anda), numbers of most species have dropped drastically over the last decade, although common guillemots and razorbills have been doing reasonably well where they breed in shelter (Barrett *et al.*, 2013, 2015). Access to shallow coastal waters and fjord systems in close vicinity of the colonies seems however to be of extra value when the supply of pelagic prey fails, as illustrated by an overall poorer success in these years for the pelagic species at Røst than at the other key-sites (SEAPOP data portal, www.seapop.no). A key factor in this context is the long-term lack of 0-group herring, perhaps the most important food source for pelagic seabirds along the mainland coast of the Norwegian Sea. Breeding failure has been observed as the typical result for both Atlantic puffins and black-legged kittiwakes when herring year-class strength drops below one third of its historical maximum (Cury *et al.*, 2011). The Norwegian spring-spawning herring has not produced a strong year class since 2004, and none of the breeding seasons after 2006 can be termed as successful for pelagic seabirds in this part of the Norwegian Sea. This is surprising as the general environmental conditions for the production of *Calanus finmarchicus* were seemingly reasonably adequate over the same period (Frederiksen *et al.*, 2013). It is therefore of extra interest to know to what extent the failing recruitment of herring can be attributed to the extreme expansion and stock increase of mackerel in the Norwegian Sea since 2007 (Nøttestad *et al.*, 2015). The extensive tracking of seabird movements with geolocator loggers now undertaken by the SEATRACK module of

SEAPOP, will vastly increase our knowledge of where seabirds spend the non-breeding season, and allow us to study effects on their population dynamics from conditions encountered far away from their breeding grounds. An interesting example is the impact of Thecosomata snail abundance off New Foundland in winter on the adult survival of black-legged kittiwakes from Hornøya (Reiertsen *et al.*, 2014).

In contrast to Atlantic puffins and black-legged kittiwakes, breeding common guillemots and razorbills are able to forage efficiently in shallow waters where they can access and utilize other prey such as sandeels (including greater sandeel) and 0-group saithe. As these large auks are doing better where they breed in shelter, the decrease of their populations on exposed ledges is probably also an effect of increased disturbance and predation pressure from non-breeding white-tailed eagles that boosted in numbers on the Norwegian coast in the late 1990s (Hipfner *et al.*, 2012). This effect is also documented as a very significant factor limiting chick production of black-legged kittiwakes (Anker-Nilssen and Aarvak, 2009b). The rich kelp forest along this coastline is also the nursery ground for young saithe, which has proved to be an important food source for European shag (Lorentsen *et al.*, 2015), probably also for common guillemots, black guillemots, and Arctic terns (SEAPOP data portal www.seapop.no and unpublished data).

Ecosystem interactions

The numbers of breeding pairs of three species of seabirds (kittiwake (*Rissa tridactyla*), Atlantic puffin (*Fratercula arctica*) and common guillemot/common murre (*Uria aalge*)) have been declining more or less the whole time-series from early 1980s. The main diet of these species varies from zooplankton, fish larvae and juveniles, to adult pelagic fish. The reasons for the declining seabird populations are not obvious and possibly not the same for the three species focused in this report. All three spp. also feed on adult sandeels and capelin.

6.9 Human pressures

Human pressure on pelagic fish stocks

The most prominent human pressure in the Norwegian Sea is commercial fishing. Shipping and non-renewable energy production, oil and gas, are other large activities, but in spatial scale these activities are not regarded as significant pressures on the Norwegian Sea ecosystem. Therefore, fishery is the only human activity discussed. Total annual landings of the different pelagic species are highly variable and range from 7000 tonnes to 2.4 million tonnes over the period 1969–2014 (Figure 6.9.1a). Landing numbers are provided as the total annual landings in all ICES rectangles (ICES, 2015a). Landing volumes cannot be subsampled to present only fishing that occurred within the Norwegian Sea for the whole time-series. For the time-series, average annual landings are similar for all species, range from 0.65 to 0.77 million tonnes. Apparently, the mackerel landings vary the least. It is worth noting that mackerel landings were probably higher than reported landings in the period before 2000 as large amount of landings were likely not reported (Simmonds *et al.*, 2010; ICES, 2014).

Fishing mortality (F) for the three pelagic species is displayed in Figure 6.9.1b. For the period of study, blue whiting has the highest average F and the largest variability of F ranging from 0.04 to 0.56. Herring has the lowest average F, which is equal to F_{MSY} (maximum sustainable yield, 0.15) and annual variability is relatively small. Compared to herring, mackerel and blue whiting have higher average F which exceed the recommended F_{MSY}, 0.22 and 0.30, respectively (ICES, 2015).

There is a seasonal pattern in geographical location of fishing and this pattern has changed extensively during the last two decades. General overview of historical catch distribution patterns can be found in ICES (2013e) for mackerel, Anon (2014) for herring, and NEAFC (2014) for blue whiting. The most recent description of the fishing pattern derives from 2014 (ICES 2015a), which shows that the mackerel winter (Q1) fishery mainly occurs on the shelf and shelf edge from Portugal to Hebrides and expands to the Norwegian Sea, south coast of Iceland and the North Sea in spring (Q2). In summer (Q3), majority of catches are caught north of latitude 63 N across the NE-Atlantic from Greenland to Norway. In autumn (Q4) fishing occurs in the southern part of the Norwegians Sea but concentrates in the northern North Sea (ICES, 2015a). The blue whiting is mainly harvested during and after spawning to the west of the British Isles and south of the Faroe Islands during winter and spring. Herring is harvested along the Norwegian Coast in winter. There is limited fishery during spring. Summer fishery occurs mainly outside the Norwegians Sea in Icelandic, Faroese and Greenlandic waters, extending northward to Jan Mayen and Svalbard. In autumn the fishery moves gradually northwestwards to the overwintering grounds.

Fishing pressure in the Norwegian Sea is constantly changing depending on spatial distribution of the fish stocks, economic conditions, fisheries regulations, market option etc. These changes occur within and between years or over long periods. The Norwegian fishery in the Norwegian Sea is to large extent carried out by purse-seines while the rest of the European fishing fleet uses pelagic trawl. Some jigging occurs but purse-seine and pelagic trawls are the most common fishing gears used in the Norwegian Sea ecosystem.

Fisheries of pelagic fish species are reported through the national fisheries authorities and is statistically treated and stored within ICES by the working group on widely dispersed stocks (WGWIDE).

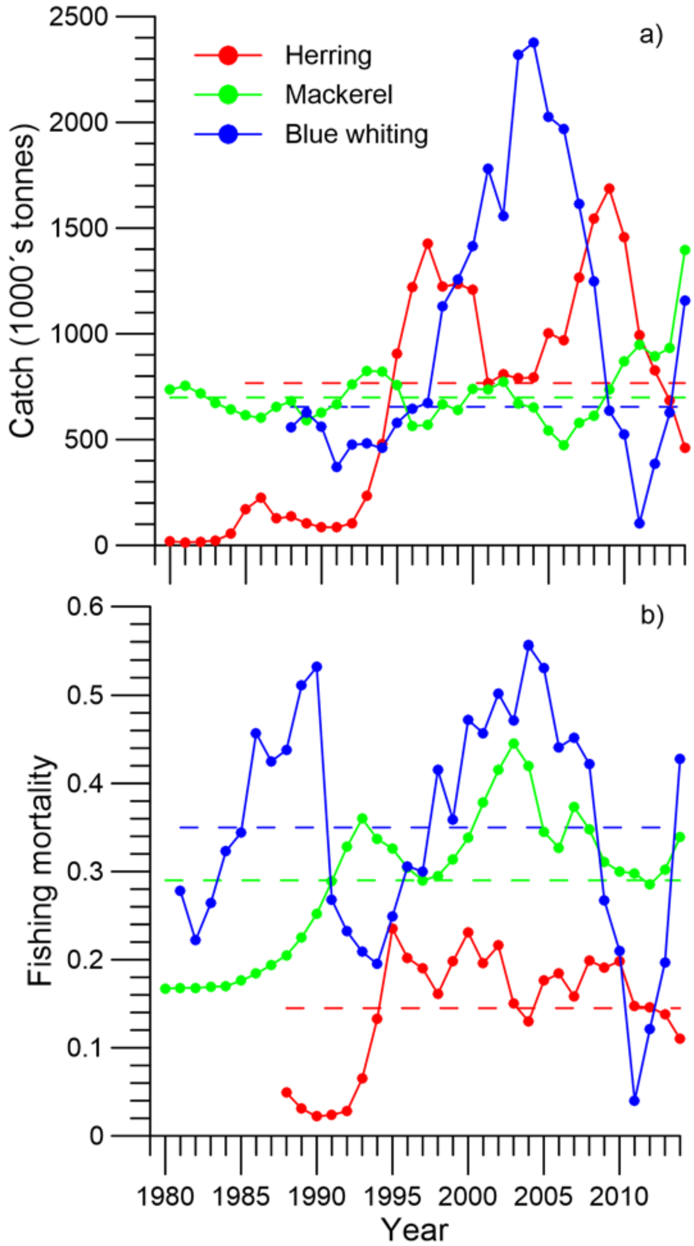
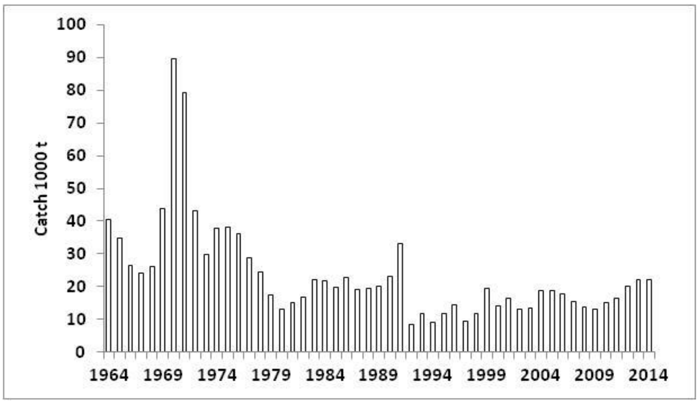


Figure 6.9.1. Annual landings (a) and fishing mortality (b) of NE Atlantic Mackerel, Norwegian spring-spawning herring and blue whiting (ICES,2015a). Also displayed is average value for each time-series (broken horizontal line). Average herring catch is calculated for 1985 to 2014 as the herring fishery was closed from 1980 to 1984.

Human pressure on demersal fish stocks

Catch of Greenland halibut in ICES areas I and II was high and unregulated until 1992 when a moratorium was introduced, with the exception fisheries by artisanal vessels in Norway and research quota (Figure 6.9.2.1). The moratorium was ended in 2009 and the fisheries are now managed by TAC. Since 1992, catches have been in the range 10–20 thousand tonnes, and harvest rate rather stable.

A pelagic fishery for *S. mentella* has developed in the Norwegian Sea outside EEZs since 2004 (Figure 6.9.2.2). This fishery is managed by the North-East Atlantic Fisheries Commission (NEAFC) who, by consensus, adopted a TAC for 2014 of 19 500 t. Other catches of *S. mentella* are taken as bycatch in the demersal cod/haddock/Greenland halibut fisheries, as juveniles in the shrimp trawl fisheries, and occasionally in the pelagic blue whiting and herring fisheries in the Norwegian Sea. In March 2014, Norway opened for directed fishing by Norwegian vessels with pelagic and demersal trawls targeting *S. mentella* in the Norwegian Economic zone, with a TAC for 2014 of 17 280 t. This TAC must also cover catches of redfish in other fisheries. The Russian bycatch of redfish (*S. mentella* and *S. norvegicus* combined) in the Norwegian EEZ is in 2014 limited to 4000 t.



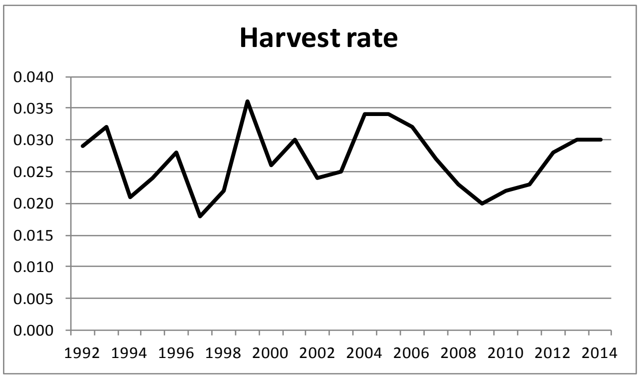


Figure 6.9.2.1. Greenland halibut in Subareas I and II. Catches (thousand tonnes) and harvest rate (defined as reported catch in a year divided by modelled biomass at the start of the year) (AFWG).

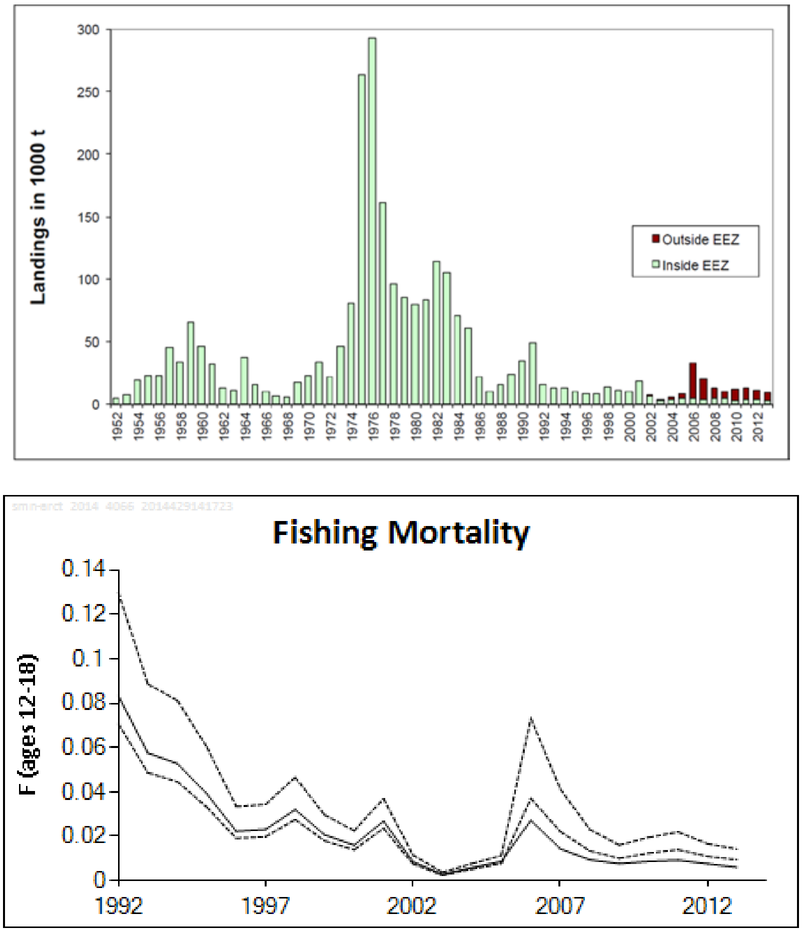


Figure 6.9.2.2. *Sebastes mentella* catches in Norwegian Sea outside and inside of EEZs during the period 1952–2013 (upper panel) and estimated fishing mortality with 95% confidence interval around it (lower panel) (AFWG).

6.10 Interactions between ecosystem components and overall ecosystem trends

A fair amount of work has been done in the past to explore the interaction between the ecosystem components in Norwegian Sea and a general overview been provided by Skjoldal *et al.* (2004) (Figure 6.10.1). Different environmental pressures are affecting these different ecosystem components in various ways. The following discussion represents some very preliminary and not yet fully analysed results on compiled data by WGINOR of relevant ecosystem components in Norwegian Sea and their interaction.

One of the things that was accomplished at the 2015 WGINOR meeting was to calculate the zooplankton index from the May survey (IESNS) in a more robust way than the previously used index (see section 6.4), which has been used in various publications (e.g. Ólafsdóttir *et al.*, 2015) and reports (ICES, 2015b; Homrum *et al.*, 2016). Consequently, the Working Group recommends using these new indices for the different areas in future, which are provided in Table 6.4.1. There is a clear discrepancy between the new and old estimations of mean dry weight of zooplankton in the whole Norwegian Sea (Figure 6.10.1), so all relationships previously used and/or tested (e.g. between zooplankton and fish stock's related variables) need to be revisited and revised.

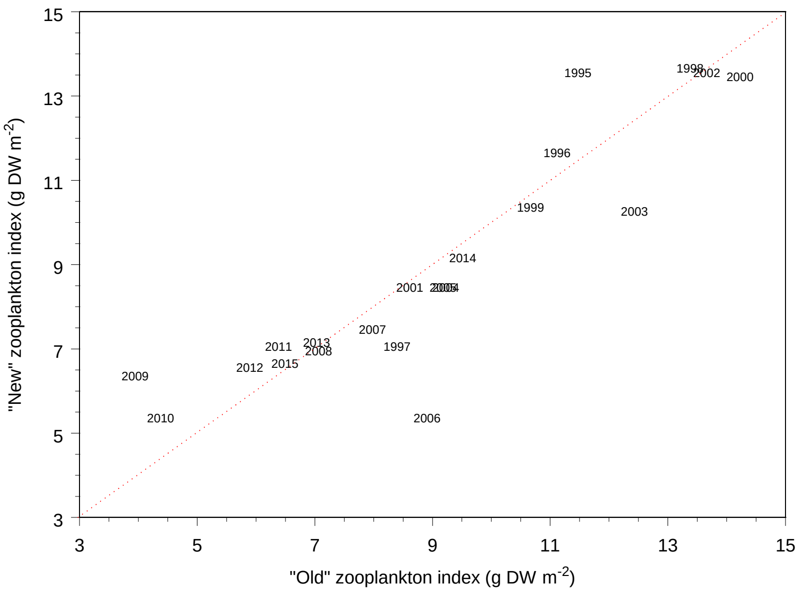


Figure 6.10.1. Comparison of "old" (e.g. time-series provided in ICES, 2015b) and "new" (from Table 6.4.1) indices of mean mesozooplankton dry weight (g m^{-2}) in the Norwegian Sea in May 1995–2015, where years are shown on the graph.

In the period from mid 1980s to 2009, the total biomass of herring increased gradually but there have been a downward trend in recent years due to poor recruitment from 2005 and onwards (Figure 6.5.1). During the same period (~ 2000–2010) there was an opposite trend for the individual length-at-age (Figure 6.5.2), which has been shown to be density-dependent (Homrum *et al.,* 2016). Similar pattern was observed for mackerel, or a negative relationship between the total biomass (Figure 6.5.1) and length-at-age since mid-2000s (Figure 6.5.2 and Figure 6.5.3) representing density-dependent growth (Ólafsdóttir *et al.*, 2015). The index of zooplankton in the Norwegian Sea (i.e. the new index; Figure 6.4.3) was found to be negatively related to herring SSB ($r^2 = 0.31$, n = 20, p = 0.01) and mackerel SSB ($r^2 = 0.20$, n = 20, p = 0.05), while not to biomass of blue whiting ($p > 0.05$). Thus, the biomass of zooplankton could apparently be affected by the biomass of mackerel and herring, while strong interpretation from the results should not be drawn until a more comprehensive analyses have taken place.

The numbers of breeding pairs of three species of seabirds have been declining more or less the whole time-series from early 1980s. The main diet of these species varies from zooplankton, fish larvae, and juveniles, to adult pelagic fish (guillemot). The reason for the declining seabird populations is not obvious and the reason is possibly not the same for all three seabird species.

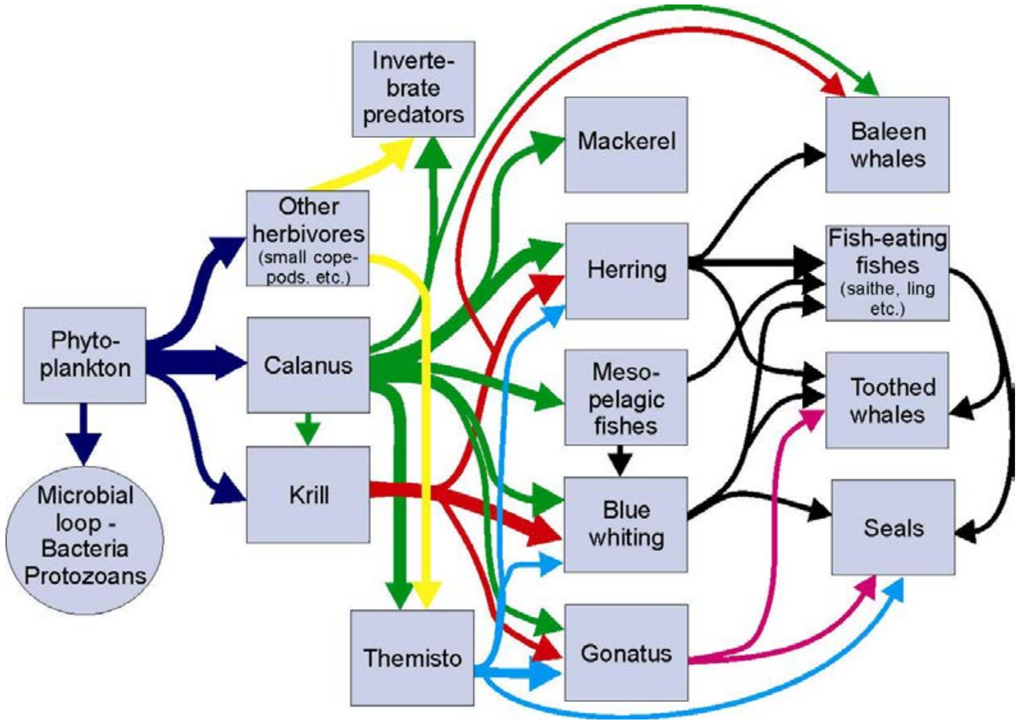


Figure 6.10.1. A conceptual diagram for the structure and functioning of the Norwegian Sea ecosystem.

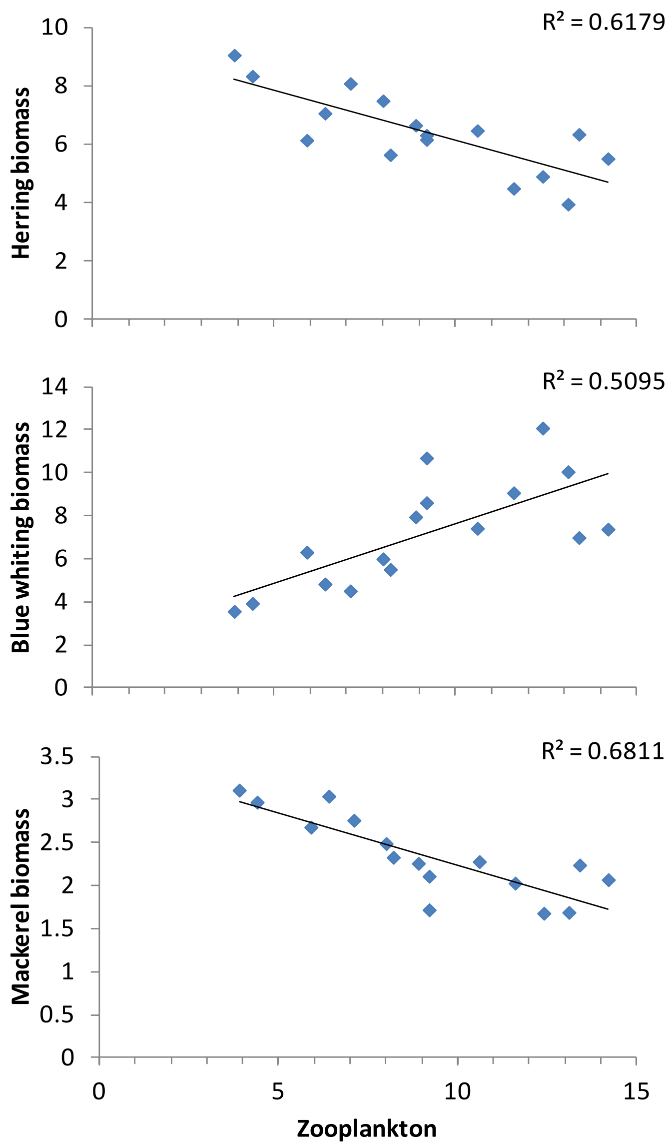


Figure 6.10.2. Scatterplot of the biomass of pelagic fish against the mesozooplankton in the Norwegian Sea.

6.11 Trophic ecology of the NEA mackerel, NSS herring and blue whiting in the Norwegian Sea

The feeding and diet composition of the NEA mackerel, NSS herring, and blue whiting in the Norwegian Sea both during spring and summer, from 2005 to 2010, have been investigated at the IMR (Norway) (Bachiller *et al.*, 2016; Bachiller *et al.*, in prep.). All the analyses were based on data from Norwegian fish stock monitoring surveys as well as from commercial vessels fishing in the area (Figure 6.11.1). A similar work was done for NSS herring and NEA mackerel collected in surveys during the feeding season in 2009–2011 in Icelandic waters (Óskarsson *et al.*, 2015) and the results are as well presented here as appropriate.

Stomach fullness degree in NSS herring decreased from spring to summer and feeding incidence was lower than that of NEA mackerel in summer. However, stomach fullness degree was not different between the two species, indicating that herring maintain equally effective feeding as NEA mackerel in summer. Feeding incidence increased with decreasing water temperature for all species, and for NEA mackerel also stomach fullness degree, indicating that feeding activity is highest in areas associated with colder water masses. For blue whiting, stomach fullness degree, feeding incidence and condition factor increased with length. These results suggest that the three species have the ability to adapt their feeding activity to different conditions all over the Norwegian Sea and during the whole feeding period (Bachiller *et al.*, 2016).

Regarding the diet composition, blue whiting generally had low diet overlap with NEA mackerel and NSS herring, broader diet composition and a dominance of larger prey like euphausiids and amphipods (Figures 6.11.2. and 6.11.3). NEA mackerel showed high feeding overlap with NSS herring in summer (especially when they co-occurred) and similar diet width, mainly based on calanoid copepods, especially *C. finmarchicus* (dominant in the Norwegian Sea), but also incorporating larger prey when available (Figures 6.11.2 and 6.11.3). In addition, it seemed that NSS herring changed the diet composition from May to July, with higher ingestion on larger prey later in summer, when NEA mackerel was incorporated to the feeding area. These results are in coherence with the adjoining Icelandic waters where Copepoda were the most important food of mackerel in most areas while Copepoda and Euphausiacea were the most important food items for herring during summer (Óskarsson *et al.*, 2015). However, the diet composition can vary interannually. For instance, appendicularians dominated NSS herring diets from 2007 to 2009 in the Norwegian Sea, and almost 75% of blue whiting diet consisted of *C. finmarchicus* in spring 2005 (Figure 6.11.3) (Bachiller *et al.*, 2016). These results suggest a higher potential trophic interaction between NSS herring and NEA mackerel, and less effect on blue whiting, normally distributed in deeper waters than the other two species and with a different diet composition (Bachiller *et al.*, submitted). However, if food is in sufficient amount, a high diet overlap does not necessarily mean competition between the species (Bachiller and Irigoien, 2015). In order to determine the potential effects of different feeding success between the species, both the intraguild predation and the zooplankton consumption have to be investigated.

According to the intraguild predation, Skaret *et al.* (2015) investigated the potential effects of the NEA mackerel predation on herring larvae in an area of spatial overlap within the Norwegian coastal shelf (between about 66°N and 69°N), in early summer 2013. NEA mackerel were dispersed close to the surface but were caught in all but one of the trawl hauls for the study; herring larvae were caught in all samples. 45% of the NEA mackerel guts contained herring larvae, with a maximum of 225 larvae counted in a single gut; herring larvae contributed an important amount of the total ingested prey weight in the mackerel diet in that period and area (Figure 6.11.4). Both the frequency of guts containing herring larvae and the average amount of herring larvae increased in line with increasing abundance of larvae. On the other hand, no spatial correlation between mackerel abundance and herring larvae abundance was found at the station level. The results suggest that mackerel fed opportunistically on herring larvae, and that predation pressure therefore largely depends on the degree of overlap in time and space (Skaret *et al.*, 2015).

On the other hand, a study by Bachiller *et al.* (in prep.) is now using bioenergetics modelling to estimate the annual consumption of the main zooplankton groups by the NEA mackerel, NSS herring, and blue whiting in the Norwegian Sea. By incorporating information about seasonal growth (derived from fish length and weight observations; Figure 6.11.1; Bachiller *et al.*, in prep) and changes in the diet from stomach content analyses (Bachiller *et al.*, 2016), annual consumption of the different zooplankton groups by pelagic fish can be estimated. Preliminary results show that NSS herring and NEA mackerel increased their total zooplankton consumption from 2005 to 2009, decreasing a bit in 2010 (Figure 6.11.5). The total consumption is higher in NSS herring than in NEA mackerel or blue whiting (Figure 6.11.5), but NEA mackerel had a higher consumption/biomass ratio from 2006 to 2008 (consuming between 9 and 11 times their total biomass), and differences were small for the other years (Figure 6.11.6). This estimated ratio for NEA mackerel is around three times higher than previously estimated by Skjoldal *et al.* (2004) for mackerel in Norwegian Sea and by Óskarsson *et al.* (2015) for mackerel feeding in Icelandic waters assuming gross conversion efficiency of 10%. Blue whiting showed much lower total zooplankton consumption (e.g. consuming 3–4 times their total biomass) compared with the other two species (Figures. 6.11.5 and 6.11.6). The main prey groups consumed were calanoids, appendicularians or euphausiids and amphipods, but the relative importance of each group show interannual variability, with differences in the relative importance compared with observations based on the diet composition analysis (Bachiller *et al.*, 2016). For instance, in 2005–2006 the total consumption of herring was mainly comprised by calanoids, whereas in 2007 and 2008 the predation pressure seemed to be unexpectedly higher upon appendicularians and larger krill (Figure 6.11.7) (Bachiller *et al.*, in prep.).

Since the total consumption estimates are dependent on the assumed total fish biomass (i.e. SSB for NEA mackerel and NSS herring, TSB for blue whiting; ICES, 2015c), an illustrative example is presented in Figure 6.11.8, where consumption estimates were calculated as a mean value for the period 2005–2010 (from Bachiller *et al.*, in prep.) and extrapolated to a longer time-series, applying the total fish biomass in the Norwegian Sea estimated in previous and later years (ICES, 2015c). Although this is a preliminary analysis, these kind of estimates and interannual and interspecific variations will be useful for understanding fundamental pelagic predator–prey interactions as well as to inform advanced multispecies ecosystem models.

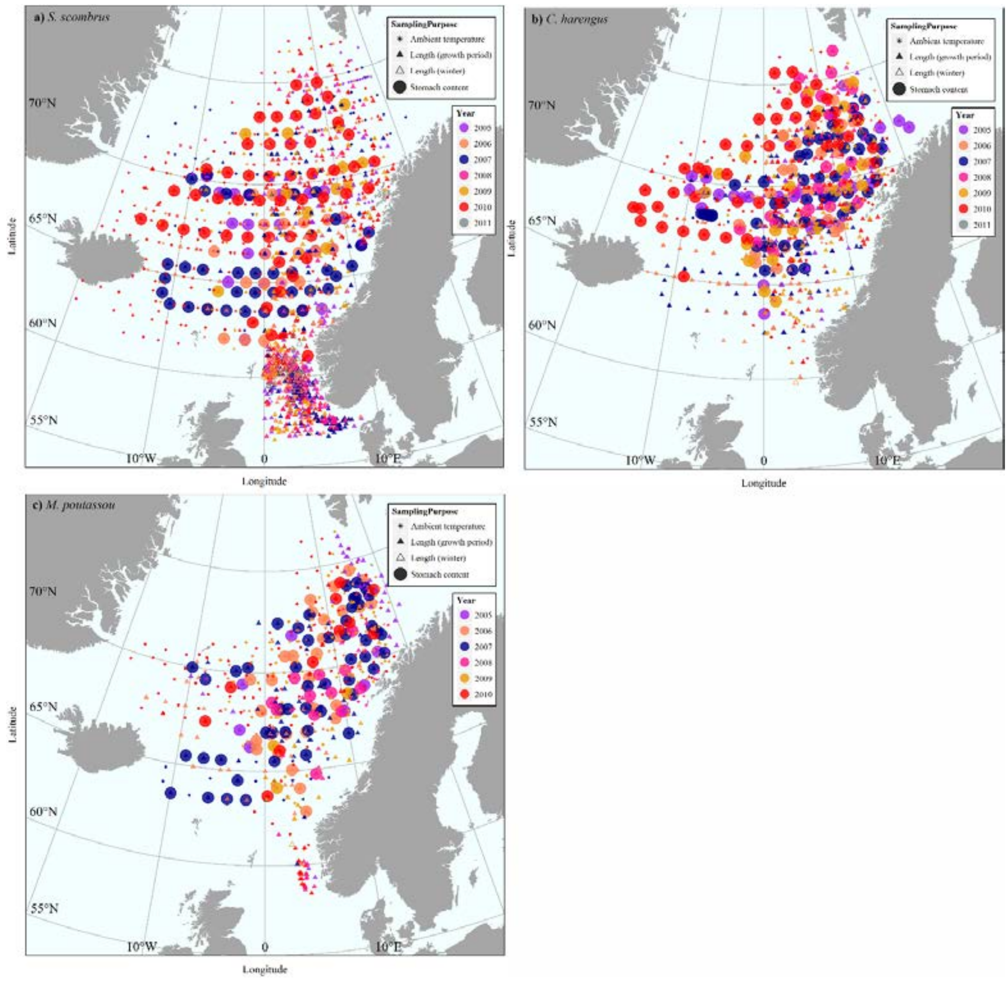


Figure 6.11.1. Distribution of samples of (a) NEA mackerel, (b) NSS herring and (c) blue whiting, used to get different information used as input for the analysis in feeding ecology. Triangles represent sampling stations considered for fish length and weight measurements used as input for the growth considered in the bioenergetics consumption estimation model (Bachiller *et al.,* in prep.). Filled circles are stations used for the diet characterization analysis in Bachiller *et al.* (2016).

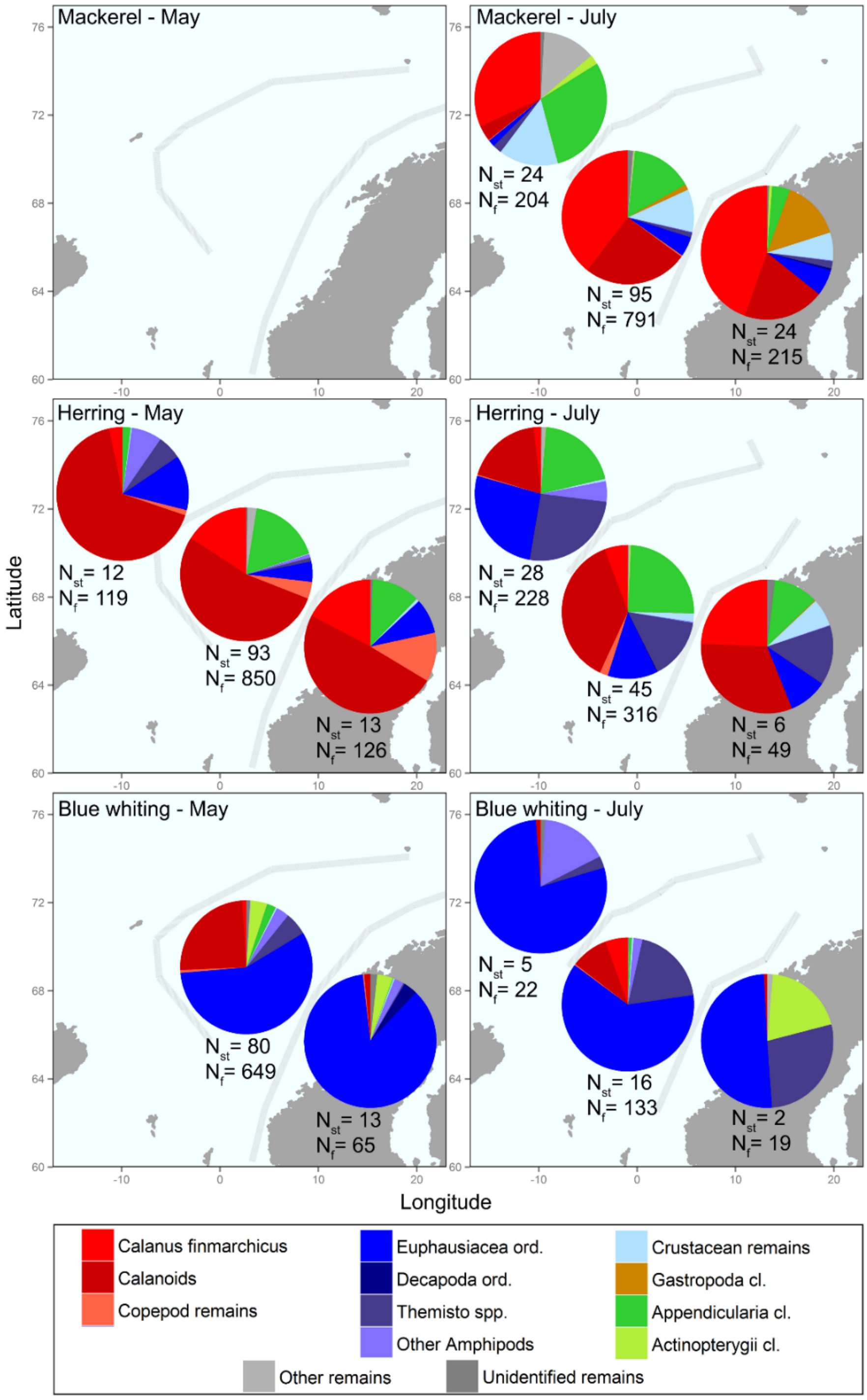


Figure 6.11.2. Average (2005–2010) diet composition (mean prey group mg fish^{-1} weighted by the total estimated abundance per station), in percentages, for NEA mackerel, NSS herring and blue whiting in different water masses in May and July. Light grey lines represent the average water mass boundaries during each season. N_{st} and N_f are the number of stations and fish samples, respectively. Empty stomachs were excluded from this analysis. Modified from Bachiller *et al.* (2016).

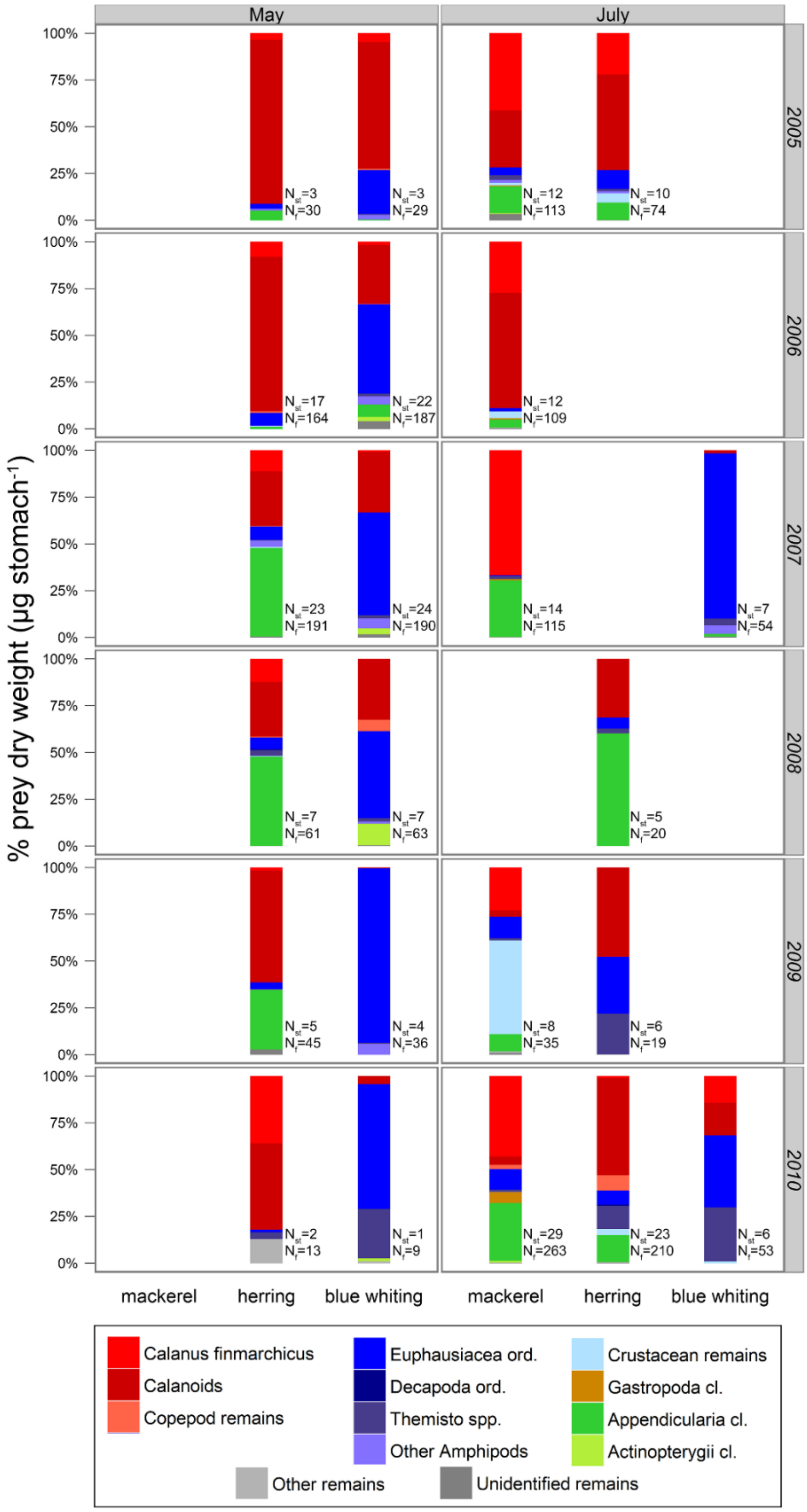


Figure 6.11.3. Average diet composition (mean prey group mg fish-1 weighted by total estimated abundance per station), in percentages, for NEA mackerel, NSS herring and blue whiting, per year (i.e. from 2005 to 2010) and season (i.e. May and July). Stations included in this analysis were those within the Atlantic water mass and with spatial overlap between ≥ 2 predator species (Figure 1). N_{st} and N_f are the number of stations and fish samples, respectively. Empty stomachs were excluded from this analysis. Modified from Bachiller *et al.* (2016).

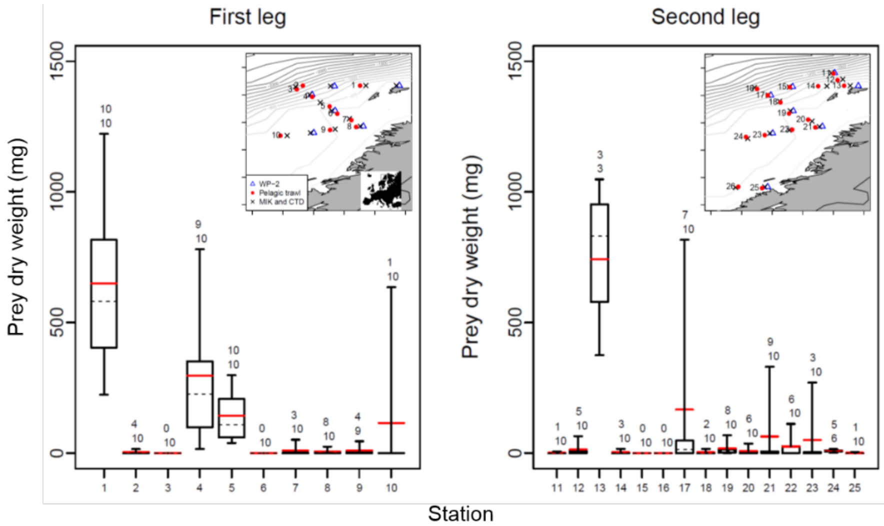


Figure 6.11.4. Dry weight of herring larvae in mackerel guts by stations, carried out during the first (30.05–03.06; left) and second (03.06–08.06; right) survey coverage (see small maps within each corresponding panel). Fully drawn horizontal lines indicate means, whereas dotted horizontal lines indicate medians. The boxes extend to the 25 and 75% quantiles, respectively, and the whiskers to the 5 and 95% quantiles. The number of mackerel guts containing herring larvae is denoted above the upper whisker (upper number) for each station together with the total number of mackerel guts sampled (smaller number). Modified from Skaret *et al.* (2015).

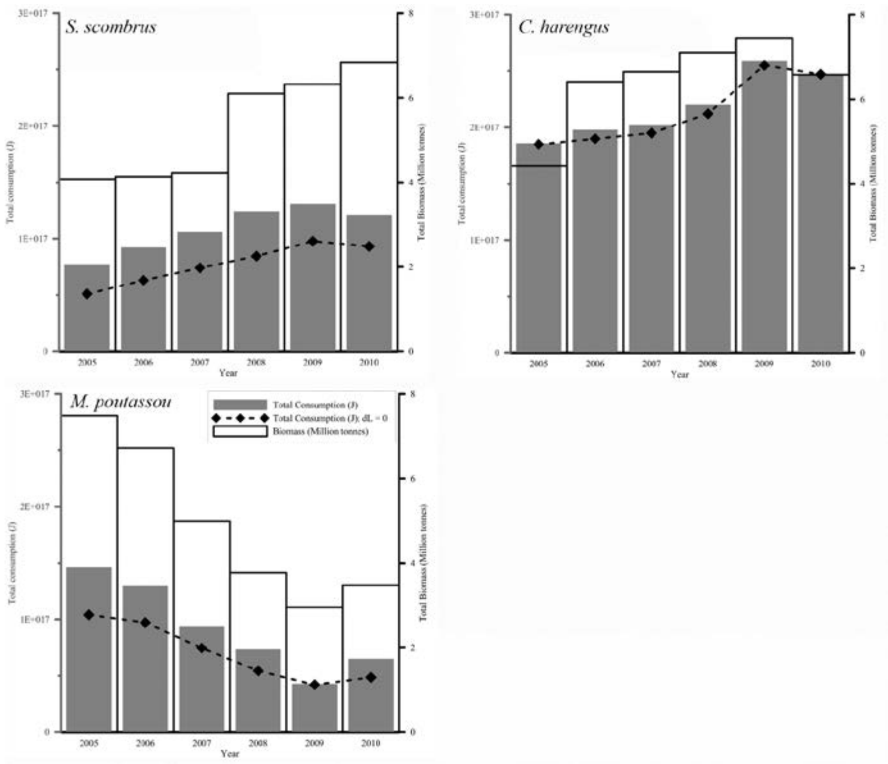


Figure 6.11.5. Total annual zooplankton consumption by NEA mackerel, NSS herring and blue whiting, indicated as grey bars (left *y*-axis). Empty bars (based on right *y*-axis) indicate the total biomass from the assessment (TSB for mackerel and blue whiting, SSB for herring; ICES, 2014). Dotted line represents consumption estimates when daily growth of fish is not considered in the bioenergetics model (i.e. following the methodology from Varpe *et al.*, 2005). Modified from Bachiller *et al.* (in prep).

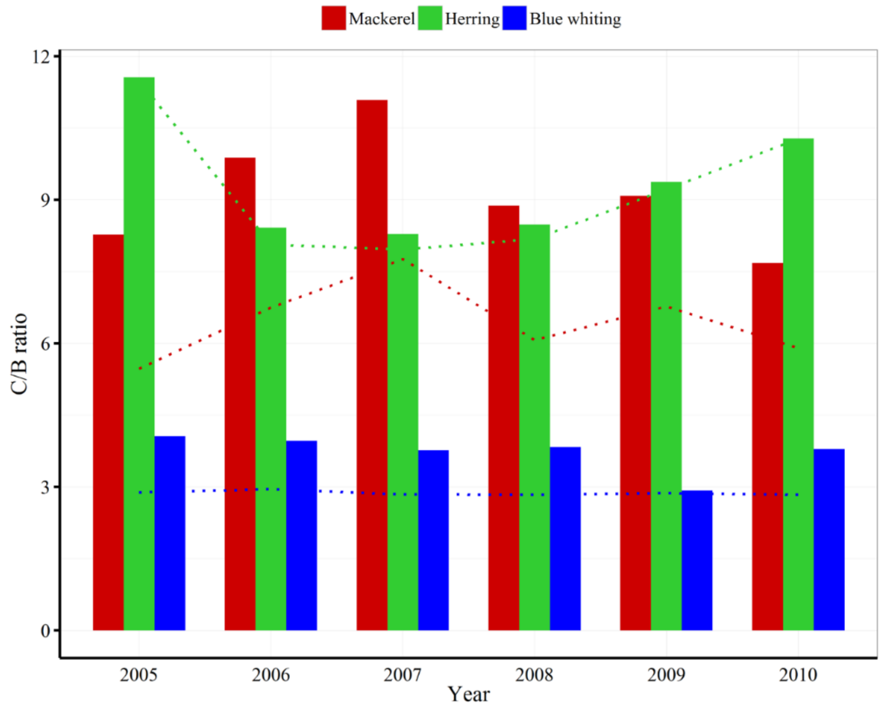


Figure 6.11.6. Consumption/Biomass ratios per year and species, calculated from the bioenergetics model in Bachiller *et al.* (in prep.). Dotted lines represent estimates when daily growth of fish is not considered (Varpe *et al.*, 2005) in the model.

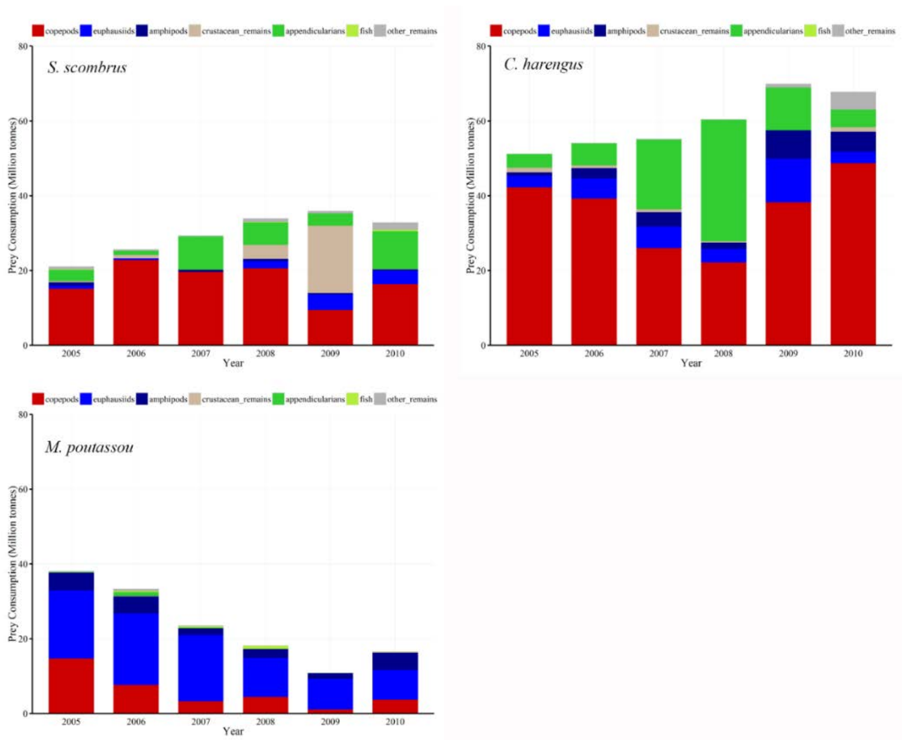


Figure 6.11.7. Annual prey consumption estimates for NEA mackerel, NSS herring, and blue whiting, obtained from the bioenergetics model in Bachiller *et al.* (in prep.).

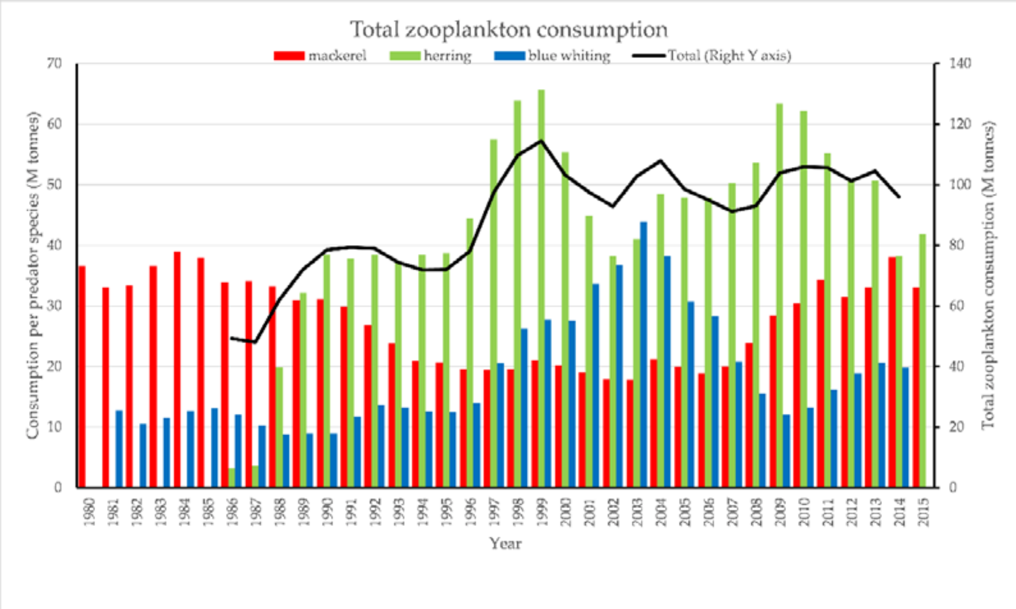


Figure 6.11.8. Total zooplankton consumption by NEA mackerel, NSS herring and blue whiting in the Norwegian Sea, from 1980 to 2015. Estimates are based on the mean consumption values from 2005–2010 (Bachiller *et al.*, in prep) which were then extrapolated to the total fish biomass reported for different years by ICES - WGWIDE (ICES, 2015c). Black line represents the total consumption by the three species (right *y*-axis).

Ambient temperature (mac-her-bwh distribution)

A study about the feeding ecology of the NEA mackerel, NSS herring and blue whiting from 2005 to 2010 (Bachiller *et al.*, 2016), showed that mackerel was generally found in waters with higher temperatures than the other species. Mackerel ambient temperature ranged from 7°C, more related to the Arctic water mass, to temperatures close to 11–13°C, in the Atlantic and Coastal water masses. Herring was mostly found in temperatures between 2–4°C in the Arctic water mass, and 4–8°C in the other water masses, with a maximum value of 13°C in Coastal waters in July 2009. Blue whiting was generally distributed within the Atlantic and coastal water masses both in May and July and showed a narrower ambient temperature range than the other species, occurring in waters from 4 to 7°C in almost all seasons (spring, summer), years (2005–2010) and water masses (Bachiller *et al.*, 2016).

6.12 Multivariate analysis of ecosystem components

The first approach was to check for indications of regime shifts in the ecosystem. To get an overview of the system, the variables were standardized and sorted according to the anomaly value for the beginning of the period (1980–1985). In cases with regime shifts, there is a clear temporal trend in the anomalies for the majority of the variables. There are no indications of large changes in the ecosystem during the last three decades (Figure 6.12.1). The overall picture is that the variables have random fluctuations in the period.

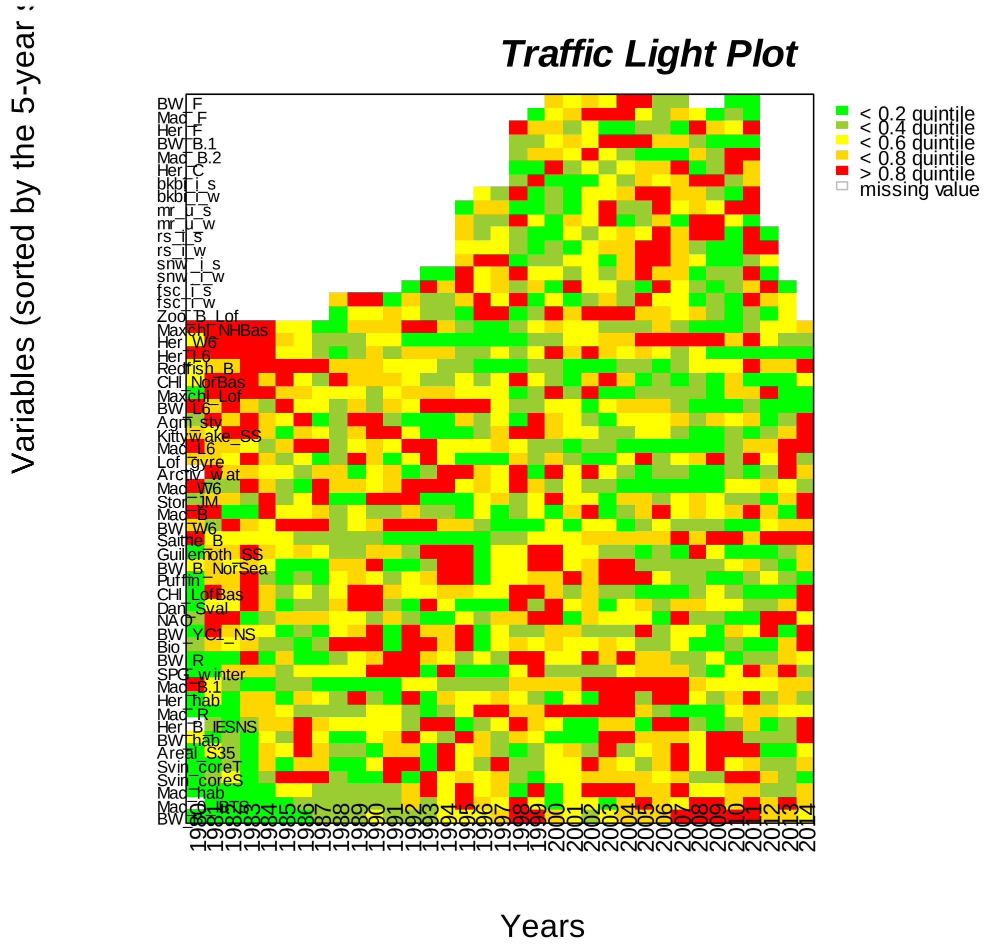


Figure 6.12.1. Overview of temporal development in anomalies for all variables considered for the Norwegian Sea ecosystem. Data are sorted vertically by average anomaly values for the first 5 years of the period.

The original dataset has a wide range of variables. Several of them are describing the same aspects. Examples are recruitment estimated from the assessment and survey indices of recruitment, and both weight-at-age and length-at-age. The dataset was therefore reduced to make it easier to capture the main trends in the ecosystem. A principal component analyses was performed for the key component of the ecosystem. The period was restricted to 1995–2014 as no information is available for several components prior to 1995. The first (PC1) and second (PC2) axes accounted for 36.4% and 16.3% of the observed variance in the dataset, respectively (Figure 6.12.2). The emphasis was therefore put on the first principal component The early period is characterized by a weak Subpolar Gyre index (SPG) in the winter, resulting in relative cold waters in the Norwegian Sea. This is correlated with high max levels of chlorophyll, high biomass of zooplankton and good recruitment of blue whiting (Figure 6.12.2). The second period is characterized by warmer waters and a strong SPG index, high abundance of herring and mackerel and maximum chlorophyll concentration late in spring.

There is a clear unidirectional temporal trend in the dataset along axis 1, from the earlier years (1995–2004) on the right panel to the later years (2005–2015) on the left panel (Figures 6.12.3 and 6.12.2). Along the second axis we also see a grouping of years, 2000–2007 on the upper panel and the years 1995–1999, and 2008–2015 on the lower panel (Figure 6.12.3). The years 2000–2007 had higher blue whiting biomass, good recruitment of herring and a lower NAO index than the rest of the years.

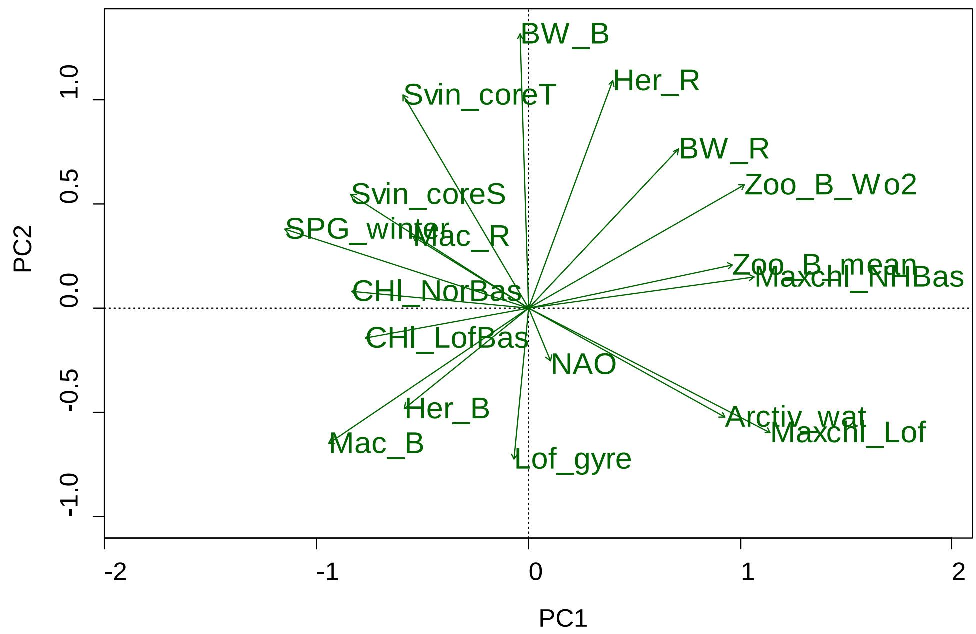


Figure 6.12.2. Biplot showing the variables on the first two principal component axes.

The analyses only indicate which variables correlate and not the causal mechanisms regulating the system. Warm Atlantic waters flowing into the area limits the advection of cold water masses containing zooplankton. At the same time, warm waters are in general favorable for mackerel and blue whiting and allow these species to feed over a large area, as the available feeding habitat increases. Hence, it is possible with both bottom–up and top–down regulation of the system.

The correlation between high maximum chlorophyll concentration, late phytoplankton bloom and high zooplankton abundance is not fully understood. One hypothesis is that an early bloom, which gives high maximum chlorophyll concentrations, is beneficial for zooplankton. Another hypothesis claims that when zooplankton is abundant, grazing on phytoplankton result in delayed maximum chlorophyll concentrations and a lower peak in abundance.

Another aspect is the correlation between mackerel recruitment and the SPG winter index. It seems to be a pattern with much warm Atlantic water flowing northwards and favorable conditions for mackerel. The opposite pattern has been described for blue whiting, with good recruitment when the ward water masses flow further west providing a larger available spawning area for blue whiting (Hátún *et al.*, 2009). The mechanisms are not fully understood, and further research on this issue is encouraged.

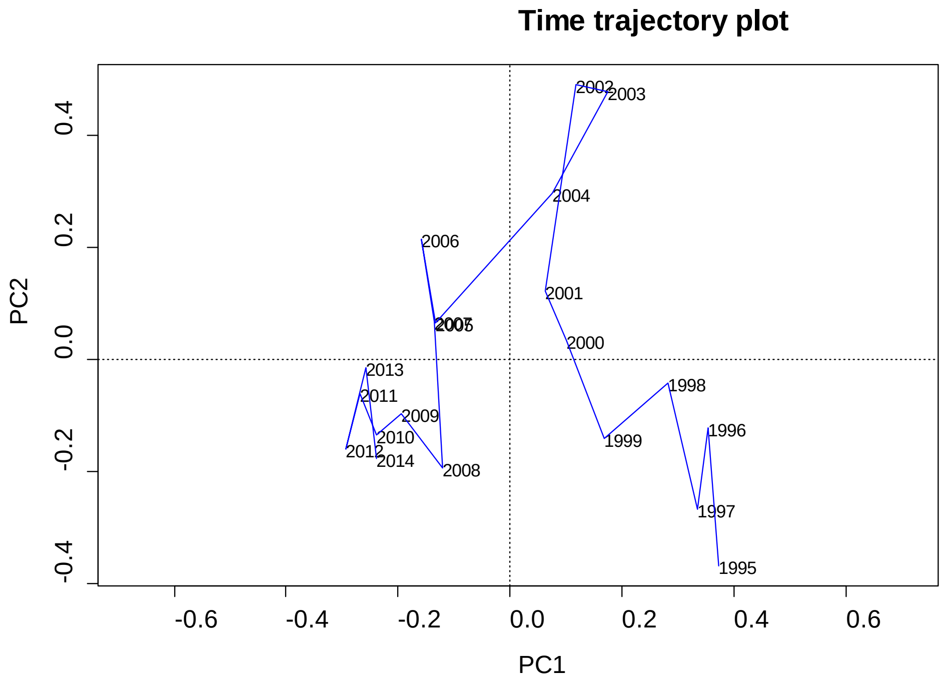


Figure 6.12.3. Time trajectory plot for the years according to the two first principal components.

7 Investigating potential for multispeices management of the pelagic stocks in the Norwegian Sea (Tor c)

7.1 Introduction

The Enac-model is a multispecies model for management strategy evaluation (MSE) (Bunnefeld *et al.*, 2011) of pelagic fish the Norwegian Sea. The model is parameterized for NSS-herring, blue whiting and mackerel. As the model includes the three species simultaneously, the effect of intra- and interspecific interactions can be investigated. Other fish stocks and zooplankton are not explicit included in the model. The main purpose of the model is to test how various interactions can affect evaluation of HCR in the long-term perspective, and the potential effect this will have on the optimal HCR.

7.2 Material and methods

The model consists of four different submodels; an operational model (OM), an observation model (OBM), a harvest models (HM) and a resource operating model (ROM). There are monthly time-steps and no spatial resolution in all submodels. The OM represents the perceived "real world" where the dynamics of the stocks are described by recruitment, growth, maturation, and mortality. The OBM adds bias to the output from the OP to mimic that researchers never have exact knowledge of stock sizes, but base their knowledge of indices from commercial catches, research surveys etc. These biased number at length data are sent to the HM. The HM projects the development of the stocks forward in time and estimate a fishing mortality (F) based on a HCR. In the ROM the Total Allowable Catch (TAC) is calculated based on F from the HM, and the quotas are split into seasons to mimic the fisheries that vary throughout the year. After an initializing period of 20 years to build up realistic stock sizes, the model is run for 100 year. The model is mainly an extension of the model published by Skagen *et al.* (2013) applied to real fish stocks.

The OM projects the stocks forward in time using functions of recruitment, growth, maturation and mortality. The parameters for the various processes were as far as possible taken from the analytic assessment (ICES, 2015a) or from evaluations of long-term management plans for the species. The model is both age and length structured as several processes are modelled using a length based approach. The stocks are modelled by using Super Individuals (SI) (Scheffer, 1995) with Attribute Vectors (AV) (Chambers, 1993). A full description of the model is not provided here, but it follows the standard approach for models used for long-term management strategies. The key mechanisms that are changed between simulations are given below.

Growth

Growth was modelled using Von Berfalanffy Growth Function (VBGF) (Beverton and Holt 1957). For each time-step *t*, a super-individual will grow according to the following equation

$$L(i,t+1) = L(i,t) + [(L]_\infty(i,t) - L(i,t)) * \left(1 - e^{-K(i-t)}\right) \quad (1)$$

where L_∞ is the maximum length of the fish, L is the actual length and K is the intrinsic growth rate. Species-specific K and L_∞ was applied. The model was run with either a constant or a variable K, depending on the scenario run. The constant K was derived by fitting equation *1* to the average length-at-age in the last 35 years, which was calculated by applying a length weight conversion to the weight-at-age used in the assessment (ICES, 2015a). The variable K was calculated by fitting equation 1 to the maximum and minimum length-at-age from the assessment. This was modelled as a density-dependent effect where both the target species and herring accounted for 50% of the variation. Maximum growth was obtained when SSB for both species were below B_{lim} and minimum growth when SSB for both species were at the maximum level recorded in the period 1980–2015.

The abundance of mackerel further north has increased in recent years (Nøttestad *et al.*, 2015). This has led to observations of predation on blue whiting (Payne *et al.*, 2012) and herring larvae (Skaret *et al.*, 2015) from mackerel. Predation from mackerel is included in the model with the function given below

$$E = 1 - \frac{SSB_{mac} - 2}{10} \qquad SSB_{mac} \text{ (million tonnes) c } [2, 4] \qquad (2)$$

where E is the survival of larvae after mackerel predation. $E = 1$ if mackerel SSB is less than 2 million tonnes and $E = 0.8$ if mackerel SSB is above 4 million tonnes. E is multiplied with the initial number of fish larvae from the stock–recruitment model, hence reducing the number of 0-group fish in the model.

Scenarios

Biological scenarios

The model was run with three sets of biological assumptions. The first scenario has no interactions between the stocks. In the second scenario are there interactions limiting individual growth. It was assumed that growth is density-dependent due to intraspecific competition within the stock and interspecific competition with herring (Huse *et al.*, 2012; Ólafsdóttir *et al.*, 2015). This was modelled by varying K in equation 1 as described above. The third biological scenario is intraguild predation from mackerel on herring and blue whiting larvae, calculated based on equation 2.

Harvest control rules

For each set of simulations, it was used three different harvest control rules; the present HCR (Table 7.1), a HCR with a fixed target F irrespective of SSB (hereafter called fixedF HCR), and an HCR with increased target F when the total biomass of pelagic fish reach high levels (hereafter called ecosystem HCR). The present HCR follow the rules currently applied for the three stocks (Table 7.1). The fixedF HCR apply the same F even when SSB drops below B_{lim}. The ecosystem HCR increases the target F when the total biomass of pelagic fish in the Norwegian Sea exceeds 12 million tonnes, given that SSB for the given species in above B_{pa}.

Table 7.1. Reference points and values used in present HCR.

	Blue whiting	Mackerel	NSS-herring
Target F	0.30	0.24	0.125
Min F	0.05	0.01	0.05
B_{pa}	2 250 000	3 000 000	5 000 000
B_{lim}	1 500 000	1 840 000	2 500 000

Simulations

Hence, the model was run with three sets of simulations with varying biological assumptions and three sets of HCRs, giving a total of nine simulations. Each simulation consisted of 1000 iterations.

The HCRs are evaluated based on long-term performance (50–100 years) given the mean spawning-stock biomass (SSB), total allowable catch (TAC), risk of stock collapse (RSC) and interannual variation (IAV). For a full understanding of the optimal management taking into account interactions between and within species, an extensive set of simulations is needed. The simulations should be run with a wide range of target F to find F_{MSY}. The presented simulations are with the same target F, but with different HCR. The results are providing an indication of the effect of alternative HCRs when interactions are considered in long-term management evaluation. The two alternative HCRs, the fixedF and ecosystem HCR, are evaluated by comparing the performance to the same HCRs for the no interactions scenario.

7.3 Results

The results from the simulations are presented in Tables 7.2–7.4.

The model predicts the long-term average SSB of NSS-herring to be around 7.3 million tonnes, mackerel around 2.7 million tonnes and blue whiting around 3.5 million tonnes. These values are realistic according to historic long-term perspective, but different from the present stock levels. The general result is that the interactions don’t have a large effect on the long-term management of these stocks. However, due to the large biomass and economical importance of these stocks, minor improvement of the management is still important.

General picture HCRs

The present HCR provides acceptable results with low levels of IAV and RSC. The fixedF HCR will in general result in lower SSB, higher TAC, lower IAV and higher RSC compared to the present HCR. This HCR is not sustainable for mackerel and blue whiting as RSC is above 5%, which is the applied maximum acceptable level. Ecosystem HCRs will in general lower the SSB and increase IAV for herring and blue whiting. It does not have a significant effect on RSC and TAC for these two species.

General result biological scenarios

Density-dependent growth significantly affects the predicted SSB and TAC for blue whiting but not for mackerel. The limited effect for mackerel can be explained by the fact that the tested HCRs will in the long-term lead to a SSB which gives individual growth close to the long-term average. Intraguild predation from mackerel on herring and blue whiting larvae will naturally result in lower SSB and TAC for herring and blue whiting.

Density-dependent growth

The inclusion of density-dependent growth in the model does not make it more favorable to apply the fixedF or ecosystem HCR. The present HCR with density-dependent growth leads to an increase in SSB and TAC of around 8% for blue whiting, which is higher than the increase for the other HCRs. There are only minor differences for mackerel, except for the fixedF HCR were the inclusion of density-dependence leads to lower SSB and TAC, and higher IAV.

Intraguild predation

Predation on fish larvae will over time reduce the average SSB and long-term yield irrespective of the applied HCR. However, when intraguild predation is occurring, the ecosystem HCR or the fixedF HCR improves its performance. For blue whiting and herring, the reduction in TAC due to intraguild predation is 7 % with the present HCR, but only 3 % if a no B_{pa} HCR is applied.

Table 7.2. Evaluation of HCRs for blue whiting given different biological scenarios. All values are the average from 1000 iterations. The last four columns give the difference in percentage from the no-interaction scenario. DD-density-dependence, Mac pred-mackerel predation on blue whiting larvae.

Scenario	HCR	SSB	TAC	RSC	IAV	Diff SSB	Diff TAC	Diff RSC	Diff IAV
No inter	pres HCR	3 431 829	990 918	0	0.26				
No inter	fixedF HCR	3 289 647	994 898	0.06	0.15				
No inter	eco HCR	2 977 940	1 013 423	0	0.33				
DD grow	pres HCR	3 709 641	1 071 199	0	0.26	108.10%	108.10%	0.00%	100.00%
DD grow	fixedF HCR	3 537 832	1 066 512	0.08	0.16	107.54%	107.20%	133.33%	106.67%
DD grow	eco HCR	3 085 865	1 082 905	0	0.34	103.62%	106.86%	0.00%	103.03%
Mac pred	pres HCR	3 239 975	921 035	0	0.28	94.41%	92.95%	0.00%	107.69%
Mac pred	fixedF HCR	3 182 463	962 725	0.09	0.15	96.74%	96.77%	150.00%	100.00%
Mac pred	eco HCR	2 854 117	947 876	0	0.34	95.84%	93.53%	0.00%	103.03%

Table 7.3. Evaluation of HCRs for mackerel given different biological scenarios. All values are the average from 1000 iterations. The last four columns give the difference in percentage from the no-interaction scenario. DD-density-dependence

Scenario	HCR	SSB	TAC	RSC	IAV	Diff SSB	Diff SSB	Diff RSC	Diff IAV
No inter	pres HCR	2 671 825	586 126	0	0.28				
No inter	fixedF HCR	2 226 714	591 642	0.14	0.09				
No inter	eco HCR	2 628 147	584 131	0	0.36				
DD grow	pres HCR	2 676 346	590 638	0	0.28	100.17%	100.77%	0.00%	100.00%
DD grow	fixedF HCR	2 155 575	571 857	0.22	0.09	96.81%	96.66%	157.14%	100.00%
DD grow	eco HCR	2 621 920	587 317	0	0.37	99.76%	100.55%	0.00%	102.78%

Table 7.4. Evaluation of HCRs for herring given different biological scenarios. All values are the average from 1000 iterations. The last four columns give the difference in percentage from the no-interaction scenario. Mac pred - mackerel predation on herring larvae.

Scenario	HCR	SSB	TAC	RSC	IAV	Diff SSB	Diff SSB	Diff RSC	Diff IAV
No inter	pres HCR	7 912 756	1 001 128	0	0.15				
No inter	fixedF HCR	7 868 502	1 003 215	0	0.13				
No inter	eco HCR	6 933 495	1 086 131	0	0.22				
Mac pred	pres HCR	7 358 426	926 658	0	0.15	92.99%	92.56%	0.00%	100.00%
Mac pred	fixedF HCR	7 623 596	971 992	0	0.13	96.89%	96.89%	0.00%	100.00%
Mac pred	eco HCR	6 602 355	999 491	0	0.23	95.22%	92.02%	0.00%	104.55%

7.4 Conclusion

The general result is that density-dependent growth will not favor the alternative HCRs for improved management of the stocks. However, the expected TAC and SSB for blue whiting increased when including density-dependent growth, and this can have a significant impact on long-term management plans and should be considered when reevaluated. The extent of intraguild predation is not known, but mackerel preys on both herring and blue whiting larvae. The simulations show that alternative HCRs may be more appropriate to stocks affected by intraguild predation. It should be discussed whether a target F below F_{MSY} should be recommended as a precautionary approach. The idea is that a fishing mortality below the optimum will be a good way to ensure keeping the stocks above B_{lim}, although the long-term yield is slightly below the optimal. However, considering intraguild predation, the precautionary approach is not necessarily to apply a target F below F_{MSY}, as this can have negative effects on other stocks. One can raise the discussion whether recommendations from ICES to managers should take this into account. The effect of intraguild predation is not known, and can therefore not be included explicitly in the present management. However, when the extent of an action is unknown, the precautionary approach can be to fish at F_{MSY}.

8 Towards absolute abundance estimates of zooplankton and pelagic fish (Tor d)

One of the planned tasks of WGINOR was to explore other estimates of fish abundance than the official WGWIDE assessments. Therefore survey based abundance indices for the three pelagic fish stocks have been compiled and made available on the WGINOR SharePoint. They are both based on swept-area and acoustic estimates and provide indices of total biomass, SSB, and recruitment. WGINOR relies on absolute estimates of stock size of fish feeding in the Norwegian Sea Ecosystem to be able to model the role of e.g. the mackerel with regard to consumption etc. Hence, abundance estimates from the surveys and the tagging data are considered important and may be used in modelling and analyses of the ecosystem to get closer to the actual situation.

There is generally a discrepancy between the survey abundance estimates and those from the survey. Moreover, there is often a retrospective pattern in the assessment results. This applies both to the mackerel (Figure 8.1) and NSS-herring (Figure 8.4). Therefore it is not obvious to use the assessment biomass results for ecosystem modelling instead of maybe more spatially constrained survey biomass indices.

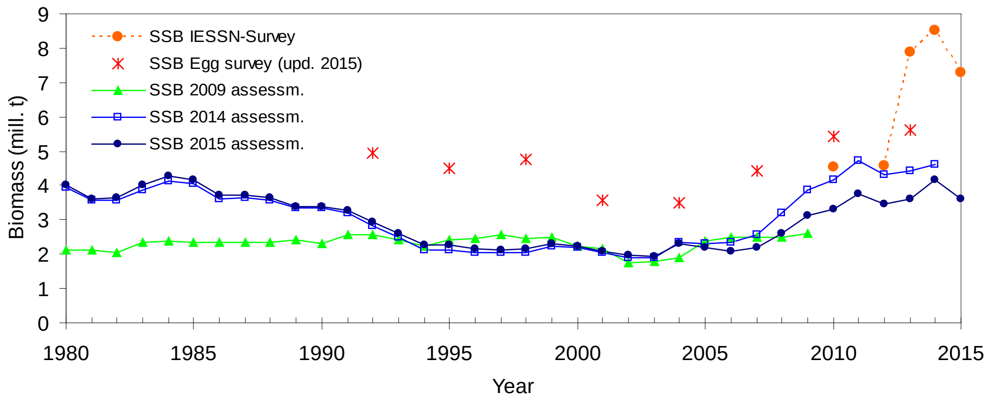


Figure 8.1. Estimation of spawning-stock biomass (SSB) of mackerel from the IESSNS swept-area survey (survey reports), the Egg Survey (ICES, 2015a) and from analytical assessments (ICES reports) during 1980–2015.

The mackerel biomass estimates show a large discrepancy (Figure 8.1) and not obvious who is most appropriate to the WGINOR modelling work. Considering also the expansion of the feeding area into areas outside the Norwegian Sea, spatially based abundance indices such as the IESSNS data need to be included in one way or another. Furthermore, abundance indices of mackerel derived from tagging data will also be available in the near future. Tenningen *et al.* (2011) demonstrated that estimate of mackerel SSB based on tagging data with internal steel tags, recovered with metal detectors at commercial factories from 1986–2006, showed large fluctuations in the stock. Starting with high levels of around 7 million tonnes around 1990, down to 3 million tonnes around 2000, and rising again to 7 million tonnes in 2006. The mackerel SSB from the new assessment of mackerel (ICES, 2015a) follows a similar trend but the level of SSB is around 60% lower in the assessment (Figure 8.1). The new assessment incorporates data from the tagging-recapturing program of Institute of Marine Research (IMR) in Bergen until 2007. That leaves out data from the new tagging technology with RFID (Ratio frequency identification). Over the years 2011–2015 around

200 thousands mackerels have been tagged with the new tags and hundreds have been recaptured by RFID antenna and reader systems in factories. A biomass estimate obtained from the whole tagging-recapture series will most likely be available in 2016.

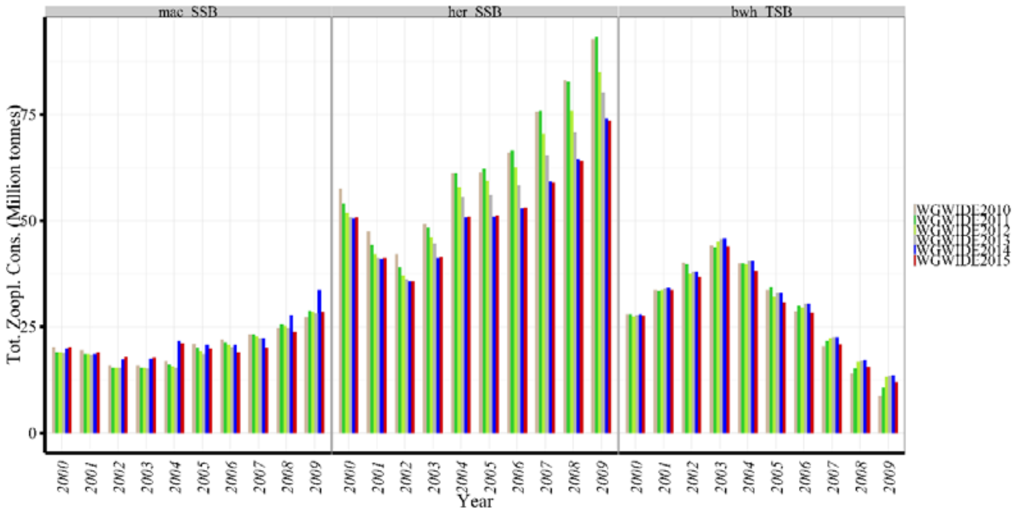


Figure 8.2. The zooplankton consumption by mackerel (left), NSS herring (middle), blue whiting (right) based on assessments done in different years.

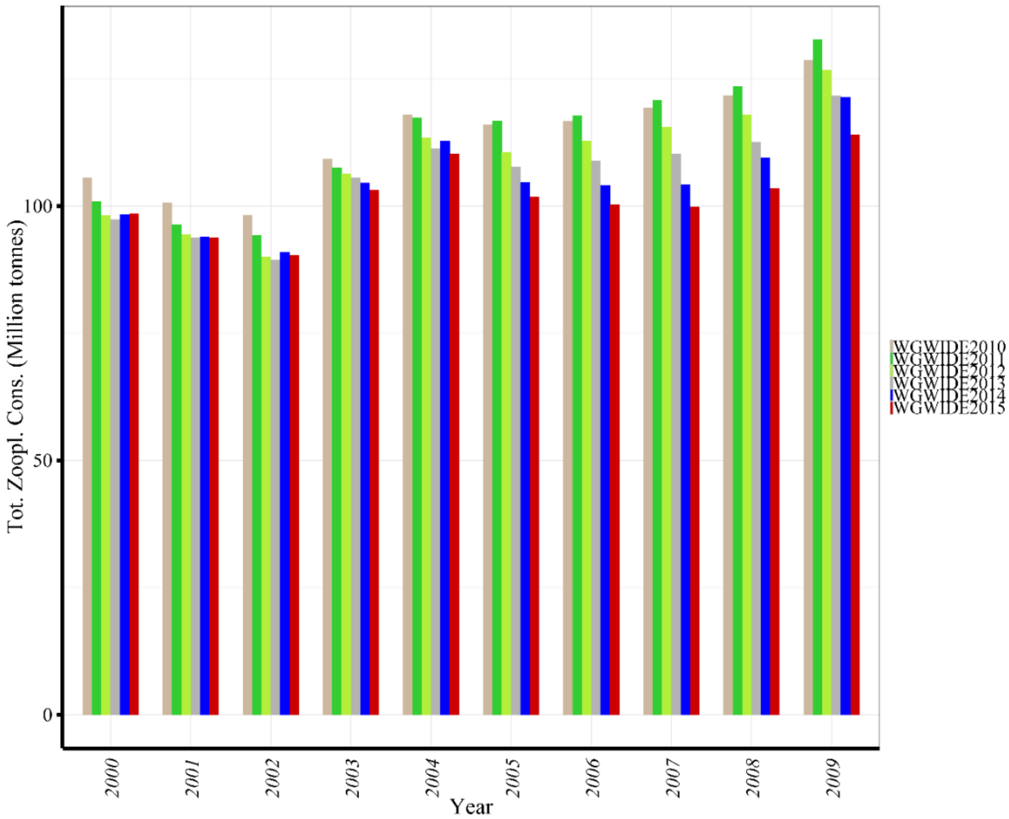


Figure 8.3. The zooplankton consumption by planktivorous fish (NEA mackerel, NSS herring, and blue whiting) based on assessments done in different years.

The total biomass estimation of herring in the Norwegian Sea from the IESNS acoustic survey during 1996–2015 is at similar level as the SSB estimation from the analytical assessments for some periods while above for others (Figure 8.4). The analytical assessments show however, a strong retrospective pattern with the tendency of decreasing the estimates every year. The question is then, which estimate of herring biomass, or mackerel biomass, should be applied in ecosystem modelling? Because WGINOR relies on absolute estimates of fish stock size feeding in the Norwegian Sea Ecosystem, this needs to be considered in the coming years by the group. For example, estimation of total zooplankton consumption of planktivorous fish is heavily dependent on the stock size used (Figures 8.2 and 8.3).

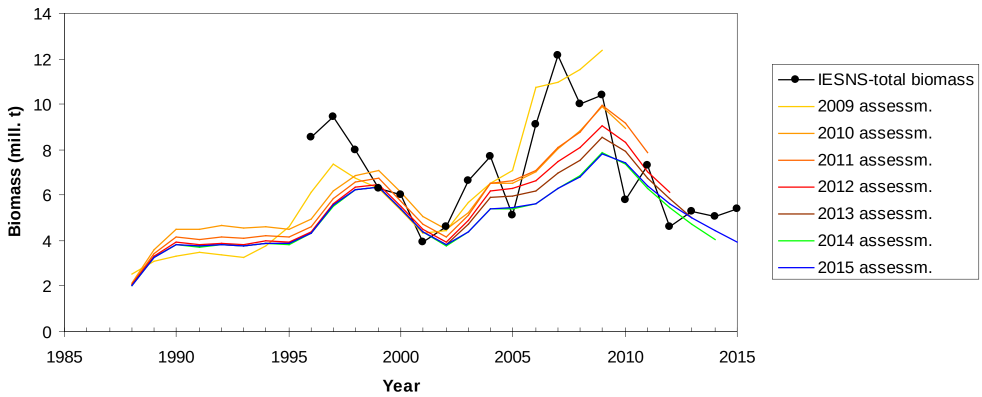


Figure 8.4. Estimation of total biomass of Norwegian spring-spawning herring in the Norwegian Sea from the IESNS acoustic survey (survey reports) and Spawning-stock biomass from analytical assessments (ICES reports) during 1988–2015. Note that the drop between the 2009 and 2010 assessments is partly explained by changes in maturity ogive estimations.

Absolute levels of zooplankton

The abundance levels of mesozooplankton are fairly well estimated using the conventional zooplankton sampling with WP2 nets. However, the macroplankton component with krill and amphipods as key groups are much less well sampled. Estimates done in the late 1990s (Dalpadado *et al.*, 1998) indicate that the density of the macroplankton can be very high in the Norwegian Sea and a key component in the diet of the planktivorous fish (see above). However, it is difficult to assess the status of these components since they are poorly sampled by conventional sampling gear. A new macroplankton trawl has been developed with fixed fine scale net tailored to sampling macroplankton. This gear has recently become as and additional standard sampling gear in the May survey in Norwegian Sea (IESNS) for some participating countries and it will be important to operationalize this to improve our ability to provide updated estimates for macroplankton

9 Sampling requirements for integrated assessment of the Norwegian Sea (Tor e)

ToR e covers development of sampling requirements for integrated assessment of the Norwegian Sea. The data availability and status of ecosystem components within the different disciplines, which are candidates for indicators for integrated ecosystem assessment for Norwegian Sea, were first addressed in the 2013 WGINOR report and then revisited the years after. Several gaps in data sampling and availability were recognized. These gaps are introduced in Table 9.1 and it is requested that recommendations concerning them will be handled adequately by the different groups and the relevant institutes in order to facilitate further an integrated ecosystem assessment of the Norwegian Sea. Some of these gaps have already been considered during this 3-year period by some groups, as indicated in Table 4.

Table 9.1. List of gaps in data sampling and availability of relevant ecosystem components for integrated assessment of the Norwegian Sea.

Ecosystem component	Recommendation/request of sampling/analyses	To whom
Phytoplankton	1. Data on chlorophyll (fluorescent) and nutrients are not routinely collected by all participants in the IESNS survey in May (e.g. Iceland). It is recommended that such sampling takes place by all participants.	WGIPS and Institutes participating in the IESNS survey. *<u>Reaction during 2013–2015:</u> Sampling of chlorophyll data has become a standard procedure on all vessels in IESNS, while the data are not yet stored in the common database.*
	2. There is very few data on primary production from monitoring surveys. New fluorescence based instruments, such as the FRRF (Fast Repetition Rate Fluorometer) (Kromkamp and Forster, 2003) allows improved estimation of primary productivity and WGINOR propose to establish a routine data collection of primary productivity based on such technology.	WGIPS and Institutes participating in the IESNS survey. *<u>Reaction during 2013–2015:</u> WGINOR is not aware of any action on this issue.*
Zooplankton	3. Large zooplankton such as krill, amphipods and juvenile *Gonatus fabricii* are poorly represented in WP2 nets. They need to be sampled in a quantitative manner with the new macroplankton trawl down to 500 m depth. It is recommended that such sampling will take place in the IESNS survey in May at some stations (min. 5 tows per vessel).	WGIPS and Institutes participating in the IESNS survey. *<u>Reaction during 2013-2015:</u> Krill trawls are now used regularly by 2 of the 5 vessels in IESNS.*
	4. IESNS survey data for some earlier years in the time-series on zooplankton in the NAPES database in Faroe Island are missing. It is recommended that they will be uploaded by the responsible nations before the end of year 2013.	ICES WGIPS and Institutes participating in the IESNS survey. *<u>Reaction during 2013-2015:</u> The most of the data are still missing, but work is ongoing.*
	5. There are indications for some differences in methodology in zooplankton dry weighting among	ICES WGIPS and Institutes participating in the IESNS and IESSNS surveys.

Ecosystem component	Recommendation/request of sampling/analyses	To whom
	nations participating in the IESNS and IESSNS (i.e. removal of phytoplankton from the samples prior to drying). This needs to be fully standardized and described in Manuals for the surveys. It is strongly recommended that this is fully described in the manuals and fulfilled during the surveys. Work on updating the manual for the July-August survey is in progress and this request should be included in this manual.	*Reaction during 2013–2015: This has not been fulfilled and is still applicable.*
Fish	6. The stomach fullness of pelagic fish is not recorded by all participants in the IESNS and IESSNS surveys. It is recommended that it will be done by all participants in future surveys.	WGIPS and Institutes participating in the IESNS and IESSNS surveys. *Reaction during 2013–2015: This has not been fulfilled, but stomach weight is recorded instead by some participants.*
	7. During IESNS survey in May, some acoustic registrations are interpreted as meso-pelagic fish. However, these registrations have never been quantified systematically in the survey reports or by other means. These information might be relevant to WGINOR and it is requested that some analyses of these data take place, i.e. prepare figures/data with mean acoustic values in rectangles that can be used to calculate total echo abundance for meso-pelagic fish in Norwegian Sea interannually.	SCICOM/ACOM, ICES WGIPS and Institutes participating in the IESNS survey. *Reaction during 2013–2015: This has not been fulfilled and is still applicable.*
	WGINOR recommends regular monitoring and assessment of the biomass, productivity, and diversity of the mesopelagic fauna in the Norwegian Sea.	WGIDEEPS/SSGESST in coordination with WGIPS
Seabirds	8. It is recommended that relevant scientists specialised in Seabirds ecology becomes member of the WGINOR group, especially from Norway, Faroe Island, and Iceland.	Relevant National Institutes, e.g. NINA (Norway). *Reaction during 2013–2015: This has not been fulfilled and is still applicable.*
	9. Existing data on annual estimates of number of breeding pairs and breeding success of Seabirds around the Norwegian Sea needs to be made accessible to WGINOR. It is requested that involved institutes attain these data from appropriate sources.	Relevant Faroese and Icelandic Institutes. *Reaction during 2013-2015: This has not been fulfilled and is still applicable.*
Marine mammals	10. Whales are important top predators in the Norwegian Sea ecosystem. In order to improve understanding and quantification of their predatory effects WGINOR propose to establish routine whale counting on May and July surveys in the Norwegian Sea.	ICES WGIPS and Institutes participating in the IESNS survey. *Reaction during 2013–2015: This has not become a routine practice but huge effort was done in 2015.*

10 Next meeting

The group proposes that the next meeting should be held in the fourth quarter of the year at IMR (Norway), but leave the detailed planning up to the new chairs.

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12 Annexes

Annex 1: List of participants and agenda of the meeting

Name	Country	Institution	E-mail
Eydna i Hömrum	Faroese Islands	Faroese Marine Research Institute	eydnap@hav.fo
Cecilia Elisabeth Klitgaard Kvaavik	Iceland	Marine Research Institute	cecilia@hafro.is
Anna Ólafsdóttir	Iceland	Marine Research Institute	annao@hafro.is
Gudmundur J. Oskarsson	Iceland	Marine Research Institute	gjos@hafro.is
Hildur Petursdottir	Iceland	Marine Research Institute	hildur@hafro.is
Héðinn Valdimarsson	Iceland	Marine Research Institute	hv@hafro.is
Geir Huse	Norway	Institute of Marine Research	geir.huse@imr.no
Hein Rune Skjoldal	Norway	Institute of Marine Research	hrs@imr.no
Kjell Utne	Norway	Institute of Marine Research	kjell.utne@imr.no
Øistein Skagseth	Norway	Institute of Marine Research	oistein.skagseth@imr.no
Elvar H. Hallfreðsson	Norway	Institute of Marine Research	elvar.hallfredsson@imr.no
Eneko Bachiller	Norway	Institute of Marine Research	eneko.bachiller@imr.no
Teunis Jansen	Greenland	Greenland Institute of Natural Resources	teja@natur.gl
By correspondence:			
Gro I. van der Meeren	Norway	Institute of Marine Research	grom@imr.no
Benjamin Planque	Norway	Institute of Marine Research	benjamin.planque@imr.no
Tycho Anker-Nilssen	Norway	Norwegian Institute for Nature Research - NINA	Tycho.Anker-Nilssen@nina.no
Svein-Håkon Lorentzen	Norway	Norwegian Institute for Nature Research - NINA	svein.lorentsen@nina.no

Agenda of the meeting at MRI in Reykjavík, Iceland, 7–11 December 2015:

Monday

09:00

- Meeting opens
- Housekeeping, Introductions, planning (GH and GJÓ).
- Review of TORs and of last year's report, the work ahead (GH and GJÓ).

10:30 Presentations

- Guðmundur/Eydna/Kjell: Results of this year's surveys in Norwegian Sea (in May and July-August).
- Anna: Changes in weight-at-length and size-at-age of mature Northeast Atlantic mackerel (Scomber scombrus) from 1984 to 2013: effects of mackerel stock size and herring (Clupea harengus) stock size.

- Eydna: The annual cycle and interannual variation in body condition and growth rate of Norwegian spring-spawning herring.
- Eneko: Mackerel predation on herring larvae during summer feeding in the Norwegian Sea.

12:30 Lunch at MRI

13:00 Presentations continued

- Eneko: Feeding ecology of Northeast Atlantic mackerel, Norwegian spring-spawning herring and blue whiting in the Norwegian Sea.
- Eneko: Bioenergetics modelling of the annual consumption of zooplankton by pelagic fish feeding in the Norwegian Sea.
- Cecilia: Trophic interactions of mackerel (*Scombrus scomber*) and herring (*Clupea harengus*) on the Icelandic shelf – A study of diet using stable nitrogen and carbon isotopes.
- Øystein: Recruitment of NSS herring in relation to hydrographic conditions.

15:00 End of working day (Had to end the working day at three o'clock due to a hurricane warning for the Reykjavik area).

Tuesday

- Elvar: The mesopelagic community in the Norwegian Sea (Lia Siegelman and B. Planque).
- Teunis: "Mackerel gastric evacuation model review" and "Diel vertical feeding behavior of Atlantic mackerel".
- Kjell: Preliminary multivariate analysis of WGINOR time-series.
- Eydna: The annual cycle and inter-annual variation in body condition and growth rate of Norwegian spring-spawning herring.
- Geir: Planning of work in WGINOR.
- Working in groups the rest of the day.

Wednesday-Friday

- Working in groups with occasional plenary groups as the rest of the week.
- End of meeting 15:00 on Friday.

Annex 2: Table A1: Dataseries used in integrated analysis of the Norwegian Sea ecosystem (1995–2015).

Variable	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004
Herring R	19.595	58.595	33.552	208.991	167.923	57.648	34.915	350.094	159.928	286.575
Blue whiting R	9 830	28 948	45 627	28 233	20 999	36763	55 450	46 782	49 625	31 611
Mackerel R	3 051 061	3 992 787	3 207 492	3 645 485	3 984 809	3 150 274	4 601 993	7 579 820	2 813 669	3 269 017
Herring B	3.86	4.34	5.55	6.24	6.35	5.39	4.38	3.8	4.41	5.41
Blue whiting B	2.28	2.18	2.47	3.75	4.6	4.29	4.65	5.18	6.93	6.69
Mackerel B	2.26	2.15	2.12	2.14	2.31	2.21	2.07	1.96	1.95	2.32
Beaked redfish B	0.25	0.24	0.29	0.35	0.44	0.54	0.48	0.6	0.69	0.7
Saithe B	0.04	0.03	0.03	0.04	0.07	0.1	0.13	0.16	0.19	0.17
Herring W6	0.296	0.261	0.229	0.217	0.24	0.271	0.247	0.275	0.272	0.241
Blue whiting W6	0.167	0.17	0.166	0.178	0.17	0.156	0.163	0.155	0.148	0.146
Mackerel W6	0.432	0.425	0.401	0.383	0.392	0.394	0.398	0.36	0.401	0.406
Blue whiting L6	32.04736842	31.69491525	32.98333333	31.5	31.28448276	31.44285714	30.66780822	30.83012821	30.91836735	29.85828877
Mackerel L6	36.65454546	36.75	37.3258427	37.00657895	37.41144414	38.01612903	37.65591398	38.3375	37.68	37.06060606
Herring L6	31.74	30.88	30.99	31.48	32.38	32.48	32.09	32.26	31.79	31.76
Maxchl Norwegian basin				2.307778891	1.895307885	1.657957328	1.591225471	1.943778339	2.335303947	2.108419756
YDmaxChl Norwegian basin				138.6082474	148.6701031	161.6185567	146.1958763	159.3092784	140.2164948	142.1546392
Maxchl Lofoten basin				3.674347307	3.299793815	2.112601081	1.608009066	2.114057283	1.783169644	1.902610843
YDmaxChl Lofoten basin				141.0833333	145.8333333	163.1666667	163.4166667	144.0833333	146.25	141.75
Blue whiting R index					15 782.90323	27 668.3871	4 919.677419	11 512.25806	15 888.3871	17 632.25806
Blue whiting biomass index						18 552.90323	39 839.03226	26 424.19355	31 544.19355	30 668.3871

Variable	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004
Puffin stock size	956 026	902 370	1 027 844	953 807	973 941	960 085	852 154	859 223	922 870	837 704
Kittywake stock size	140 753	140 282	133 415	122 745	117 931	112 982	92 230	84 697	72 562	60 313
Guillemoth stock size	72 299	62 434	61 324	74 628	78 751	101 004	47 621	52 918	43 680	16 719
Nao_djfm	3.96	-3.78	-0.17	0.72	1.7	2.8	-1.9	0.76	0.2	-0.07
dp : Agmasalik-Stykkis	3.2558	-3.955	-0.0576	0.0764	2.3498	0.6105	-0.5766	-1.3151	-3.802	-0.4799
dp: Scoresbysund-Jan Mayen	9.9412	0.5917	4.3926	6.0805	7.5529	6.9995	5.0798	5.7159	2.5248	6.4203
dp: Danmarksh-Svalbard	12.6461	4.142	6.7181	4.8353	7.6378	12.6498	7.5427	8.9096	5.1806	7.5648
spg_index (winter cent)	-2.28	-1.27	-0.63	-0.44	-0.24	-0.2027	-0.53	-0.19	0.01	0.32
Norw-Lof gyre index	2.0433	-2.2709	-0.1871	1.3845	1.3148	0.3067	-0.6485	-0.6742	-1.6238	0.2821
Svinoy-coreT	7.93	7.86	8.08	8.25	7.92	8.37	8.28	8.82	8.68	8.31
Svinoy-coreS	35.227	35.208	35.212	35.255	35.234	35.257	35.239	35.275	35.284	35.283
Areal for S>35 (km2)	80.84	106.35	110.33	101.02	85.74	104.97	112.56	103.63	116.96	104.21
Herring habitat	6.0231	5.9783	5.6037	6.2185	6.1416	6.1384	6.2345	6.1128	6.6251	6.4554
Blue Whiting Habitat	6.0071	6.0488	6.0648	6.1224	6.1961	6.1	6.1	6.0103	6.4106	6.4811
Mackrel habitat	2.5298	2.4176	2.0173	3.1252	3.1573	2.5072	3.01	3.724	3.8745	3.929
Arctic Water in NS	0.6139	0.5462	1.8871	0.7532	0.6608	0.6414	0.1633	0.4424	0.1029	0.0408
Mackerel 0-group index				0.066974794	0.070762502	0.060229695	0.080503501	0.080147024	0.0601185	0.083588153
Herring B from Norwegian Sea survey		8 532	9 435	8 004	6 299	6 001	3 937	4 628	6 653	7 687
Zooplankton B	11.47066904	11.11614757	8.397769063	13.378	10.66590784	14.22615904	8.6148	13.65966115	12.43030457	9.225732

Variable	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004
Zooplankton B, Lofoten basin	14.9	11.7	5.9	13.900	10	13	8.7	13.7	7.6	8.2
Zooplankton B, Norwegian basin	11.1	9.7	6.900	12.4	10.8	11.9	7.1	13.3	10.7	7.8
Zooplankton B west of 2W	15.5	16.7	12.7	16.000	13.1	18.2	12.5	14.4	20	13.6
Zooplankton mean_øs	13.9	12	7.3	13.400	10.7	13.7	8.9	13.4	10.7	8.6
fsc_i_w	6.1234	5.3962	6.1658	6.9878	3.9688	5.5825	4.0376	4.6142	6.2726	4.7362
fsc_i_s	4.4791	5.0572	3.919	2.2937	3.3003	3.0462	5.414	4.9133	4.5597	4.1519
snw_i_w	45.782	28.39	36.781	37.525	35.32	30.825	26.074	28.741	25.699	32.556
snw_i_s	39.037	27.586	25.866	26.637	26.171	25.23	26.034	25.727	23.139	28.255
rs_i_w	9.8117	8.4534	8.1022	10.205	5.4254	4.3689	2.9518	4.6614	5.8605	6.9494
rs_i_s	8.823	2.934	3.7906	2.1545	1.9525	1.8112	3.9929	2.961	4.3172	4.8211
mr_u_w	-38.97	-21.526	-25.762	-35.118	-35.245	-33.731	-25.064	-28.852	-20.825	-35.601
mr_u_s	-32.5	-19.763	-24.269	-27.075	-23.614	-27.19	-28.426	-25.437	-19.86	-27.198
bkbi_i_w	10.567	11.181	11.374	13.529	5.8999	5.9583	3.0966	8.5334	8.6733	9.4931
bkbi_i_s	11.621	7.7493	8.5046	5.5024	3.4933	3.338	4.7274	5.9867	9.4876	8.2329
Herring C	905501	1220283	1426507	1223131	1235433	1207201	766136	807795	789510	794066
Mackerel C	755,800	563,611	569,613	666,664	640,311	738,608	737,462	772,905	669,600	650,221
Blue whiting C	578905	645982	672437	1128969	1256228	1412927	1780170	1556792	2318935	2377568
Herring F	0.235	0.201	0.19	0.161	0.198	0.231	0.196	0.215	0.15	0.13
Mackerel F	0.326	0.304	0.29	0.295	0.314	0.338	0.378	0.415	0.445	0.42
Blue whiting F	**0.249**	**0.306**	**0.3**	**0.415**	**0.359**	**0.472**	**0.457**	**0.502**	**0.471**	0.556

Variable	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014
Herring R	72.272	83.339	30.173	20.35	69.104	15.307	34.827	18.2	100.481	47.406
Blue whiting R	18 532	6 859	3 734	4 574	4 965	15 007	20 563	18 718	11 162	11 410
Mackerel R	4 338 330	8 186 524	3 949 107	4 282 297	4 061 244	5 015 281	5 909 076	4 569 891	3 084 808	7 519 423
Herring B	5.45	5.64	6.28	6.82	7.83	7.41	6.39	5.63	5	4.455
Blue whiting B	5.85	5.89	4.67	3.49	2.61	2.54	2.57	3.4	3.92	3.87
Mackerel B	2.18	2.07	2.19	2.61	3.11	3.33	3.75	3.45	3.62	4.16
Beaked redfish B	0.77	0.72	0.88	0.81	0.93	0.83	0.81	0.86	0.83	0.83
Saithe B	0.2	0.2	0.21	0.22	0.2	0.19	0.2	0.13	0.11	0.11
Herring W6	0.267	0.272	0.265	0.269	0.27	0.251	0.246	0.273	0.305	0.301
Blue whiting W6	0.137	0.138	0.13	0.133	0.138	0.163	0.169	0.172	0.162	0.155
Mackerel W6	0.403	0.402	0.362	0.354	0.354	0.346	0.366	0.309	0.32	0.31
Blue whiting L6	29.35677083	28.83333333	29.12931035	29.74157303	30.56547619	30.85416667	32.671875	32.61290323	33.875	33.875
Mackerel L6	37.72440945	37.0130719	36.35820896	37.4	35.72413793	34.97814208	35.69354839	34.74766355	34.19	35.6
Herring L6	31.94	32.58355795	31.51	31.35	30.84	30.75	31.41	32.32	32.42	32.46
Maxchl Norwegian basin	1.285335154	1.659686214	1.653747488	1.684481169	1.613878726	2.096307726	1.432943961	1.030928308		
YDmaxChl Norwegian basin	145.742268	149.371134	147.7216495	147.0206186	140.0927835	155.5979381	155.1030928	163.2680412		
Maxchl Lofoten basin	1.35036352	1.325404624	1.333465831	1.930502269	1.974071913	1.851409184	1.104166926	1.269771957		
YDmaxChl Lofoten basin	176.6666667	143.1666667	147.2916667	149.9166667	139.75	159.5	152.8333333	170.75		
Blue whiting R index	183.8709677	6.774193548	9.35483871	0	0	466.7741935	9 425	241	1 402	8 728
Blue whiting biomass index	30 801.93548	13 895.80645	4 035.16129	1 274.516129	859.3548387	143.8709677	1 836.774194	13 532	6 938	8 872
Puffin stock size	800 000	810 102	842 005	723 647	564 353	643 396	567 959	373 847	558 415	
Kittywake stock size	80 000	72 930	60 918	58 077	57 567	52 690	52 428	57 726	49 357	
Guillemoth stock	5 000	10 139	1 947	426	1 103	814	878	645	168	

Variable	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014
size										
Nao_djfm	0.12	-1.09	2.79	2.1	-0.41	-4.64	-1.57	3.17	-1.97	3.1
dp : Agmasalik-Stykkis	-1.0405	-0.5719	-0.1827	-1.3123	-0.744	-0.6364	0.0378	-2.1929	-0.261	3.7
dp: Scoresbysund-Jan Mayen	6.0992	3.9489	5.9526	4.2227	4.9935	4.3909	4.7543	3.8039	4.242	5.77
dp: Danmarksh-Svalbard	9.2563	6.0309	8.9971	8.9023	7.4653	7.5159	7.3948	6.7177	6.4643	4.52
spg_index (winter cent)	0.69	0.94	0.89	0.62	0.26	0.38	1.05	0.96	1.32	0.66
Norw-Lof gyre index	0.6081	-0.5633	0.2956	0.137	-0.4785	-0.354	0.7459	0.2143	-0.8049	1.95
Svinoy-coreT	8.24	8.59	8.83	8.17	8.76	8.42	8.53	8.27	8.35	8.22
Svinoy-coreS	35.275	35.273	35.284	35.266	35.324	35.317	35.308	35.276	35.26	35.23
Areal for S>35 (km2)	107.6	108.9	123	94.33	100.01	125.57	124.24	92.57	120.3	112.25
Herring habitat	6.2089	6.4682	6.3754	6.3273	6.4586	6.3466	6.3978	6.1512	6.385	6.46
Blue Whiting Habitat	6.3818	6.3113	6.3081	6.2409	6.2025	6.4106	6.1384	6.1961	6.2953	6.49
Mackrel habitat	3.1349	3.5351	3.596	3.2117	3.8457	3.3398	3.1541	2.6738	3.0132	3.06
Arctic Water in NS	0.0206	0.0646	0.098	0.0703	0.122	0.0933	0.0286	0.0965	0.0243	0.023
Mackerel 0-group index	0.098808751	0.094132945	0.075337645	0.071033429	0.065389631	0.089285081	0.103440179	0.084659561	0.081859108	0.095786088
Herring B from Norwegian Sea survey	5 109	9 100	12 161	9 996	10 406	5 777	7 298	4 629	5 291	5 064
Zooplankton B	9.179697196	8.908655738	7.980467432	7.066093735	3.946682143	4.380820896	6.383082278	5.89415736	7.028518072	9.514232877
Zooplankton B, Lofoten basin	8.9	4.6	7.5	8	6.9	6.2	7.6	7.7	7.3	
Zooplankton B,	8.8	4.6	6.5	6	6.6	4.8	5.2	5.8	6.2	

Variable	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014
Norwegian basin										
Zooplankton B west of 2W	10.2	10.4	11	6.3	3.5	3.9	9.7	4.8	9.3	
Zooplankton mean_øs	8.4	5.5	7.8	6.9	6.5	5.3	7	6.5	7.3	
fsc_i_w	8.2107	5.3445	5.742	5.315	3.9128	2.4793	7.4639			
fsc_i_s	3.9555	5.4491	4.765	3.8679	4.0815	4.0399	4.9246			
snw_i_w	44.199	33.15	34.011	28.586	27.582	27.635	35.189			
snw_i_s	29.577	29.423	27.143	22.793	24.194	19.577	25.438			
rs_i_w	15.576	8.2632	6.7484	6.3743	5.0278	1.475	9.518			
rs_i_s	4.4808	5.4508	4.8766	2.1934	1.9612	2.9115	5.439			
mr_u_w	-30.944	-27.023	-32.229	-29.066	-22.092	-28.362	-33.036			
mr_u_s	-27.119	-18.522	-25.376	-17.466	-19.173	-17.892	-21.823			
bkbi_i_w	22.155	11.894	9.9808	11.544	8.6334	4.1054	11.234			
bkbi_i_s	11.574	9.8222	10.31	7.946	7.2803	6.2144	9.9903			
Herring C	1 003 243	968 958	1 266 993	1 545 656	1 687 371	1 457 015	992 997	826 000	684 743	461 306
Mackerel C	543 486	472 652	579 379	611 063	734 889	869 451	946 661	894 684	933 165	1 394 454
Blue whiting C	2 026 953	1 968 456	1 612 330	1 246 465	635 639	523 832	103 592	384 016	626 036	1 155 279
Herring F	0.176	0.184	0.158	0.199	0.191	0.198	10.147	0.146	0.138	0.11
Mackerel F	0.345	0.327	0.373	0.348	0.311	0.3	0.298	0.285	0.302	0.339
Blue whiting F	0.531	0.441	0.452	0.422	0.267	0.21	0.04	0.121	0.197	0.428

Annex 3: WGINOR multiannual terms of reference for the next meeting

WGINOR have finalized its 3-year terms of reference and have proposed that the group should be continued. Below we propose terms of reference for the next period. The group proposes Guðmundur J. Óskarsson, Iceland, and Per Arneberg, Norway as new co-chairs for the working group.

	Meeting dates	Venue	Reporting details	Comments (change in Chair, etc.)
Year 2016	28 Nov.– 2 Dec.	IMR, Bergen, Norway	Interim report by 9 January 2017 to SSGIEAand SCICOM	
Year 2017	To be decided	Havstovan, Torshavn, Faroe Island	Interim report by January 2018 to SSGIEA and SCICOM	
Year 2018	To be decided	MRI, Reykjavik, Iceland	Final report by January 2019 to SSGIEA and SCICOM	

ToR descriptors:

ToR	Description
A	Perform up to date integrated assessment for the Norwegian Sea ecosystem focusing on fisheries, but also considering other human pressures.
B	Utilize multispecies and ecosystem models to investigate effects of single and multispecies harvest control rules on fishing yield and ecosystem state for the purpose of developing ecosystem based advice.
C	Update the Ecosystem Overview for the Norwegian Sea.

Summary of the Work Plan

Year 1	Focus on understanding expectations of IEA end-users, continue the compilation of relevant time-series, and continue the work on integrated assessment for the Norwegian Sea
Year 2	Focus on, through modelling, single vs. multispecies harvest control rules for development on ecosystem based advice, and outstanding issues for integrated assessment,
Year 3	Focus on advancing IEA in management advice, revise the time series, perform integrated asssessment, and update the Ecosystem Overview.

Supporting information

Priority	WGINOR aims to conduct and further develop Integrated Ecosyste Assessments for the Norwegian Sea, as a step towards implementing th ecosystem approach.
Scientific justification	**Term of Reference b)** There have been international fish-plankton centred surveys in the Norwegian Sea in May and since the mid 90s. In the most recent years these surveys have transitioned into ecosystem surveys that caputure most of the key components of the ecosystem. These datasets are a firm foundation for undertaking integrated assessment of ecosystem status in the Norwegaian Sea which is yet to be done. A fairly recent book on the Norwegian Sea ecosystem is a good starting point for the assessment. **Term of Reference c)** At present a multispecies fisheries model and an end to end ecosystem model are being set up for the Norwegian Sea. These models are ideal for investigating the effects of existing single species and alternative multispecies harvest control rules on the ecosystem structure and functioning. Although there is some petroleum exploration in the outskirts of the Norwegian Sea, fishing by far represents the most important antropognic impact on this ecosystem. The model analyses will be an integrated part of the assessment. **Term of Refrence f)** Update ecosystem overview for the Norwegian Sea.
Resource requirements	Several national and international research projects support the activiti indicated and no further resources are needed in the short term. In the lor term the group should try to develop an integrated project
Participants	We expect around 15 people to attend.
Secretariat facilities	None.
Financial	No financial implications.
Linkages to advisor committees	It is very important to link this group to ACOM and ensure cooperatic between science and advice.
Linkages to othe committees or groups	There are linkages to the other regional seas programmes and WPIPS whic is the survey planning group and WGWIDE where the stock assessment fo the key pelagic Norwegian Sea stocks is performed.
Linkages to othe organizations	No recognized links.

Annex 4: Recommendations

Recommendation	To Whom
Attending members to the WGINOR meeting in Reykjavík in December 2015, recommends that the WG will continue for another 3 years term within the ICES system. Consequently, new ToRs were proposed (Annex 3) and Guðmundur J. Óskarsson, Iceland, and Per Arneberg, Norway, have agreed to chair the group for that period.	SCICOM and ACOM

Annex 5. Ecosystem Overview for the Norwegian Sea (Tor f)

1. Introduction

Term of Reference f) is to prepare an intial draft of the Ecosystem Overview for the Norwegian Sea, following the structure and criteria given in the 2013 WKECOVER report (ICES, 2013d), and it is presented here. Section 1 and 2 are prioritized while Section 3 is preliminary and incomplete.

The working group participants defined the sections and subsections they would like to see included in the overview, developed, and populated draft overviews for the Norwegian Sea. The ecosystem overview of the Norwegian Sea provides a concise and informative introduction to ecoregion (e.g. Large Marine Ecosystems-LMEs) considered in the ICES advice.

This chapter is mainly cited from the annual IMR marine state report (Bakketeig *et al*., 2015), the book on the Norwegian Sea Ecosystem (Skjoldal, 2004), Huse *et al.* (2012; The INFERNO-report), and Sundby *et al.* (2013; the KILO-report), previous ICES WGINOR reports (2013; 2014a) and other ICES working group reports and advices (2014b; 2014c; 2015a) and the Norwegian report on information for revision of the management plan for the Norwegian Sea (2014).

Additional data are provided from the international ecosystem survey of the Norwegian Sea (IESNS and IESSNS as well as additional IMR surveys), the Mareano-surveys (Buhl-Mortensen *et al.*, 2012a; 2012b), seabird monitoring (SEAPOP 2015) and target survey for single species (Egga nord 1994–2009 Greenland halibut *Reinhardtius hippoglossoides*; Whale counting; Surveillance of corals and sponges; the phyto- and zooplankton transect Svinøy-Gimsøy) and hydrography; (NACO-Norwegian Atlantic Currents Observations).

2. Ecoregion description

The Norwegian Sea, the Greenland Sea, and the Iceland Sea comprise the Nordic Seas, which are separated from the rest of the North Atlantic by the Greenland–Scotland Ridge (Figure 1).The Norwegian Sea (NS) connects with the Northeast Atlantic Ocean to the southwest, the Iceland and Greenland Sea to the west along the edge to the shallower Iceland sea between the Faroe Islands, and northwards to Jan Mayen. To the south it borders to the shallower North Sea along the 62°N parallel between Norway and the Faroes Islands and the shallower Barents Sea to the northeast.

The Norwegian Sea covers more than 1.1 million km^2, consisting of two deep basins (between 3000 and 4000 m deep), the Norwegian Basin and the Lofoten Basin, separated by the Vøring plateau (between 1000 and 3000 m deep). The Norwegian Sea is separated from the Greenland Sea to the north by the Mohn Ridge. To the west, the basin slope forms the transition to the somewhat shallower Iceland Sea. The upper ocean of the Nordic Seas consists of warm and saline Atlantic water to the east, and cold and fresh Polar water from the Arctic to the west.

The Norwegian and Barents seas are transition zones for warm and saline waters on their way from the Atlantic to the Arctic Ocean. The major current, the Norwegian Atlantic Current (NwAC), is a poleward extension of the Gulf Stream and the North

Atlantic Current, that acts as a conduit for warm and saline Atlantic Water from the North Atlantic to the Barents Sea and Arctic Ocean (Polyakov *et al.*, 2005).

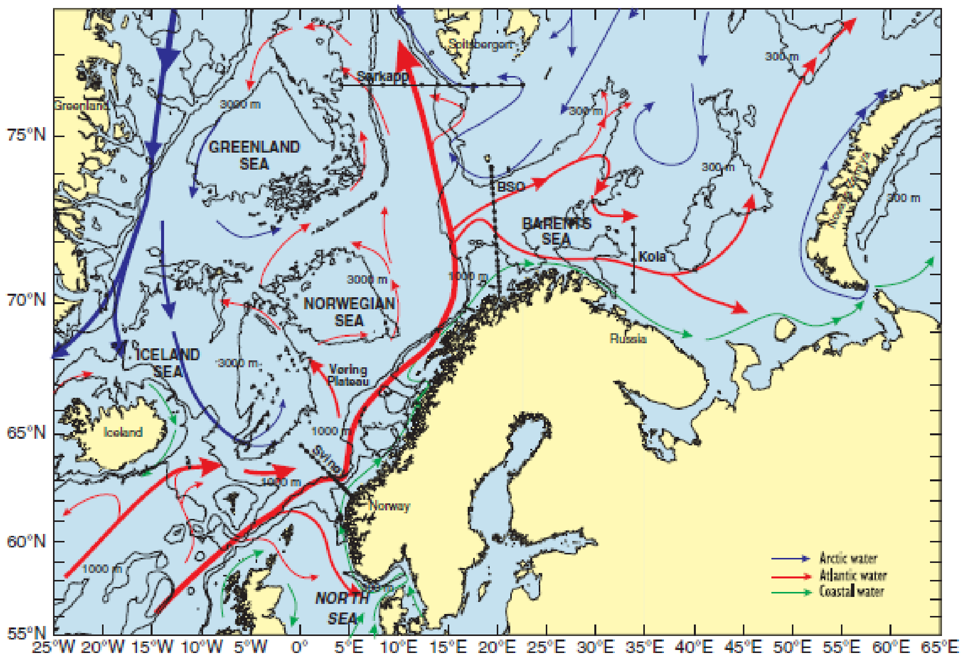

Figure 1. Schematic of surface currents in the Norwegian Sea; red arrows represent warm Atlantic Water and blue arrows denote Polar Water.

3. Key signals within the environment and ecosystem

- Many observations indicate that the Northeast Atlantic water has been cooling in the recent 7 to 8 years (the AMO index). This agrees with earlier findings about a 60–70 year natural climate variability, which for the next quarter of a century may hide the predicted heating due to greenhouse gases.
- The last decade is the warmest on record, with highest temperatures ever recorded in this period.
- Both the surface and bottom-waters temperature have been above the long-term trend in the last decade peaking in 2007 in the 50–500 m depth water at almost 1.5˚C above the long-term mean. Even if the 2014 level was near and slightly above and 2015 level at and below the long-term mean, the temperature trend is still positive, due to inflow of Atlantic waters at the western entrance. The heat content of Atlantic water in the Norwegian Sea has since 2000 been above the long-term mean.
- A decrease in zooplankton biomass index for the whole Norwegian Sea observed during the last decade has stopped. The index increased again from 2010 to 2014, but had a drop in 2015.
- In the past decade, the mackerel *Scomber scombrus* stock has increased both its geographic distribution during summer feeding and stock size. Colder surface temperature in 2015 has limited the northern distribution range compared to the previous years.

- The Norwegian spring-spawning (NSS) herring *Clupea harengus* stock has not produced large year classes after the relatively productive period of 1998–2004 and is in need of a strong year class to help bring the stock back to higher levels.
- The blue whiting *Micromesistius poutassou* biomass reached a maximum level in mid 2000s, declined thereafter to around 2010, but has since then shown an upward trend with income of strong year classes.
- The alien species comb jelly *Mnemiopsis leidyi* are occasionally observed along the Norwegian coast, latest in 2014. It could be considred that this species may be a possible key signal for temperature change.
- There are no indications in 2015 that any of the ecosystem components are in critical state.

4. Pressures

The evaluation of human activities is cited from ICES WGINOR (2013), ICES WGWIDE (2015a) and the Norwegian Directorate of Environment Report (2014). The content is also checked and supplied with additional information coming from the conclusions in the status report to the Norwegian management plans for the NS reports on ecosystem state and trends (Arneberg *et al*., 2013), Revised management plan for the NS (Meld.St. 2008–2009) and report for evaluation of the Norwegian Sea managing plan (Direct. of climate and Environment 2014), IMR annual report (2015). The glossary of principal pressures in ICES ecoregions used in this section is presented in Table 10.2 and the table on human activities, pressures and state of ecosystem components in Table 10.3.

The NS is strongly influenced by human activity; historically involving the fishing and hunting of marine mammals. More recently, human activities also involve transportation of goods, oil, gas, and tourism.

In the last years, interest has increased on the evaluation of the most likely response of the NS ecosystem to the future climate changes due to anthropogenic effects on climate warming. Human induced climate change and ocean acidification may have large influence on the NS in future. Changing distributions of valuable fish stocks (e.g. mackerel and NSS herring) leads to international disputes on harvest rights and quota sharing. It may also lead to changes in spawning success and changes in migration patterns and ecological cascades with unknown outcome.

Fishing for pelagic fish stocks are the major fishing activity in the region, with multinational fleets. The number of fishing vessels is declining while the sizes of the vessels are increasing. The Norwegian commercial fleet has the highest fishing activity in the shelf area, particularly along the coast of Møre, the Sklinnabank, Sklinna deep, and along the Egga edge in Norwegian waters (Figures 2a and 2b). The Icelandic vessels operate mainly with pelagic trawl in the region and bottom trawl and longlines in the outskirts of the region (Figure 2.c). The Working Group lacks information on fishing activity of other parties (e.g. Russia, Faroe Island, and European Union) but can infer from maps showing fishery of NSS-herring, mackerel, and blue whiting in the WGWIDE reports (e.g. ICES 2015) that it is considerable and most likely mainly taken by pelagic trawlers.

Bottom trawls are regulated along the Norwegian continental slop through closed areas to avoid extended damage on fragile and vulnerable benthic societies and reef building organisms.

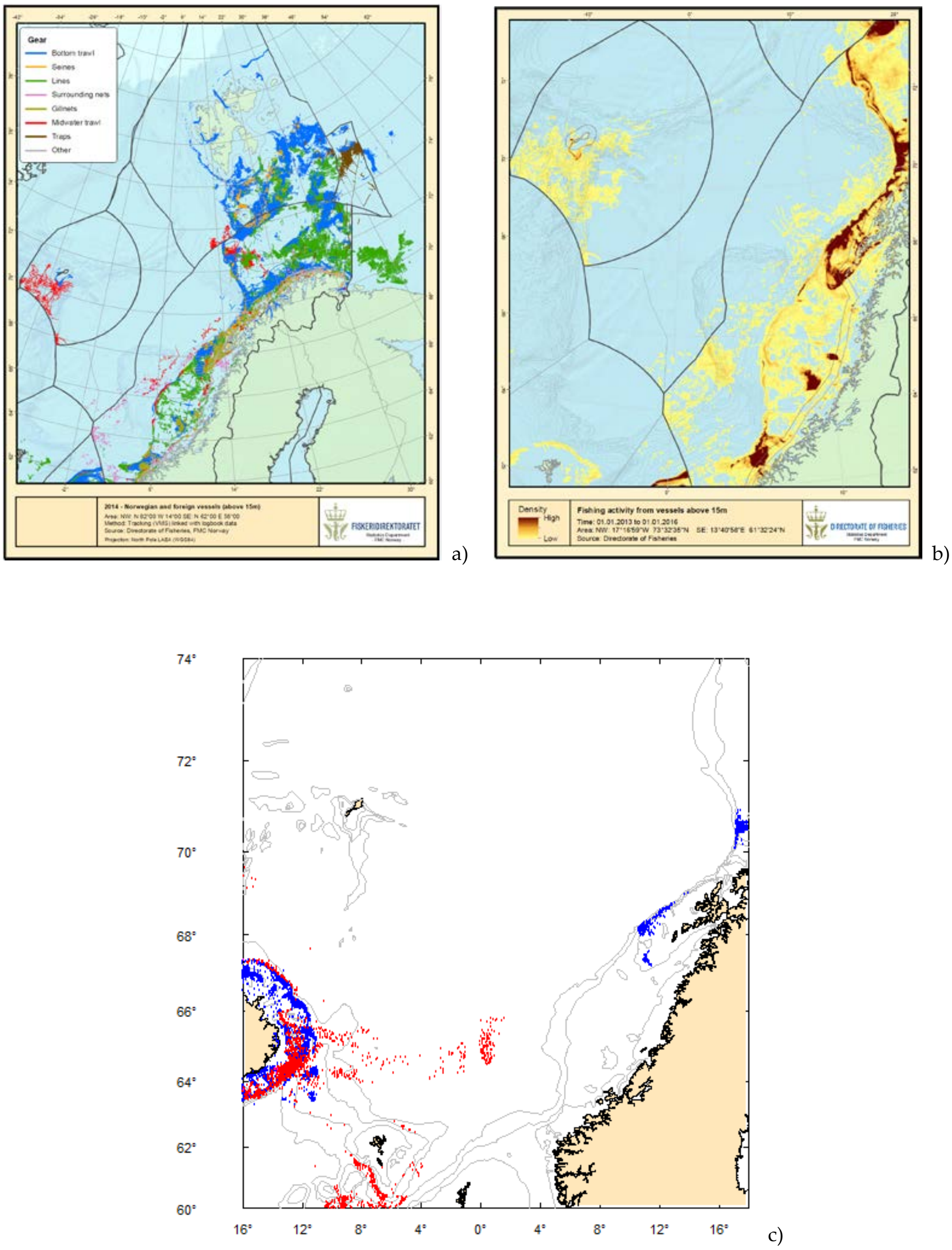

Figure 2. Representation of fishing activity in the Norwegian Sea (a) by the Norwegian fleets (larger than 15 m) in 2014 with pelagic trawls (red dots), bottom trawls (blue dots), gillnets (light green), longlines (green), and seines (orange), by (b) Norwegian and foreign fishing commercial fleets (larger than 15 m) and fishing vessels used for research purposes from 01.01.2013 to 01.01.2016, as reported (VMS) to Norwegian authorities (Source: AFWG 2015; Norwegian Directorate of Fisheries; WGIBAR, 2015), and by (c) the Icelandic fishing fleet in 2014 with pelagic trawls (red dots), bottom trawls (blue dots) and purse-seines (orange).

The oil and particularly gas related activities are managed through governmental licenses for predesigned areas and purchases of already opened areas between operational petroleum companies. Seismic investigations kept on a relatively stable level and are prohibited in the Norwegian sector during the spawning periods of NEA cod and NSS herring.

Releases of NO_x, CO_2, and pollutants (oil releases to the sea, climate gases, organic acids (declining), phenols, PAH, radioactive compounds; Table 10.1) in produced water from the petroleum activities is fairly stable or in some cases slowly raising (total amount of produced water, heavy metals, aromatic carbon compounds, and other compounds).

Table 10.1. Releases of produced water, pollutant compound-wise for selected pollutants for the years 2008–2012 (Source: Directorate of Climate and Environment, 2014).

Report year	Other compounds	Benzen, Toluen, Ethylbenzen and Xylen BTEX	Phenols	Oil-mixed water	Organic acids	PAH
2008	1 036 721	234 611	81 193	114 409	3 404 180	18 705
2009	1 533 626	281 028	84 278	181 296	3 269 116	20 239
2010	1 687 508	278 238	94 821	175 721	3 142 347	18 394
2011	1 887 642	325 995	96 127	188 648	2 809 525	22 309
2012	2 135 859	310 256	86 257	178 775	2 129 863	20 000

Marine traffic has a slight increasing trend, in particular in tourist traffic. Most ships are following the main traffic lanes, vessel density are high near the coasts, in addition to the centre of the Norwegian EZZ. (Figure 3).

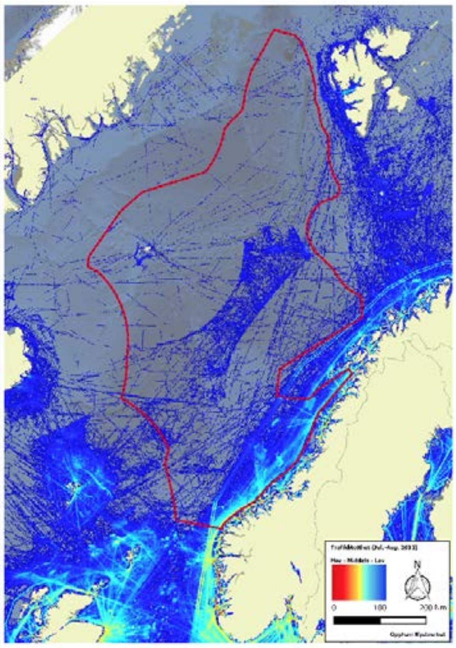

Figure 3. Density plot for vessels movements (AIS-data) in the Norwegian Sea for July through August 2013 (Source: Directorate for shipping).

The assessments on impacts are based on the present activity landscape. If risk assessments are to be included in the ecosystem overview at some time, this assessment will have to be revised. The principal cumulative pressures in the NS are described below.

4.1 Selective extraction of species (including non-target catch)

Annual catches varies between 700 000 metric tonnes to almost 1 million metric tonnes (2012) were reported from the stocks of NSS herring, mackerel, blue whiting, NEA saithe *Pollachius virens*, redfish *Sebastes* sp., and silver smelt *Argentina silus*. While the common redfish *S. marinus* stock is on a dramatic low, the beaked redfish *S. mentella* stock has recovered and fishing quotas are set to 30 000 t annually until 2017. The fisheries management plan sets the upper limits for landings in the region and new regulations in 2011 puts restrictions on the use of bottom trawls in areas with coral reefs and deeper than 1 000 m. Some bycatch of Seabird are known but not quantified.

4.2 Seafloor integrity

Mareano, a Norwegian seafloor mapping programme has located several vulnerable habitat locations, where a set of coral and sponge communities are protected from bottom fishing activities and petroleums-related activities in the Norwegian EZZ, in particular at the Møre plateau and the continental shelf outside Northen Norway (Figure 4). Still, commercial fisheries are the largest human activity directly towards living marine resources in for of the wide distribution and high intensity. The impacts on the fish stocks in the NS will indirectly have some impact on the functioning of the whole ecosystem. However, the observed variation in both fish species and the ecosystem is also affected by other factors such as climate and trophic interactions. The most widespread gear used in the central BS is pelagic trawl and purse-seine for NSS herring and mackerel. Bottom trawls, longline, and gillnets are used in the demersal fisheries.

Currently, there is a multinational fishery operating in the NS using different fishing gears and targeting several species. The largest commercially exploited fish stocks (NSS herring and mackerel) are now harvested at fishing mortalities close to those in the management plan and have full reproductive capacity. However, some of the smaller stocks (golden redfish *Sebastes marinus* and coastal cod *Gadus morhua* in Norway) are overfished. Other stocks are commercially harvested (blue whiting, silver smelts, greenland halibut *Reinhardtius hippoglossoides*, halibut *Hippoglossus hippoglossus*, beaked redfish *Sebastes mentella*, deep-water shrimps *Pandalus borealis*, *Calanus finmarchicus*, and minke whales *Balaenoptera acutorostrata*. After 15 years with recommendations of no directed fisheries for *S. mentella*, the stock is at present close to being rebuilt, and ICES advises again on annual catch. Damage to benthic organisms and habitats from trawling as well as unavoidable bycatch of marine mammals and Seabirds fisheries has been documented (Kutti *et al.*, 2005; St. meld. 2008–2009; Meld.St. 2010–2011; Skjoldal *et al.*, 2013). Further detailed information on the fisheries impact on the NS ecosystem can be found in ICES WGWIDE report (2015).

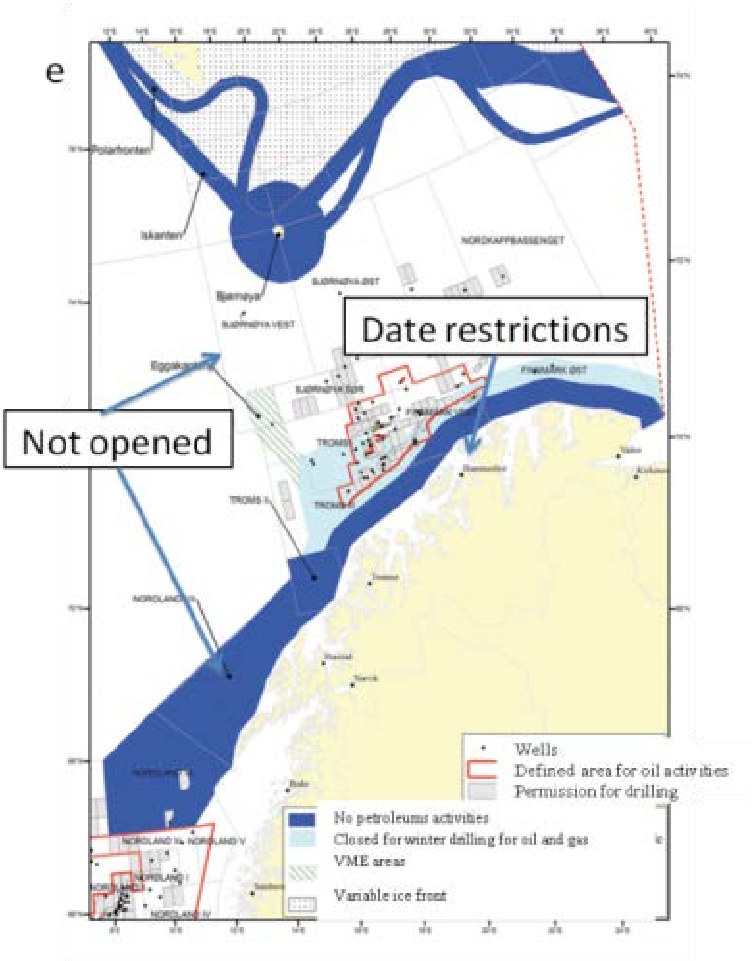

Figure 4. Norwegian VME areas protected from petroleum-related activities due to reef-building organisms and the variable ice front (Source: Meld. St. 2010–2011).

4.3 Introduction of non-synthetic and synthetic compounds

The major sources of contaminants in the NS are long-range transport from outside the region, natural processes, accidental releases from local activities, and ship fuel emissions. The NS remains relatively clean with low pollution levels compared to marine areas in many industrialized parts of the world.

Like for the Barents Sea, transport of oil and other petroleum products from ports and terminals in northwest-Russia have been increasing over the last decade and in a five-ten years perspective, the total available capacity from Russian arctic oil export terminals can reach the level of 100 million tonnes/year (Bambulyak and Frantsen, 2009). Therefore, the risk of large accidents with oil tankers will increase in the years to come, unless considerable measures are imposed to reduce such risk.

The consequences of major oil releases are analysed and discussed in several reports including Huse *et al.* (2012) and Sundby *et al.* (2013).

4.4 Substratum loss

Oil and gas extraction is being developed in the NS. Currently offshore development is limited in the Norwegian economic zone. Currently there are plans for the development of new gas-and oil activities in the region. Pipelines and seabed production units are being planned and developed.

4.5 Nutrient and enrichment

Aquaculture is growing along the coasts and in fjords of central Norway. There are several commercial fish farms producing salmonids (salmon, trout) and shellfish. With aquaculture the nutrients and enrichment increase and can be a problem locally but is not considered having any impact on the open ocean of the Norwegian Sea.

River run-offs are negligible and not regarded in this overview.

4.6 Compiled overview of the impact by human activities

The human activity with the strongest impact in the NS region is still the fisheries. Fishing has therefore been listed with impact factor 3 for deliberate extractions and 2 for bottom trawling induced physical damage of the physical habitats and for smothering fragile benthic species. Petroleum-related activities are more developed in the NS than in the BS, but have limited areal distribution. For the actual areas, it may be considered to have impact factor 2 but for the NS as a whole it is given impact factor 1.

An overview of the human activities with potential pressures on the elements of the NS ecosystem is provided in Appendix, Table 2. The alleged strength of the relations between the pressures are given in a scale from 1 (least impact) to 3 (strongest impact).

How ecosystem overviews like this can achieve the purpose of presenting more specific and better informed assessments and advices should be further discussed, but based on the template prepared for the ICES regional overview reports, the present overview seeks to include the best available information to give a best possible overview.

Note, the strength of pressures scaled in this overview should be understood as a relevant strength between the human activities listed and not as an assessment of the actual pressure on the ecosystem.

5. State (trends and variability)

Trend and variability of the main ecosystem live components are listed below. The summary of state is presented in the executive summary of WGINOR 2014 and under Chapter 2: "Key signals within the environment and ecosystems in the current overview".

5.1 Phytoplankton

Due to lack of long-term data and registrations, no trend is made for phytoplankton spring bloom timing, and species compositions and distributions. The calculated biomass varies substantially between the years but any trends are yet to be found.

5.2 Zooplankton

Zooplankton also varies, and it was a decline in the biomass from early in the 2000s until 2009, when the trend turned to an increase that is still ongoing, and reached the long-term mean in 2014 but dropped in 2015. Productivity has been good through the period.

A less understood and monitored group of plankton is the deep-scattering layer of mesopelagic species between 200 m and 800 m depth. Beside beaked redfish and blue whiting, a range of small-sized organisms like crustaceans, jellyfish, cephalopods, and small mesopelagic fish species as lanternfish *Myctophidae*. It is expected that this biological layer may function almost like benthic societies in shallower seas, but little research has been undertaken on this layer of the Norwegian Sea and no commercial harvesting is taking place.

5.3 Benthos and shellfish

Northern shrimp (*Pandalus borealis*) is harvested by bottom trawls along the shells regions and the edges between shallow shelfs and the deeper basins. Compared to the shrimp harvests in the Greenland Sea, Barents Sea, and North Sea, this fishery is not at the same scale.

Reef-building organisms, like sponges and cold-water corals are protected on designated VMPs.

5.4 Fish

The major trends in fish distribution and abundance in Norwegian Sea during the last ten years have been the expansion and increase in the mackerel stock since 2007 and the decline in the NSS herring stock after 2009.

The NSS herring is now considered to be below the precautionary level at 5000 million tonnes. The herring are getting older and a new strong cohort is needed to sustain the breeding stock. A benchmark assessment will be undertaken by ICES in March 2016.

The mackerel stock size has been revised historically through benchmark procedure by ICES WKPELA (2014c) resulting in a revised calculation showing a strong increase reported through ICES WGWIDE (2014b). The resulting assessment shows a general declining stock size during the 1980s, low stock size during the mid-1990s, but increasing again since the mid-2000s (ICES 2015).

The blue whiting stock, which utilizes especially the slope areas of Norwegian Sea and adjacent waters for feeding both as juveniles and adults, was at maximum recorded level in the 2005. Then a decrease followed until around 2011 when the stock size started to increase again due to strong year classes entering the stock (ICES, 2015).

The beaked redfish stock has recovered from the low level it was at some years ago, while the golden redfish has a record low stock size (Planque and Nedreaas, 2015).

The stock size of saithe is relatively stable in the eastern part of Norwegian Sea, and it is mainly found along the Norwegian coast and off the coast in the NS. However, there are large uncertainties in the stock assessment and the landings are advised to be kept stable with no increase.

Lumpfish *Cyclopterus lumpus* is widely distributed across the Norwegian Sea and adjacent waters. As an example, it is caught in almost all pelagic trawl hauls in IESSNS in July-August in the whole region.

Landings of Greenland halibut have been quite low since 1992, but show a slight positive trend since 2009. The stock estimate is uncertain and the landings may not reflect the stock development. Migration studies show that the stocks in the BS and in the NS probably are connected and possibly the same stock.

5.6 Marine mammals

Only minke whales *Balaenoptera acutorostrata* are exploited in the NS. Some decline in the calculated population is seen in the area near Jan Mayen while in the rest of the distribution area from the BS to the North Sea seems to be stable. A new survey in 2014 will look at the whale density near Svalbard, to see if the decline in that region between 2008 and 2011 is prolonged.

5.7 Seabirds

The kittiwake *Rissa tridactyla* had again a consistently bad year in 2014, with almost total breeding failures in most of the Norwegian colonies. Similar to 2013, common guillemots *Uria aalge* had a moderate to good year in all colonies On Røst (northern Norway) puffins *Fratercula arctica* failed to produce fledglings for the 8th year in a row, while production was moderate/good in the other colonies being monitored. More detailed information is presented in Barrett *et al.* (2015).

5.8 Non-indigenous species

No species are found as invasive in the Norwegian Sea, but the comb jelly *Mnemiopsis leidyi* are occasionally registered in zooplankton samples, usually in warmer periods and latest in 2014.

Table 10.2. Glossary of principal pressures in ICES Ecoregions.

Abrasion (interaction of human activities with the seafloor and with seabed fauna/flora)	Abrasion pressures relate to disturbance of the substratum below the surface of the seabed where there is limited or no loss of substratum from the system. This pressure is associated with activities such as anchoring, hydrodynamic dredging, cable burial, propeller wash from vessels and certain fishing activities, e.g. Scallop dredging and beam trawling.
Introduction of Non- synthetic compounds (e.g. Heavy metals, hydrocar- bons) and Introduction of Synthetic compounds (e.g. pesticides, antifoulants, pharmaceuticals)	Introduction of non-synthetic substances and compounds (e.g. heavy metals, hydro-carbons, resulting, for example, from pollution by ships and oil, gas and mineral exploration, atmospheric deposition, riverine inputs) For marine sediments the main transition elements of concern are Arsenic, Cadmium, Chromium, Copper, Mercury, Nickel, Lead, and Zinc. Organo-metallic compounds such as the butyl tins (Tributyl tin and its derivatives) can be highly persistent and chronic exposure to low levels has adverse biological effects, e.g. Imposex in molluscs. Hydrocarbon and PAH contamination. Includes those priority substances listed in Annex II of Directive 2008/105/EC Synthetic compound contamination (incl. pesticides, antifoulants, pharmaceuticals). Includes those priority substances listed in Annex II of Directive 2008/105/EC
Non indigenous species	The direct or indirect introduction of non-indigenous species, e.g. Chinese mitten crabs, slipper limpets, Pacific oyster, and their subsequent spreading and outcompeting of native species. Ballast water, hull fouling, stepping stone effects (e.g. offshore wind farms) may facilitate the spread of such species. This pressure is also associated with aquaculture, mussel or shellfishery activities via imported seed stock imported or from accidental releases.
Nutrient and enrichment	Increased levels of the elements nitrogen, phosphorus, silicon (and iron) in the marine environment compared to background concentrations. Nutrients can enter marine waters by natural processes (e.g. decomposition of detritus, riverine, direct, and atmospheric inputs) or anthropogenic sources (e.g. wastewater run-off, terrestrial/agricultural run-off, sewage discharges, aquaculture, atmospheric deposition). Nutrients can also enter marine regions from 'upstream' locations, e.g. via tidal currents to induce enrichment in the receiving area. Nutrient enrichment may lead to eutrophication (see also organic enrichment). Adverse environmental effects include deoxygenation, algal blooms, changes in community structure of benthos and macrophytes.
Organic enrichment	Resulting from the degraded remains of dead biota and microbiota (land and sea); faecal matter from marine animals; flocculated colloidal organic matter, and the degraded remains of: sewage material, domestic wastes, industrial wastes etc. Organic matter can enter marine waters from sewage discharges, aquaculture or terrestrial/agricultural run-off. Black carbon comes from the products of incomplete combustion (PIC) of fossil fuels and vegetation. Organic enrichment may lead to eutrophication (see also nutrient enrichment). Adverse environmental effects include deoxygenation, algal blooms, changes in community structure of benthos and macrophytes.

Selective extraction of species, including incidental non-target catch (e.g. By commercial fishing, recreational angling, and collecting/harvesting) (figure on fishing effort etc. + bycatch text)	The commercial exploitation of fish and shellfish stocks, including smaller scale harvesting, angling and scientific sampling. The physical effects of fishing gear on seabed communities are addressed by the "abrasion" pressure type so this pressure only addresses the direct removal/harvesting of biota. Ecological consequences include the sustainability of stocks, affecting energy flows through foodwebs and the size and age composition within fish stocks. Bycatch associated with all fishing activities ecological consequences include foodweb dependencies, population dynamics of fish, marine mammals, turtles, and seabirds (including survival threats in extreme cases, e.g. Harbour porpoise in central and eastern Baltic).
Selective extraction of living and non-living resources on seabed and subsoil (e.g. Sand and gravel extraction, exploration of subsoil, maerl extraction)	This pressure type relates to temporary and/or reversible change, e.g. from marine mineral extraction where a proportion of seabed sands or gravels are removed but a residual layer of seabed is similar to the predredge structure and as such biological communities could recolonize; navigation dredging to maintain channels where the silts or sands removed are replaced by non-anthropogenic mechanisms so the sediment typology is not changed. Associated effects are the direct removal of benthic organisms, alteration of seabed topography (affecting feeding and colonization) and wider trophic implications for higher predators. Management measures can include actions to leave the seabed in similar physical condition to the preextraction state to enhance the likelihood and rate of physical and biological recovery.
Smothering (by man-made structures or disposal of materials to the seafloor)	Smothering pressures relate to the settling out of silt/sediments suspended in the water column (siltation or sedimentation). Activities associated with this pressure type include mariculture, land claim, navigation dredging, disposal at sea, marine mineral extraction, cable, and pipeline laying and various construction activities.
Substratum Loss (sealing by permanent construction, e.g. Coastal defences, wind turbines)	This pressure type includes both the: permanent loss of marine habitats (associated with activities such as land claim, new coastal defences); and permanent change of one marine habitat type to another marine habitat type, through the change in substratum, including artificial substrata (e.g. concrete). Habitat change involves the permanent loss of one marine habitat type but has an equal creation of a different marine habitat type. Associated activities include the installation of infrastructure (e.g. surface of platforms or wind farm foundations, marinas), pipelines and cables), the placement of scour protection.

Table 10.3. Overview over human activities causing pressures that may induce impacts on the status of selected ecosystem components. The strength of each activity producing pressures and strength of each the pressures on the status of defined ecosystem component pressures are reflecting the different scales of the activity levels in the Norwegian Sea region. This strength scale is not to be read as the strength of the potential for impacts on the ecosystem. The scale goes from 3 (highest) to 1 (least). No scaling is done when available documentation was not available.

HUMAN ACTIVITIES TO...	STRENGTH	PRESSURES	PRESSURES TO...	STRENGTH	STATUS
Fishing	3	Selective extraction of species (including non-target catch)	Selective extraction of species (including non-target catch)	1	Productivity
	2	Physical damage (abrasion)		1	Foodwebs
	1	Physical loss (sealing or smothering)		1	Plankton
Maritime transport	1	Death or injury by collision		2	Benthos
	1	Marine litter		3	Fish
	1	Contamination by hazardous substances (synthetic and non-synthetic)		1	Sea mammals
Oil- and gas production	1	Contamination by hazardous substances (synthetic and non-synthetic)	Physical damage (abrasion)	1	Habitat
	1	Physical damage (abrasion)		1	Benthos
	1	Physical loss (sealing or smothering)		1	Fish
	1	Underwater noise	Physical loss (sealing or smothering)	1	Benthos
Offshore structures	na	Selective extraction non-living	Death or injury by collision	1	Seabirds
Military	na	Underwater noise		1	Sea mammals
			Marine litter	1	Seabirds
Coastal constructions	na	Physical damage		1	Sea mammals
Coastal discharges	na	Physical loss (sealing or smothering) Contamination	Contamination by hazardous substances (synthetic and non-synthetic)	1	Habitat
Tourism and recreation	na	Selective extraction		1	Benthos

Human activities to…	Strength	Pressures	Pressures to…	Strength	Status
Aquaculture	na	Introduction of non-indigenous species		1	Birds
		Nutrient and organic enrichment		1	Fish
				1	Mammals
				1	Foodwebs
			Underwater noise	1	Fish
				1	Mammals

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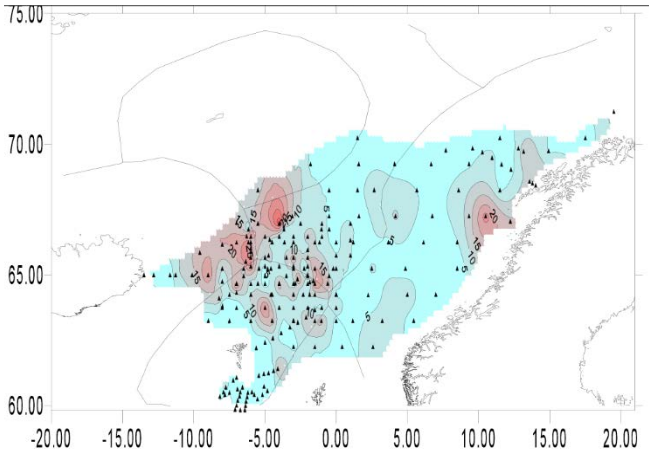
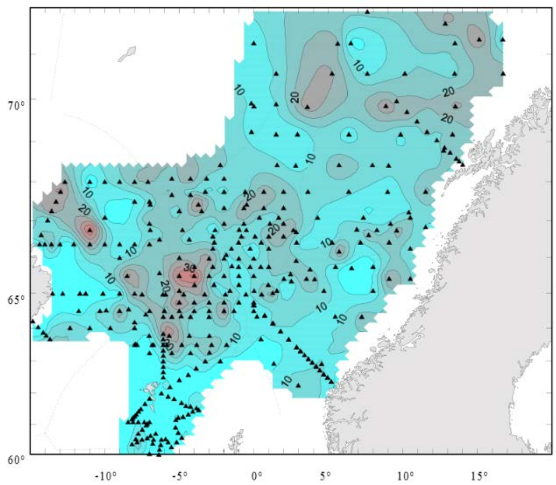
Annex 6. Compilation of zooplankton distribution maps

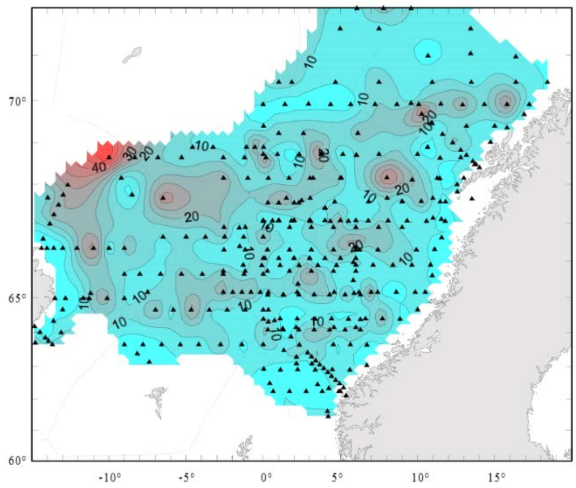
A compilation of maps from various survey reports showing zooplankton biomass indices (g dry weight m^{-2}; 0–200 m) derived from WP2 plankton nets in the Norwegian Sea and adjoining waters for the years 1997–2015 in either May (International Ecosystem Survey in Norwegian Sea, IESNS) or in July-August (International Ecosystem Summer Survey in Nordic Seas, IESSNS, and other national and international surveys prior to 2010).



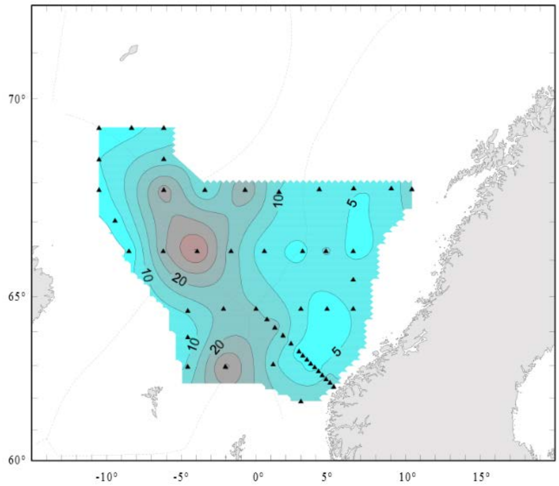
May 1997



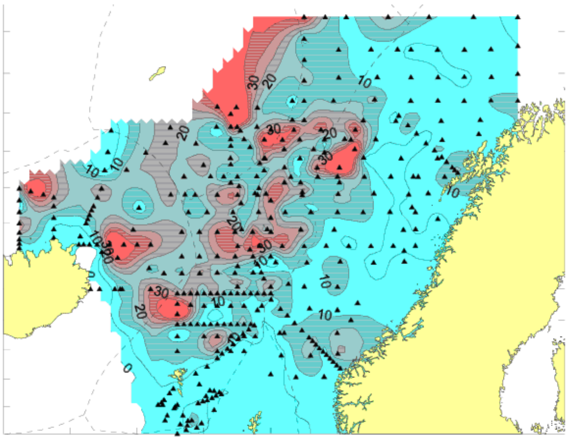
May 1998



May 1999



July-August 1999



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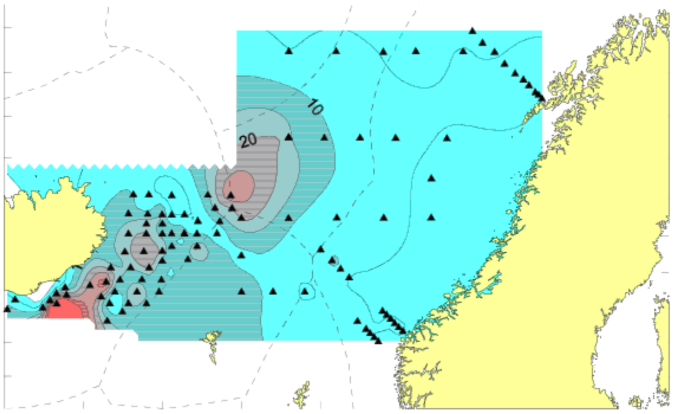
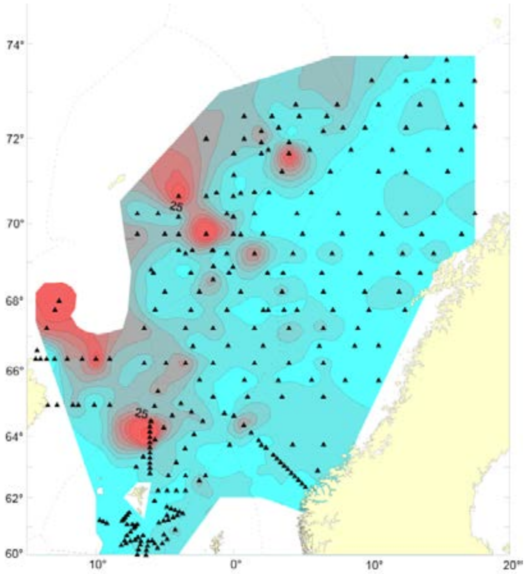


July-August 2000



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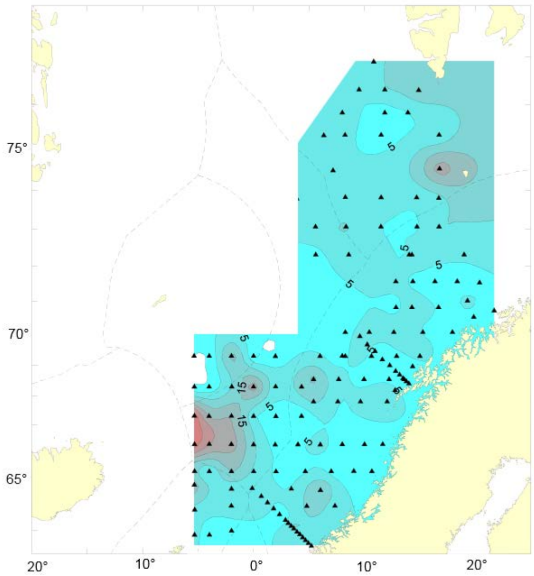
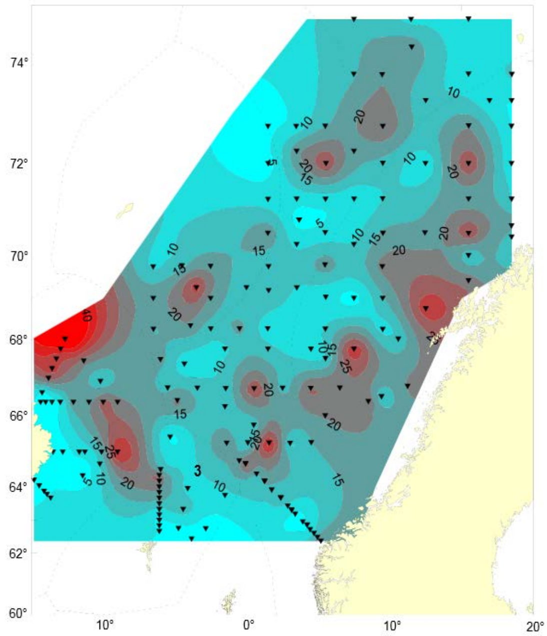
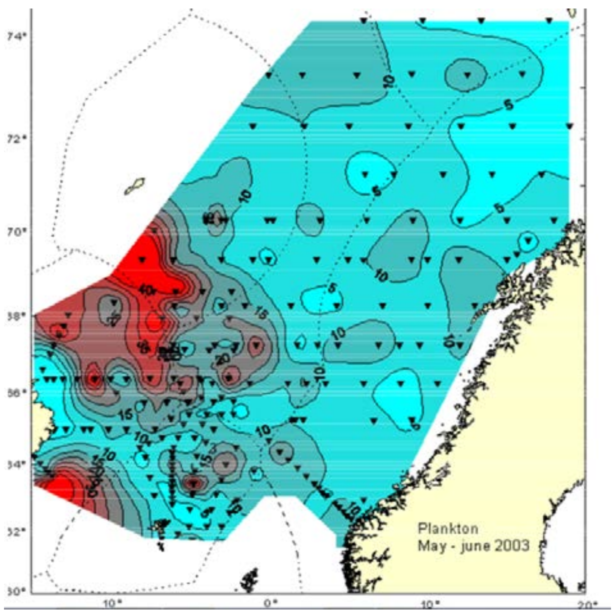


July-August 2001





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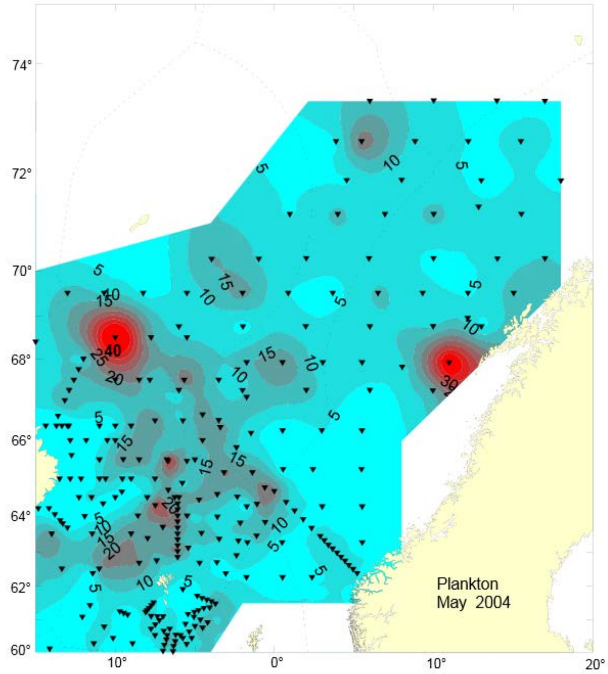

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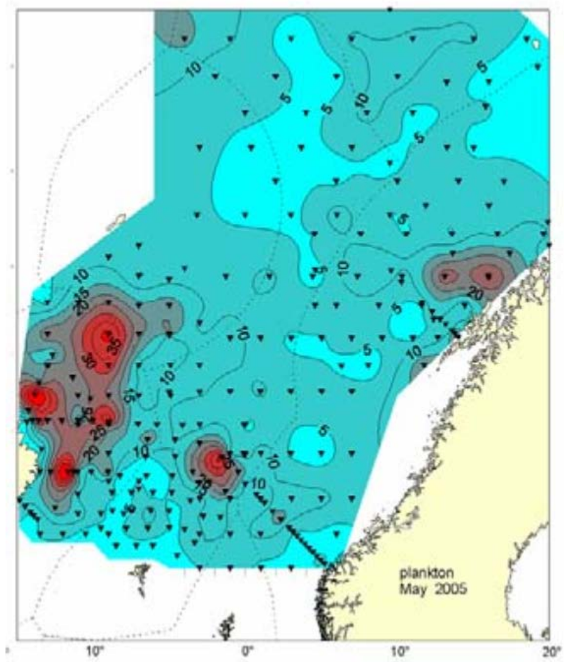

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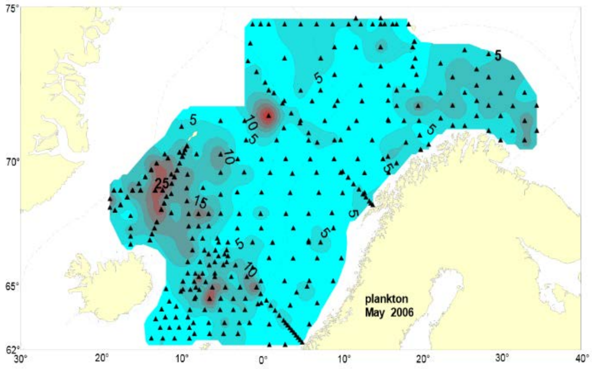

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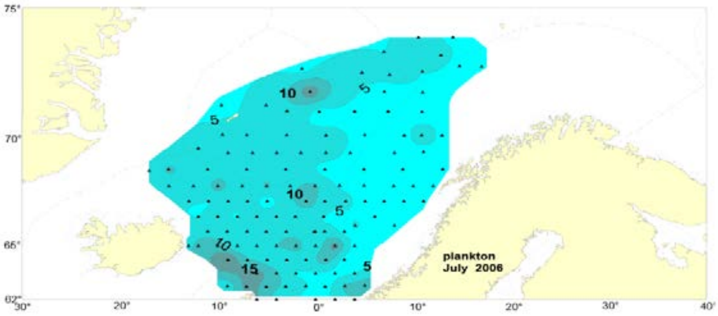
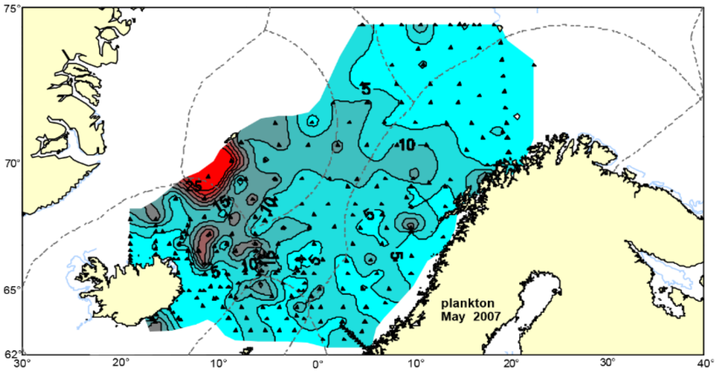


July 2006



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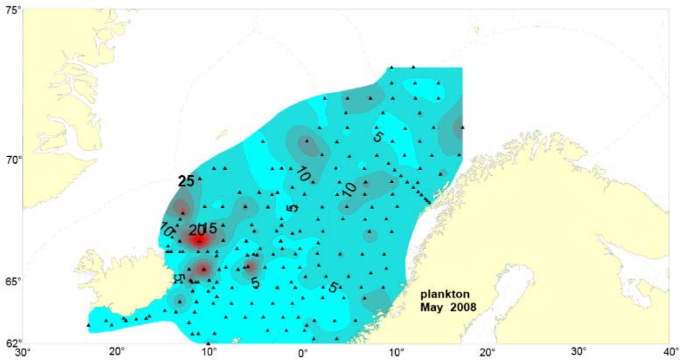
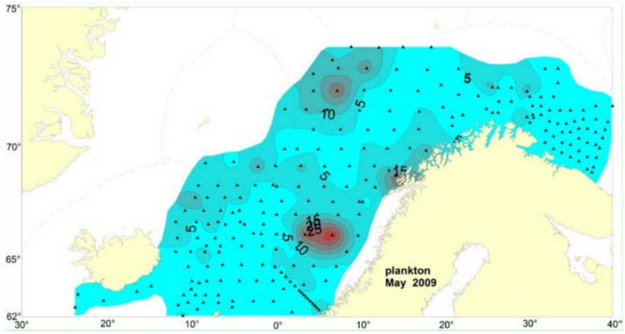
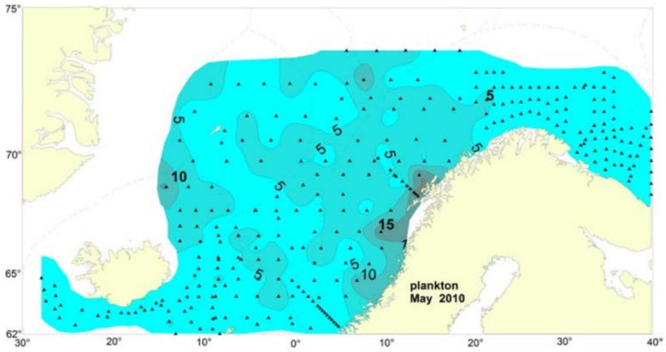


May 2008



May 2009



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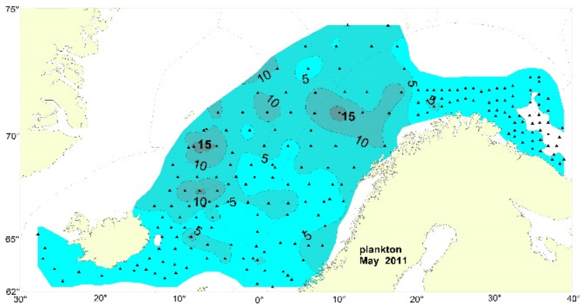

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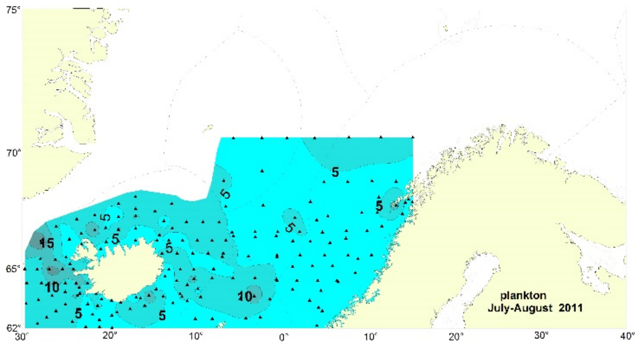
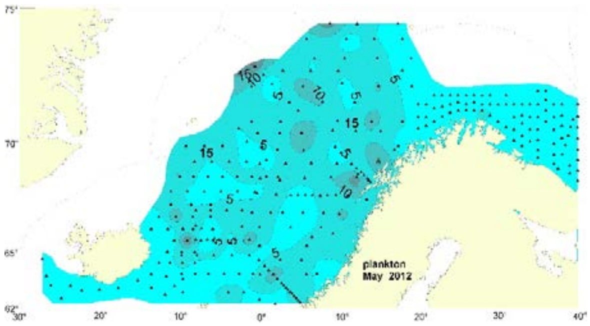


July-August 2011



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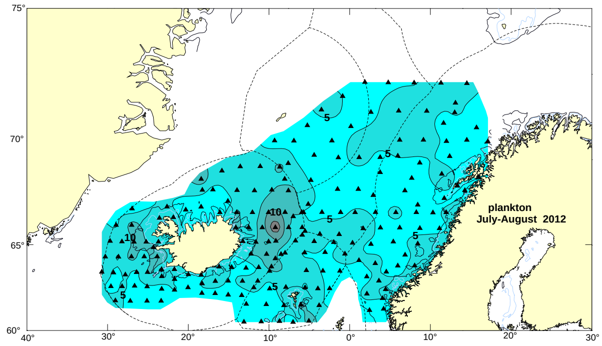

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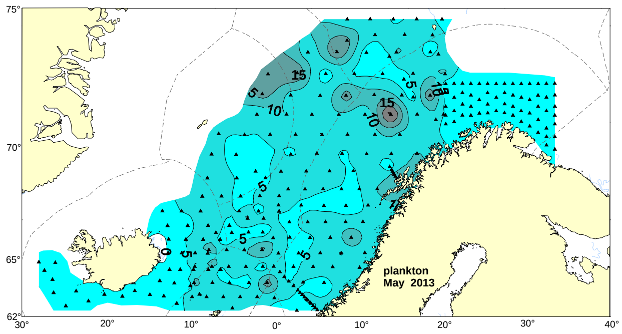

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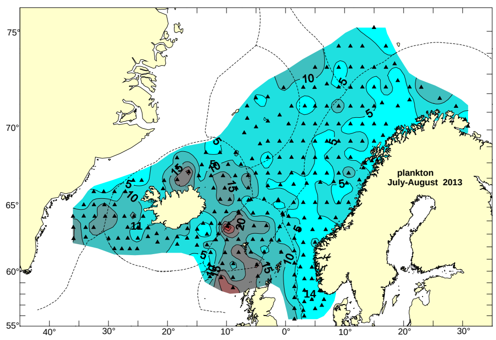

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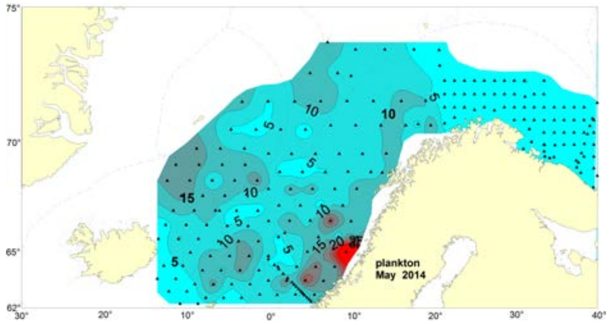

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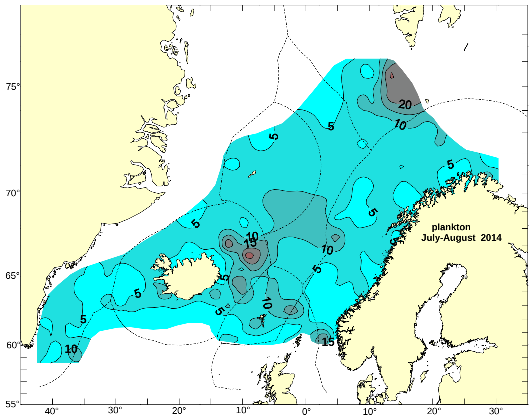

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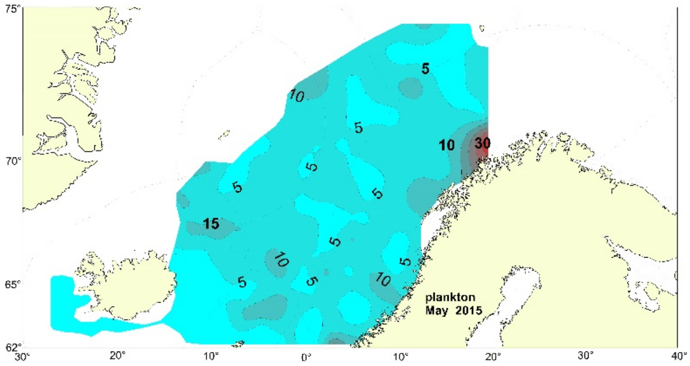
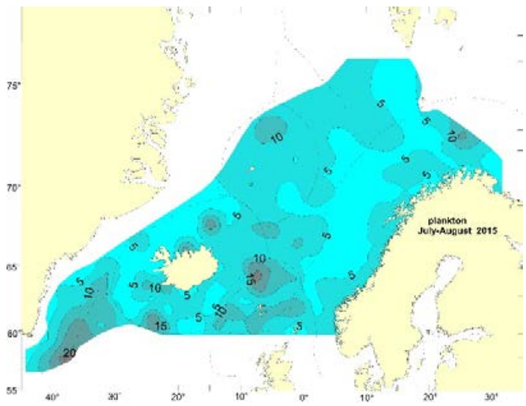


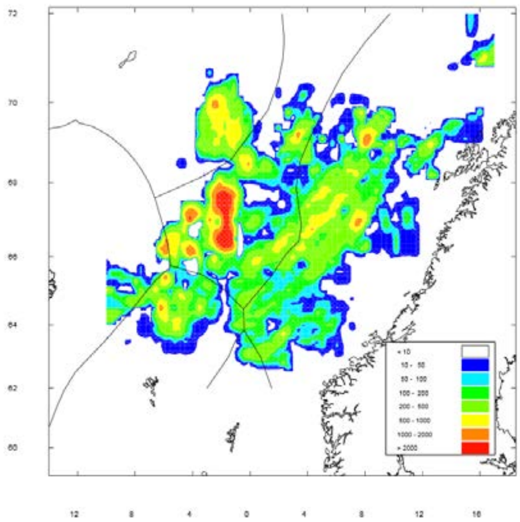
May 2015



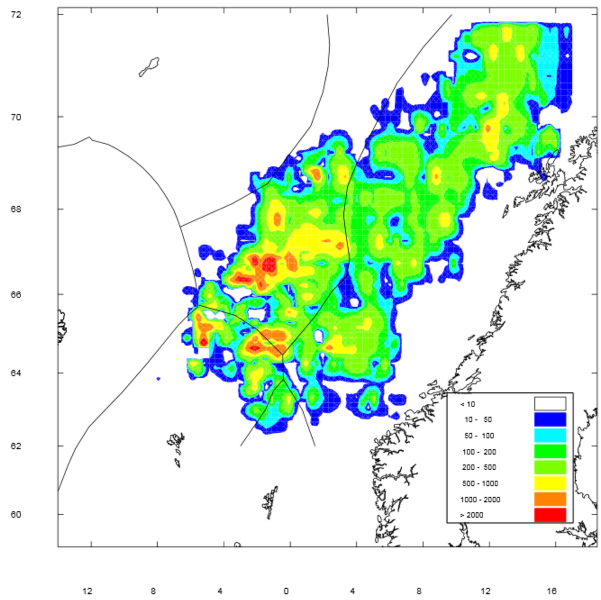
July-August 2015

Annex 7. Compilation of herring distribution maps

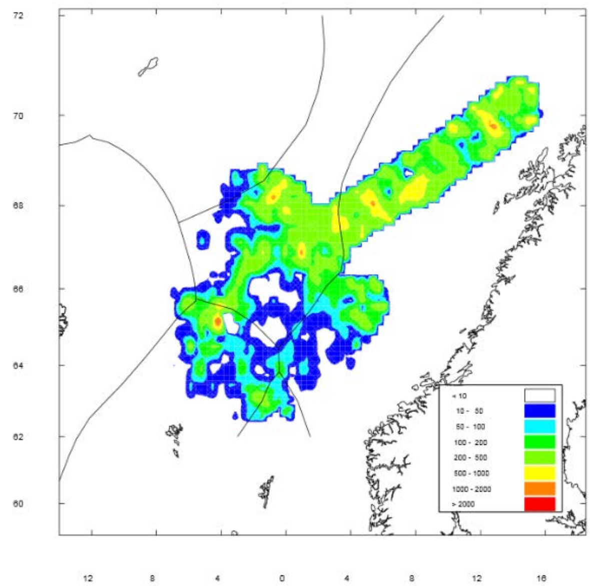
A compilation of maps from various survey reports showing acoustic values (S_A-values; m^2/nm^2) of Norwegian spring-spawning herring in the Norwegian Sea and adjoining waters for the years 1997–2015 in either May (International Ecosystem Survey in Norwegian Sea, IESNS) or in July-August (International Ecosystem Summer Survey in Nordic Seas, IESSNS, and other national and international surveys prior to 2010).



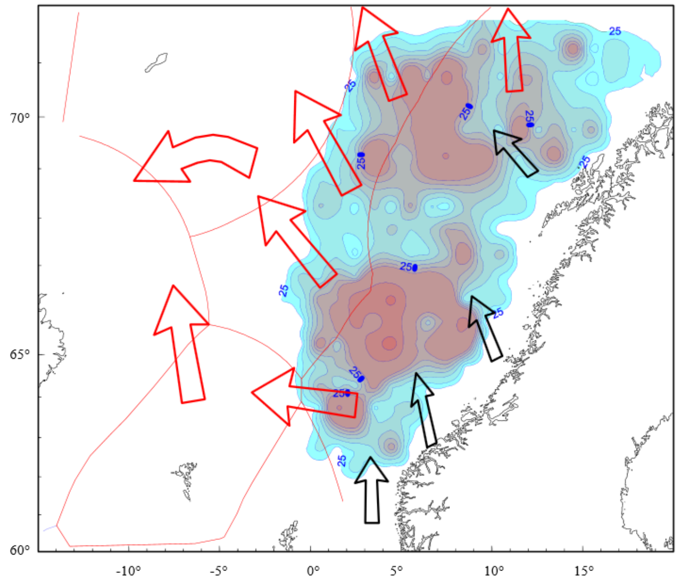
May 1996



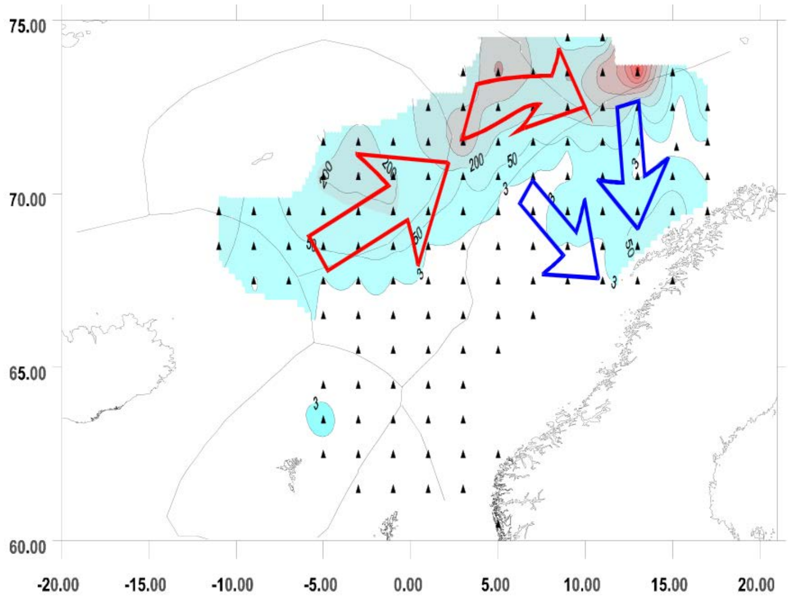
May 1997



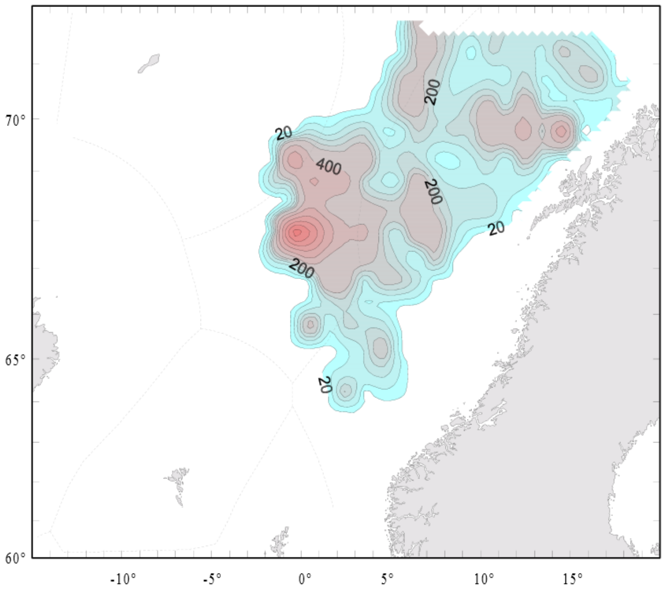
July 1997



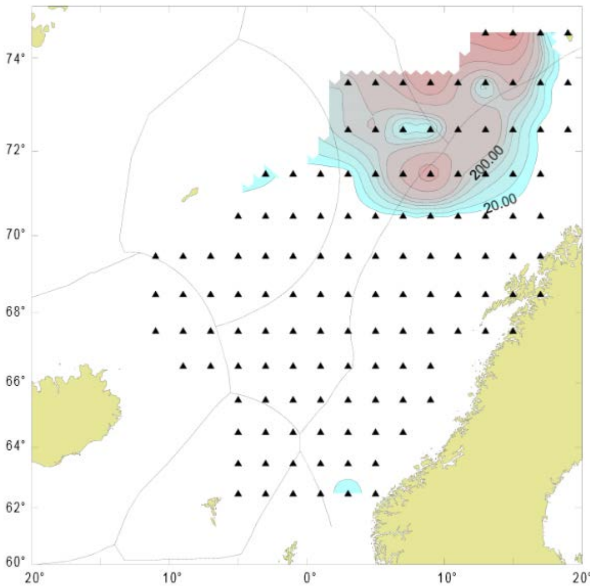
May 1998



July 1998



May 1999



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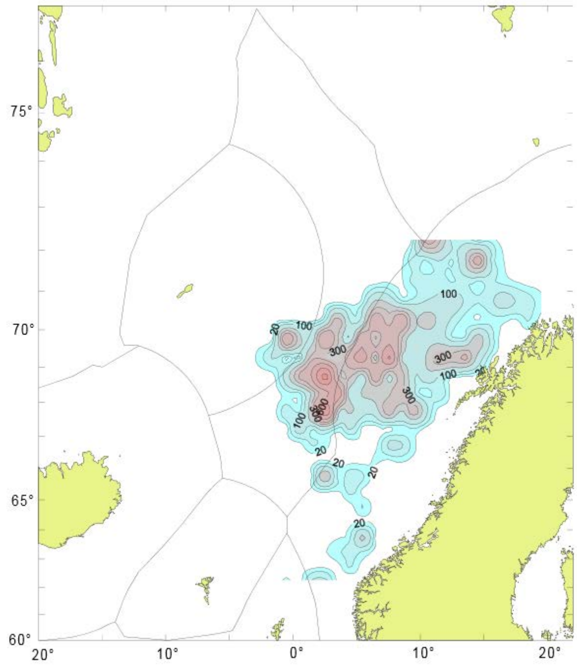
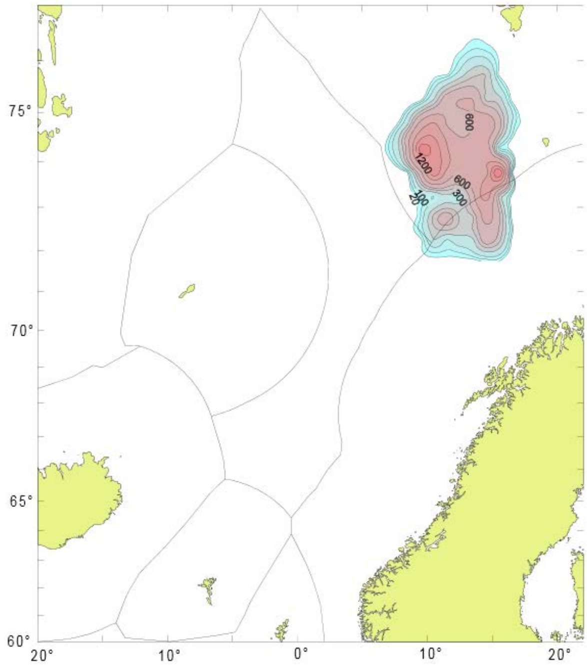


May 2000



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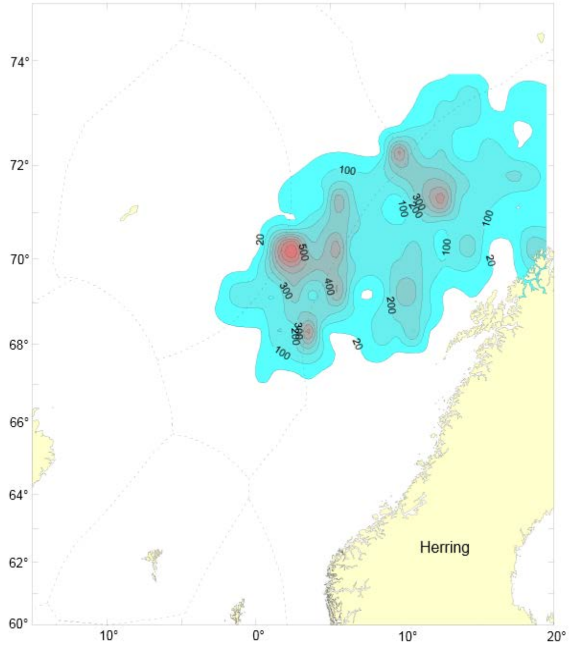
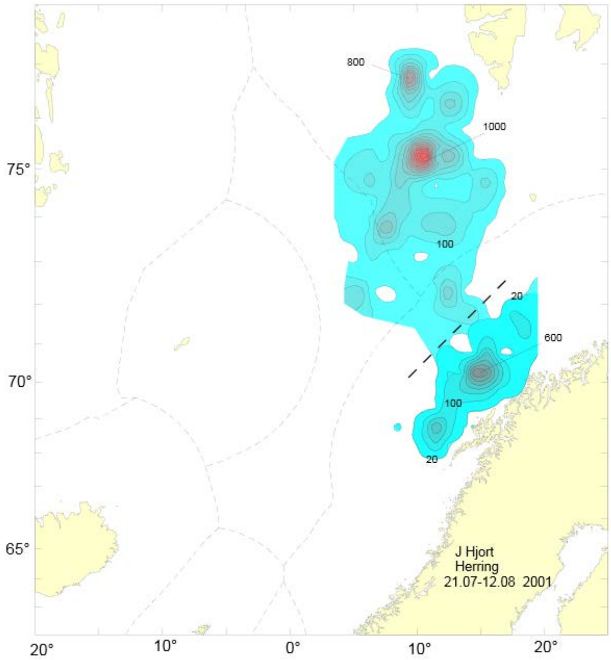


May 2001



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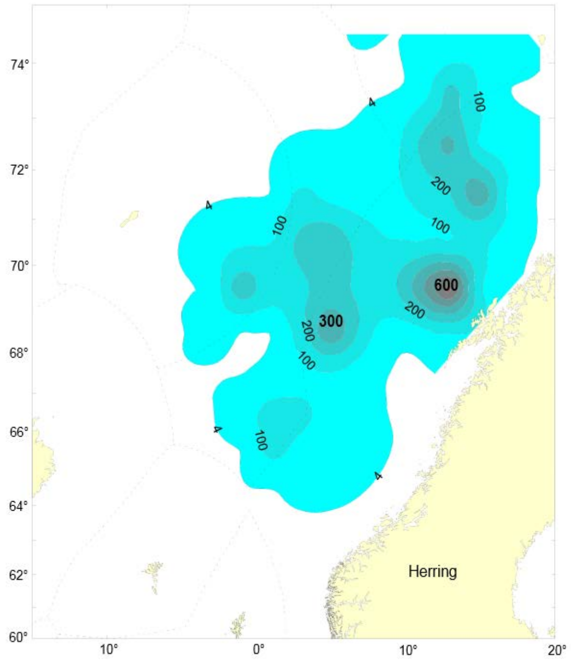
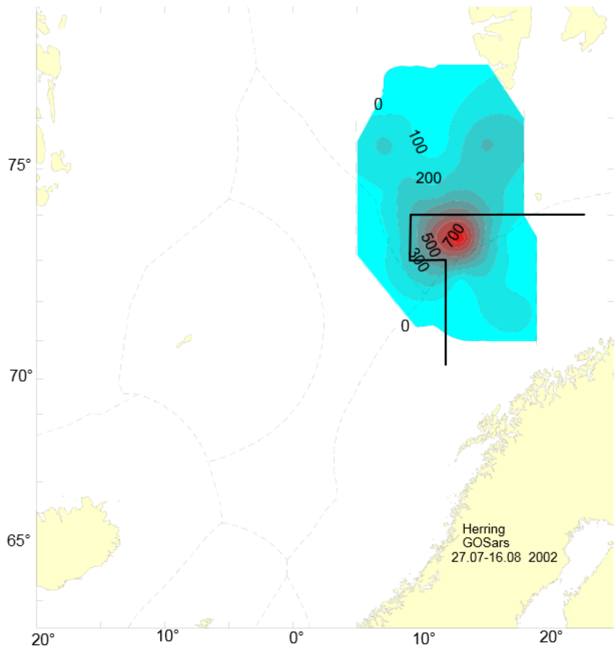


May 2002



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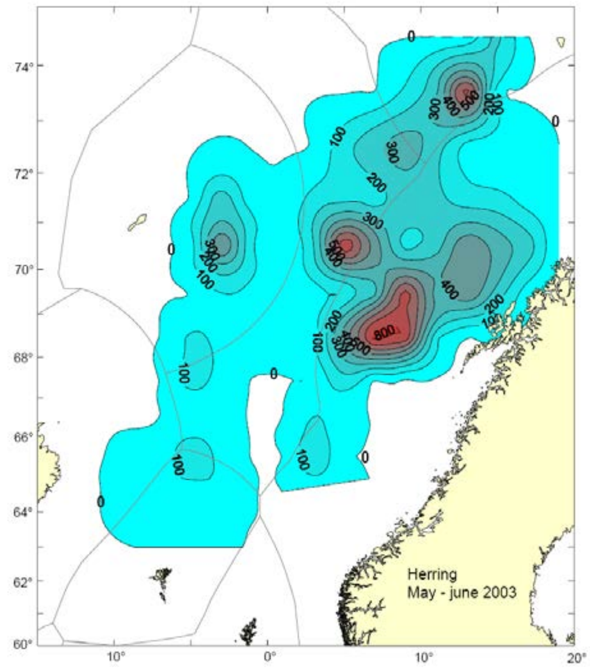

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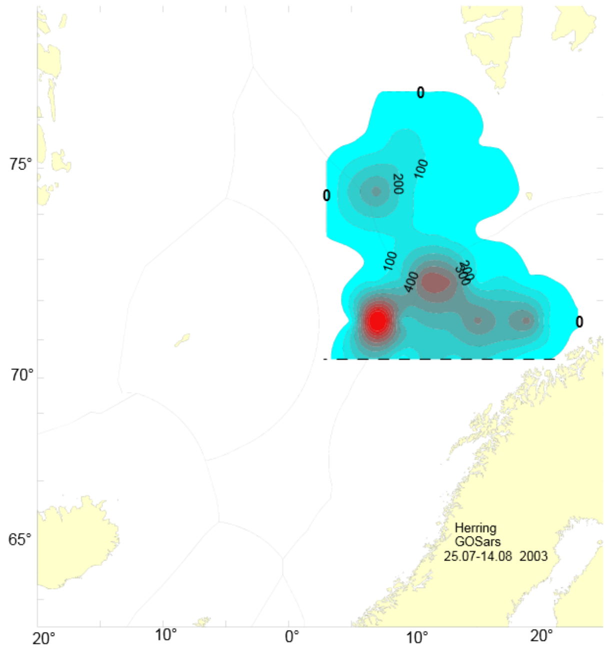

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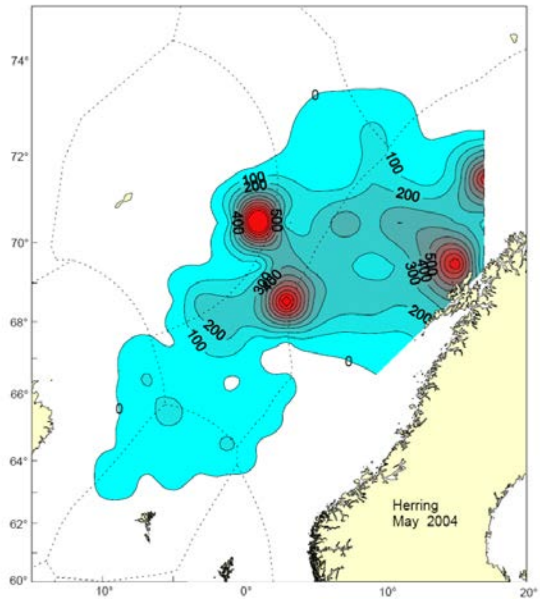
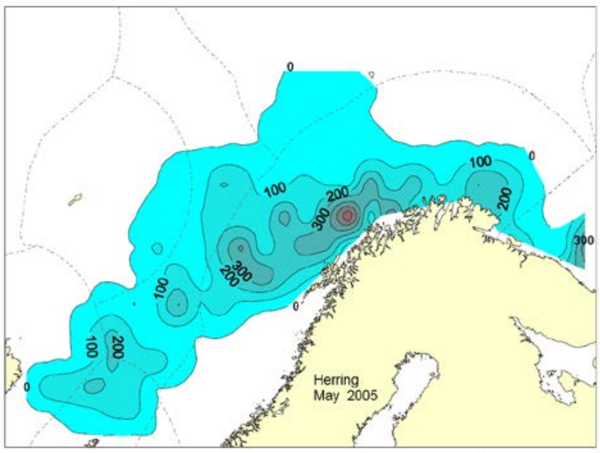


May 2004



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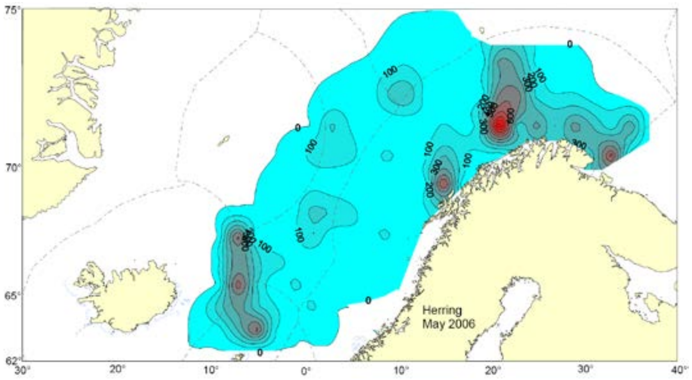

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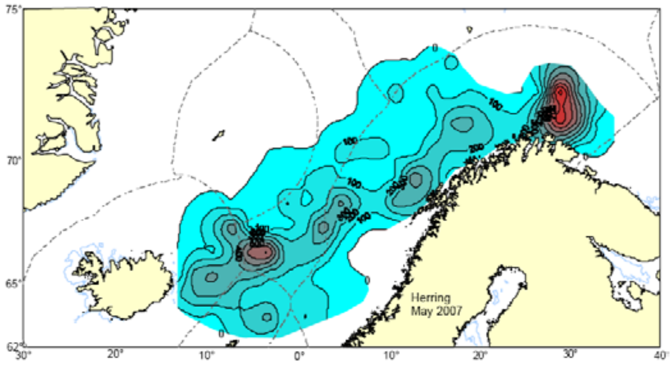

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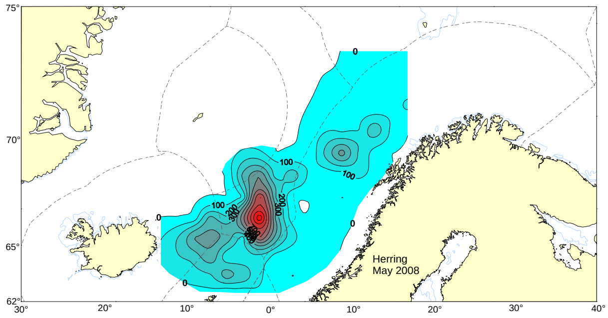

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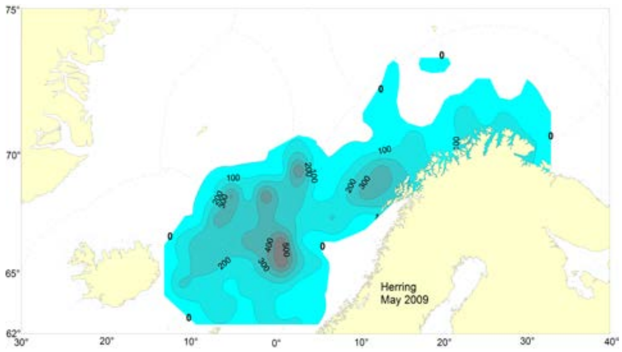

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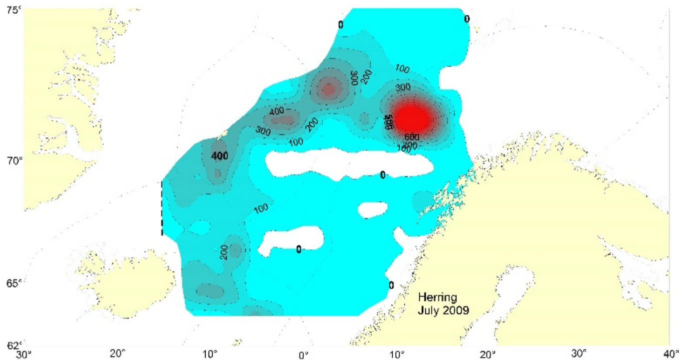

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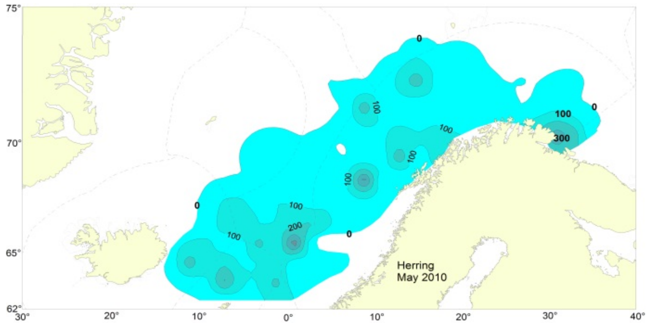

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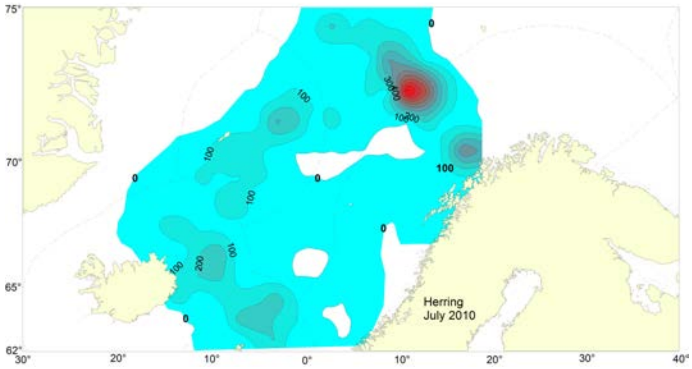

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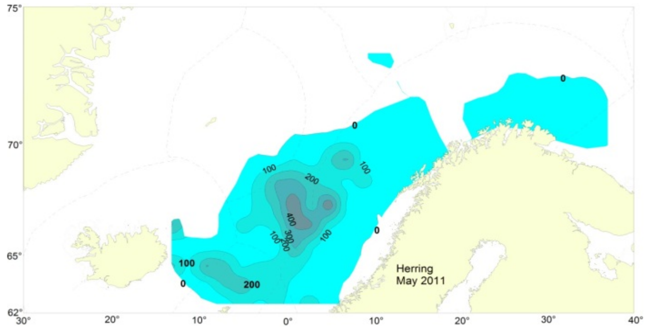

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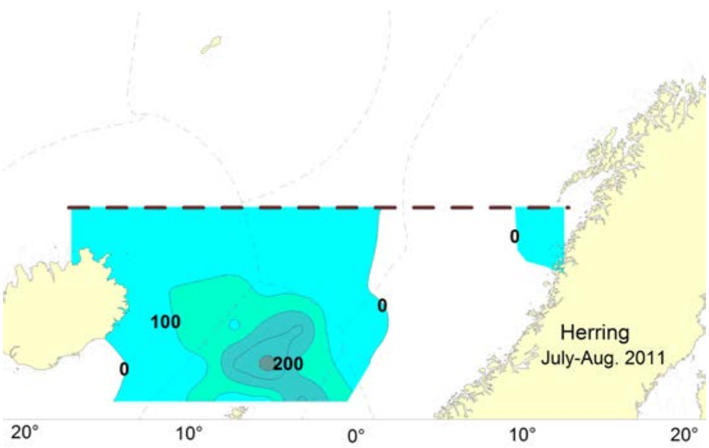

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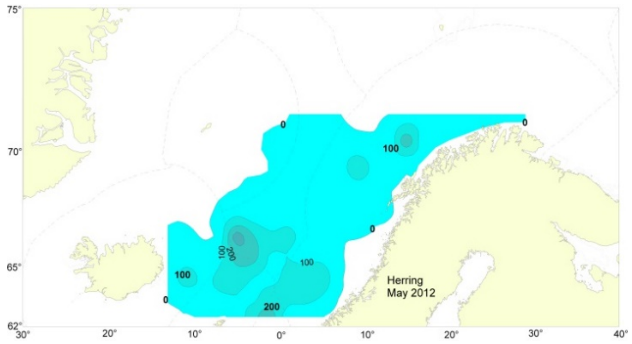

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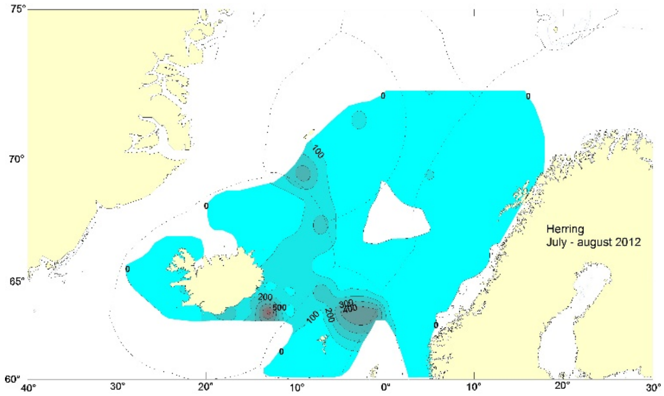

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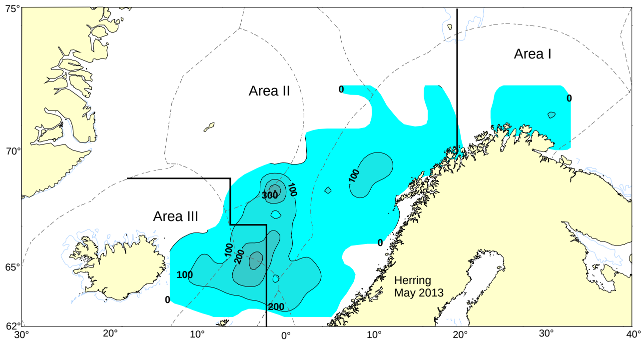
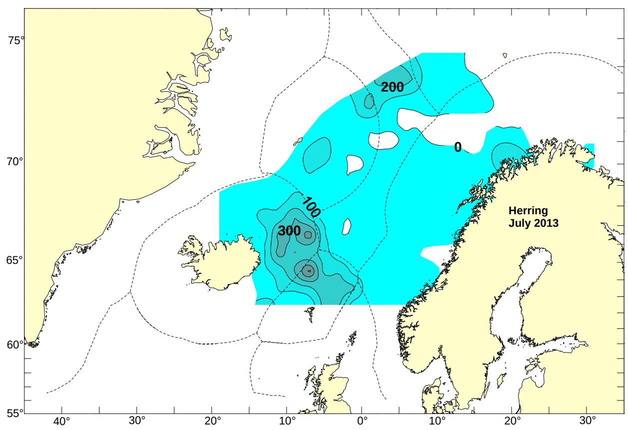


May 2013



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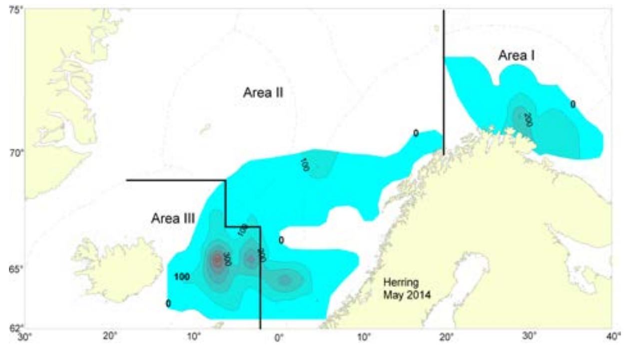
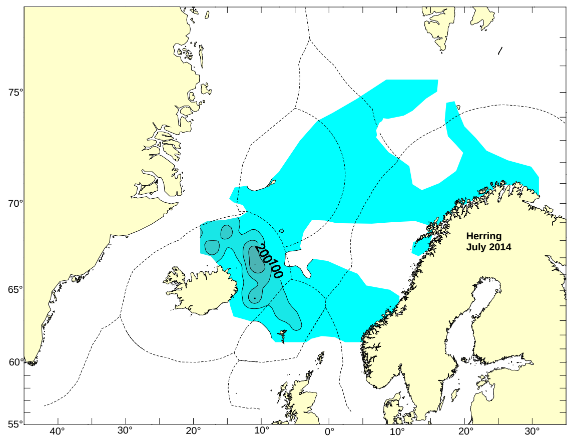
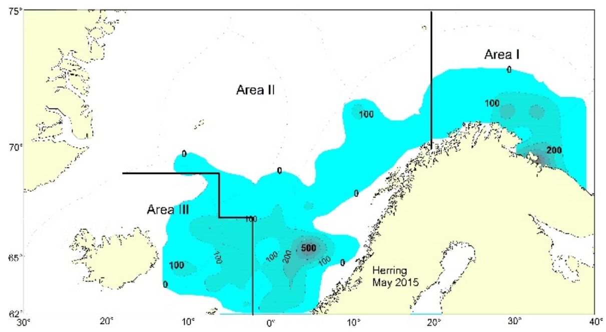


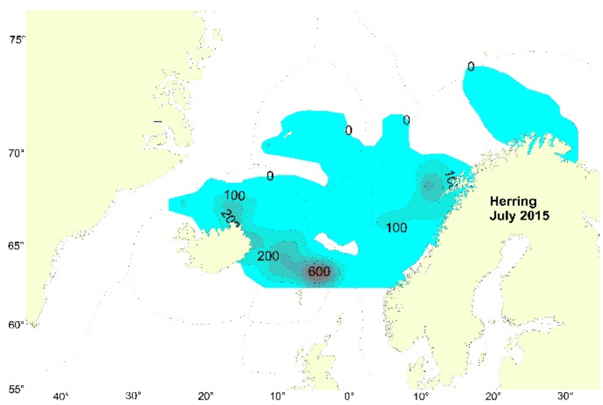
May 2014



July-August 2014



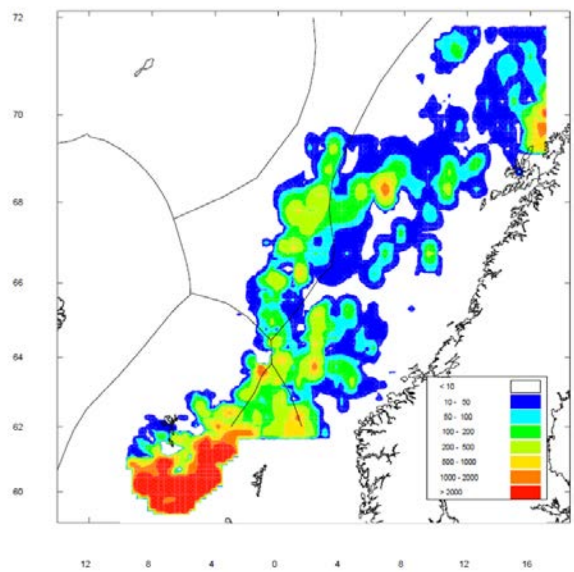
May 2015



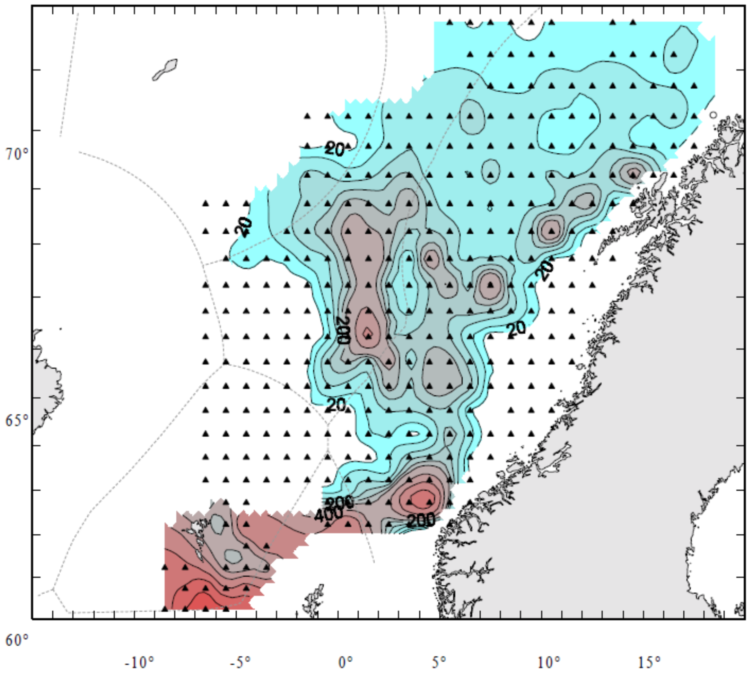
July-August 2015

Annex 8. Compilation of blue whiting distribution maps

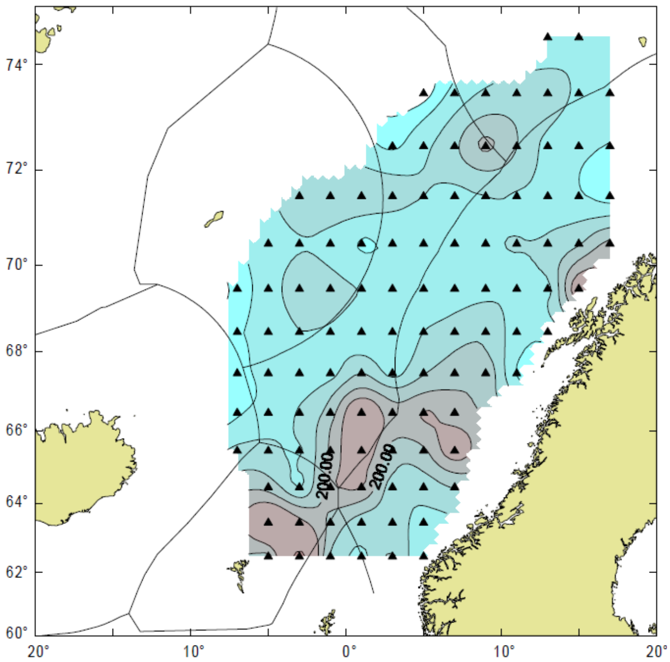
A compilation of maps from various survey reports showing acoustic values (S_A-values; m^2/nm^2) of blue whiting in the Norwegian Sea and adjoining waters for the years 1997–2015 in either May (International Ecosystem Survey in Norwegian Sea, IESNS) or in July-August (International Ecosystem Summer Survey in Nordic Seas, IESSNS, and other national and international surveys prior to 2010).



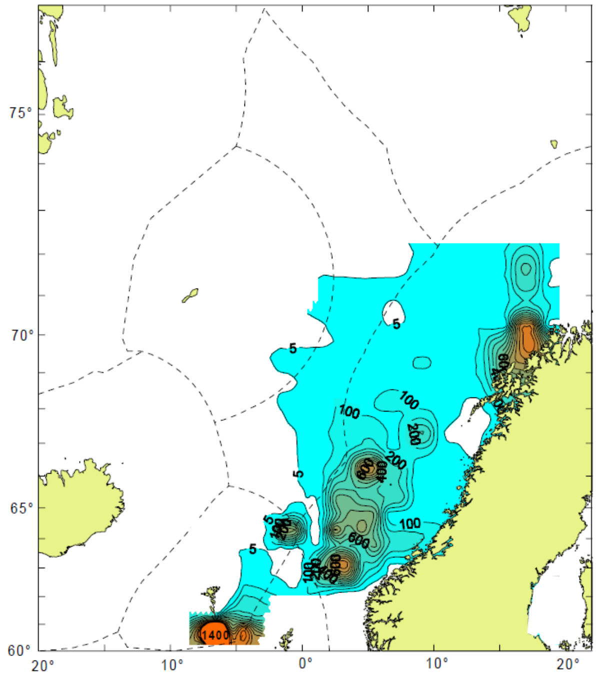
May 1997



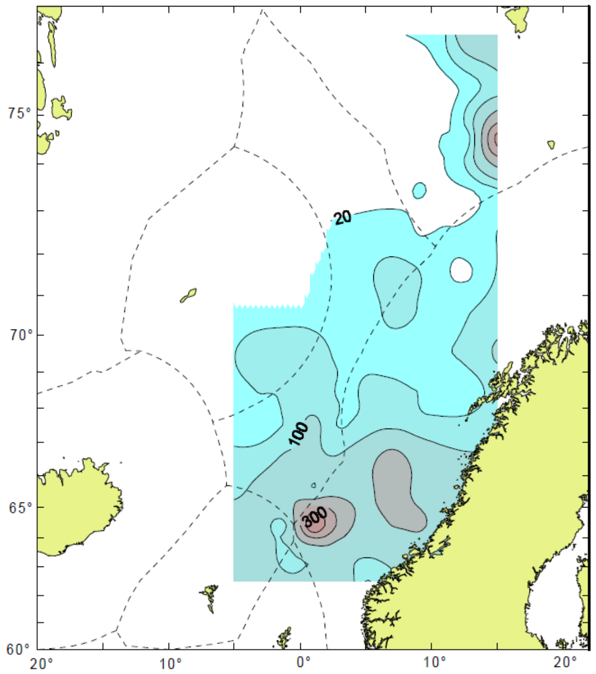
May 1999



July-August 1999



May 2000



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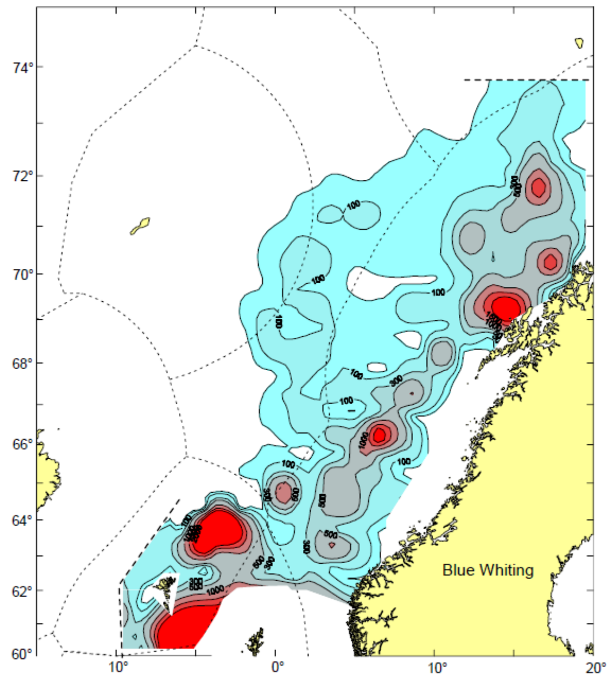
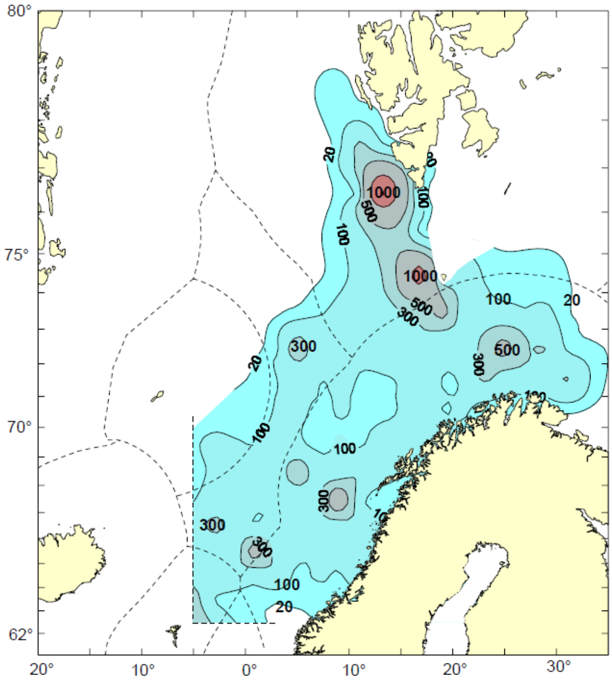
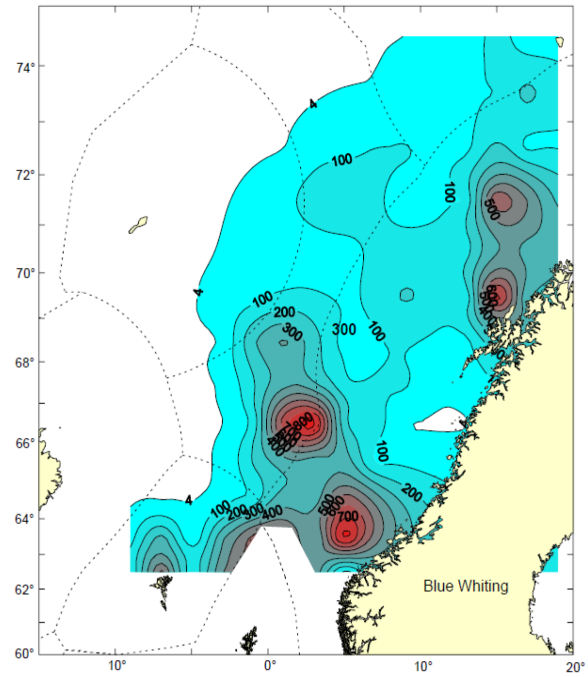


May 2001



July-August 2001



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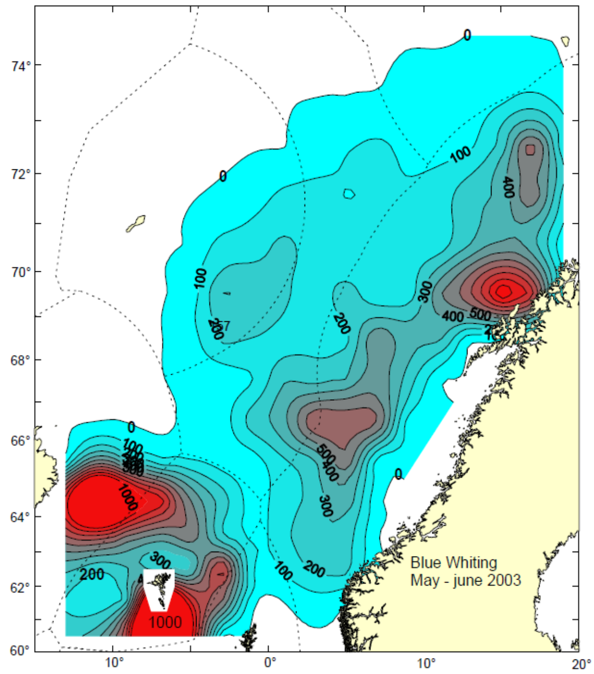
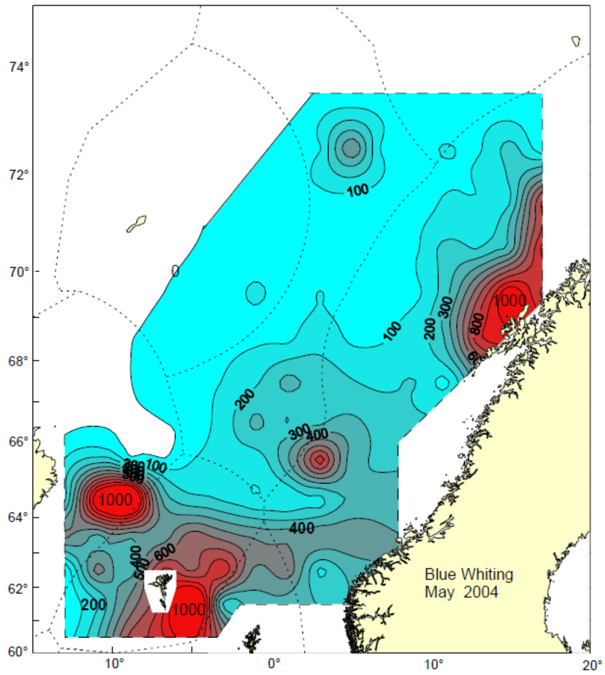
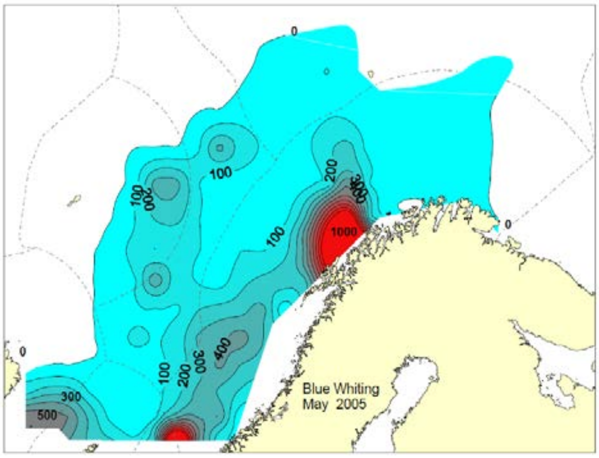


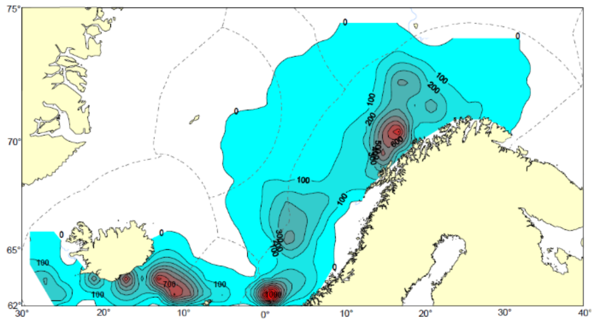
May 2003



May 2004



May 2005



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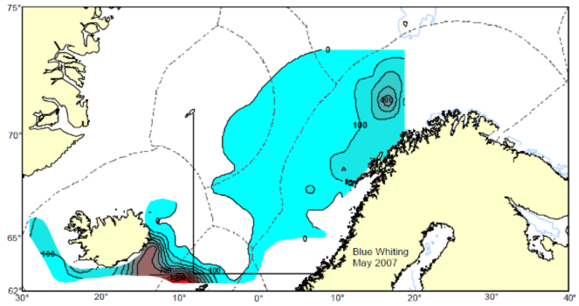

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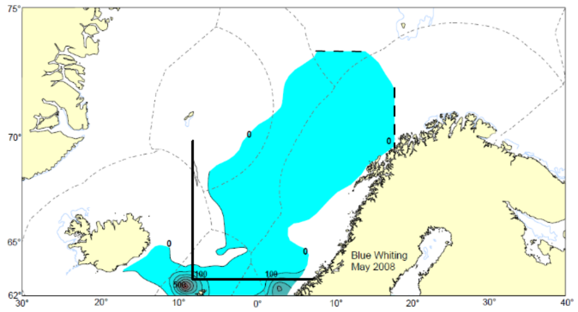

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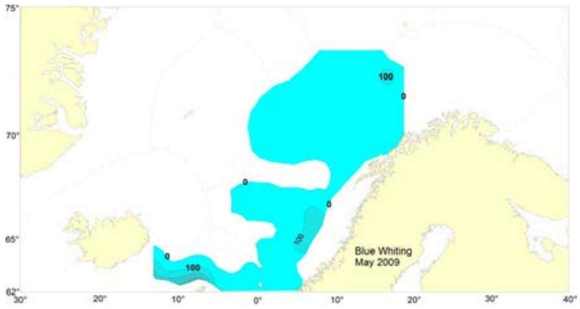

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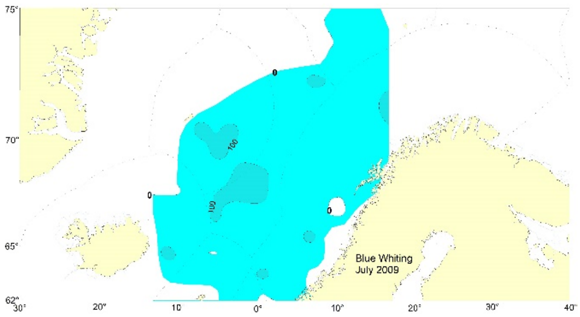

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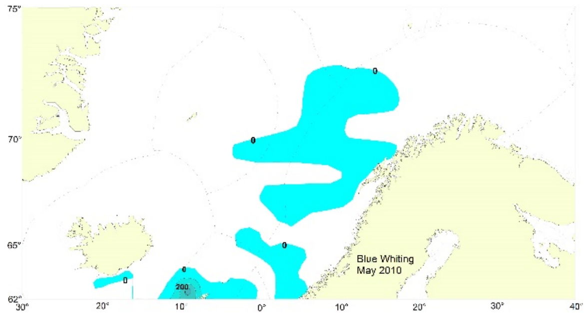

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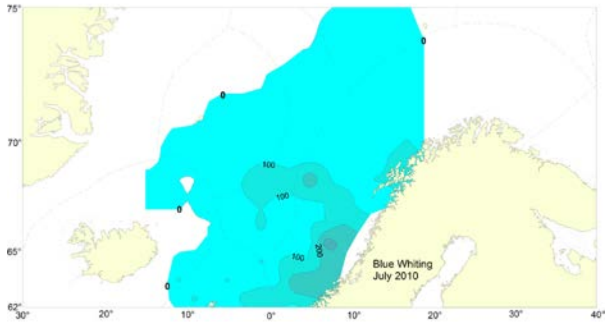

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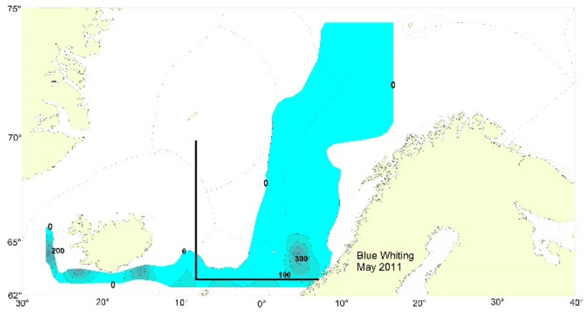

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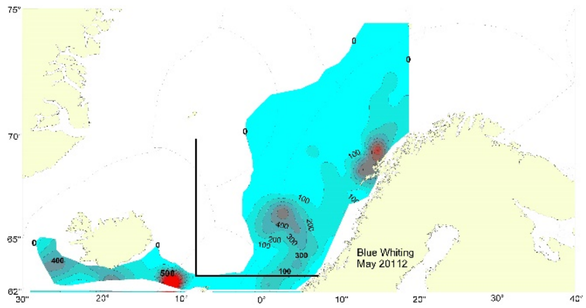

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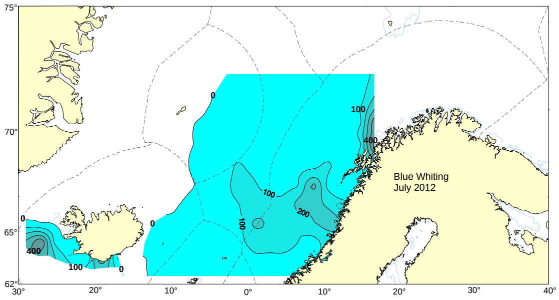

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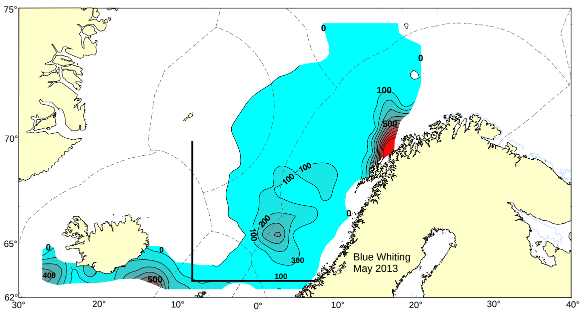

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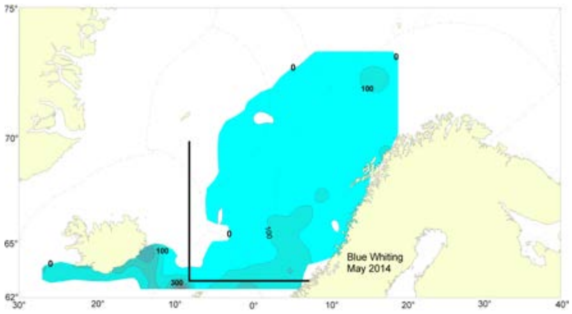

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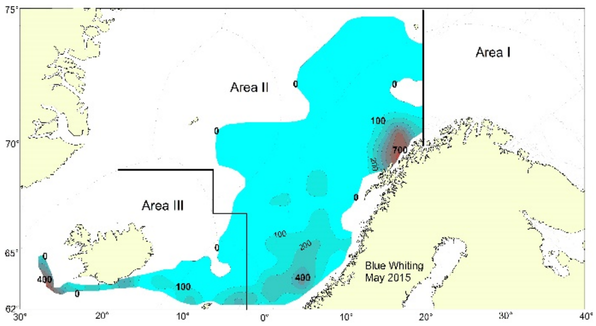

May 2015

Annex 9. WGINOR Multi Annual Self evaluation

1) **Working Group name:** ICES/HELCOM Working Group on Integrated Assessments of the Norwegian Sea (WGINOR).
2) **Year of appointment**: 2013.
3) **Current Chairs**: Geir Huse, Norway and Guðmundur J. Óskarsson, Iceland
4) **Venues, dates and number of participants per meeting**: Bergen, Norway, 19–23 August 2013 (21 participants); Torshavn, Faroe Island, 18–22 August 2014 (7 participants); Reykjavik, Iceland, 7–11 December 2015, (14 participants)

WG Evaluation

5) **If applicable, please indicate the research priorities (and sub priorities) of the Science Plan to which the WG make a significant contribution.**

_ EPD

_ EPI

X IEA

_ IEOM

6) **In bullet form, list the main outcomes and achievements of the WG since their last evaluation. Outcomes including publications, advisory products, modelling outputs, methodological developments, etc. ***

- An decision of operational approach to integrated assessment of Norwegian Sea
- Compilation of relevant time-series of ecological, environmental, biological and fishery related variables. **It is considered the Number 1 achievement as it makes the foundation for integrated assessment of the Norwegian Sea and required considerable effort.**
- Preliminary integrated assessment on basis of the time-series.
- Reconstruction of highly relevant time-series of zooplankton abundance indices in Norwegian Sea and adjoining waters for the period 1995-2015.
- Further development of a multispecies model (Enac-model) using a Management Strategy Evaluation (MSE) approach, with the main focus on the three big pelagic fish stocks in the Norwegian Sea.
- Recognize and list gaps in sampling requirements for integrated assessment.
- Construction of a draft of Ecosystem Overview for the Norwegian Sea, following the WKECOVER criterion.
- Number of publications of relevance for the WGINOR work, both by WGINOR members and others, have appeared during the last three years and are addressed in the WGINOR report adequately.

7) **Has the WG contributed to Advisory needs? If so, please list when, to whom, and what was the essence of the advice.**

No, only mentioned in the section "Ecosystem Considerations" in the WGWIDE (2015) report for NSS-herring.

8) **Please list any specific outreach activities of the WG outside the ICES network (unless listed in question 6). For example, EC projects directly emanating from the WG discussions, representation of the WG in meetings of outside organizations, contributions to other agencies' activities.**

The POLSHIFT conference held in Reykjavik 14-15 April 2015 (http://polshifts.neowordpress.fr/), which dealt with Poleward shifts in the pelagic complex and its relation to climate change, was in part emanating from the WG discussions and the aims of the WG were addressed there.

9) **Please indicate what difficulties, if any, have been encountered in achieving the workplan.**

Absence of participants at WGINOR meetings from two parties (Russia and EU), which are involved in the most relevant survey for the group (IESNS in May annually), has not been helpful with in the process of regaining lost data from the central database for the survey. This applies for all the survey data from 1995-2007, which got lost in the database several years ago and effort has been set by the remaining parties to find these data and upload them again. This is very important for the WG, as well as other WGs relying on these time-series.

Future plans

10) **Does the group think that a continuation of the WG beyond its current term is required? (If yes, please list the reasons)**

Yes that is a mutual opinion. The reasons are:

a. The WG has in practice only been in function for two years (from 1st to the 3rd meeting) and with rather little direct activity between meetings, it has only started to touch on issues relate to some of the ToR.
b. There is a lot of research activity ongoing for this ecosystem, and many new publications arrived and/or are arriving. It is important to make use of their outcome and their effort to enhance an integrated assessment of the region, which is most appropriate via WGINOR.
c. The compiled time-series of ecological, environmental and biological variables needs further attention and analyses on in the near future, as the WG has not had a time and man power for that yet.
d. The ecosystem modelling is still in its early phase and needs a further effort in the near future and such work would be most appropriate within a group like WGINOR.
e. The Ecosystem Overview made for the region in this first term, is regarded as the first step of comprehensive overview, and it will most likely require some adjustment following its first review.

11) **If you are not requesting an extension, does the group consider that a new WG is required to further develop the science previously addressed by the existing WG.**

(*If you answered YES to question 10 or 11, it is expected that a new Category 2 draft resolution will be submitted through the relevant SSG Chair or Secretariat.*)

No, not for the time being.

12) What additional expertise would improve the ability of the new (or in case of renewal, existing) WG to fulfil its ToR?

Generally, the WG has been well presented, physically or by correspondence, by experts in the different fields during these three meetings. The groups suffers probably most by a physical presence of chemical oceanographers, and biologists dealing with seabirds and marine mammals. Future work might also call for participation of social scientists.

13) Which conclusions/or knowledge acquired of the WG do you think should be used in the Advisory process, if not already used? (please be specific)

Preliminary results of an integrated assessment applying various environmental, ecological and biological time-series suggest that large-scale changes took place in the Norwegian Sea after 2004. The early period is characterized by a weak subpolare gyre index (SPG) in winter, resulting in relative cold waters in the Norwegian Sea. This is correlated with high max levels of chlorophyll, high biomass of zooplankton and good recruitment of blue whiting. The second period is characterized by warmer waters and a strong SPG index, high abundance of herring and mackerel and maximum chlorophyll concentration late in spring. The mechanisms are not fully understood, and further research on this issue is encouraged.

New rectangle based calculations of zooplankton indices for the Norwegian Sea in May during 1995-2015, which was possible after recompilation of the survey data, show somewhat similar pattern as previously shown. However, the pattern and the magnitude of spatial difference vary among areas and years. These new and improved time-series need to be compared and analysed further with respect to environmental and ecological variables (bottom–up control) and fish abundance (top–down).