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Joint Norwegian-Russian environmental status report on the Barents Sea Ecosystem

Update for current situation for climate, phytoplankton, zooplankton, fish and fisheries in 2011

P. Arneberg, O. Titov, A. Filin and J.E. Stiansen
Editors

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The report is also published on internet and can be accessed at http://www.barentsportal.com. The web publication is identical to the printed report, but you will in addition find ads that supplements and broadens some aspects in the contents. Furthermore, you will find a Web Map Service which gives you the opportunity to have a more geographic focus on some of the thematic presentation of environmental issues, and e.g. add other maps on top for comparison. An interesting feature is the possibility to give your comments on all text and figures.

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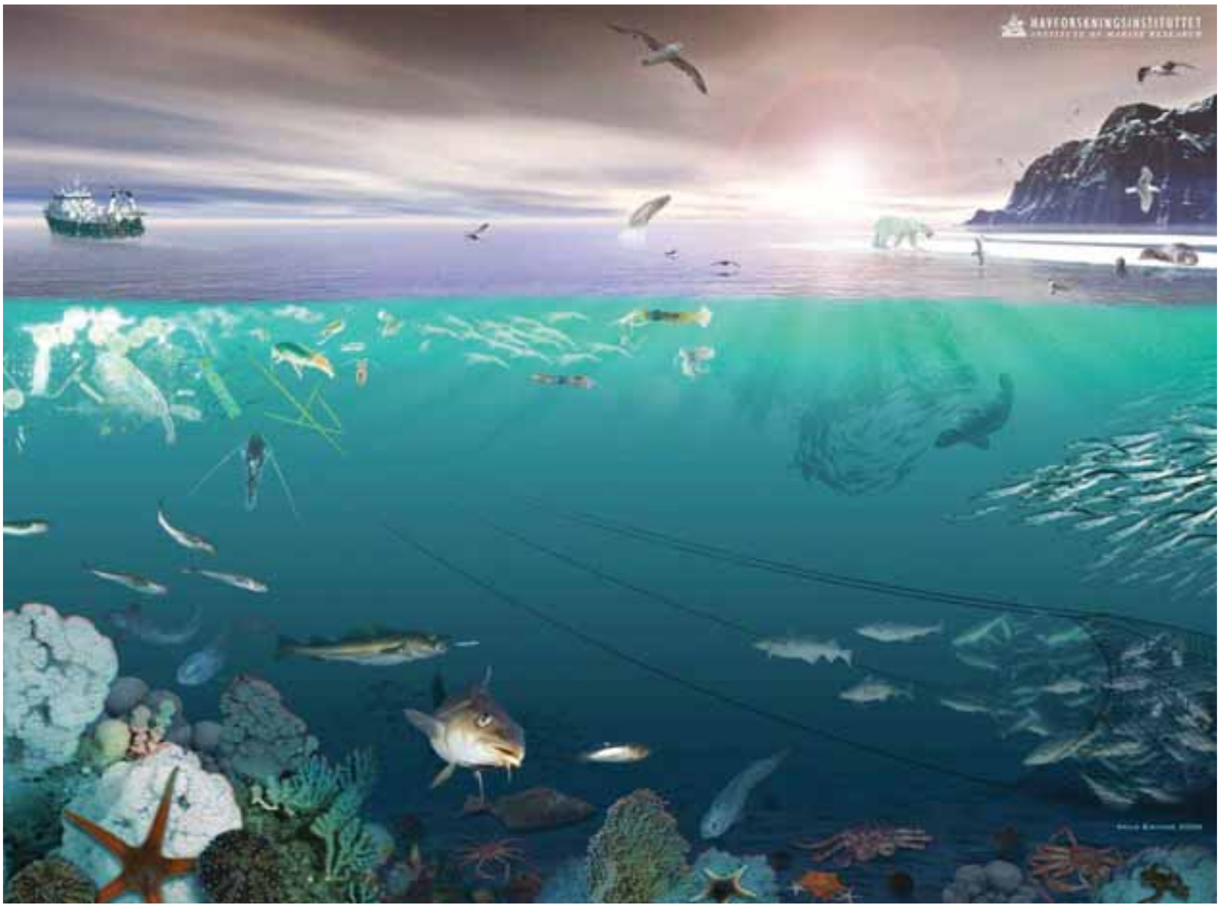

Illustration of the rich marine life and interactions in the Barents Sea

Contents

Introduction

P. Arneberg, O. Titov, A. Filin, and J.E. Stiansen

The joint Russian-Norwegian environmental status report for the Barents Sea was published for the first time in 2009 (Stiansen et al 2009). More than 100 scientists and other experts from a total of 9 Russian and 20 Norwegian institutions participated in preparation of the report, which was a co-operation project between the Joint Russian - Norwegian Commission on Environmental Cooperation and the Joint Russian-Norwegian Fisheries Commission. The work was carried out under the umbrella of the Marine Working Group of the environmental commission and was build on the experiences from the series of previous joint PINRO/IMR reports on the status of the Barents Sea ecosystem.

The report covers all major types of biological and abiotic components of the ecosystem (including climate) as well as human activities and impact. It was prepared to contribute to the knowledge basis for development of an ecosystem based management plan for the Russian part of the Barents Sea and contribute to further development of the ecosystem based management plan for the Norwegian part of the Barents Sea. The Barents Sea has internationally been identified as a single large marine ecosystem (LME). The scientific basis from this project will therefore also contribute to the whole Barents Sea ecosystem being a consideration when the two countries further develop ecosystem based management in their respective parts of the sea area.

To fulfil these aims, the report needs to be updated at regular intervals. As indicated by the number of people and institutions involved in the original report, preparation of this was a major undertaking. The report was therefore structured in a way that should make it possible to update smaller parts each year. In particular, general descriptions and background information for each ecosystem theme and type of human activity is gathered in chapter 2, while data on current status and discussion on this is given i chapter 4. Thus, new information on the current situation can be added by updating chapter 4 only.

Here, updates are given for the subchapters in chapter 4 dealing with the current status for 2011 for climate, phytoplankton, zooplankton, fish and fisheries. A summary of the main findings from the subchapters is also given. To facilitate comparisons with the original report, chapter numbers are kept unchanged from the original report. A full list of references is not given, but references added in this update are given at the end of subchapters.

Further updates of report are planned and will be carried out if funds are available. These will be published electronically in the joint Russian-Norwegian environmental data portal (The Barents Portal - http://www.barentsportal.com) and on paper in the IMR/PINRO Joint Report Series.

4.1 Overview of state and expected situation

A.Filin (PINRO) and J.E.Stiansen (IMR)

Below, key points from the other chapters are summarised.

4.1.1 Overview of abiotic components

Overview of climate

The winter of 2010/2011 was characterized by a relatively small negative value of the North Atlantic Oscillation (NAO) index. The following development of the positive phase, lasting to April, was accompanied by strengthening of westerlies in the North Atlantic. The air temperature over the Barents Sea in 2011 was above the long-term mean in most areas and periods and was also slightly warmer than in 2010.

The water temperature in the Barents Sea in 2011 was above the long-term mean but lower than in 2010. Variations of sea surface temperature (SST) in 2011 were similar to those of air temperature. The SST anomalies were predominantly positive and gradually increasing during the year. In the bottom layer, positive temperature anomalies continued to dominate. Compared to 2010, there was a temperature reduction in the bottom layer in the central and southern Barents Sea, while in the east, northeast and northwest, an increase in temperature was registered. Salinity in 2011 was higher than the long term mean and also higher than in 2010. Inflow of Atlantic waters at the western entrance in the first half of 2011 was quite similar to 2010 and was close to the 1997-2010 mean. Ice extent in 2011 was less than normal, and similar to the situation in 2010. Oxygen saturation in the southern Barents Sea in 2011 was slightly below the normal and remained close to the levels from the previous year.

4.1.2 Overview of biotic components

Overview of phytoplankton and zooplankton

In Norwegian waters, no large aberration in the annual succession in the phytoplankton along the fixed transect (Vardø – North and Fugløya-Bear Island) was observed in the period 2008-2011. In general, the spring blooms starts during March along the coastline and is dominated by the common spring diatom species (e.g. *Chaetoceros*, *Fragilariopsis*, *Skeletonema*, and *Thalassiosira*). During summer the phytoplankton shows a patchy distribution. No large blooms or areas with high densities of phytoplankton have been observed in the open part of the Barents Sea during the latest years. The autumn phytoplankton species composition has been more or less normal, with larger dinoflagellates as the dominating group.

The average mesoplankton biomass measured in August–September 2011 was similar to levels in 2010 and slightly below the long-term mean. The parameter has been reasonable stable during the last four years. The areas with highest biomasses of zooplankton were found in the northeastern Barents Sea. Here, the most abundant copepod species were the Arctic species *C. glacialis*, *Pseudocalanus minutus*, *M. longa*, as well as the North Atlantic species *C. finmarchicus.*

The macroplankton survey conducted in late autumn and winter of 2010 showed that in the west and northwest areas of the Barents Sea, the abundance and biomass of krill (euphausiids) were lower than in 2009 but still higher than the long-term means. Arctoboreal *Thysanoessa inermis* has been a dominant species. In the recent years, the area and abundance of *Th. raschii* has been reduced because of increase in water temperature in the Barents Sea.

The abundance of large gelatinous zooplankton was higher in 2011 compared to 2010. Overall the distribution and abundance of large gelatinous zooplankton in 2011 was similar to what was observed in 2008.

Overview of fish

Based on the most recent estimates of spawning stock biomass, ICES classifies the stocks of cod and haddock to have full reproductive capacity and being harvested sustainably in 2011.

The SSB of NEA cod is now record high and the total stock biomass is close to the highest ever observed. Fishing mortality was reduced to below F_{MSY} in 2007 and is now close to its lowest value. Surveys indicate that year classes 2009–2011 are above average. Cod has expanded northwards and eastwards in recent years, and is now has the widest geographic distribution ever reported. The main prey items of cod in 2011 were capelin, krill, polar cod, haddock, cod, shrimp and amphipods. In comparison with 2010, the changes in prey composition are small.

The SSB of haddock has been increasing since 2000 and reached the highest values recorded in the time series in 2011. Fishing mortality has been around F_{MSY} since the mid-1990s. Recruitment-at-age 3 has been at or above average since 2000. The year classes 2004–2006 are estimated to be very strong and are now dominating the spawning stock. Surveys indicate that the year classes 2008 and 2010 are below average, while 2009 and 2011 year classes are above average.

There is at present no accepted assessment for Greenland halibut, and only landings and survey trends of biomass are available for this stock. Biomass estimates indicate a stable or increasing trend since 1992.

Golden redfish SSB has been decreasing since the 1990s and is currently at the lowest level in the time-series. Fishing mortality has been increasing since 2005 and is currently at the highest level in the time-series. Recruitment is very low. ICES advise that there should be no fishery, given the very low SSB and poor recruitment.

Due to poor year classes during the period 1996–2003, the spawning-stock biomass of beaked redfish (*Sebastes mentella*) is decreasing. However, signs of improved recruitment are now seen in the Barents Sea. In the Barents Sea the catches of *S. mentella* are taken as bycatches in the demersal fisheries and as juveniles in the shrimp trawl fisheries.

The size of the capelin stock in 2011 was around average level, with a slight increase compared to 2010. Based on the most recent estimates of SSB and recruitment ICES classifies the stock as having full reproductive capacity. The 2011 year class is higher than long term average and can be characterized as relatively strong. The total distribution area of capelin at age 1+ in the Barents Sea in August-September 2011 was wider than in 2010. The total stock size estimated during the ecosystem survey in September 2011 was around 3.7 million tons.

The abundance of young herring in the Barents Sea in decreased from 2010 to 2011. In 2011 it was the lowest since monitoring started in 1999. The 2011 year-class of herring is lower than the average level, and can be characterized as poor.

The total biomass of blue whiting in the Barents Sea in autumn 2011 was estimated to 130,000 tons, which is at the same low level as in 2008-2010. However, in the winter of 2012 the abundance of 1-group blue whiting was the highest since 2005. Thus the blue whiting abundance is expected to increase. The polar cod stock was estimated to be 0.9 million tons in 2011. This is lower than in 2010, but at about the same level as in 2009 and somewhat above the long-term mean. The 2011 year-class of polar cod is slightly above average.

Abundance of cold-water fish species in the Barents Sea decreased from 2000 to 2010. However in 2011 a slight increae in abundance of this group was recorded. Since 2008, there has been observed a tendency for decreasing abundance of warm-water fish species.

4.1.3 Overview of human activities/impact

In this update, fisheries are the only human activity described and discussed. Overview of other human activities and discussion on their impacts will be given in later updates.

Fishing is the largest human impact to the fish stocks in the Barents Sea, and thereby the functioning of the whole ecosystem. The fishery is not considered sustainable if it impairs the recruitment of the fish stocks.

The largest commercially exploited fish stocks (capelin, Northeast Arctic cod, haddock and saithe) are now harvested within sustainable limits and have full reproductive capacity. However, some of the smaller stocks (golden redfish, beaked redfish and coastal cod) are overfished. For Greenland halibut, after many years of overexploitation of the stock the current exploitation seems to be sustainable and hence not influencing the ecosystem negatively.

Estimates of unreported catches of cod and haddock in 2002-2008 indicate that this has been a considerable problem which now seems to be decreasing. From 2011 onwards, the minimum mesh size for bottom trawl fisheries for cod and haddock is 130 mm for the entire Barents Sea (previously the minimum mesh size was 135 mm in the Norwegian EEZ and 125 mm in the Russian EEZ). It is still mandatory to use sorting grids. From 2011 onwards, a change/harmonization of the minimum legal catch size for cod from 47 cm (Norway) and 42 cm (Russia) to 44 cm for all, and for haddock from 44 cm (Norway) and 39 cm (Russia) to 40 cm for all was set.

There was no fishery for capelin in the area in 2004-2008 due to low stock levels, but in 2009-2011 the stock was again sufficiently large to support a quota between 320 000 and 400 000 tonnes. Russia is the only nation currently fishing polar cod and fished 19 600 tonnes in 2011.

Damage to benthic organisms and habitats from trawling as well as unavoidable by-catch of marine mammals and sea birds in the Barents Sea has been documented. Research has been undertaken to explore the possibility of using pelagic trawls when targeting demersal fish. The purpose is to avoid impact on bottom fauna and to reduce the mixture of other species. It will be mandatory to use sorting grids to avoid catches of undersized fish.

4.2 Abiotic components

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4.2.1 Meteorological conditions

4.2.1.1 North Atlantic Oscillation

The winter of 2010/2011 was characterized by relatively small negative value of the North Atlantic Oscillation (NAO) index. In that period, there was a change in the atmospheric circulation, under which the negative phase of NAO in December-January turned to a positive one in February. The following development of the positive phase, lasting to April, was accompanied by strengthening of westerlies in the North Atlantic and minor and short-term reduction in the of Arctic ice coverage (Figure 4.2.1).

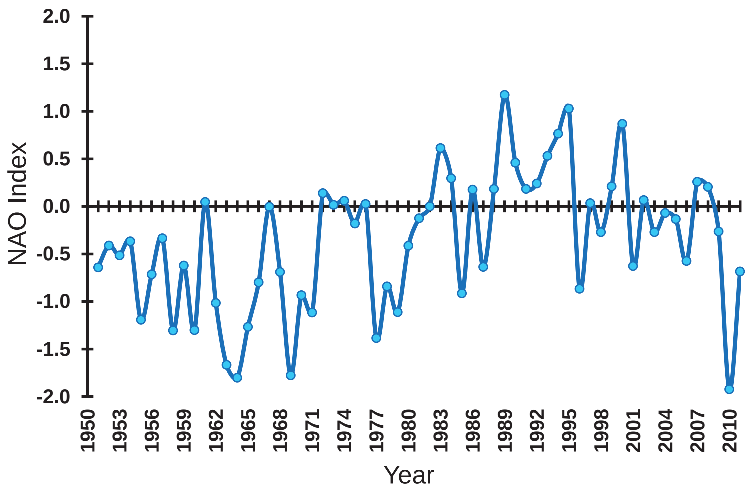

Figure 4.2.1 Winter NAO index in 1951-2011

4.2.1.2 Air temperatures

Air temperature data were taken from http://nomad2.ncep.noaa.gov and averaged over the western (70-76°N, 15-35°E) and eastern (69-77ºN, 35-55ºE) parts of the sea. Positive air temperature anomalies dominated the Barents Sea during 2011, with maximum anomalies exceeding 5°C in March and December in the eastern Barents Sea (Figure 4.2.2).

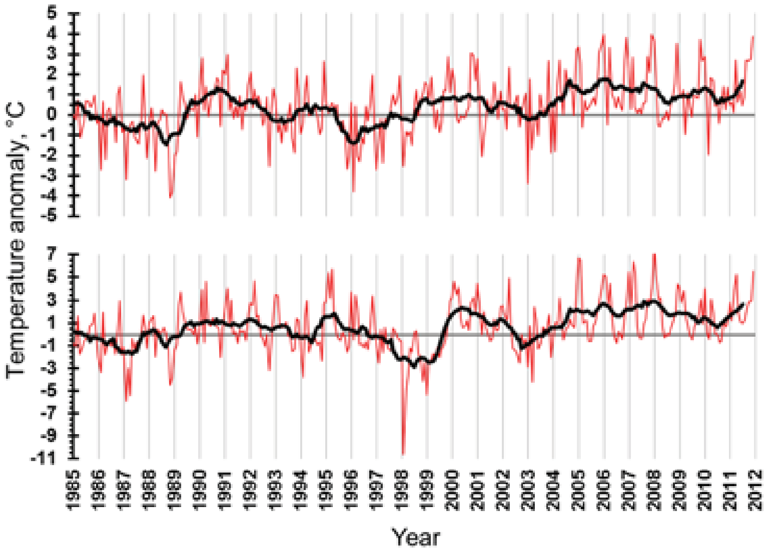

Figure 4.2.2. Air temperature anomalies over the western (upper) and eastern (lower) Barents Sea in 1985-2011.

Table 4.2.1.1 summarizes air temperature anomalies at some meteorological stations at the western and southern Barents Sea during the period from late 2010 through 2011. In the winter of 2010/2011, air temperature over the region was generally colder-than-normal (by 0.5-3.0 °C), with the largest negative anomaly in Murmansk (-6.8 °C in February 2011). During spring, summer and autumn (March-October) temperature anomalies were relatively small and predominantly positive. In November and December, positive anomalies rose to 2.0-5.9 °C. Mean annual air temperature in 2011 was warmer-than-average by 0.7-1.5 °C. Mean annual air temperatures in 2011 were slightly warmer than in 2010 (by 0.1-0.5 °C).

Table 4.2.1.1. Mean air temperature anomalies at weather stations around the Barents Sea in December 2010-December 2011, yearly mean anomaly in 2011, maximum anomalies and years when they were observed.

	Year/Month														
	2010	2011												2011	
Station	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	mean	Max/Year
Svalbard airport	-0.1	-1.7	1.3	0.8	4.4	1.4	1.9	0.4	1.5	3.3	2.4	2.5	4.9	1.5	4.3 2006
Bear Island	2.3	-0.6	2.0	1.3	4.8	0.9	-0.6	-0.2	0.8	2.8	2.1	2.0	3.5	1.8	2.9 2006
Tromsø	-0.4	-0.5	-0.8	0.7	2.0	1.2	1.9	-0.7	1.0	2.7	2.8	4.3	1.7	1.2	1.5 1938
Vardø	0.1	-0.6	-2.2	0.6	2.7	1.0	0.9	0.9	0.3	2.4	2.3	2.9	3.7	0.9	1.5 1937/2005
Murmansk	-1.2	-1.2	-6.8	2.0	2.8	1.6	2.1	1.1	-0.1	2.5	2.5	3.4	5.9	0.7	2.0 2005
Kanin Nos	-0.8	-1.2	-3.2	1.8	2.7	1.9	1.8	0.8	-0.4	2.1	2.6	2.5	5.1	0.9	2.5 1937

4.2.2 Oceanographic conditions

4.2.2.1 Temperature at the surface, 100 m and in the bottom layer

Sea surface temperature (SST) data were taken from http://iridl.ldeo.columbia.edu and averaged over the Bear Island – Svalbard area (74-79ºN, 08-25ºE) and the south-eastern Barents Sea (69-73ºN, 42-55ºE). Variations in SST in 2011 were similar to those of air temperature. The SST anomalies were predominantly positive and increased gradually during the year. Positive anomalies increased in the eastern Barents Sea where they rose from 0.5°C to 2.2°C from March to October. In the central part of the sea, a steady growth of positive anomalies began in June. In the western areas weak negative SST anomalies (<0.5°C) were registered from January to August. In September-October, SST was higher-than-normal by 0.5-0.7 °C. (Figure 4.2.3).

The time series from the coastal waters at the fixed station Ingøy show that during 2010-2011 surface temperature was above the long-term mean (Figure 4.2.4). The highest temperatures (compared to the mean) were observed in late fall/early winter 2011-2012. The same signal took place in the deeper waters (at 250 m), and in late 2011/early 2012 the temperatures in the deeper waters were well above the mean.

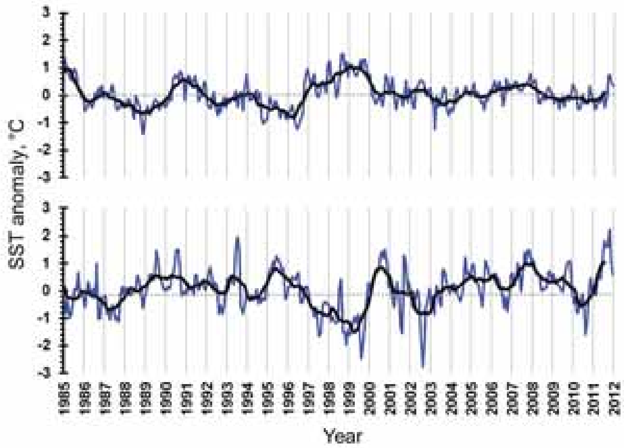

Figure 4.2.3. Sea surface temperature anomalies in the western (upper) and eastern (lower) Barents Sea in 1985-2011.

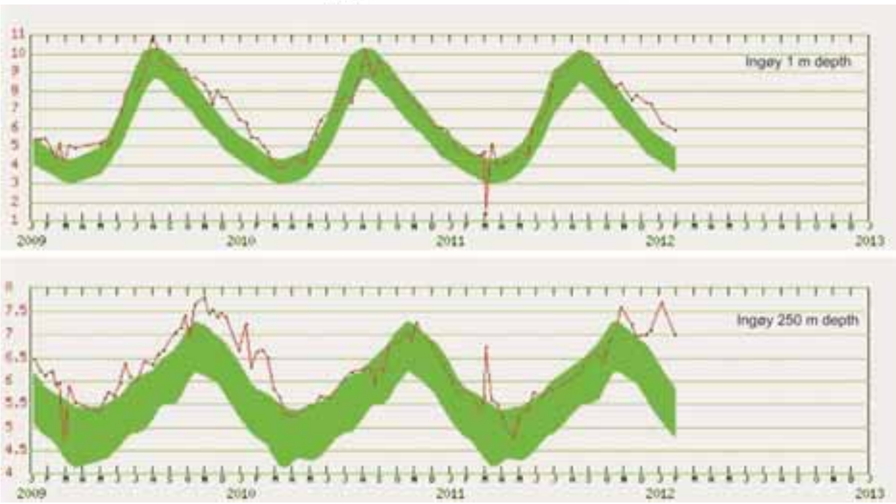

Figure 4.2.4. Monthly mean temperature at 1 m and 250 m depth at the fixed station Ingøy, northern Norway, situated in the Coastal Current at the entrance to the Barents Sea. Vertical axis is temperatures (^{o}C) and horizontal axis is month. The green areas are the long-term mean for the period 1936-1944 and 1968-1993 +/- one standard deviation and represent the typical variations.

Observations from 100 m depth in August-October 2011 show that temperatures were still above the long-term mean in most of the Barents Sea (Figure 4.2.5). Highest positive anomalies are seen in the northern areas. In the southern Barents Sea and upstream in the Norwegian Sea, temperatures are close to the long-term mean.

In the bottom layer, positive temperature anomalies continued to dominate in 2011. The highest anomalies (>1.5°C) were observed in the eastern and southeastern parts of the sea, as well as in the Bear Island - Spitsbergen area. Negative anomalies of bottom temperature were registered in the southern Barents Sea, in the area of the coastal branch of the Murman Current (Figure 4.2.6).

Compared to 2010, there was a temperature reduction in the bottom layer in the central and southern Barents Sea, while temperatures increased in the east, northeast and north-west.

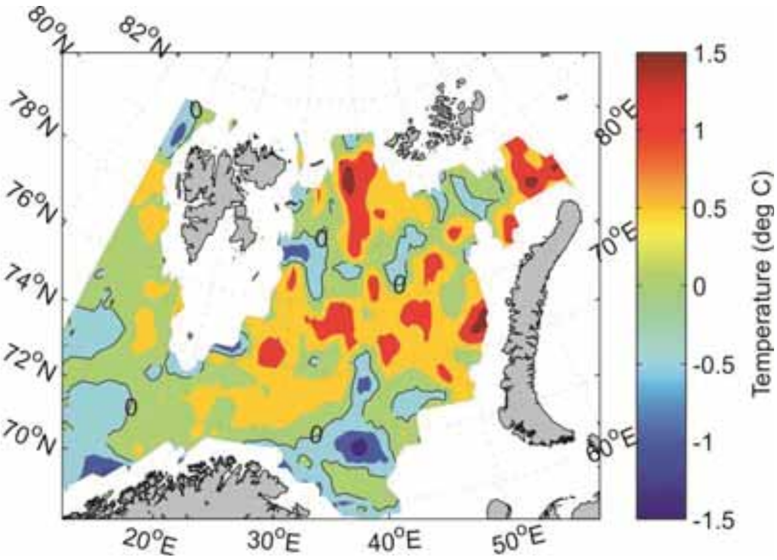

Figure 4.2.5. Temperature anomalies at 100 m depth in the Barents Sea in August-September 2011 (Anon., 2012).

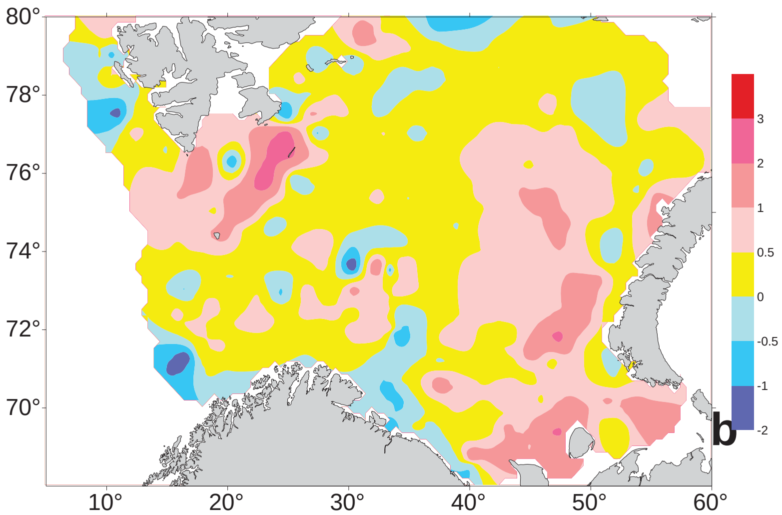

Figure 4.2.6. Bottom temperature anomalies in the Barents Sea in August-September 2011 (Anon., 2012).

4.2.2.2 Temperature and salinity in the standard sections

In the Fugløya-Bear Island Section, which captures all the Atlantic water entering the Barents Sea from south-west, temperatures were only 0.1-0.2 °C above the long-term mean early in 2011 (Figure 4.2.7). During 2011 temperatures increased (compared with the mean), and in August they were 0.5 °C above the long-term mean in the south-west (Figure 4.2.7). Variations in salinity are often similar to those in temperature, but since 2009 salinity has increased while temperature has decreased (Figure 4.2.7).

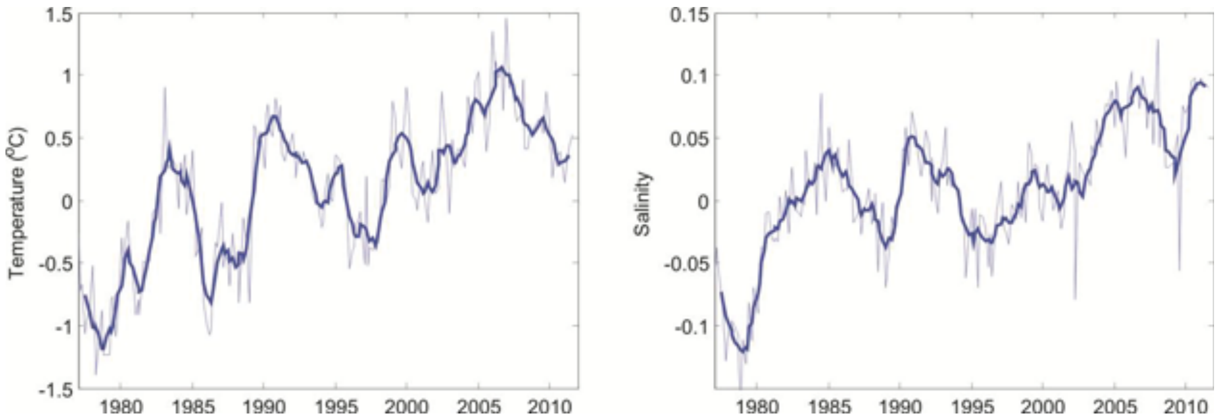

Figure 4.2.7. Temperature (left) and salinity (right) anomalies in the 50-200 m layer of the Fugløya-Bear Island Section.

According to the data from the Kola Section, which was occupied nine times in 2011, the beginning of the year was much colder than 2010 and characterized by small positive anomalies (0.1-0.2 °C) in all the layers with maximum values of up to 0.3 °C in the main branch of the Murman Current (Figure 4.2.8). In spring positive anomalies grew in all the branches of the warm currents. This growth was most pronounced in the northern part of the section and in the central branch of the North Cape Current. In the North Cape Current anomalies reached 1°C, and in April were higher than in 2010. In summer and autumn, positive anomalies in the Murman Current branches were reduced. From August to November, in in the active layer (0-200 m) of the coastal branch of the Murman Current, anomalies were not larger than 0.1 °C, i.e. temperature conditions corresponded to the level of normal years. In the central branch of the Murman Current, positive anomalies were a bit lower than in spring and ranged from 0.6 to 0.8 °C. From September to December, temperature was warmer than previous year (Figure 4.2.8). It should be noted that averaged across the whole year, temperature in the near-bottom layer of the Murman Current was close to the long-term mean. However, in some months (mainly in the autumn), small negative anomalies of up to 0.3°C were observed. Later in the year, positive anomalies increased in all the branches of the warm currents crossed by the section. In the central branch of the North Cape Current and the coastal branch of the Murman Current, the positive anomalies reached 1°C and were much higher than in the previous year (Figure 4.2.8).

An opposite trend was observed for salinity. During most of the year, positive anomalies of 0.05-0.1 were registered with maximal values in the coastal branch of the Murman Current.

In October-December, salinity dropped in all the branches of the Murman Current, and in the coastal branch, negative anomalies reached 0.05 (Figure 4.2.8).

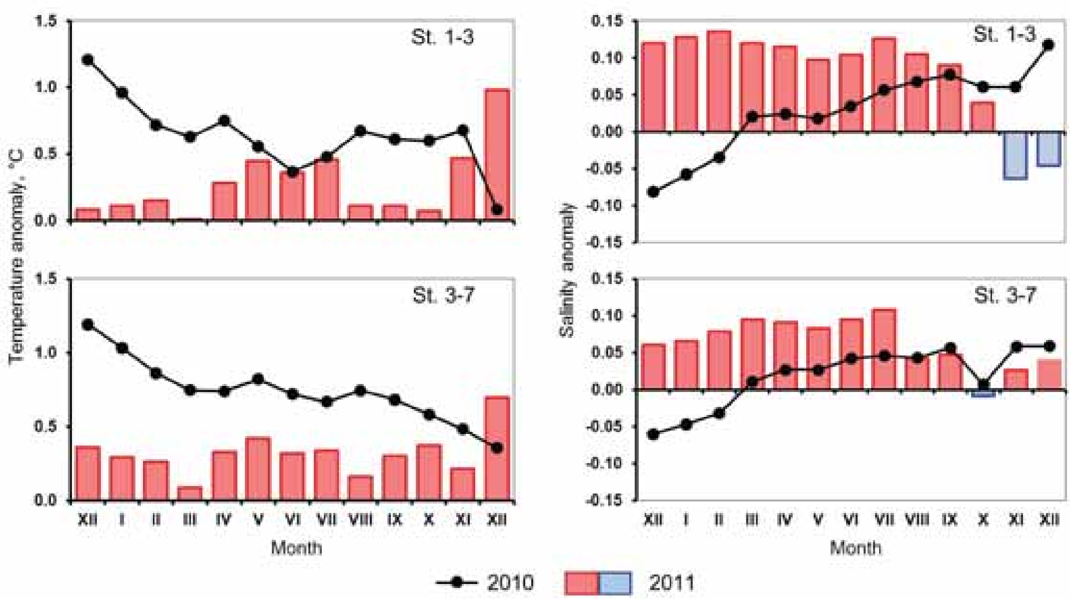

Figure 4.2.8. Monthly mean temperature (left) and salinity (right) anomalies in the 0-200 m layer of the Kola Section in 2010 and 2011. St. 1-3 – coastal waters, St. 3-7 – Murman Current (Anon., 2012).

It should be noted that although the mean annual temperature in the 0-200 m layer in the Kola Section in 2011 was at the level of warm years, it was lower than in 2010. The mean annual salinity was higher than the previous year and also compared with the normal (Figure 4.2.9).

In 2011, the North Cape-Bear Island Section was occupied in April, May, July and November. In the 0-200 m layer of the North Cape Current, positive temperature anomalies increased from 0.6 °C in May to 1.0 °C in November.

The Bear Island-West Section (along 74°30'N) was made twice, in March and November. In the 0-200 m layer of the eastern branch of the Norwegian Current (74°30'N, 13°30'–15°55'E), the temperature was higher than normal by 0.8°C in March and by 1.1°C in November.

During 2011, the Bear Island-East Section (along 74°30'N) was made four times. In 0-200 m layer of the northern branch of the North Cape Current (74°30'N, 26°50'–31°20'E), positive temperature anomalies increased from 0.5 °C in March to 1.1 °C in November.

In 2011, the Kharlov Section was made two times, in May and December. Positive anomalies of temperature in the 0-200 m layer of the main branch of the Murman Current were 0.7 and 0.9 °C respectively.

Along the Kanin Section, located in the eastern Barents Sea (along 43°15'E), observations were made in February and August. In the 0-200 m layer of the Novaya Zemlya Current (71°00'–71°40'N, 43°15'E) positive temperature anomalies increased from 0.5 °C in February to 0.7°C in August.

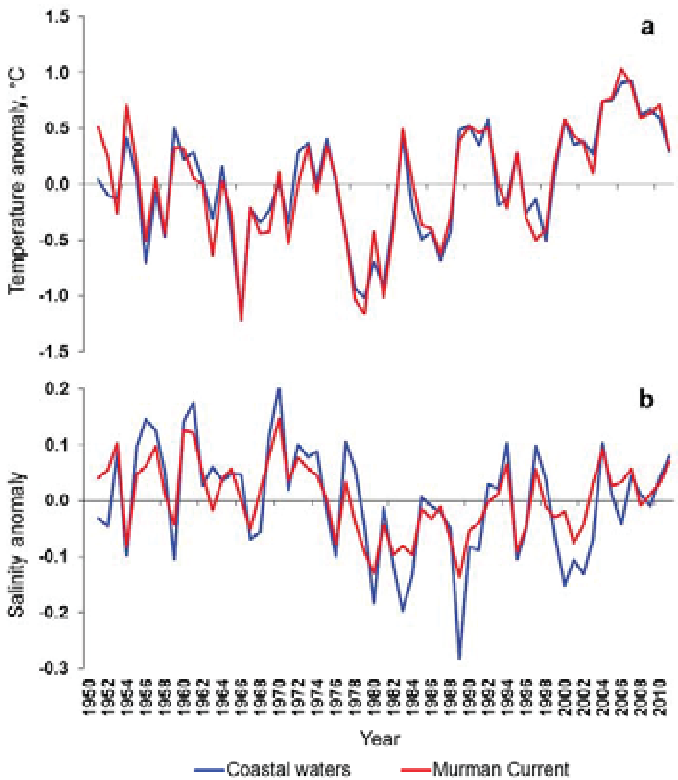

Figure 4.2.9. Mean annual temperature (a) and salinity (b) anomalies in the 0-200 m of the Kola Section in 1951-2011. Coastal waters – St. 1-3, Murman Current – St. 3-7 (Anon., 2012).

4.2.2.3 Currents and transports

The volume flux into the Barents Sea varies with periods of several years, and was significantly lower during 1997–2002 than the period 2003–2006 (Figure 4.2.10). In 2006 volume flux was at a maximum during winter and very low during fall. After 2006 the inflow has been relatively low, in particular during spring/summer. There has been, however, a weak increasing trend since 2009, and the volume flux during the first half of 2011 was close to the 1997-2011 mean. The data series presently stops in summer 2011. Thus no information about the fall and early winter 2011 is available. On annual time scales the volume flux and temperature in the inflowing Atlantic Water does not vary in syncrony, and the temperature has shown a declining trend since 2006. Thus since 2009 the temperatures has decreased while the volume flux has inreased slightly.

Monthly wind-driven and total volume fluxes and their anomalies were calculated with a numerical model (Trofimov, 2000) for the main currents of the Barents Sea in 2011 (Figure 4.2.11).

In 2011, on the average, volume fluxes in the northern and central branches of the North Cape and Novaya Zemlya Currents differed slightly from the long-term mean while, in the Bear Island, North Cape and Murman Currents they were lower than usual by approximately 0.5σ. In March 2011, in all the studied currents of the Barents Sea, volume fluxes were higher-than-normal. In May and October, on the contrary, they were lower-than-normal.

Compared to 2010, mean annual volume fluxes were lower throughout the Barents Sea in 2011, mainly owing to lower volume fluxes in February, May, June and August.

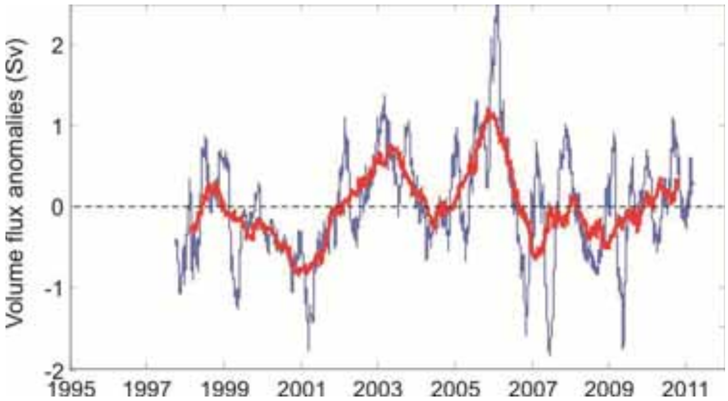

Figure 4.2.10. Observed Atlantic Water volume flux through the Fugløya-Bear Island Section estimated from current meter moorings. Three months (blue line) and 12-months (red line) running means are shown.

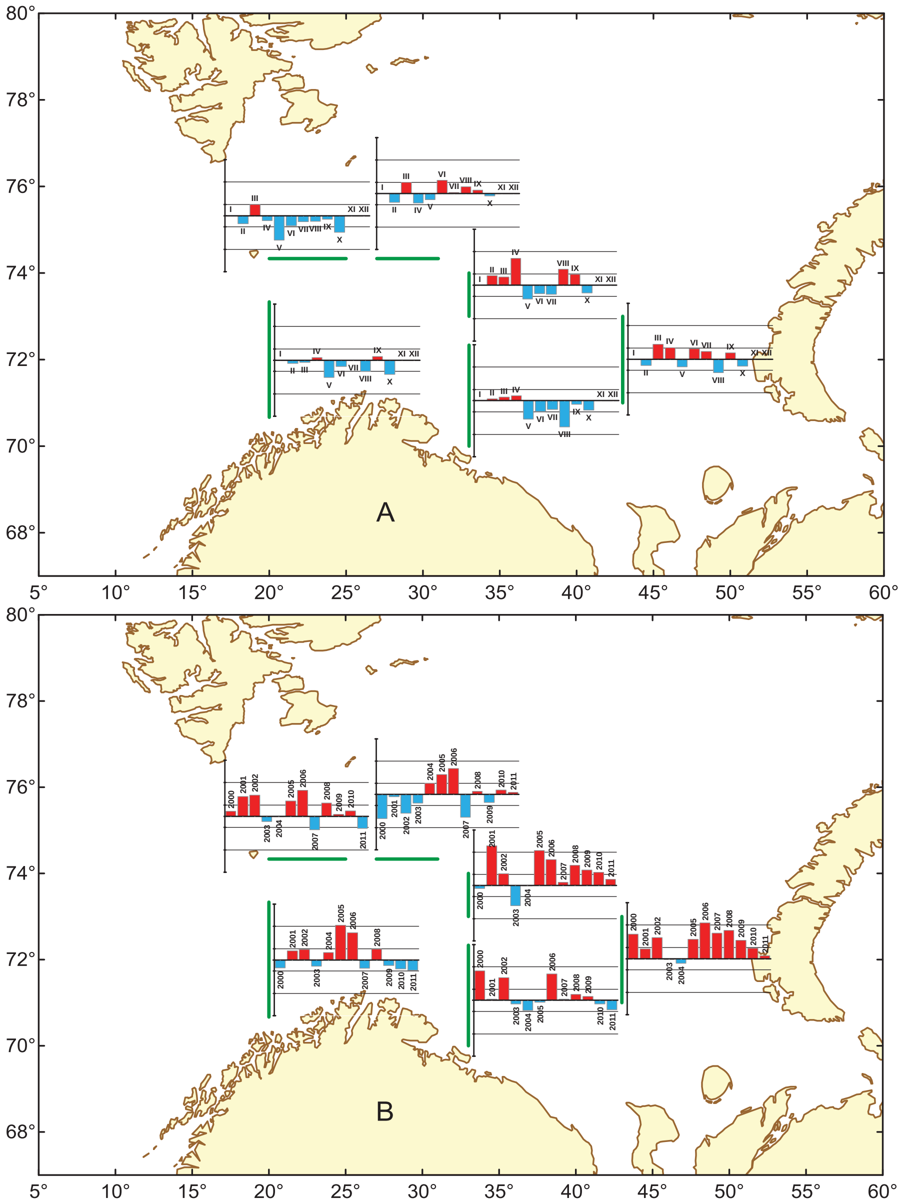

Figure 4.2.11. Monthly (A) and annual (B) total flux anomalies in the Barents Sea in 2011 and for the period of 2000-2011 respectively (normalized by standard deviation (σ); the vertical scale range is 5σ, a vertical scale interval is 1σ).

Wind-driven currents, on the whole, promoted strengthening of the general circulation in the Barents Sea in March, April and September 2011. On the average the Bear Island Current was weakened and the central branch of the North Cape Current and the Murman Current were strengthened in 2011 because of wind driven circulation.

4.2.2.4 Ice conditions

The meteorological situation over the Barents Sea in late 2010 – early 2011 favored widening of the area covered by sea ice. In January and February, the area was close to the long-term mean and 2.5% larger than in 2010. In winter and spring, the prevalence of westerlies and higher air temperature over the sea slowed down ice formation to a great extent. From March to May, the total ice cover was 10-13% smaller than normal and 11 % smaller than in 2010. Ice melting began already in June and was more intensive than in the previous year, especially, in the southwestern area, which had already been ice free by the end of June. Nevertheless, from June to August, ice coverage was 1-3% more extensive than in 2010. Ice formation was slow and started in late October in the northernmost part of the sea. In September and October total ice coverage of the sea was 1 and 3%, respectively. That is 6-12% less than normal and close to the levels the previous year. In November-December, sea ice coverage was 13-18% lower than in 2010 and 16% lower than the long-term mean (Figure 4.2.12).

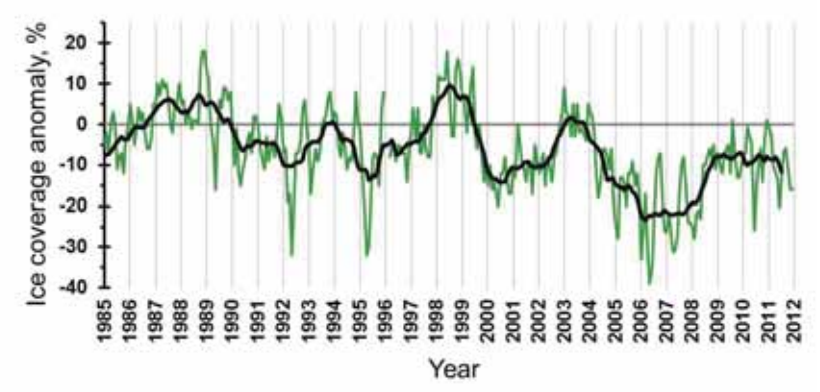

Figure 4.2.12. Anomalies of mean monthly ice extent in the Barents Sea in 1985-2011. The green line shows monthly values, the black one – 11-month moving average values (Anon., 2009)

4.2.2.5 Chemical conditions

In the bottom layer of the southern Barents Sea in 2001, oxygen saturation of waters was lower-than-normal and remained close to the level from 2010. This was mainly because of large negative anomalies in the second half of 2011. The average oxygen saturation anomaly for the first ten months of 2011 was -0.90%, compared with -0.85% at the same period of 2010 (Figure 4.2.13).

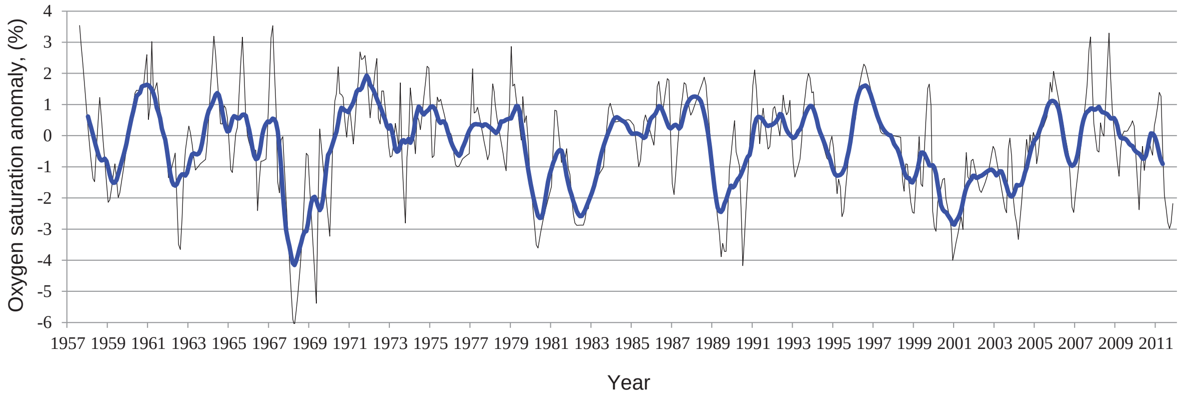

Figure 4.2.13. Monthly and annual oxygen anomalies in the bottom layer of the Kola Section in 1958-2011 (Anon., 2012).

4.2.2.6 Expected situation

The ocean has a "long memory" compared to the atmosphere, and it is therefore feasible, at least a priori, to realistically predict ocean temperature much further ahead than the typical weather forecast. The prediction is complicated by variation being governed by processes of both external and local origin, which operate on different time scales. Thus, both slowly moving advective propagation and rapid barotropic responses due to large-scale changes in air pressure must be considered.

According to computation by a prediction model (Boitsov and Karsakov, 2005), which is based on harmonic analysis of the Kola Section temperature time series, temperature of Atlantic waters in the Murman Current (in the Kola Section) is expected to remain at the level of warm years in 2012 and decline to the level of normal years in 2013 (Table 4.2.2.1).

Table 4.2.2.1 Predicted temperature in the Kola Section (0-200 m), representing the southern Barents Sea.

Year	Observation 2010	Observation 2011	Prediction 2012	Prediction 2013
Temperature	4.8	4.4	4.4	4.2

It should be noted that the predictions in this chapter are fundamentally different from the global change scenarios for 50 or even 100 years ahead (e.g. ACIA, 2005; IPCC, 2007). These long-trend trend scenarios are adressed in chapter 4.6.1.1 of the orginal report.

Due to the decreasing temperatures and the extreme minimum in sea ice extent the recent years, ice cover is expected to increase but will likely remain below the long-term mean.

4.3 Biotic components

4.3.1 Phytoplankton

Naustvoll, L. J. (IMR), M. Skogen (IMR)

There is large interannual and geographical variation in the distribution and abundance of phytoplankton species in the Barents Sea. However, the main the annual succession pattern is rather stabile despite variability between years in abiotic factors (e.g. temperature). The start of the spring bloom will vary between years. This is largely controlled by the onset of necessary stability of the water column for bloom formation. Large blooms, with exception of the spring and autumn situation, might occur some years along the coast or in the open waters of the Barents Sea.

In Norwegian waters no large aberration in the annual succession in the phytoplankton along the fixed transect (Vardø – North and Fugløya-Bear Island) was observed in the period 2008-2011. The phytoplankton production season starts with a larger spring bloom. This starts in the coastal waters and fjord systems and spreads out into the open areas. In general, the spring blooms starts during March along the coastline. This has been the case also in recent years. The spring bloom is dominated by the common spring diatom species (e.g. *Chaetoceros*, *Fragilariopsis*, *Skeletonema*, and *Thalassiosira*). The cruise activity along the fixed transects has not covered the spring bloom period during the recent years. However, data collected before and after the bloom indicate that the spring bloom has occured within the normal time period (April-Mai) in the open ocean.

In summer phytoplankton is patchily distributed. This goes for both abundance and species occurrence. The phytoplankton typically consists of small flagellates, dinoflagellates (*Ceratium*, *Gymnodinium* and *Gyrodinium*). In some years and at some stations, diatoms (mostly *Chaetoceros* spp.) can dominate in the June-August period. The coccolithophore *Emiliania huxleyi* has been observed in blooming concentrations along the Norwegian coast in 2008-2011. The highest densities have been observed in the western part of the Barents Sea in the fjord systems and close to the coast. Since 2007 the blooming period for *E. Huxleyi* has gradually extend in the autumn, well into September. No large blooms or high densities of *E. Huxleyi* have been observed in the open part of the Barents Sea during the latest years, and there have been only sporadic observations of the species in the eastern areas.

The autumn phytoplankton species composition has been more or less normal, with larger dinoflagellates dominating. However, in the western part along the Fugløya- Bear Island transect, the diatom *Proboscia alata* and the flagellate *Dichyocha speculum* has been relatively numerous the two last years. In the period 2005-2008 there have been sporadic observations of warm water species in the western part and along the coast in the autumn. In recent years there have been very few observations of southern species.

4.3.2. Zooplankton

T. Knutsen (IMR), E. Orlova (PINRO), P. Dalpadado (IMR), V. Nesterova (PINRO) and I. Prokopchuk (PINRO)

This chapter focuses on the current and expected state of the zooplankton communities in the Barents Sea. An overview of the communities of meso-, macro- and gelatinous zooplankton in the open sea and in the coastal waters off the Kola Peninsula is given. Some thoughts are also given on how the copepod communities react on changes in the hydrographical condition in the Barents Sea.

4.3.2.1 Mesozooplankton

The horizontal distribution of mesozooplankton in 2011 is shown in Figure 4.3.2.1 Average zooplankton biomass was clearly below the long-term mean in 2011. Particularly low biomass was observed in the central parts of the Barents Sea. In the western part of the Barents Sea, well defined areas of higher zooplankton abundance were observed in Storfjorden just south of Spitzbergen and south of Bear Island. For the latter region, this was relatively similar to what was observed in 2009 and 2010. Another region with high mesozooplankton biomass was west of Novaja Zemlja and east of approximately 38°E, in the Russian sector of the Barents Sea. Although biomass levels were high in the north-eastern corner of the Russian sector, close to Franz Josef Land, they were considerably lower in 2011 compared with the two preceding years.

Based on Norwegian data, average zooplankton biomass was estimated to be 5.88 g dry weight m^{-2} in the western and central Barents Sea in 2011. This is lower than the estimates from 2008 (6.48) and 2007 (7.13) and 2006 (8.63) in this region, but similar to the levels seen in the most recent years. Combining Russian and Norwegian data for the entire Barents Sea gives an estimate of average zooplankton biomass of 6.7 g dry weight m^{-2} in 2011 for the whole area. This is less than what was found in 2008 (7.15 g m^{-2} dry weight), 2007 (7.7) and 2006 (8.4). In the Russian sector alone, average biomass in 2011 was estimated to be 8.05 g dry weight m^{-2}.

The zooplankton community is dominated by the three copepod species *Calanus finmarchicus*, *Calanus glacialis* and *Calanus hyperboreus*, but euphausiids, chaetognaths, and in some cases pteropods also had high biomass. *C. finmarchicus* was the main species in terms of biomass in the western parts of the Barents Sea, whereas *C. glacialis* dominated in the northeastern parts.

Biomass of meso-zooplankton varies considerably from year to year in different parts of the Barents Sea. Variation in temperature, advection from the Norwegian Sea and predation pressure are important factors that may explain this.

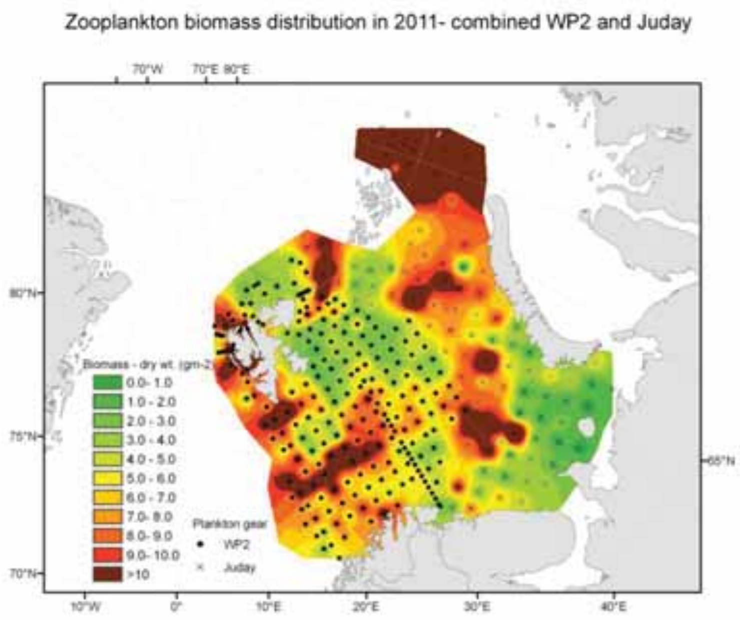

Figure 4.3.2.1 Distribution of zooplankton dry weight (g m^{-2}) from bottom-0 m in 2011. Data based on Norwegian WP2 and Russian Juday net samples (IMR/PINRO).

Northern and eastern parts of the Barents Sea

In 2009-2010, the highest biomass was recorded in northern and eastern areas (Figure 4.3.2.2). *C. glacialis*, *C. hyperboreus*, *M. longa* and *Pseudocalanus minutus*, which are all Arctic species, and *C. finmarchicus*, a North Atlantic species, were the most numerous species in this area (Figure 4.3.2.3).

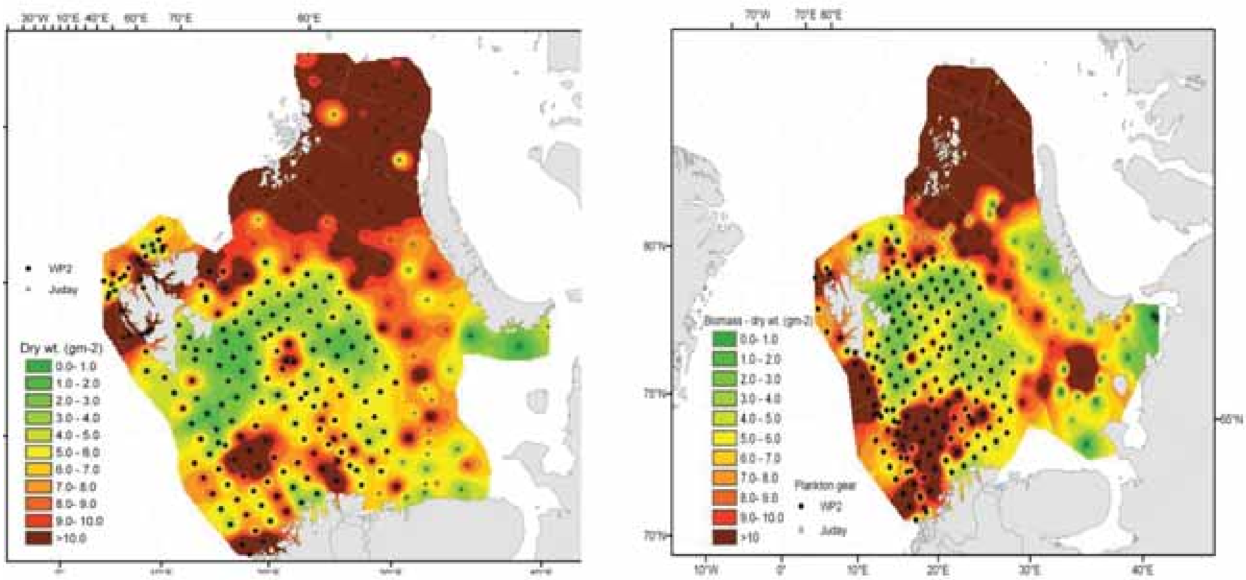

Figure 4.3.2.2. Distribution of zooplankton dry weight (g· m^{-2}) from the bottom-0m layer in 2009 (left panel) and 2010 (right panel). Data based on Norwegian WP2 and Russian Juday net samples (IMR/PINRO).

In 2009, the greatest concentrations of *C. glacialis*, *P. minutus* and *C. finmarchicus* occurred near Franz Josef Land and north of the Great Bank areas. Calanoida eggs and nauplii were recorded in considerable numbers everywhere within these areas. In the western Novaya

Zemlya Bank areas, where *C. finmarchicus* dominated, no calanoida eggs were found and nauplii were considerably less abundant.

Biomass was moderate in the northern areas, (up to 200-500 mg m^{-3}with minimum values of 100 mg m^{-3}) and lower east of 65°E (Figure 4.3.2.4). The highest biomass of *C. glacialis* and *C. hyperboreus* was recorded within the Franz Josef Land area. Similar biomass of *C. finmarchicus* and *C. glacialis* was reported in the Great Bank area north of 78°N.

In 2009, distribution of the *Calanus* species were as follows: *C. glacialis* dominated in cold waters (mainly north of 79°N) in the central Barents Sea down to 100 m depth. Higher abundances of *C. finmarchicus* were recorded in the area with positive temperatures in the entire water column from 75°-78°N and 44-60°E, while a wide distribution of *M. longa* was found in deeper layers. Abundance of *C. hyperboreus*, which occurred in the entire water column only in the Franz Josef Land area, was very low.

From 2009 to 2010, the relative abundance of *C. finmarchicus* as well as the total abundance of zooplankton declined considerably in the northeastern part of the Barents Sea, and *P. minutus* became the most abundant species (Figures 4.3.2.2 and 4.3.2.3). *M. longa* was also found in relatively great numbers. The biomass was still largely made up of *C. glacialis* in this region (Figure 4.3.2.4). Biomass of *C. hyperboreus* was low while *C. finmarchicus* contributed significantly to biomass in the southern part of the region.

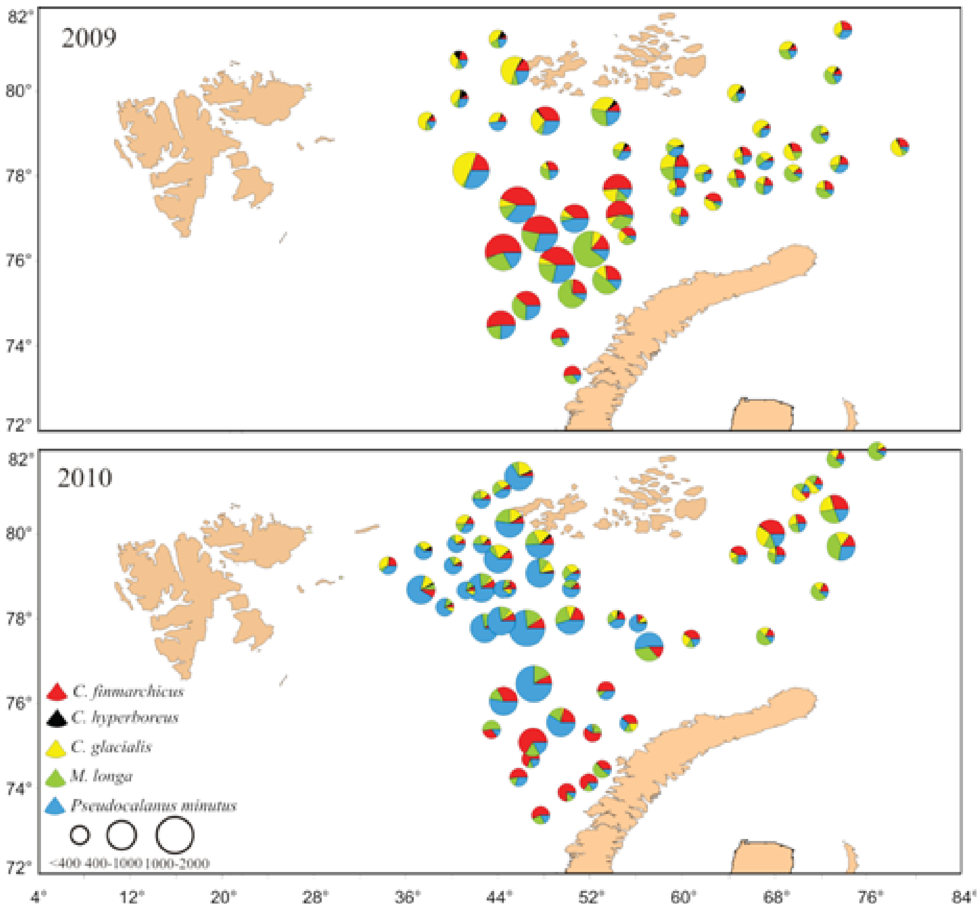

Figure 4.3.2.3. Relative abundance of different species of copepods in the 0-bottom layer in the Barents Sea in August-September 2009-2010 (ind. · m^{-3})

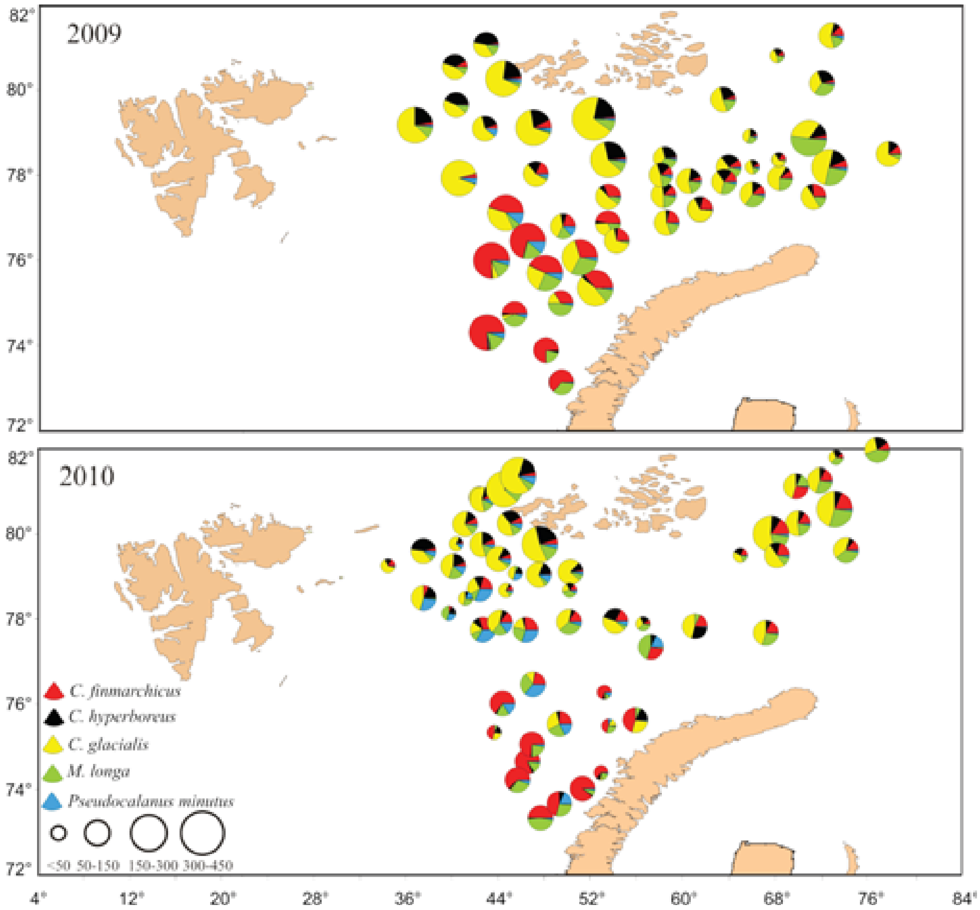

Figure 4.3.2.4. The biomass of different species of copepods in 0-bottom in the Barents Sea in August-September 2009-2010 (mg · m^{-3}).

The Kola section

In the Kola section, which is located in the southern part of the Barents Sea, northwards from the Kola Peninsula, abundance of *Calanus finmarchicus* varied considerably during the years 2008-2010 (Figure 4.3.2.5). The population was represented by all developmental stages from nauplii to adults but copepodites in stages CI-CIII dominated in abundance. In 2008-2009, abundance of *C. finmarchicus* declined from the surface to the bottom in this area, and in 2010, the highest biomass of *C. finmarchicus* was recorded in the 50-100 m layer (8700 ind. m^{-3}), while it declined approximately by a factor of two in the near-bottom layers (4570 ind. m^{-3}). In the 0-50 m and 50-100 m layers, nauplii and copepodites, stages CI-CIII, dominated in abundance in all the years, whereas in 2010 they were also abundant in the 100 m-bottom layer. Abundance of individuals representing late copepodite stages (CIV-VI) was low and their relative percentage was higher beyond 100 m especially in 2009 (Figure 4.3.2.5).

In 2011, 30 samples of mesozooplankton were collected in the Kola Section. A preliminary analysis suggests that *C. finmarchicus* dominated, but its abundance was lower than in 2010. Due to the weak warming of waters in May 2011, the development of *C. finmarchicus* was slow and the proportion of smaller individuals in the population was larger than in 2010.

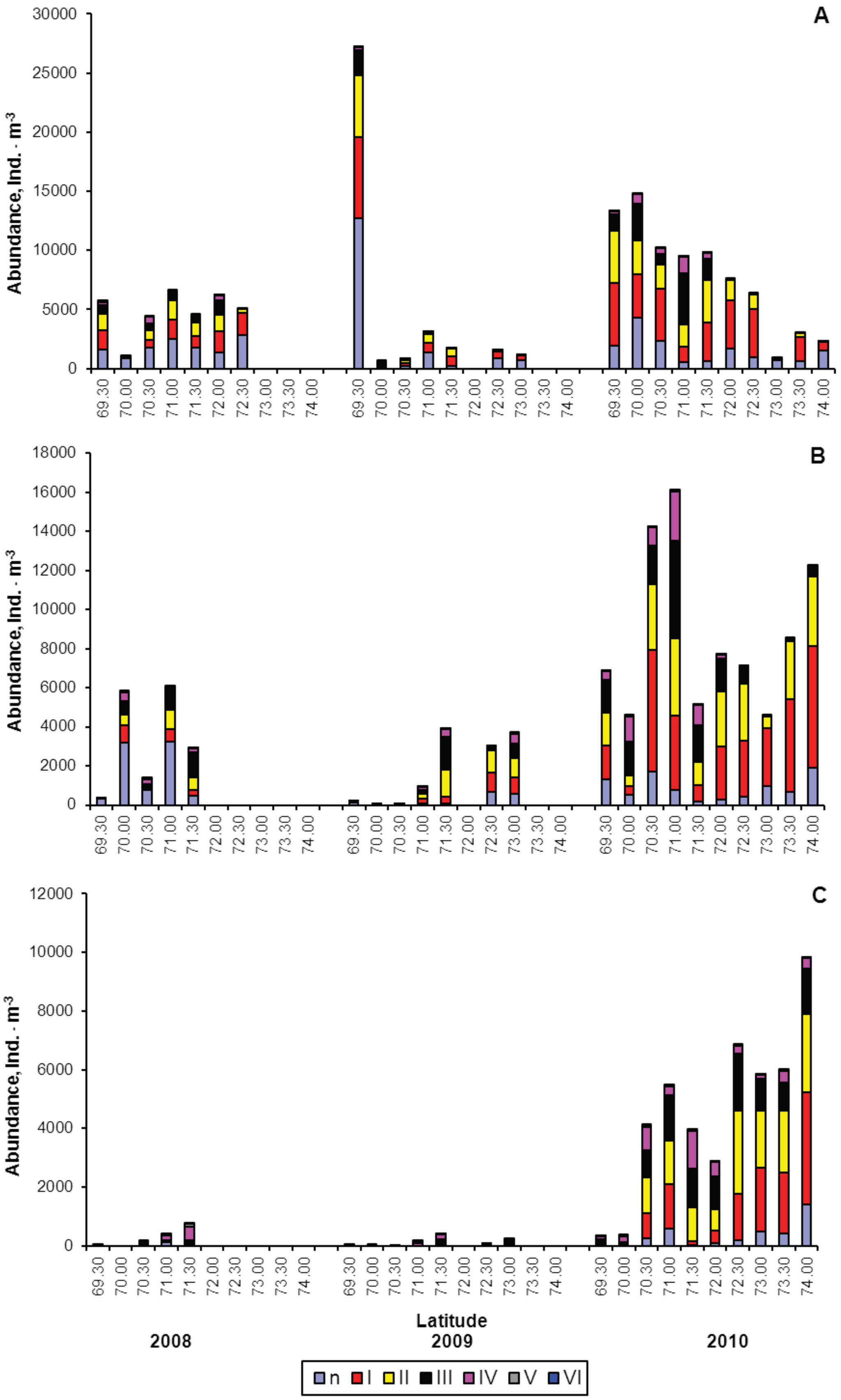

Figure 4.3.2.5. Abundance of *C. finmarchicus* (ind. · m^{-3}) in Juday net catches in the 0-50 m (A) 50-100 m (B) and 100 m-bottom (C) layers in the Kola Section in late May – early June 2008-2010.

The Fugløya-Bear Island (FB) transect

The Fugløya-Bear Island (FB) transect is taken at fixed positions located at the western entrance to the Barents Sea. The numbers of sampled stations are normally 5 to 8 depending on weather conditions. Here data from four locations have been analysed. They represent different water masses (coastal, Atlantic, and mixed Atlantic/Arctic water) and covers the years 2004 to 2011.

Abundance estimates of the two most abundant species, *C. finmarchicus*, and *C. glacialis* are shown in Fig. 4.3.2.6. *C. finmarchicus* displays large inter-annual variations in abundance. The highest abundances were recorded in 2010 over the whole transect except for the northernmost locality at 74º00’N, where abundance was considerably lower. Looking across all years, abundance of *C. finmarchicus* has been highest at the locality 73º30’N. As expected *C. glacialis* has its highest abundance at the two northernmost localities, where Atlantic and Arctic waters mix. This species is subject to large inter-annual variations, and its abundance the last couple of years is considerably below what can be considered the log-term mean for the two northernmost localities.

Occurrence of *C. helgolandicus* have been registered in March and August. *C. helgolandicus* is similar in appearance to *C. finmarchicus*, but is a more southerly species with a different spawning period. *C. helgolandicus* has in recent years become more frequent in the North Sea and southern parts of the Norwegian Sea (Svinøy transect), and may increase in abundance in the western part of the Barents Sea in the years to come.

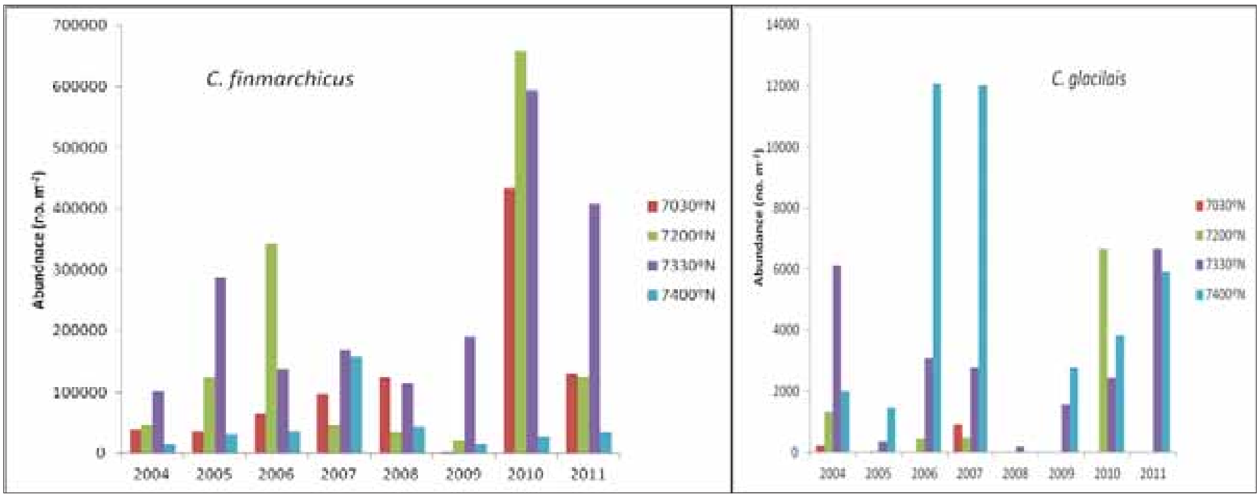

Figure 4.3.2.6. Development of copepod abundance along the transect Fugløya-Bear Island during the period 2004 - 2011. On a few occasions, when stations were lacking at a particular position, stations closest to that position were analyzed.

4.3.2.2 Macrozooplankton

During the PINRO autumn bottom trawl survey in 2009-2010, samples were collected to estimate the pre-spawning stock of euphausiids (Figure 4.3.2.7). Similar to what was found in 2007-2008, the arctoboreal species *Thysanoessa inermis* dominated. Abundance of *Thysanoessa raschii*, a more cold-loving species, had decreased substantially from 2007/2008 to 2009/2010.

The average abundance of euphausiids declined from 2009 to 2010 in all parts of the Barents Sea (Figure 4.3.2.8). Abundance of *Meganyctiphanes norvegica*, a larger advected species, followed a similar pattern (Figure 4.3.2.9).

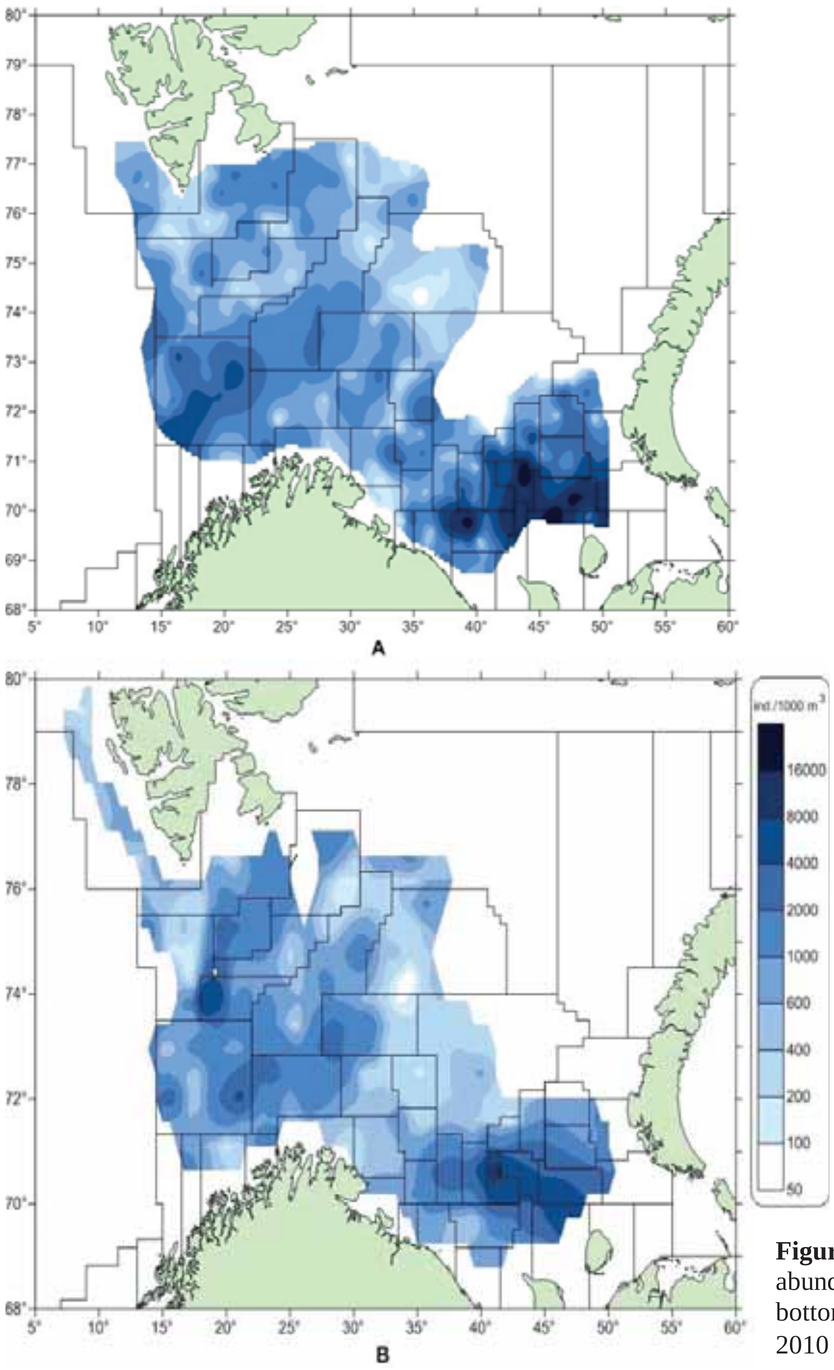

Figure 4.3.2.7. Distribution and abundance of euphausiids in the near-bottom layer in autumn 2009 (A) and 2010 (B), measured as ind. · 1000 m^{-3}.

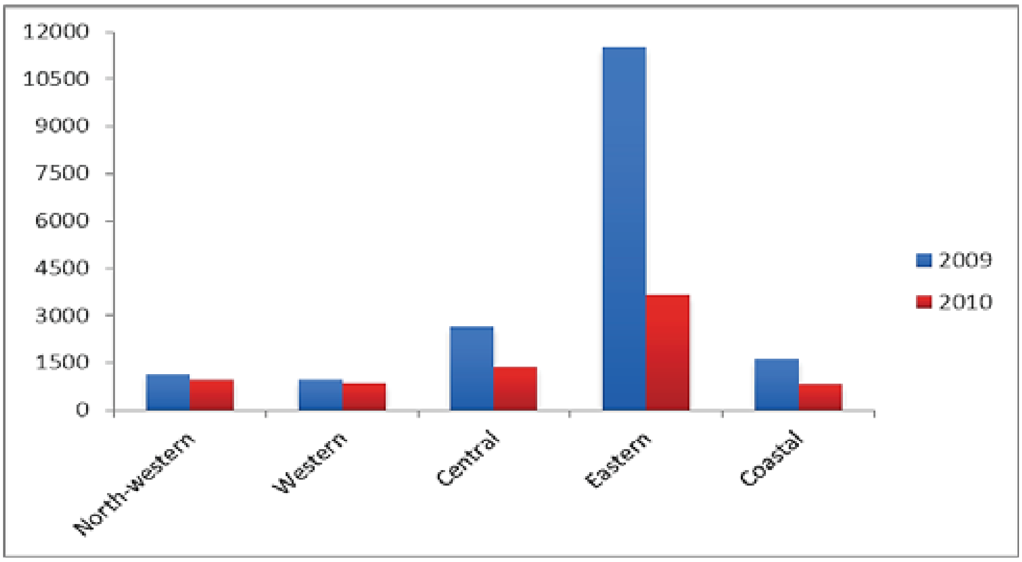

Figure 4.3.2.8. Mean abundance indices of euphausiids in the North-Western, Western, Central, Eastern and Coastal areas of the Barents Sea in autumn 2009 and 2010 (based only on Russian data from trawl net samples), ind. · 1000 m^{-3}.

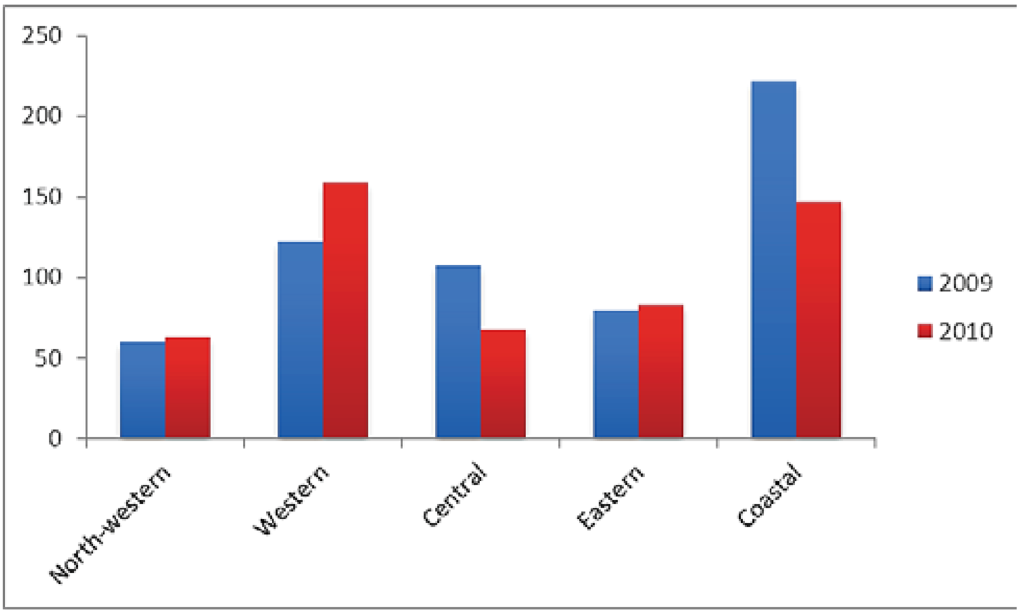

Figure 4.3.2.9. Mean abundance indices of *Meganyctiphanes norvegica* in the North-Western, Western, Central, Eastern and Coastal areas of the Barents Sea in autumn 2009 and 2010 (based only on Russian data from trawl net samples), ind. · 1000 m^{-3}.

The data collected indicates that abundance of krill declined considerably in the central Barents Sea in 2010. This decline was probably real, whereas results from coastal and particularly in eastern areas could have been affected by fewer samples collected in these regions that year. Despite the fact that the mean number of euphausiids in the southern Barents Sea decreased by a factor of approximately 2.5, in 2010 compared to 2009, the decline in the north-western areas was slight and remained above the long-term mean.

Recruitment of euphausiids by advected age 0+ individuals changed from 2009 to 2010. Abundance of 0+ individuals of *T. inermis* increased considerably in north-western and western areas, while it decreased by a factor of 3-4 in central and eastern areas, and remained unchanged in coastal areas. From 2009 to 2010, abundance of age 0+ individuals of *T. raschii* continued to declinine in eastern areas. Maximum concentrations decreased by a factor of 5 and remained at the level of 2009 in central areas. In 2010, a clear change in the quantitative ratio of age 0+ individuals of *T. longicaudata* was observed. They declined by a factor of two in the northwest, while they increased by a factor of 3-5 in the west. Compared to 2009, recruitment to the *M. norvegica* population by age 0+ individuals increased by 1.5-2 times in the north-western Barents Sea, by a factor of 3 in the western part of the sea and by a factor of 2 in the central area, while it decreased by a factor of more than 10 in coastal areas and remained unchanged in the eastern Barents Sea.

The considerable decline in the abundance of euphausiids in the southern Barents Sea from 2009 to 2010 was presumably associated with consumption by capelin, which has increased considerably in abundance over the last years (44 % only in 2010). The presence of older capelin individuals over the last years, which mainly feed on euphausiids, is an essential factor affecting the increased consumption of euphausiids by capelin. Euphausiids were similarly affected by predation from haddock, which has increased in abundance. The geographical distribution of haddock has also overlapped with aggregations of euphausiids in the central Barents Sea. Consequently, euphausiids constituted a high proportion of the haddock diet (up to 90% by weight). The simultaneous increase in abundance of age 0+ individuals from the majority of euphausiid species indicate that recruitment is still high and that considerable large-scale advection and dispersion occurred in 2010.

Preliminary data from the 2011 autumn survey indicate that abundance of small crustaceans was high in western areas, similar to what was observed in 2010. In the Nordkyn Bank area, the increase in the euphausiid abundance was 1.8 times higher than in 2010, whereas abundance of euphausiids on the Demidov Bank remained almost the same as in 2010. In other areas, the abundance of euphausiids declined by a factor of 1.6-4. The mean index of abundance for western areas decreased compared to 2010.

4.3.2.3 Gelatinous zooplankton

Figure 4.3.2.10 shows the occurrence of gelatinous zooplankton in pelagic trawls in 2010 and 2011. Estimated abundance of large gelatinous zooplankton was higher in 2011 than in 2010. The centre of distribution and highest abundance was located in the south-western part of the Barents Sea in 2011. The distribution and abundance in 2011 was similar to what was observed in 2008. Both in 2010 and in 2011, the occurence of “jellyfish” overlapped substantially with regions low mesozooplankton biomass. The data should however be interpreted with caution since many smaller “jellyfish” species are not sampled adequately with the method used.

The majority of hauls were conducted as standardized stepwise hauls in the 40-20-0 m depth interval, but a few hauls were operated deeper. The catches were adjusted for time of trawling. It is assumed that the results mainly reflect the occurrence of the larger Scyphozoan medusa like the genus *Aurelia* and *Cyanea*. The occurrence of Ctenophora (“comb-jellies”) cannot be verified due to lack of proper taxonomic classification. Both *Ctenophora* and smaller “jellyfish” are however caught in the WP2 net, but this gear has limitations with respect to the small volume sampled. Initial trials using a larger vertically operated WP3 net (UNESCO, 1968) has been initiated and is probably what should be applied in the future.

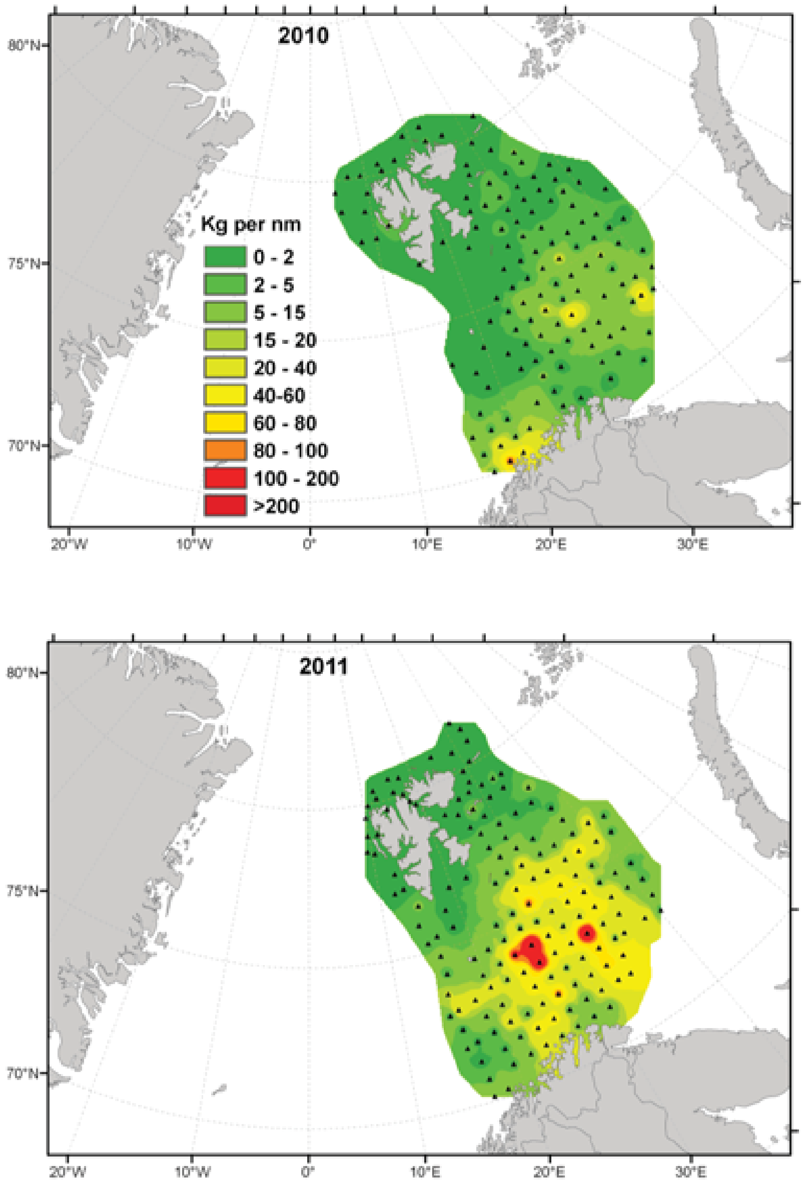

Figure 4.3.2.10. Distribution of catches of gelatinous zooplankton in pelagic Harstad trawl in 2010 and 2011. Numbers are standardized to kg·trawl distance^{-1}.

4.3.2.4 Expected situation

The average mesozooplankton biomass in August and September 2011 for the Norwegian sector of the Barents Sea was below the long-term mean. Over the last four years the average biomass has been relatively stable at this level in this region. The highest biomass of mesozooplankton in the Norwegian sector was found in the Atlantic water masses, where transport of zooplankton from the Norwegian Sea into the central and western parts of the Barents Sea occurs. The continued, and lower than average biomass of mesozooplankton in the Norwegian sector of the Barents Sea, suggests that the initial conditions for local production here could be suboptimal also in 2012.

The considerable decline in the abundance of euphausiids in the southern Barents Sea from 2010 to 2009 is probably associated with increased consumption by capelin. The abundance of pre-spawning euphausiids by early 2011 is estimated to be 1.2 times above the long-term mean in the southern Barents Sea and 1.3 times above the long-term mean in the north-western Barents Sea. For 2012 and 2013, advection of *M. norvegica,* a warmth-loving euphausiid species, will most likely remain at the level of 2010. Water temperatures will likely decrease in 2013, and this may favour an increase in the abundance of the arcto-boreal *Thysanoessa raschii* in the eastern areas, as this species seems to prefer shallow shelf regions and colder, less saline coastal water.

A general warming of the Barents Sea and further decline in winter sea ice extent is expected to facilitate expansion of warm water species towards the north and east in the Barents Sea. Evidence for such expansions is the findings of considerable amounts of euphausiids in the stomach content of capelin north of Svalbard in 2007 and in the stomachs of both capelin and polar cod in the central and eastern Barents Sea during the recent years. Recent findings of juvenile euphausiids north of 78ºN, and the regular occurrence of high biomass of krill north-west and south-east in the Barents Sea, support the impression that krill is expanding its distributional range in the Barents Sea, either due to local recruitment (*Thysanoessa inermis* and *Thysanoessa raschii*) or because of intrusion of Atlantic water masses (*Meganyctiphanes norvegica, Thysanoessa longicaudata* and *Nematocelis megalops*). The increasing occurrence of the latter species over the last 10 years illustrated how a typical Atlantic krill species spreads into the Barents Sea. However, it is uncertain how these species will interact with other species in the Barents Sea and whether they are able to successfully reproduce and complete their life cycle in the areas they have expanded into.

The below average mesozooplankton biomass in the Barents Sea is probably linked to high biomass of capelin. Other plankton consumers like 0-group herring, cod, haddock and redfish are also considered to have an important influence on the zooplankton biomass. In 2011 this was probably true for 0-group cod, which had highest year class on record, and capelin and haddock, which also had strong year classes. The total biomass of the four most abundant 0-group fish (cod, haddock, herring and capelin) reached 2.5 million tonnes in August-September 2011. Hence, the predation pressure on zooplankton from many 0-group plankton consumers was considerable during autumn 2011. It should be noted that the conditions for lower trophic level production could have been above average despite the low levels of mesozooplankton biomass. If so, this may have prevented mesozooplankton biomass from being reduced to even lower levels.

Gelatinous zooplankton, like medusa and ctenophores are also considered important predators on meso-zooplankton in the Barents Sea, but their influences are difficult to assess quantitatively. However, it should be noted that the low zooplankton abundance in the central part of the Barents Sea in 2010 and 2011 to a large extent coincided with high gelatinous zooplankton abundance. This is similar to what has been observed in the three preceding years. How this may affect the distribution of capelin and its consumption is not known. Gelatinous zooplankton may prefer a different size spectrum of zooplankton and fish larvae than capelin. If so their impact as competitors to capelin may be smaller than if diet overlap is larger.

Based on what we know about hydrographic conditions and long-term dynamics of zooplankton development, we expect spawning of copepods and euphausiids to start in mid April in the south-western areas of the Barents Sea. Having overwintered, these groups of crustaceans, along with the warm water species that are transported from the Norwegian Sea, will create a zone with high density of zooplankton in the north-western and western part of the Barents Sea. In 2008, a region with considerably elevated zooplankton biomass, extending in the north-south direction, was observed west of Novaja Zemlja in the Russian sector. This region also had higher abundances of meso-zooplankton biomass in the period 2009-2011, albeit with reduced levels compared with 2008. The high biomass of meso-zooplankton found south to south-east of Franz Josef Land in 2009 and 2010 was apparently reduced in 2011. This area overlaps to a large extent with the distribution of polar cod and capelin in the north-eastern part of the Barents Sea, suggesting that predation from these two species on zooplankton has been considerable here. The relatively low zooplankton biomass observed in the central parts of the Barents Sea appears to be a recurring phenomenon. It may be caused by heavy predation from capelin, although gelatinous zooplankton could also be important. Since this is among the more shallow regions of the Barents Sea, the meso-zooplankton here has few possibilities to migrate to deeper waters to reduce predation.

The low average meso-zooplankton biomass in the Barents Sea in 2011, the large and widely dispersed capelin stock and the additional predation from polar cod, suggests that survival and overwintering success of meso-zooplankton like *Calanus* spp. will be low compared to the previous couple of years. However, import of zooplankton from the west and favourable production conditions during spring and summer 2012 could compensate for the loss of meso-zooplankton from predation. Therefore, one might expect that meso-zooplankton biomass in 2012 would not be above the long-term average, although regionally high production could be expected, particularly in the western Barents Sea and along the eastern edge of the Svalbard archipelago.

References added in this update

Orlova, E., Knutsen, T., Berchenko, I., Dalpadado, P., Falk-Petersen, S., Prokopchuk, I., Yurko, A., Nesterova, V. and Yurko, O. 2009b. Zooplankton. In Joint Norwegian-Russian environmental status 2008 Report on the Barents Sea Ecosystem, Part II – Complete report, pp. 39-43, 201-211. Ed. by J.E. Stiansen, O. Korneev, O. Titov, and P. Arneberg. IMR/PINRO Joint Report Series, 3/2009.

UNESCO (1968) Monographs on Oceanographic Methodology: Zooplankton Sampling. UNESCO, Paris.

4.3.5 Fish

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4.3.5.1 Cod (*Gadus morhua*)

Based on the most recent estimates of spawning stock biomass (SSB, Figure 4.3.5.1), ICES classifies the stock as having full reproductive capacity and being harvested sustainably. The SSB has been above B_{pa} since 2002 and is now at a record high level, while the total stock biomass is at a level not seen since the early 1950s.

Fishing mortality was in the range 0.50-0.70 from 2001-2006, but dropped to 0.36 in 2007 and has since then been around 0.30. This fishing mortality is below that intended under the agreed management plan (0.40), but is in the range that is associated with high long-term yield and low risk of depleting the production potential. The accepted harvest control rule gave a TAC advice for 2013 of 940 000 t.

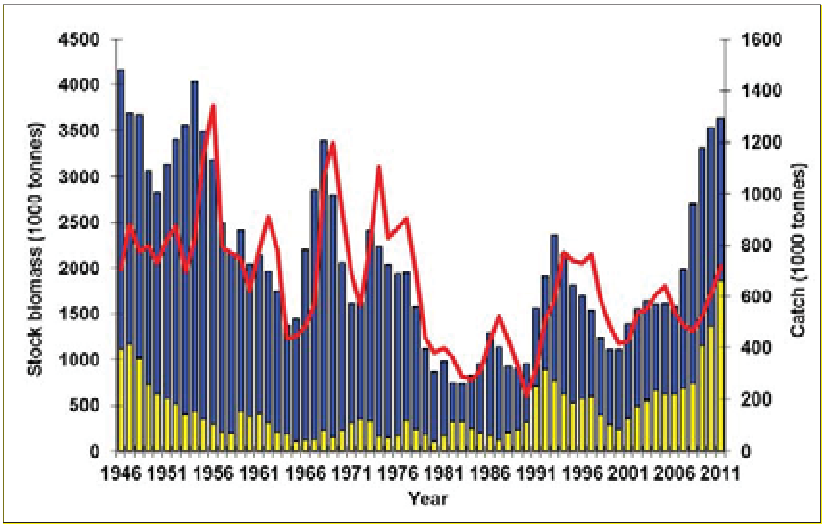


Figure 4.3.5.1. Northeast Arctic cod, development of spawning stock biomass (yellow bars), total stock biomass (age 3 and older, blue bars) and landings (red curve).

The geographical distribution of this stock is expanding to the north and east (Figure 4.3.5.2). This is related to the high temperatures observed in the Barents Sea in recent years as well as the high stock abundance. It is important that the spatial coverage of the surveys is increased to take this into account.

4.3.5.2 Haddock (*Melanogrammus aeglefinus*)

Based on the most recent estimates of SSB (Figure 4.3.5.3), ICES classifies the stock as having full reproductive capacity and being harvested sustainably. The fishing mortality has fluctuated around F_{pa} during the last 10 years. The assessment indicates that the spawning stock is at a record high level. Very strong year classes of 2004-2006 recruited to the fishable stock in 2008-2010, and thus the stock in 2010-2011 reached the highest level observed in the time series, which go back to 1950. The 2007 and later year classes seems to be around average, and the stock is predicted to decrease in the coming years. The accepted harvest control rule gave a TAC for 2013 of 238 000 t. Haddock is taken both as a directed fishery and as bycatch in the NEA cod fishery.

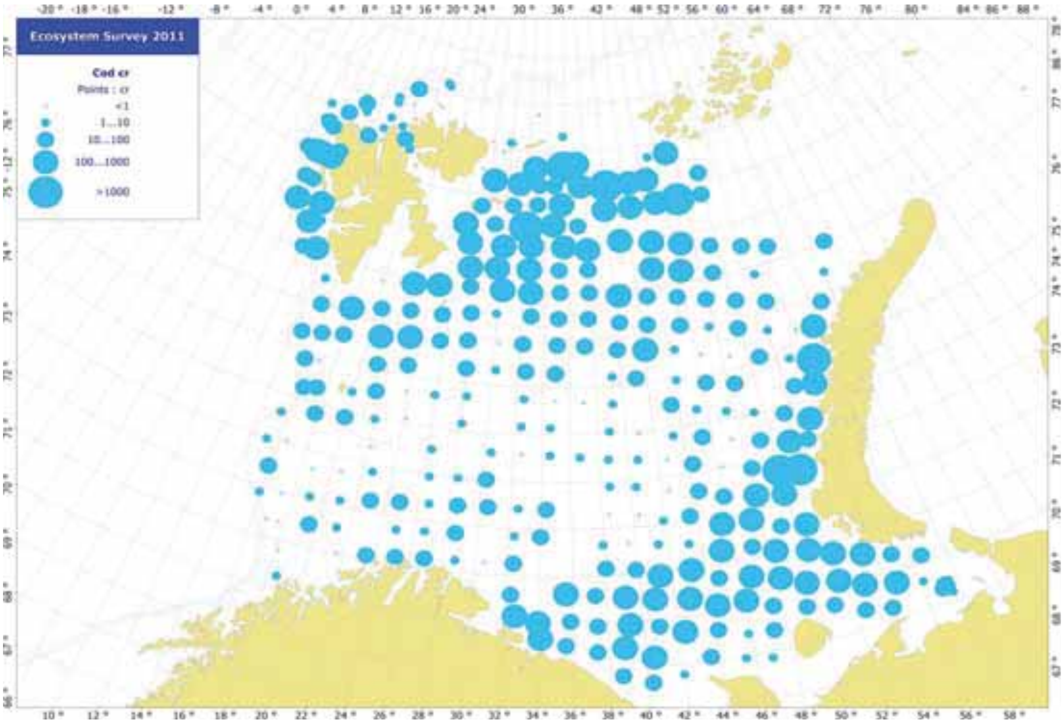


Figure 4.3.5.2. Distribution of Northeast Arctic cod, August-September 2011.

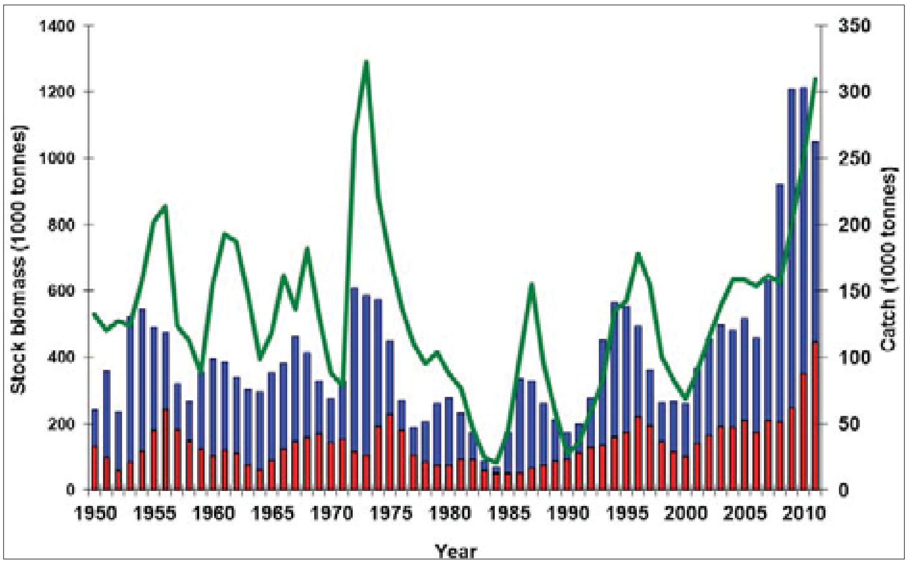


Figure 4.3.5.3. Northeast Arctic haddock, development of spawning stock biomass (red bars), total stock biomass (age 3 and older, blue bars) and landings (green curve).

4.3.5.3 Redfish (Sebastes mentella and Sebastes marinus)

Deep-Sea Redfish (Sebastes mentella)

Recruitment failure has been observed in surveys for more than a decade (Figure 4.3.5.4). However, signs of improved recruitment are now seen in the Barents Sea. In this regard, it is of vital importance that the juvenile age groups be given the strongest protection from being caught as bycatch in any fishery, e.g., the shrimp fisheries in the Barents Sea and Svalbard area. This will ensure that the recruiting year classes can contribute as much as possible to stock rebuilding.

The only year classes that can contribute to the spawning stock in the coming years are those prior to 1991 as the following year classes are extremely poor. Several years of protection and growth of these year-classes could have caused the higher abundance and densities recently encountered along the continental slope and pelagic in the Norwegian Sea. These year classes need to be protected as they offer the only opportunity of increasing the spawning stock for a number of years to come.

A directed pelagic fishery for deep-sea redfish (*S. mentella*) in international waters of the Norwegian Sea has developed since 2004. This fishery increased to record levels in 2006, and the total catch in 2006 was 33 thousand tonnes, the highest level since 1991. The total landings of *S. mentella* in Subareas I and II in 2011, demersal and pelagic catches, amount to 12,422 t, and the catches in 2012 are expected to be at the same level. For many years, no directed fishery has been advised for this stock. After a new assessment model was accepted in 2012, ICES decided to give advice on catch levels. The advice given for 2013, 47 000 t, corresponds to $F_{0.1}$. There are no reference points or harvest control rule for this stock, so as this text is written it is unclear whether it will be followed.

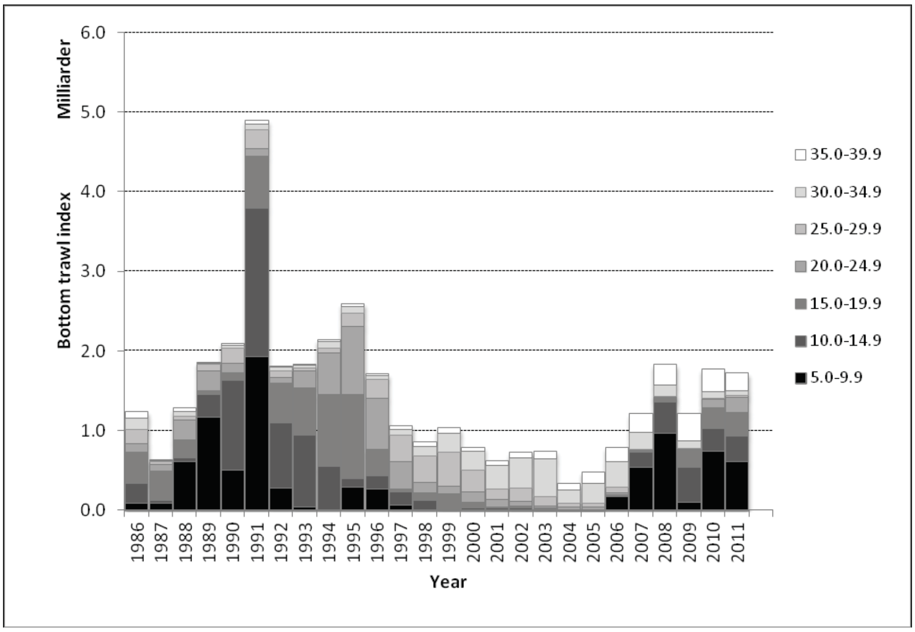


Figure 4.3.5.4. *Sebastes mentella*. Abundance indices (by length) when combining the Norwegian bottom trawl surveys 1986-2011 in the Barents Sea (winter) and at Svalbard (summer/fall).

Golden Redfish (*Sebastes marinus*)
In the absence of defined reference points the state of the stock cannot be fully evaluated. Surveys (Figure 4.3.5.5) and commercial CPUE show a substantial reduction in abundance and indicate that the stock at present is at a historically low level. The year classes in the last decade have been very low and declining. Presently, this stock is in a very poor condition.

Given the low productivity of this species, this situation is expected to remain for a considerable period.

More stringent protective measures should be implemented, such as no directed fishing and extension of the limited moratorium implemented on this stock, as well as a further improvement of the trawl bycatch regulations. It is also of vital importance that the juvenile age groups are given the strongest protection from being caught as bycatch in any fishery, e.g. the shrimp fisheries in the coastal areas as well as in the Barents Sea and Svalbard area. This will ensure that the recruiting year classes can contribute as much as possible to slowing the decline of the stock. Golden redfish is currently being caught in a directed fishery and as bycatch in the pelagic trawl fisheries for herring and blue whiting in the Norwegian Sea. Better statistics on this bycatch, and regulations to prevent this from continuing, are needed.

The catches have been around 7,000 t for the last 7 years, a level which seems to cause a continued decline of this stock.

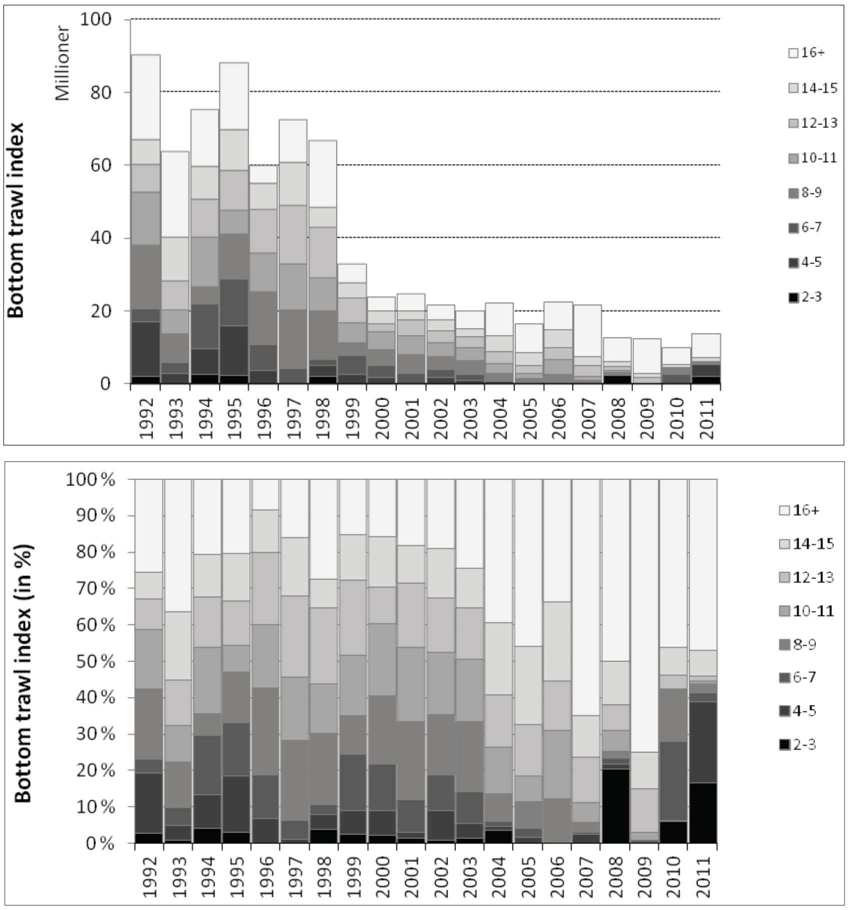
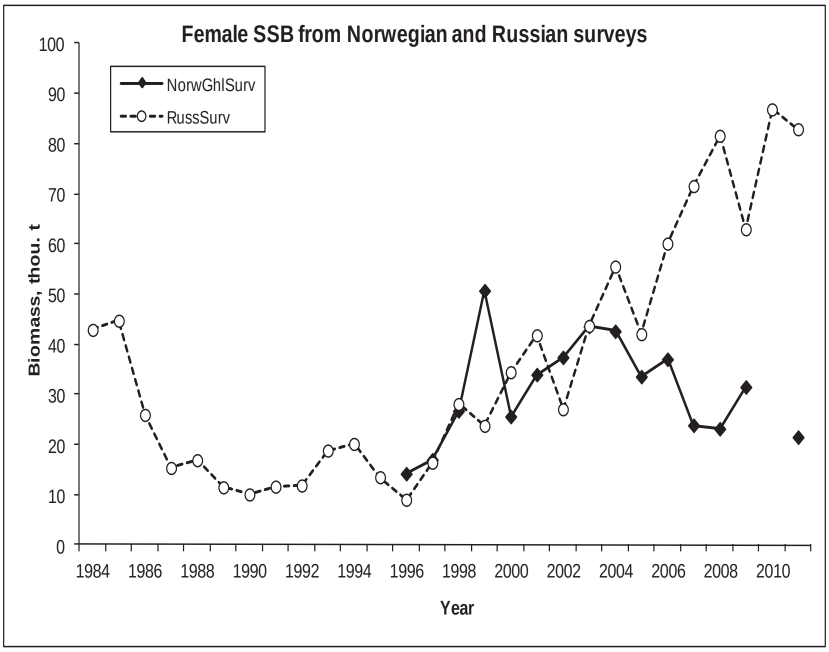


Figure 4.3.5.5. *Sebastes marinus*. Abundance indices (by age) from the Norwegian bottom trawl surveys 1992-2011 in the Barents Sea. Top: absolute index, bottom: relative frequencies. Horizontal line indicates the median age of the surveyed population.

4.3.5.4 Greenland halibut (*Reinhardtius hippoglossoides*)

In the absence of defined reference points and an accepted assessment the status of the stock, the stock cannot be fully evaluated. The stock has been at a low level for several years and it is a long-lived species which can only sustain low exploitation. Indications from fishery independent surveys are that the stock may have increased in recent years, although the signals from different surveys are conflicting (Figure 4.3.5.6). During the last 15 years, average catches have been around 13 000 t (Figure 4.3.5.7). Given the state of the stock and the paucity of information, the fishery should not exceed 15 000 t until better information is available and firm evidence of a larger stock size has been obtained.

There is at present no accepted assessment for this stock, mainly due to age-reading problems and discrepancies between different data sources. The age-reading issue is being addressed and should be resolved in future years, but corrections to past years are required.



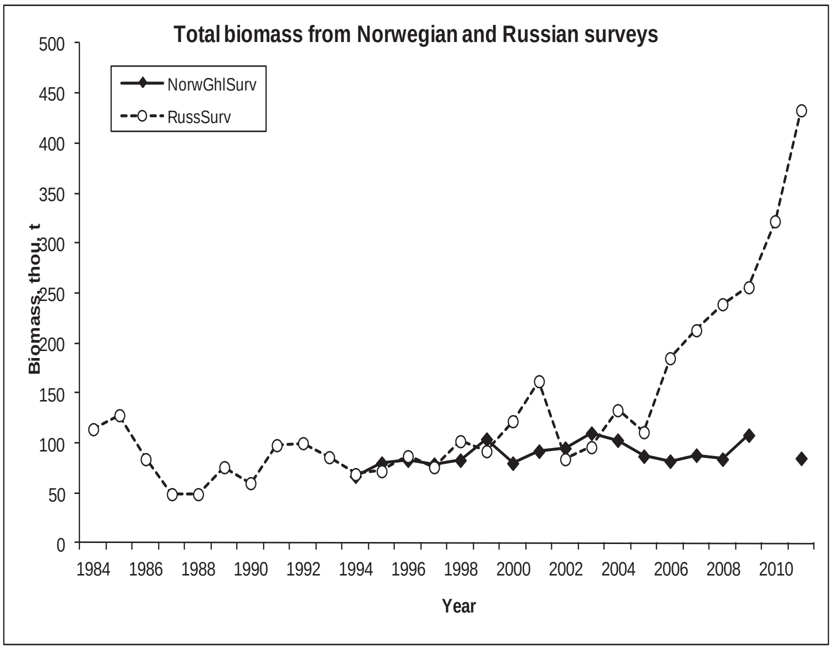


Figure 4.3.5.6. Northeast Arctic Greenland halibut. Left: Biomass (swept area) estimate of the mature female biomass (Norwegian Greenland halibut survey along the continental slope in August and Russian autumn trawl survey). Right: Total biomass estimates from the Norwegian Greenland halibut survey along the continental slope in August and Russian autumn trawl survey. No Norwegian survey was conducted in 2010.

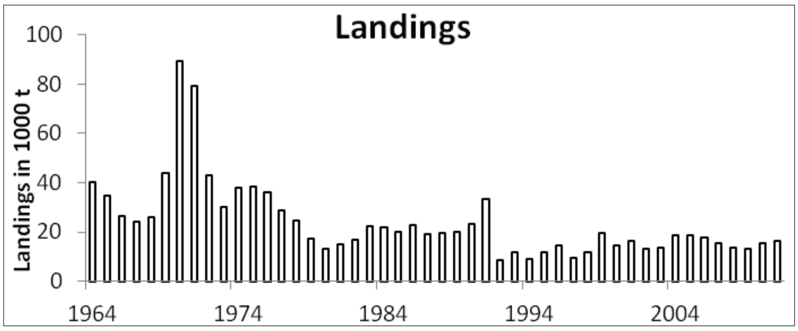


Figure 4.3.5.7. Northeast Arctic Greenland halibut; landings 1964-2011.

4.3.5.5 Capelin *(Mallotus villosus)*

The stock size has been stable since 2008 (Figure 4.3.5.8). The spawning stock of capelin in 2012 was predicted from the acoustic survey in September 2011 and a model, which estimates maturity, growth and mortality (including predation by cod). The model takes account of uncertainties both in the survey estimate and in other input data. For catch levels in spring 2012, below 320,000 t, the probability of having an SSB below 200,000 t was below 5 %. Only catches of mature fish have been considered. Based on the most recent estimates of SSB and recruitment, ICES classifies the stock as having full reproductive capacity. The maturing component in autumn 2011 was estimated to be 2.1 mill t., and SSB 1st April 2012 was predicted to be at 0.5 mill t. The spawning stock in 2012 consisted of fish from the 2008 and 2009 year classes, but the 2009 year class dominated. The survey estimate at age 1 of the 2010 year class is above the long-term average. Observations during the international 0-group survey in August-September 2011 indicate that the 2011 year class is strong.

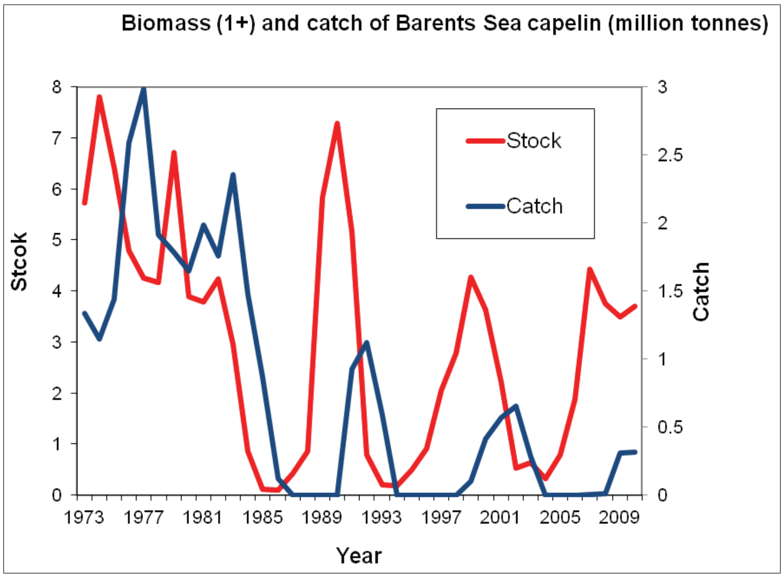


Figure 4.3.5.8. Barents Sea capelin. Total stock (1+) and total landings, 1973–2011.

The estimated annual consumption of capelin by cod has varied between 0.2 and 3.2 million t over the period 1984-2011. Young herring consume capelin larvae, and this predation pressure is thought to be one of the causes for the poor year classes of capelin in the periods 1984-1986, 1992-1994 and 2002-2005.

4.3.5.6 Herring (*Clupea harengus*)

Based on the most recent estimates of SSB and fishing mortality, ICES classifies the stock as having full reproductive capacity and being harvested sustainably. The 2002 and 2004 year classes dominate the current spawning stock which is estimated to be 7 million t in 2012. The year classes 2005-2011 are all below average. The abundance of herring in the Barents Sea is believed to be at a low level in 2012.

This stock has shown a large dependency on the occasional appearance of very strong year classes (Figure 4.3.5.9). Norwegian spring-spawning herring is fished along the Norwegian coast and in the Norwegian Sea, but not in the Barents Sea. However, juveniles from this stock play an important part role in the ecosystem in the Barents Sea.

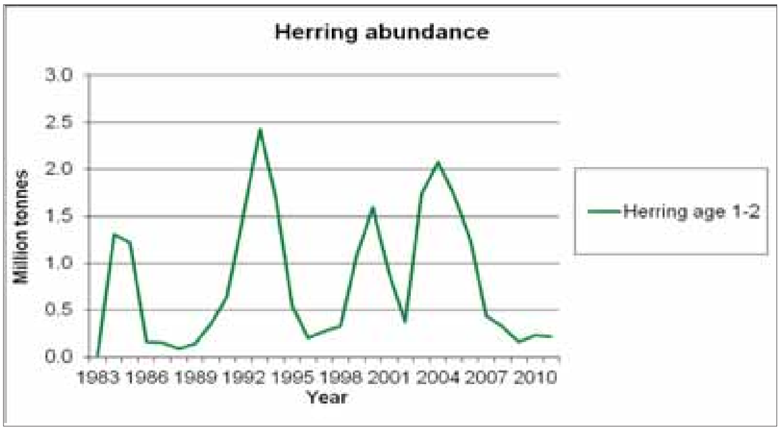


Figure 4.3.5.9 Abundance of age 1 and 2 Norwegian Spring-spawning herring (calculated by VPA). This is a good indication of the abundance of young herring in the Barents Sea.

4.3.5.7 Polar cod (*Boreogadus saida*)

The polar cod stock is presently at a high level (Figure 4.3.5.10). Norway took some catches of polar cod in the 1970s and Russia has fished on this stock more or less on a regular basis since 1970. However, the fishery has for many years been so small that it is believed to have very little impact on the stock development. The stock size has been measured acoustically since 1986 and has fluctuated between 0.1-1.9 million t. In 2011, the stock size was measured to be about 0.9 million t., which is lower than the estimate obtained in 2010. The natural mortality rate in this stock seems to be very high. This is explained by the importance of polar cod as prey for cod and different stocks of seals.

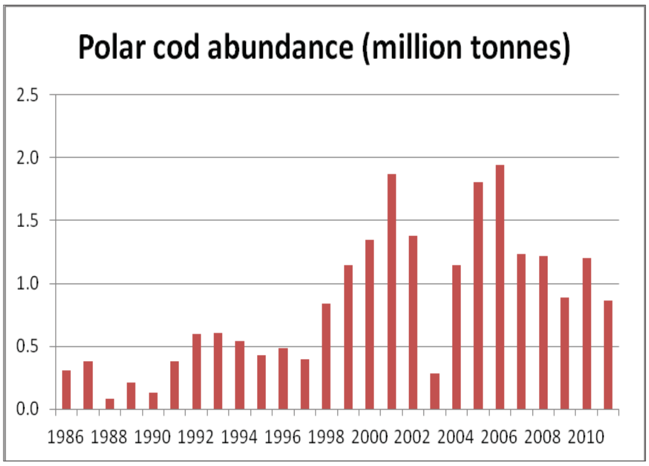


Figure 4.3.5.10. Polar cod stock size estimates obtained by acoustics, 1986–2011.

4.3.5.8 Blue whiting (Micromestisius poutassou)

Based on the most recent estimates of fishing mortality and SSB, ICES classifies the stock as having full reproductive capacity, and being harvested sustainably. SSB increased to a historical high in 2003 but has decreased since, and is now close to B_{pa}. The estimated fishing mortality is between F_{pa} and F_{MSY}. Total landings in 2010 were 0.5 mill. tonnes. Blue whiting is not fished in the Barents Sea.

The high abundance of blue whiting in the Barents Sea in the years 2004-2007 (Figure 4.3.5.11) may be due to increased temperature and high stock recruitment. Blue whiting has been observed in the western and southern Barents Sea for many years, but never in such quantities, and never as far east and north in this area as in 2004-2007. In autumn 2011, the acoustic abundance of blue whiting was estimated to 0.1 million tonnes, which is about the same as in the years 2008-2010. However, the abundance of 1-group blue whiting during the winter survey in the Barents Sea in 2012 was the highest for several years, indicating that the abundance of blue whiting in the Barents Sea may increase again.

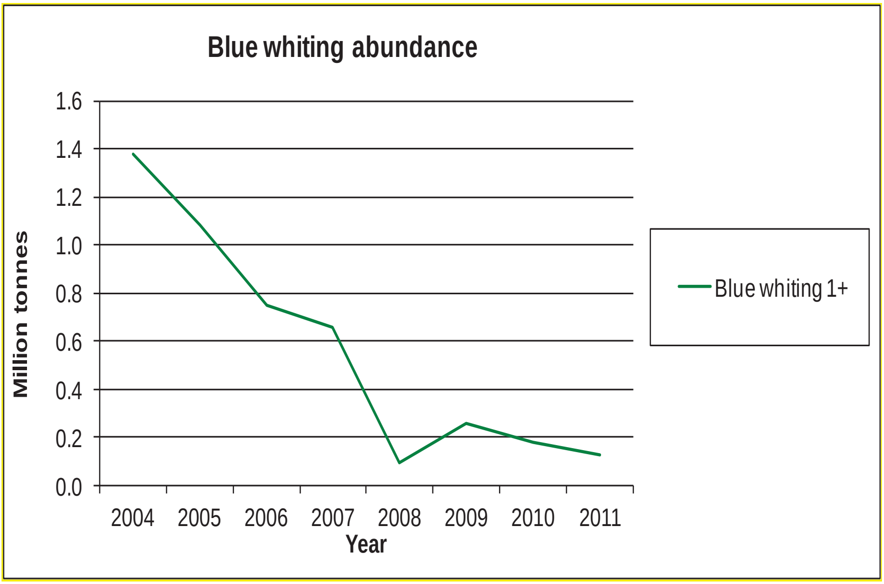


Figure 4.3.5.11. Blue Whiting. Acoustic abundance estimates from the ecosystem survey autumn 2004-2011

4.3.5.9 Saithe (*Pollachius virens*)

Based on the most recent estimates of SSB and fishing mortality, ICES classifies the stock as having full reproductive capacity and to be harvested sustainably. Fishing mortality has since 1996 been fairly stable and below F_{pa}, but is now increasing towards F_{pa}. The SSB (Figure 4.3.5.12) has since 1994 been well above B_{pa}. After a long period of low stock size, the stock recovered during the 1990s with the recruitment of several above-average year classes. ICES evaluated a Harvest Control Rule (HCR) for NEA saithe in 2007 and concluded that it was consistent with the precautionary approach. Norwegian authorities implemented the HCR autumn 2007. This rule has the objectives of maintaining high long-term yield, year-to-year stability and full utilization of all available information on stock dynamics. It aims to maintain target F at F_{pa} = 0.35 and to keep the between year TAC change to within +/- 15%, unless SSB falls below B_{pa} when the management targets should change. The highest long-term yield was obtained for an exploitation level of 0.32, i.e. a little below the target F used in the HCR

(Fpa), and ICES recommended using a lower value in the HCR. The management strategy with a target F at $F_{pa} = 0.35$ gave a TAC of 164 000 t in 2013.

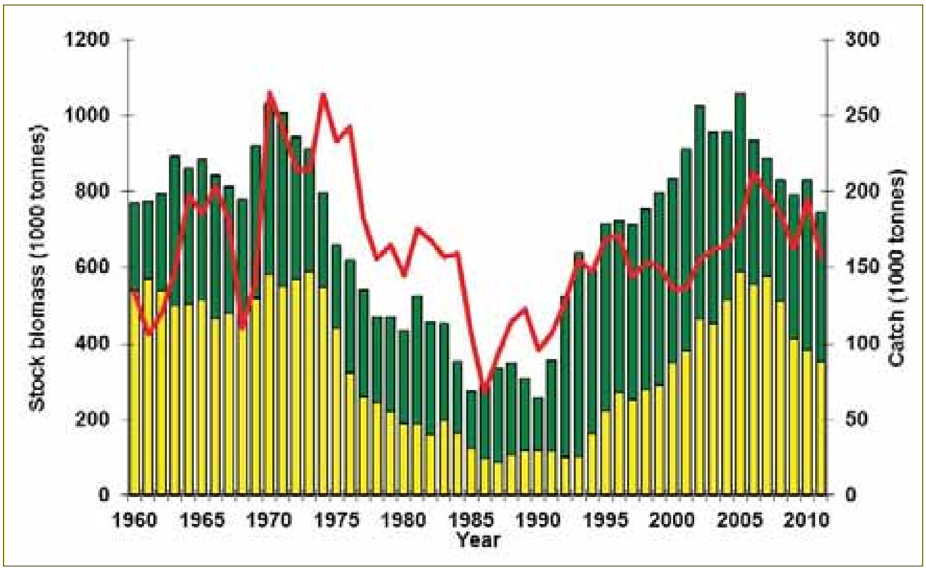


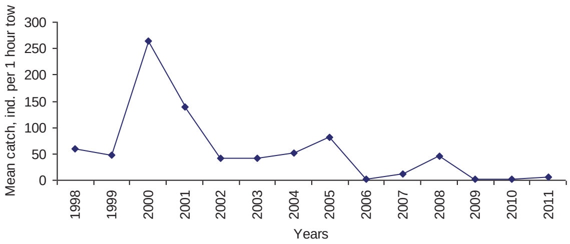
Figure 4.3.5.12. Northeast Arctic saithe, development of spawning stock biomass (yellow bars), total stock biomass (green bars) and landings (red curve).

4.3.5.10. Trends in the fish community of the Barents Sea

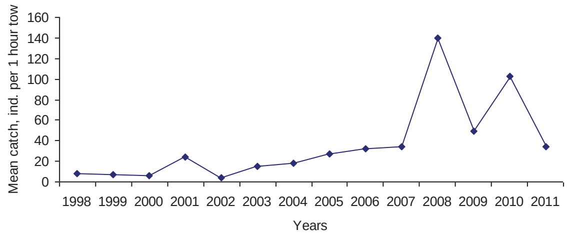
During the last warming period (1998-2011) distinct trends in abundance of fish species from different zoogeographic groups were observed (Figure 4.3.5.13). Abundance of cold-water fish species (arctic, mainly arctic and arcto-boreal groups) decreased from 2000-2001 to 2010. But since 2011, slight increases in abundance of these groups have been observed.

At the same time abundance of warm-water (boreal, mainly boreal, southern boreal and widely distributed groups) fish species have trended to increase. The highest abundance was observed in 2001-2004 and 2008-2010. Since 2008 a clear tendency to decrease has been observed for these groups. However, as mentioned above, the abundance of blue whiting increased again in 2012.

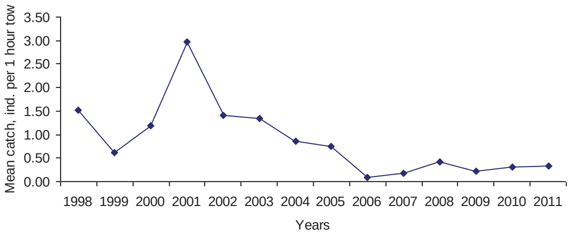
Some examples of abundance dynamics of single cold- and warm-water species are shown in Figure 4.3.5.14.



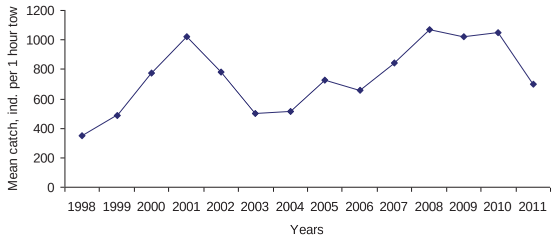
Arctic



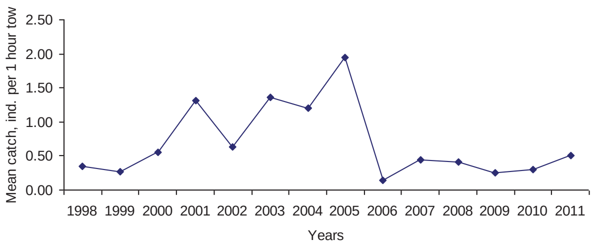
Boreal



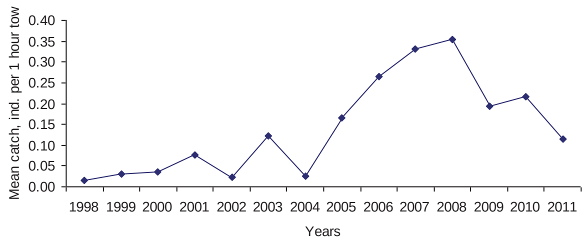
Mainly Arctic



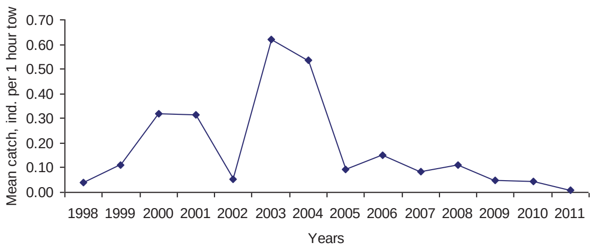
Mainly boreal



Arcto-boreal

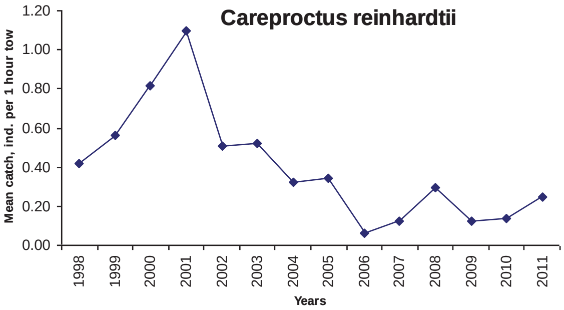


Southern boreal

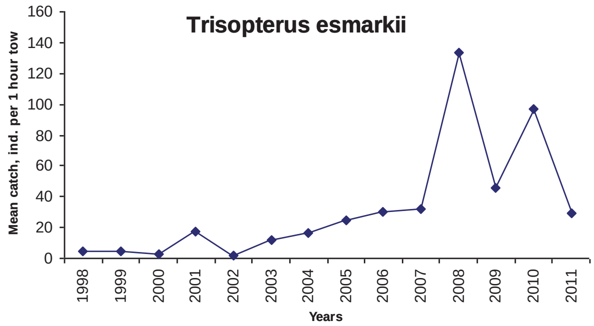


Widely distributed

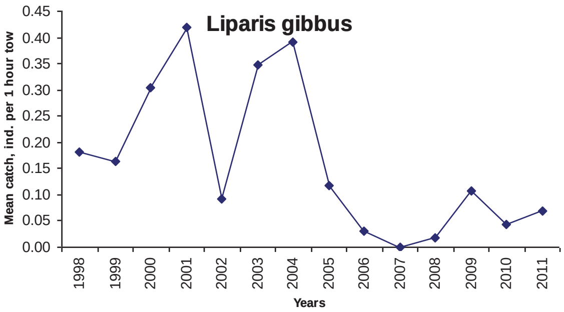
Figure 4.3.5.13. Changes in abundance of fish species from different zoogeographic groups in the Barents Sea in 1998-2011 based on the data from Russian autumn-winter demersal survey in October-December.



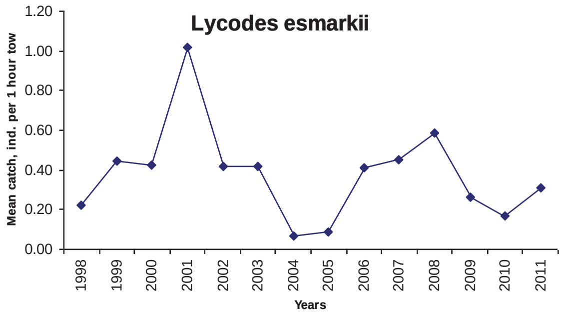
Arctic



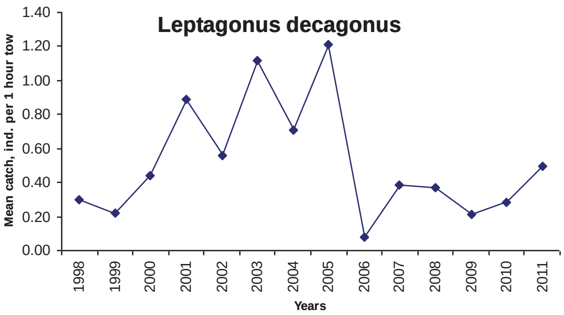
Boreal



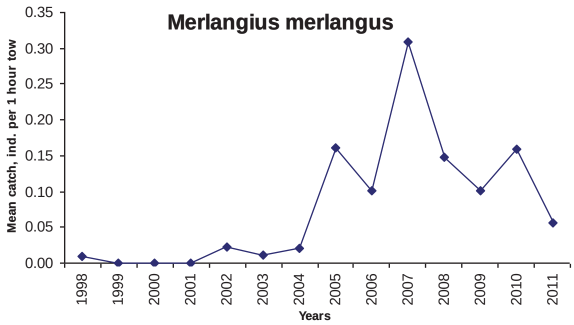
Mainly Arctic



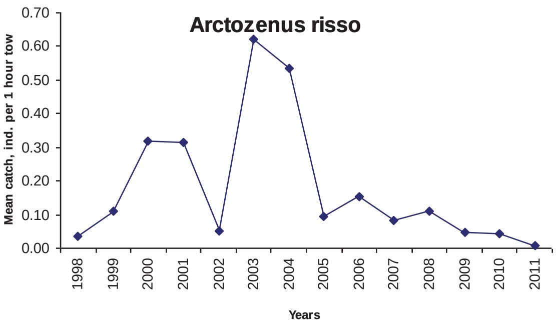
Mainly boreal



Arcto-boreal



Southern boreal



Widely distributed

Figure 4.3.5.14. Changes in abundance of selected fish species from different zoogeographic groups in the Barents Sea in 1998-2011 based on the data from Russian autumn-winter demersal survey in October-December.

4.4 Human activities/impact

4.4.1 Fisheries

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4.4.1.1 Fishes

Fisheries are meant to influence the ecosystem by removing sustainable quantities of fish as food for humans. The fishery is not considered sustainable if it impairs the recruitment of the fish stocks. Single species management often focuses on measuring the status of the fishery in relation to benchmarks called biological reference points (BRPs). BRPs for single species management are usually defined in terms of fishing mortality rate (F) and total or spawning stock biomass (TSB or SSB) and in terms of target and limit reference points. Limit BRPs suggest maximum levels of F and minimum levels of B that should not be exceeded. These BRPs are then compared to estimates of F and B from stock assessments to determine the state of the fishery and suggest management actions.

The limit reference point for fishing mortality, F_{lim}, will eventually bring the spawning stock down to B_{lim}, below which the recruitment will be impaired. F_{lim} may hence be used as an indicator for unsustainable exploitation and negative influence on the stock and the ecosystem. Keeping F below F_{lim} and the stock above B_{lim} may, however, not be considered as sufficient protection. Smaller and younger adults resulting from high fishing pressure have a lower reproductive potential than adults of a wider range of sizes and ages. The harvest rate and fishing pattern should hence fit with these biological requirements.

Recently the Maximum Sustainable Yield (MSY) concept was implemented in ICES work. The ICES approach to fisheries advice integrates the precautionary approach, maximum sustainable yield, and an ecosystem approach into one advisory framework. The aim is, in accordance with the aggregate of international guidelines, to inform policies on yields that can be taken out in the fisheries while maintaining productive fish stocks within healthy marine ecosystems. Maximum sustainable yield is a broad conceptual objective aimed at achieving the highest possible yield in the long term (an infinitely long period of time). For several stocks, MSY reference points have been identified and implemented in fishery management strategy.

Furthermore, a fishery may not be considered optimal if the fish are caught too early, i.e. if the net natural growth potential is not utilized. This is called growth overfishing and makes the total yield less than it would be if the fish were allowed to grow to a reasonable size. Introduction of minimum catch size and selective gears are the most common management measures to avoid growth overfishing.

Larvae and juveniles of all groundfish species are important predators on zooplankton. It is hence important for a sound ecosystem that there are sufficient plankton eaters present to utilize the plankton production and convert this into production of fish, both as food for humans, but also as food for other fishes, marine mammals and seabirds that depend on fish prey. It is therefore not sufficient to manage the fish stocks to the extent that the recruitment is not impaired as seen from a single species point of view, but rather to maximize the larvae production as a valuable food contribution to the ecosystem as a whole.

Northeast Arctic cod, haddock and saithe

Figure 4.4.1.1 shows the annual fishing mortalities of the gadoid stocks (Northeast Arctic cod, haddock and saithe) relative to the critical exploitation level F_{lim}, precautionary and MSY levels.

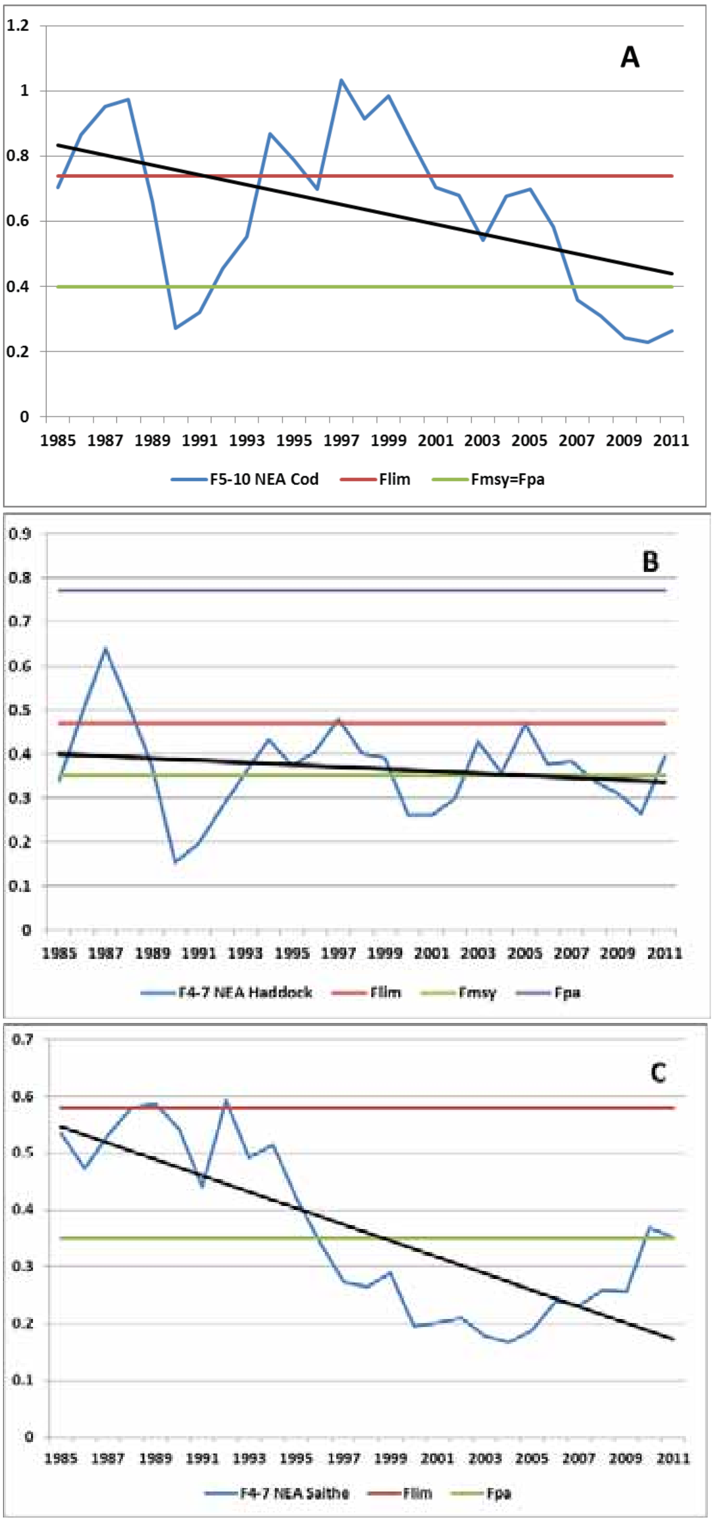

Figure 4.4.1.1. Annual fishing mortalities of the Northeast Arctic cod(A), haddock (B) and saithe (C) stocks relative to the limit levels above which the fishing mortality will impair the recruitment and precautionary levels. Trends in fishing mortality are shown as black lines (ICES 2012).

Since 1985 the exploitation rate has been critically high in some periods, especially for cod. Because of the harvest control rule and better control and enforcement, this problem seems to have been reduced in recent years. Although the exploitation rate may have been too high to fully utilize the production potential in the stocks, it may be concluded that the exploitation of these three stocks since 2000 have been sustainable and has not influenced the ecosystem negatively by impairing the recruitment.

Greenland halibut

For Greenland halibut no limit reference points have been suggested or adopted. The assessment is still considered to be uncertain due to problems with the age-reading and input data quality. The exploratory assessment may nevertheless be accepted as indicative for stock trends. Although many aspects of the assessment remain uncertain, fishery independent indices of stock size indicate positive trends in recent years.

The fishing mortality (F) matrix indicates that historically Greenland halibut were fully recruited to the fishery at approximately age 6–7 with F >0.2 for older ages, and F >0.5 in many cases. Trawlers catch more young fish compared with gillnetters and longliners. Nevertheless, F on ages 6–10 continues to represent the average fishing mortality on the major age groups targeted by the fishery. Prior to the reduction in the early 1990’s, the fishing mortality had increased continuously for more than a decade and peaked in 1991 at 0.65. For 2011 F was estimated at 0.05 which is the lowest level estimated for all years in the analysis. A maximum exploitation rate of 5% has been suggested sustainable for long lived species when the stocks show no sign of reduced reproductive potential. This corresponds to a fishing mortality of 0.05 y^{-1}, and this level is shown as a reference for the maximum sustainable exploitation rate for Greenland halibut in Figure 4.4.1.2.

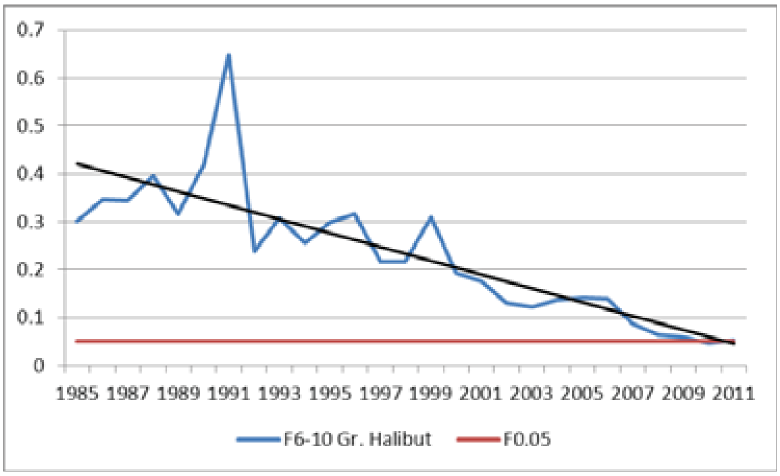

Figure 4.4.1.2. Annual fishing mortalities of Greenland halibut (*Reinhardtius hippoglossoides*) relative to the proposed maximum levels above which the fishing mortality over time probably will impair recruitment (ICES 2012).

After many years of overexploitation of the stock, the current exploitation of Greenland halibut, seems, with some reservations due to an imprecise assessment, to be sustainable and hence not influence the ecosystem negatively.

Golden redfish (Sebastes marinus)
A benchmark assessment was conducted in February 2012. Gadget was accepted as the main analytical assessment model for *S. marinus* in Subareas I and II. For golden redfish no limit reference points have been suggested or adopted. Golden redfish SSB has been decreasing since the 1990s and is currently at the lowest level in the time-series. Fishing mortality has been increasing since 2005 and is currently at the highest level in the time-series (Figure 4.4.1.3). Recruitment is very low. ICES advises that there should be no fishery, given the very low SSB (below any possible reference points) and poor recruitment.

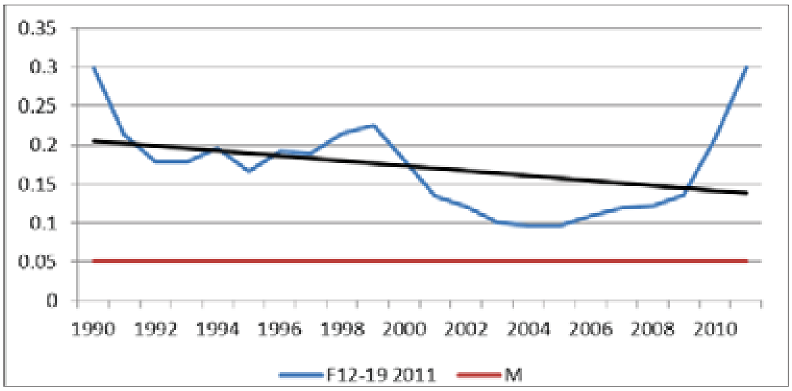

Figure 4.4.1.3. Annual fishing mortalities of Golden redfish (*Sebastes marinus*) relative to the natural mortality

Experience from other *Sebastes* stocks, e.g, in the Pacific and in the Irminger Sea, suggests that annual harvest rates of such slow growing and long-lived species should not exceed 5% if the stock is recruiting normally. At a time when this stock is not recruiting normally, even an annual exploitation rate of 5% may be too high. It can thus be concluded that the current fishery of golden redfish is too intensive and may have a negative influence on the ecosystem and the stock itself. If catches are maintained at the current level (5.8 kt annually) and recruitment is similar to the average recruitment for recent years (2001–2011), the stock size is projected to be very low by 2017.

Beaked redfish (Sebastes mentella)
The stock of *Sebastes mentella* (beaked redfish) in ICES Subareas I and II, also called the Norwegian-Barents Sea stock, is found in the northeast Arctic from 62ºN in the south to the Arctic ice north and east of Spitsbergen (Figure 4.4.1.4). The southern limit of the distribution is not well defined but is believed to be somewhere on the slope northwest of Shetland. The stock boundary of 62º N is therefore more a boundary defined for management purposes than a biological basis for stock separation, although the abundance of this species decreases south of this latitude.

The analytical assessment and advice are provided for ICES Subareas I and II combined. The fishery for S. mentella operates in national and international waters, which are managed under different schemes and by different management organizations.

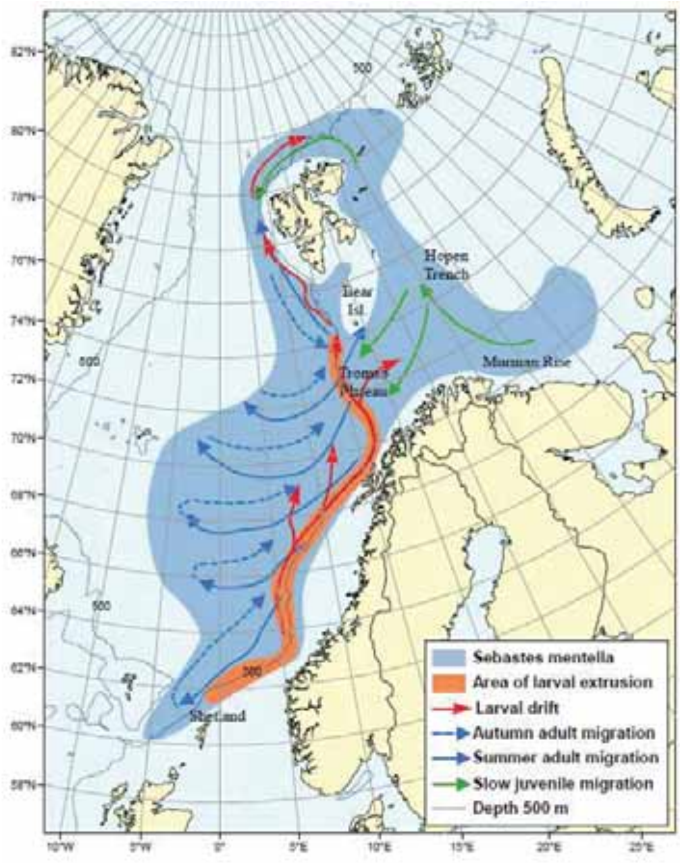

Figure 4.4.1.4 Beaked redfish *(Sebastes mentella)* in Subareas I and II. Distribution, area of larval extrusion, larval drift, and migration routes.

In international waters, the fishery is managed by NEAFC. In recent years, an Olympic fishery has been conducted with a set TAC, which is not derived from a harvest control rule. In national waters, the redfish fishery is a bycatch fishery with specific bycatch regulations. It is important that management decisions taken at national and international levels are coordinated to ensure that the total catch in ICES Subareas I and II does not exceed the recommended level.

A directed pelagic fishery for *S. mentella* in international waters (outside EEZ) of the Norwegian Sea has developed since 2004. In 2012 this fishery is limited by a total quota of 7 500 tonnes. Other catches of *S. mentella* are taken as bycatches 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.

At present, no fishing mortality or biomass reference points are defined for this stock. F0.1 = 0.065 is considered as a good candidate for FMSY proxy, and used as a basis for advice. On the basis of the MSY approach, a commercial fishery can operate on *Sebastes mentella* in Subareas I and II, given that the total catch level, including bycatches and discards, does not exceed 47 000 tonnes in 2013.

The current estimate of fishing mortality is below the assumed natural mortality (0.05) and FMSY proxy (F0.1=0.065) (Figure 4.4.1.5). Fishing at F0.1, which is close to the assumed value of natural mortality is not considered to be detrimental to the stock.

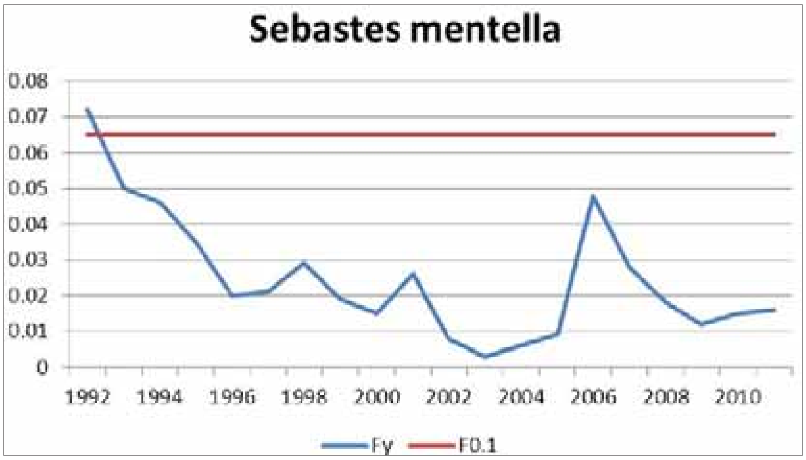

Figure 4.4.1.5. Annual fishing mortalities of beaked redfish relative to the proposed maximum levels above which the fishing mortality over time most probably will impair the recruitment (ICES 2012).

However, following several consecutive years with very low recruitment (1998–2005), SSB is expected to decline in the near future for this long-lived, late-maturing species, together with landings. The Joint Russian-Norwegian Fisheries Commission decided to avoid a sharp increase in the quotas for the next years and to go for a more precautionary approach. This is important since implementing a new analytical method may possess shortcomings. Because this is a long-lived species, there will not be any loss of long-term revenue by waiting for better evidence before increasing the TAC. Similar to the management of many other long-lived species, and in faith of responsible and precautionary practice, TAC-increases should be done on a step by step basis, and not by taking out all the potential increase in one year after signs of improvement.

Capelin

The fishery for capelin is regulated by quotas set according to a harvest control rule enforced by the Norwegian-Russian Fishery Commission. The harvest control rule is considered by ICES to be in accordance with the precautionary approach to fisheries management. The fishery is restricted to the pre-spawning period (mainly February-March) and the exploitation level is regulated based on a model taking into consideration natural mortality including predation from cod. Following the management plan agreed by the Joint Norwegian–Russian Fisheries Commission, catches in 2013 should be no more than 200 000 t. The harvest control rule in the management plan is designed to ensure that the SSB remains above the proposed Blim of 200 000 t (with 95% probability).

Polar cod

In recent years the fishery has been at a very low level compared to the stock level (about 10 000 t), implying a low exploitation level which will not influence the stock. The polar cod is fished late in autumn (in recent years only by Russia) on concentrations during spawning migration southwards along the coast of Novaya Zemlya.

Other fish species

Information about the species composition in the Norwegian fisheries north of 67°N is available from the Norwegian Reference fleet (NRF), i.e., 20 high-seas and 20 coastal fishing vessels contracted by the Institute of Marine Research. Table 4.4.1.1 shows the species composition in the trawl and longline catches by the NRF during 2011. Such data are now routinely being collected from these vessels' fishery every day. What impact the fishery may have on all the non-regulated species and the ecosystem as a whole will be a subject for further research.

Table 4.4.1.1. Species composition, incl. non-commercial species, in bottom trawl (left) and longline (right) catches done by the Norwegian Reference Fleet north of 67°N during 2011.

Norwegian longline		**Norwegian bottom trawl**	
Species	**W %**	**Species**	**W %**
Cod	41,3	Cod	46,4
Haddock	37,3	Haddock	23,3
Wolffish - Anarhichas dentkulatus	6,6	Saithe	17,8
Greenland halibut	3,8	Greenland halibut	7,3
Wolffish - Anarhichas minor	2,7	Golden redfish	1,5
Tusk	2,5	Wolffish - Anarhichas lupus	1,5
Golden redfish	1,7	Beaked redfish	0,8
Wolffish - Anarhichas lupus	1,4	Wolffish - Anarhichas minor	0,4
Amblyraja radiata	1,3	Wolffish - Anarhichas dentkulatus	0,3
Ling	0,4	Atlantic halibut	0,2
Saithe	0,2	Amblyraja radiata	0,1
Long rough dab	0,2	Ling	0,1
Atlantic halibut	0,1	Tusk	0,1
Roughhead grenadier	0,1	Lumpsucker	0,1
Chimaera monstrosa	0,1	Chimaera monstrosa	+
Anglerfish	+	Anglerfish	+
Beaked redfish	+	Long rough dab	+
Greater forkbeard	+	Raja clavata	+
Dogfish	+	Greater forkbeard	+
Whiting	+	Roundnose grenadier	+
Shagreen ray	+	Blue whiting	+
Galeus melastomus	+	Argentina silus	+
Velvet belly lantern shark	+	rajella fyllae	+
Pollock	+	Smaller redfish	+
Rajella Fyllae	+	Bathyraja spinicauda	+
Redfish unspec.	+	Common sole	+
Spinetail ray	+	Hake	+
Eelpout	+	Mackerel	+
Plaice	+	Norway pout	+
Mora	+	Herring	+
Flounder	+		
Arctic skate	+		
Blue ling	+		
Smaller redfish	+		
Grey gunard	+		

Information about the total species composition in the Russian bottom trawl fisheries in Barents Sea and adjacent waters is available from the 11 high-seas fishing vessels with sea-observer from PINRO (total 524 days at sea in 2011), which is considered representative for the whole fleet (Table 4.4.1.2). But due to the adopted amendments of the Russian Federal Law "On fisheries and preservation of aquatic biological resources" coming into force, especially concerning the destruction of biological resources caught under scientific research, sampling activities (age sample numbers and mass measurements of fish) onboard Russian fishing vessels have been reduced since 2009. The data were collected all year round and in all fishing areas of the Russian bottom trawl fleet, except some parts in Russian and Norwegian Economic Zone (Figure 4.4.1.6).

Table 4.4.1.2. Species composition, including non-commercial species, in bottom trawl catches taken by the Russian trawlers with sea-observer from PINRO during 2011.

Russian bottom trawl	
Species	**W %**
Cod	63.8
Haddock	18.5
Greenland halibut	14.6
Saithe	1.8
Wolffish - Anarhichas minor	0.2
Wolffish - Anarhichas lupus	0.2
Beaked redfish	0.2
Long rough dab	0.2
Wolffish - Anarhichas dentikulatus	0.1
Golden redfish	0.1
Capelin	0.1
Plaice	0.1
Polar cod	+
Herring	+
Amblyraja radiata	+
Ling	+
Tusk	+
Lumpsucker	+
Chimaera monstrosa	+
Anglerfish	+
Blue whiting	+
Norway pout	+
Argentina silus	+
Common sole	+

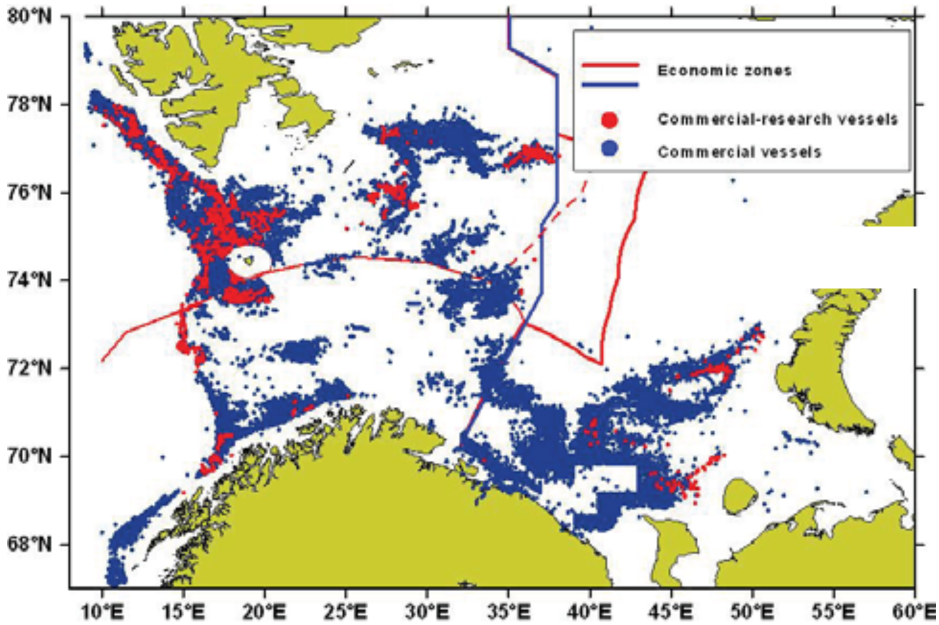

Figure 4.4.1.6. Location of Russian fishing and research-fishing vessels with observers on board in the Barents Sea and adjacent waters in 2011.

4.4.1.2 Discards

The level of discarding in the fisheries is not known, and no discards are accounted for in the assessments. Discarding is known to be a (varying) problem, e.g., in the haddock fisheries where discards are highly related to the abundance of haddock close to, but below the minimum legal catch size. Dingsør (2001) estimated discards in the commercial trawl fishery for Northeast Arctic cod during 1946-1998 and the effects on the assessment. Sokolov (2004) estimated cod discard in the Russian bottom trawl fishery in the Barents Sea in 1983-2002. The lack of discard estimates leads to less precise and accurate stock assessments. The influence of the fishery on the ecosystem is hence not fully understood. A possible way to estimate values of discarded fish is analysis of landing information (size-weight composition of catches in relation to observed one onboard commercial vessel). Norway is in 2012 conducting a pilot project to estimate the discards in some selected fisheries to test and establish methods for estimating discards in all Norwegian fisheries on a routine basis in near future.

Registration of redfish (dominated by *S. mentella*) taken as bycatch and discarded in the Norwegian shrimp fishery in the Barents Sea since 1984 show that shrimp trawlers removed significant numbers of juvenile redfish during the beginning of the 1980's. This peaked in 1985, when by-catches amounted to about 200 million individuals. As sorting grid became mandatory in 1993, by-catches of redfish were reduced drastically during the 1990's. The results also show that closure of areas is necessary to protect the smallest redfish juveniles since these are not sufficiently protected by the sorting grid. The by-catch and discard of cod consists mainly of 1- and 2-year-olds, but is generally small compared to other reported sources of mortality like catches, discards in the groundfish fisheries and cannibalism.

Noticeable discards of cod occurred in 1985, 1992 and 1998. The highest recorded numbers of cod was in 1985 (92 millions). The cod by-catches have declined in recent years (< 3 millions). Discards of haddock and Greenland halibut in the Barents Sea shrimp fishery have been estimated for the period 2000-2005, and show the highest discard in 2002 and 2000 for haddock (9.2 millions) and Greenland halibut (13.2 millions), respectively. For both species the discard in the shrimp fisheries has been low in the most recent years.

4.4.1.3 Shellfish

Northern shrimp

Norwegian and Russian vessels exploit the stock over the entire resource area, while vessels from other nations are restricted to the Svalbard fishery zone. No overall TAC has been established for this stock, and the fishery is partly regulated by effort control, licensing, and a partial TAC (Russian zone only). Bycatch is constrained by mandatory sorting grids and by temporary closures of areas where high bycatch occurs of juvenile cod, haddock, Greenland halibut, redfish, or small shrimp (< 15 mm). The minimum mesh size is 35 mm.

A major restructuring of the fleet toward fewer and larger vessels has taken place since the mid-1990s. Since 1995, the average engine size of a shrimp vessel in Subareas I and II has increased from 1000 HP (horse powers) to more than 6000 HP in the early 2010s, and the number of vessels has declined markedly. Overall catches have decreased since 2000 reflecting reduced economic profitability of the fishery. In 2011, 29 790 tonnes were caught. The 2012 stock assessment indicated that the stock has been exploited in a sustainable manner and has remained well above precautionary reference limits throughout the history of the fishery.

ICES advises that catches of 60 000 tonnes in 2013 will maintain the stock at the current high biomass. Reports from fishermen in summer 2012, however, show lower catch rates than expected.

Red king crab

The Norwegian management of the red king crab has two goals; in the area east of 26^{o} E and south of 71^{o} 30’ N, and in the Russian part of the Barents Sea, the crab is managed to sustain a long term commercial fishery applying annual total quotas (quota regulated area). Outside this area the crab is regarded as unwanted, and a free non-legislated fishery is applied in addition to a ban to release viable crabs back to the sea. The harvest rate in the quota regulated area is high aiming to keep the standing stock as low as possible to limit further spread of the crab. Both male and female crabs above a minimum legal size (CL> 130 mm) are caught in the quota regulated fishery, and there are no seasonal catch restrictions. The Norwegian management of the crab hence contradicts the basis for the management regimes applied in the Bering Sea (Alaska) and in the Russian part of the Barents Sea.

4.4.1.4 Marine mammals

Minke whale

The management of this species is based on the Revised Management Procedure (RMP) developed by the Scientific Committee of the International Whaling Commission. The inputs to this procedure are catch statistics and absolute abundance estimates. The present quotas are based on abundance estimates calculated from surveys conducted in 1989, 1995, 1996–2001 and 2002–2007. The most recent estimates (2002–2007) are 81 400 minke whales for the Northeastern stock, and 26 700 animals for the Jan Mayen area, which is also exploited by Norwegian whalers. The present (2009-2014) basic RMP quota of 885 animals annually is considered precautious, conservative and protective for the minke whale population in the Northeast Atlantic. At present only Norway utilizes this quota.

Harp seals

The Northeast Atlantic stocks of harp seals are assessed every second year by the ICES Working Group on Harp and Hooded Seals (WGHARP). The assessments are based on modelling, which provides ICES with sufficient information to give advice on both status and catch potential of the stocks. The population model applied estimates the current total population size, incorporating historical catch data, estimates of pup production and historical values of reproductive rates. The modelled abundance is projected into the future to provide a future population size for which statistical uncertainty is provided for various sets of catch options. Russian aerial surveys of White Sea harp seal pup production conducted in the period 1998-2010 indicate a severe reduction in pup production after 2003. According to ICES, the most likely explanation for this reduction seems to be a decline in the reproductive state of adult females. The Barents Sea / White Sea population of harp seals is considered data rich (available data for stock assessment not older than 5 years). Although the population model provided a poor fit to the pup production survey data, primarily due to the abrupt reduction after 2003, ICES decided to use it to provide advice in 2011. The total size of the population was estimated as 1,364,700 (95% C.I. 1 230 384 – 1 498 916). A catch of 15 827 1+ animals, or an equivalent number of pups (where one 1+ seal is balanced by 2 pups), per year would sustain the 1+ population at present level over the 10 years period 2011-2021. The catches in recent years have been much lower than the quotas, in particular after 2008 which was the last year with Russian hunt on this population.

4.4.1.5 Important indirect effects of fisheries on the ecosystem

In order to conclude on the total impact of trawling, an extensive mapping of fishing effort and bottom habitat would be necessary. In general, the response of benthic organisms to disturbance differs with substrate, depth, gear, and type of organism (Collie et al. 2000). Seabed characteristics from the Barents Sea are only scarcely known (Klages et al. 2004) and the lack of high-resolution (±100 m) maps of benthic habitats and biota is currently the most serious impediment to effective protection of vulnerable habitats from fishing activities (Hall 1999). An assessment of fishing intensity on fine spatial scales is critically important in evaluating the overall impact of fishing gear on different habitats and may be achieved, for example, by satellite tracking of fishing vessels (Jennings et al. 2000).The challenge for management is to determine levels of fishing that are sustainable and not degradable for benthic habitats in the long run.

The qualitative effects of trawling have been studied to some degree. The most serious effects of otter trawling have been demonstrated for hard-bottom habitats dominated by large sessile fauna, where erected organisms such as sponges, anthozoans and corals have been shown to decrease considerably in abundance in the pass of the ground gear. Barents Sea hard bottom substrata, with associated attached large epifauna should therefore be identified (Løkkeborg and Fosså 2011).

Effects on soft bottom have been less studied, and consequently there are large uncertainties associated with what any effects of fisheries on these habitats might be. Studies on impacts of shrimp trawling on clay-silt bottoms have not demonstrated clear and consistent effects, but potential changes may be masked by the more pronounced temporal variability in these habitats (Løkkeborg 2005). The impacts of experimental trawling have been studied on a high seas fishing ground in the Barents Sea (Kutti *et al*. 2005.) Trawling seems to affect the benthic assemblage mainly through resuspension of surface sediment and through relocation of shallow burrowing infaunal species to the surface of the seafloor.

During 2009-2011 work between Norway and Russia was conducted to explore the possibility of using pelagic trawls when targeting demersal fish. The purpose with pelagic trawl is to avoid impact on bottom fauna and to reduce the mixture of other species. During the exploratory fishery it was mandatory to use sorting grids and/or a more stable four-panel trawl geometry with square mesh in the top panel of the cod-end to avoid catches of undersized fish. The efficiency of pelagic trawling was also tested in comparison with bottom trawling with regards to reduce the oil consumption per kilo of fish caught, i.e., to improve profitability and reduce NOx emissions.

After three years of exploratory fishing with pelagic trawls, pelagic trawling for cod, haddock and other demersal fishes are still not allowed, mainly due to on average a smaller size of the fish and too big catches which are difficult to handle. The experiment has, however, led to a further development of the bottom trawls, including bigger trawl openings, better size selection and escapement windows to prevent too big catches.

Lost gears such as gillnets may continue to fish for a long time (ghost fishing). The catch efficiency of lost gillnets has been examined for some species and areas (*e.g.* Humborstad et al. 2003; Misund et al. 2006; Large et al. 2009), but at present no estimate of the total effect is available. Ghost fishing in depths shallower than 200 m is usually not a significant problem because lost, discarded, and abandoned nets have a limited fishing life owing to their high rate of biofouling and, in some areas, their tangling by tidal scouring. Investigations made by the Norwegian Institute of Marine Research of Bergen in 1999 and 2000 showed that the amount of gillnets lost increases with depth and out of all the Norwegian gillnet fisheries, the Greenland halibut fishery is the metier where most nets are lost. The effect of ghost fishing in deeper water, e.g. for Greenland halibut, may be greater since such nets may continue to “fish” for periods of at least 2–3 years, and perhaps even longer (D. M. Furevik and J. E. Fosseidengen, unpublished data), largely as a result of lesser rates of biofouling and tidal scouring in deep water. The Norwegian Directorate of Fisheries has organised retrieval surveys annually since 1980. All together 10 784 gill nets of 30 metres standard length (approximately 320 km) have been removed from Norwegian fishing grounds during the period from 1983 to 2003. During the retrieval survey in 2011 the following were retrieved and brought to land: more than 1100 gillnets, 54 red king crab traps, 13 km trawlwire, 12 km of ropes, 40 km longlines, trawl cod ends, 14 tonnes of fish and about 12000 crabs, mainly red king crab.

Other types of fishery-induced mortality include slipping (pelagic catch is released, but too late to survive), burst net, and mortality caused by contact with active fishing gear, such as escape mortality (Suuronen 2005; Broadhurst et al. 2006; Ingólfsson et al. 2007). Some small-scale effects are demonstrated, but the population effect is not known.

The harbour porpoise is common in the Barents Sea region south of the polar front and is most abundant in coastal waters. The harbour porpoise is subject to by-catches in gillnet fisheries (Bjørge and Kovacs 2005). In 2004 Norway initiated a monitoring program on by-catches of marine mammals in fisheries.

Fisheries impact seabird populations in two different ways: 1) Directly through by-catch of seabirds in fishing equipment and 2) Indirectly through competition with fisheries for the same food sources.

Documentation of the scale of by-catch of seabirds in the Barents Sea is fragmentary. Special incidents like the by-catch of large numbers of guillemots during spring cod fisheries in Norwegian areas have been documented (Strann et al. 1991). Gillnet fishing affects primarily coastal and pelagic diving seabirds, while the surface-feeding species will be most affected by long-line fishing (Furness 2003). The population impact of direct mortality through by-catch will vary with the time of year, the status of the affected population, and the sex and age structure of the birds killed. Even a numerically low by-catch may be a threat to red-listed species such as Common guillemot, White-billed diver and Steller’s eider.

Several bird scaring devices has been tested for long-lining, and a simple one, the bird-scaring line (Løkkeborg 2003), not only reduces significantly bird by-catch, but also increases fish catch, as bait loss is reduced. This way there is an economic incentive for the fishermen to use it, and where bird by-catch is a problem, the bird-scaring line is used without any forced regulation.

In 2009, the Norwegian Institute for Nature Research (NINA) and the Institute of Marine Research (IMR) in Norway started a cooperation to develop methods for estimation of bird by-catch. Data on seabirds taken as bycatch from 2006 to 2009 in the coastal reference fleet programme that is managed by IMR were analysed (Fangel et al. 2011). These estimates suggest that a total of 4,000 to 6,000 seabirds were killed by these fisheries. More detailed studies of seabird bycatch in the lumpsucker and Greenland halibut longline fisheries are recommended to provide more accurate data on bycatch and evaluate different measures to mitigate seabird bycatch.

References added in this update

Løkkeborg, S. and Fosså, J.H. 2011. Impacts of bottom trawling on benthic habitats. Pp 760-767 in Jakobsen, T. and Ozhigin, VK (editors), The Barents Sea – Ecosystem, Resources, Management. Half a century of Russian-Norwegian cooperation. Tapir Academic Press, Trondheim, Norway.

Fangel, K., Wold, L.C, Aas, Ø., Christensen-Dalsgaard, S., Qvenild, M. & Anker-Nilssen, T. 2011. Bycatch of seabirds in Norwegian coastal fisheries. A mapping and methodology study with focus on gillnet and longline fisheries. - NINA Report 71

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