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IMR/PINRO update of the "Joint Norwegian-Russian environmental status report on the Barents Sea Ecosystem"

The current situation for climate, phytoplankton, zooplankton, fish, and fisheries during 2012-13

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The report is also published on the internet and can be accessed at http://www.barentsportal.com. The web publication is identical to the printed report; however, additional information is available online that supplements and broadens the contents. The web publication also offers a Web Map Service that provides the opportunity to have a more geographic focus on thematic presentations of environmental issues, and to overlay maps for comparison and assessment. Another interesting feature is the ability for website visitors to offer comments online regarding all text and figures.

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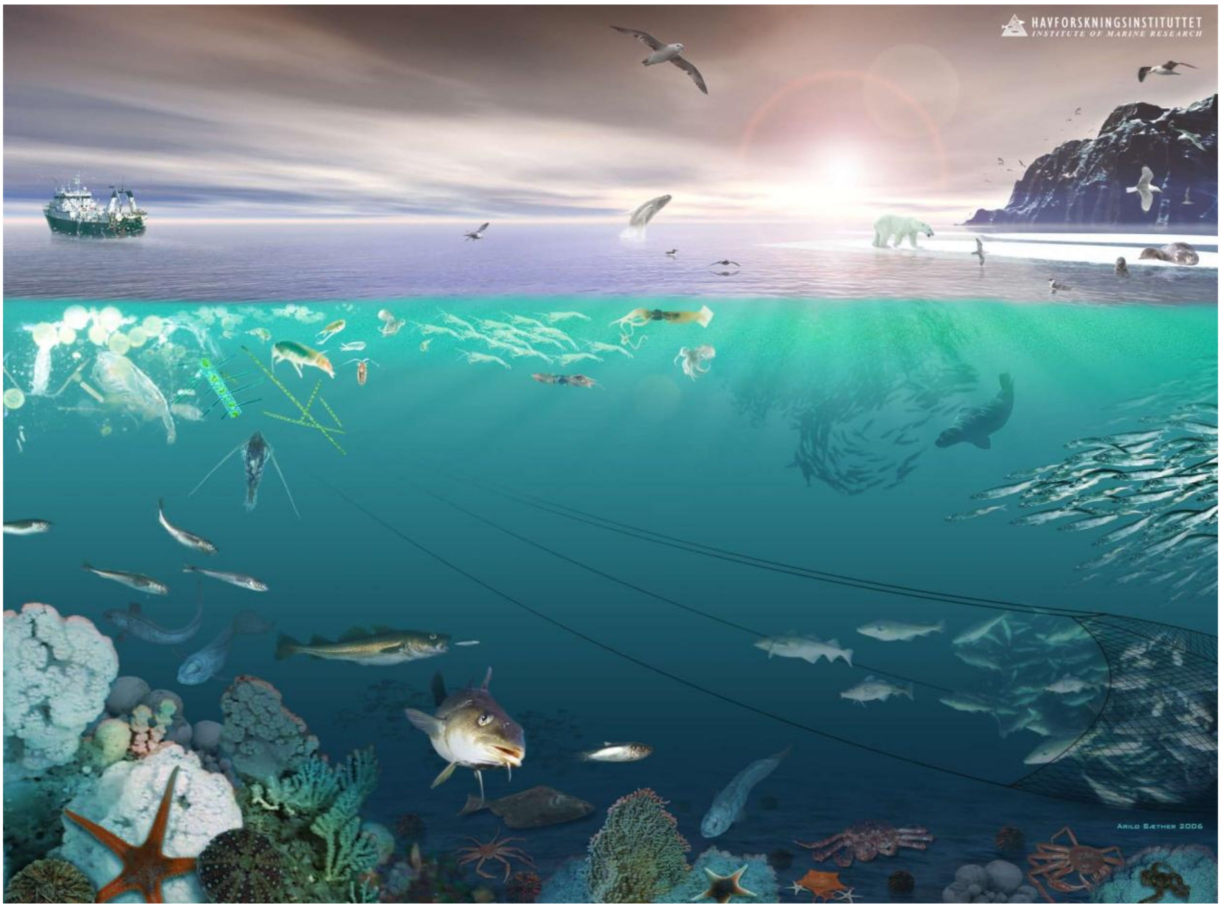

Illustration of the rich marine life and interactions in the Barents Sea

Contents

4.0 Introduction

This report presents an update of Chapter 4 of the "Joint Norwegian-Russian environmental status report on the Barents Sea Ecosystem Part II — Complete report" (Stiansen *et al.*, 2009). It updates the original report through 2012 and 2013 with information on ecosystem status with regard to meteorological and oceanographic conditions, phytoplankton, zooplankton, shrimp, fish, and fisheries in both Norwegian and Russian waters of the Barents Sea. In this update, fisheries and other harvesting are the only human activity described and discussed. Overviews of other human activities, and discussion of their impacts, will be provided in future updates. A full update of the Joint Norwegian-Russian environmental status report is scheduled for completion during the summer of 2015.

4.1 Overview of state of the Barents Sea ecosystem in 2012-2013

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

4.1.1 Abiotic components

Overview of climate

Throughout 2012 and 2013, air temperatures over the Barents Sea were above the long-term average. Easterly winds prevailed during most of 2012, except during the periods February-April and August-September when westerly winds prevailed. Air temperatures remained high during 2013. During winter 2012-2013 (from the end of 2012 to March 2013) northerly, northwesterly, and northeasterly winds prevailed over the Barents Sea; during summer (from April to August) southerly, southwesterly, and southeasterly winds prevailed. In autumn (September and October) winds changed toward an easterly and northeasterly direction. In 2013, the number of days with winds more than 15 meters-per-second (m/s) was much larger than usual, and in the eastern Barents Sea it was the highest since 1981.

Average water temperature in the Barents Sea during 2012 was much higher than in 2011, and also higher than the long-term average. In the Kola section, average Atlantic water temperature during 2012 was the highest observed since 1900. In 2013, temperatures in the Barents Sea were still higher than normal, and were typical of warm and anomalously warm years, with positive anomalies increasing eastward. The surface waters were extremely warm: between July and October in the 0–50 m layer temperatures in the Kola Section were the highest since 1951, due to stronger-than-usual seasonal warming. The deeper layers were also warmer than normal in 2013, but colder than in the previous year. The area with temperatures <0°C was larger in autumn 2013 than in autumn 2012.Temperatures remained high during 2013, but were slightly lower than in 2012. These higher temperatures during 2012 and 2013 are mostly due to the inflow of water masses with high temperatures from the Norwegian Sea, but may also be a combined effect with the reduced heat flux caused by high air temperatures.

Salinity levels for Atlantic waters during 2012 and 2013 were close to the 1951-2010 long-term average and less than in 2011. Negative salinity anomalies were observed in the coastal waters in 2013, indicating larger than usual river runoff and/or less mixing with Atlantic waters.

During 2012, oxygen saturation (dissolved oxygen) levels in the southern Barents Sea were lower than in 2011, and much lower than the long-term average. Also, the ice extent during 2012 and 2013 was much less than normal. In 2013 ice coverage in the Barents Sea was still lower than usual but higher than in 2012.

4.1.2 Biotic components

4.1.2.1 Phytoplankton and zooplankton

During the period between 2008 and 2013, no abnormalities were observed in annual patterns of succession for phytoplankton species sampled along a fixed transect of Norwegian waters extending from Vardø-North and Fugløya to Bear Island. 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, phytoplankton distribution tends to be patchy; in recent years, no large blooms or areas with high density have been observed in open part of the Barents Sea. During autumn phytoplankton species composition has been quite normal, with larger dinoflagellates as the dominating group.

Mesozooplankton biomass, measured during August–September 2012, was somewhat higher than in 2011, and close to the long-term average. Average biomass of zooplankton in 2013 was below the long-term average. In 2012-2013, as in previous years, highest levels of zooplankton biomass occurred in the northeastern Barents Sea. Arctic copepod species (*Calanus glacialis, Pseudocalanus minutus,* and *Metridia longa*) were most abundant; the North Atlantic species (*Calanus finmarchicus*) was also abundant. Results from the macrozooplankton survey, conducted during late autumn and winter 2011, indicated that in early 2012 the abundance of krill (euphausiids) was less than in early 2011. Results from the macrozooplankton survey, conducted during late autumn and winter 2012, indicated that in west and northwest areas of the Barents Sea both abundance and biomass of krill generally remained above the long-term average. The Arcto-boreal species (*Thysanoessa inermis*) was dominant during both years.

Measures of jellyfish biomass during August-September 2012 were less than in 2011, but higher than the long-term average. The largest jellyfish catches (primarily *Cyanea capillata*) were taken in southern and central areas of the Barents Sea. During 2013, the largest catches of jellyfish were taken in eastern and central areas. The calculated biomass of jellyfish in 2013 was 3 times higher than in 2012 and 3.5 times higher than the 1980-2013 long-term average.

4.1.2.2 Fish

Based on recent estimates of spawning stock biomass (SSB), the International Council for the Exploration of the Sea (ICES) classifies the cod (*Gadus morhua*) stock as having full reproductive capacity, with sustainable current harvests levels. Estimated SSB has been above the precautionary reference point for spawning stock biomass (B_{pa}) since 2002, and is now at a record high level; while total stock biomass is at a level not seen since the early 1950s. The present stock is dominated by large individuals from the very abundant 2004-2006 year classes.

In recent years, the cod distribution area has expanding northward and eastward. This is likely due to high temperatures observed in the Barents Sea in recent years, as well as high stock abundance. During 2012-2013, the main prey items for Barents Sea cod were: capelin; polar cod; juvenile cod; shrimp; krill; amphipods; and haddock.

According to the ICES 2012-2013 assessment, the Barents Sea haddock (*Melanogrammus aeglefinus*) stock had full reproductive capacity, but in danger of being harvested unsustainably. Estimates of F have increased considerably since 2010. Due to the very strong 2004-2006 year classes, during 2010-2011 the haddock stock reached the highest level observed in the 1950-2012 time series. In more recent years, however, estimates of haddock year-class size have shown a decreasing trend.

Currently, there is no accepted assessment for the Barents Sea stock of Greenland halibut (*Reinhardtius hippoglossoides*); only reported landings and estimates of biomass based on survey results are available to support fishery management decisions. Biomass estimates have indicated a stable or increasing trend since 1992.

The stock assessment for golden redfish (*Sebastes marinus*) indicates a substantial reduction in abundance to a historically low level at present. Year-class sizes during the last decade have been weak, and presently this stock is in poor condition.

For beaked redfish (*Sebastes mentella*) signs of improved recruitment are now apparent in the Barents Sea. Therefore, it is importance that juvenile age groups are given strong protection from being removed as bycatch in any fishery, including fisheries for shrimp in the Barents Sea and Svalbard area. This will ensure that recruiting year classes can contribute strongly to stock rebuilding.

The stock size of Barents Sea capelin (*Mallotus villosus*) has remained stable since 2008, and is now close to the long-term average. Estimated 2012 year-class size was above the long-term average, while the estimated 2013 year class size was average. The estimated annual consumption of capelin by cod has varied between 0.2 and 4.1 million metric tons over the period 1984-2013.

During recent years, the amount of young herring *(Clupea harengus)* entering the Barents Sea has been low and the estimated stock size in 2013, though being much higher than in 2012, is only about half of the average stock size during the period 1999 to 2013. This stock has shown a large dependency on appearance of very strong year classes. The year classes 2005-2012 are all below average, while the 2013 year class is around average.

The estimated biomass of blue whiting (*Micromesistius poutassou*) in the Barents Sea in 2013 was the same as in 2012 but was at a low level compared to 2004-2007. However, estimated high abundance for the 2011 year class may potentially improve this trend.

The Barents Sea polar cod (*Boreogadus saida*) stock is presently at a low level. In 2013, stock size was estimated to be 0.5 million metric tons, which is approximately the same as estimated in 2012. The rate of natural mortality for this stock appears to be quite high.

4.1.3 Human activities/impact

The largest commercially exploited fish stocks in the Barents Sea (capelin, Northeast Arctic cod, haddock, and saithe) are currently harvested within sustainable limits. After many years of overfishing, the Greenland halibut stock now also appears to be harvested sustainably. Some of the smaller stocks (e.g., golden redfish, beaked redfish, and coastal cod), however, continue to be overfished.

During 2012, a total catch of approximately 1,300 thousand metric tons was reported to have been removed from Barents Sea stocks of cod, haddock, saithe, redfish, Greenland halibut, and anglerfish (*Lophius piscatorius*). The total catch of capelin during 2012 was estimated to be 296,000 metric tons. Landings of other species were relatively small, including: polar cod (*Boreogadus saida*); Atlantic salmon (*Salmo salmar*); Atlantic halibut (*Hippoglossus hippoglossus*); European hake (*Merluccius merluccius*); saithe (*Pollachius virens*); whiting (*Merlangius merlangus*); Norway pout (*Trisopterus esmarkii*); lumpsucker (*Cyclopterus lumpus*); Atlantic argentine (*Argentina silus*); roughhead grenadier (*Macrourus berglax*); flatfish spp.; spiny dogfish (*Squalus acanthias*); and skate spp.

During 2012, 25,000 metric tons of northern shrimp (*Pandalus borealis*) were caught in the Barents Sea and adjacent waters (ICES Subareas I and II). The 2013 ICES assessment indicated that throughout the history of the fishery this stock has been harvested sustainably at F levels well above the precautionary reference limits.

In recent years, catch removals of harp seals (*Pagophilus groenlandicus*) from the Barents Sea have been much lower than the quotas. Since 2009, Russia has not harvested this population commercially.

Current fisheries management strategies in the Barents Sea are based on the ICES approach, which integrates the precautionary approach, maximum sustainable yield (MSY), and an ecosystem approach under a single advisory framework. Instances of unreported catch in fisheries for cod and haddock were considerable from 2002 through 2008, but now such instances appear to be decreasing. Since 2011 throughout the Barents Sea, regulated minimum mesh size has been 130 mm in bottom-trawl fisheries for cod and haddock, and the use of sorting grids has been mandatory. Fisheries are regulated through: at-sea inspections; mandatory reporting at catch-control points when entering and leaving the exclusive economic zone (EEZ); and landing inspections for all fishing vessels.

In the Barents Sea, trawl damage to benthic organisms and habitats has been documented. Instances of unavoidable bycatch of marine mammals and sea birds have also been documented (Løkkeborg and Fosså, 2011). Several bird-scaring devices have been tested for longliners. In addition, research has been conducted to explore the possibility of using pelagic trawls while targeting demersal species; this could help to reduce the impact of trawling on bottom fauna and to reduce unintended bycatch of non-target species.

4.2 Abiotic components

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4.2.1 Meteorological conditions

4.2.1.1 North Atlantic Oscillation

During the period from September 2011 to April 2012, the North Atlantic Oscillation (NAO) was characterized by positive index values (Figure 4.2.1). In May 2012, however, a negative NAO phase started that resulted in changing ice extent and temperature conditions in northern European seas. In 2013, the NAO index changed from negative values during January–March to slightly positive values which lasted the rest of the year.

During 2012, easterly winds prevailed over the Barents Sea, except during February, March, April, August, and September, when westerly winds prevailed. During winter (from the end of 2012 to March 2013) northerly, northwesterly, and northeasterly winds prevailed over the Barents Sea; while during summer (from April to August) southerly, southwesterly, and southeasterly winds prevailed. During autumn (September and October), this changed to easterly and northeasterly winds prevailing. During 2013, the number of days with winds more than 15 meters per second (m/s) was much larger than usual, and was the highest observed since 1981 in the eastern Barents Sea.

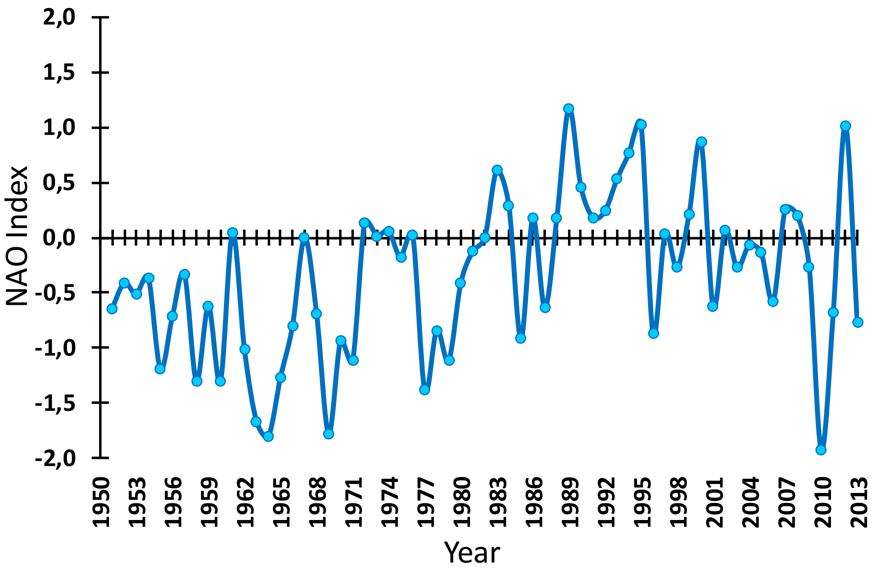

Figure 4.2.1. Winter North Atlantic Oscillation (NAO) index during 1951–2013.

4.2.1.2 Air temperature

Air temperature data from the NOMADS (NOAA Operational Model Archive Distribution System http://nomad2.ncep.noaa.gov) website were averaged over the western (70–76°N, 15–35°E) and eastern (69–77°N, 35–55°E) Barents Sea. During 2012, positive air temperature anomalies prevailed in the Barents Sea, with the largest values (4–7°C) in the eastern part of the sea from January to April (Figure 4.2.2). During 2013, air temperatures were also warmer than usual by 2-5 °C, except during March, and anomalies were higher in the western region of the Barents Sea than in the eastern region.

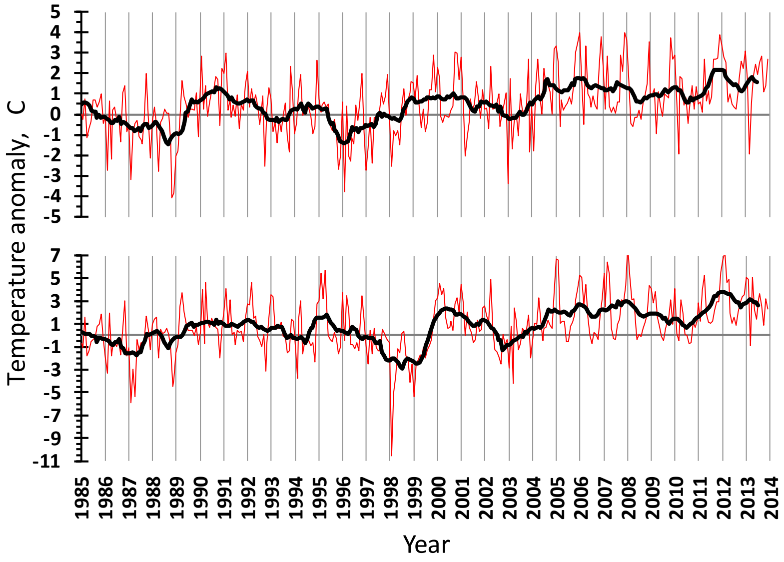

Figure 4.2.2. Air temperature anomalies over the western (upper) and eastern (lower) Barents Sea during 1985–2013 (Anon., 2013).

Table 4.2.1 summarizes air temperature anomalies at meteorological stations located in western and southern areas of the Barents Sea (Svalbard airport, Bear Island, Murmansk, and Kanin Nos) from late 2011 through 2012-2013. During this period, air temperatures over the region were generally warmer than normal, with the largest positive anomalies (>8.0°C) occurring at Svalbard airport during January–March 2012. High positive anomalies (4.3-5.3°C) at the same period occurred at the Bear Island. The largest negative anomaly (–5.8°C) was observed at the Kanin Nos in March 2013. Large negative anomalies (-4.1°C) were observed in Murmansk during December 2012 and March 2013. At most of the stations, mean annual air temperatures for 2012 and 2013 were warmer than average by 1.0–2.0°C, with the largest positive anomaly (3.4°C) at Svalbard airport in 2012; comparable air temperatures for 2011 were 0.4–1.9°C warmer than average. Stations in the southwestern Barents Sea (at Tromsø and Vardø) had relatively small anomalies, both positive and negative, and temperatures were close to those in 2011.

Table 4.2.1. Monthly mean air temperature anomalies at weather stations located in the Barents Sea between December 2011 and December 2013, the yearly mean anomalies in 2012 and 2013, maximum anomalies, and years when they were observed. Anomalies were calculated relative to the period 1981–2010.

Station	Year/Month													2012/ 2013 mean	Max/Year
	2011/ 2012	2012/2013													
	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec		
Svalbard airport	1.6/ 3.6	10.1/ 5.2	8.4/ 3.2	8.2/ -0.8	1.0/ 0.9	0.6/ 1.5	1.0/ 1.5	0.1/ 0.9	0.3/ 1.8	1.9/ 2.6	2.3/ 0.3	2.1/ 0.5	3.6/ 3.4	3.4/ 1.8	3.4 2012
Bear Island	1.4/ 2.5	5.3/ 3.4	4.3/ 2.7	4.3/ -2.5	0.1/ 0.2	0.9/ 2.3	0.3/ 2.8	-0.2/ 1.7	0.6/ 3.1	1.0/ 3.0	1.1/ 0.0	2.2/ 0.0	2.5/ 2.5	2.0/ 1.6	2.0 2012
Tromsø	1.2/ -1.5	–0.1/ 1.0	0.8/ 0.2	1.8/ -2.3	0.0/ -0.3	–1.2/ 3.2	–0.4/ 2.5	–1.2/ -0.2	–1.3/ 0.8	0.1/ 2.4	–0.3/ -0.2	1.3/ 0.1	–1.5/ 1.7	0.1/ 0.5	1.2 2005/2011
Vardø	0.9/ -0.8	0.1/ 2.4	–1.3/ 2.0	1.5/ -2.7	0.6/ 0.5	1.8/ 3.0	0.2/ 3.1	0.0/ 2.3	–0.5/ 2.9	0.8/ 2.9	1.1/ 0.4	1.9/ 0.4	–0.8/ 1.9	0.8/ 1.4	1.4 2013
Murmansk	0.7/ -4.1	0.6/ 3.6	–1.3/ 2.2	2.0/ -4.1	0.4/ 1.1	2.2/ 3.9	0.5/ 4.7	–0.7/ 1.7	–0.9/ 3.2	1.0/ 2.7	0.3/ -0.5	2.1/ 1.0	–4.1/ 2.2	1.1/ 1.4	1.7 2005
Kanin Nos	0.9/ -1.2	2.3/ 1.9	2.2/ 4.2	0.0/ -5.8	2.4/ 2.1	2.2/ 1.8	2.5/ 3.3	0.8/ 3.0	–0.3/ 3.1	1.3/ 1.9	1.8/ -0.7	1.7/ 1.7	–1.2/ 2.1	1.8/ 1.3	2.1 1937

4.2.2 Oceanographic conditions

4.2.2.1 Temperature at the surface, 100 meters, and bottom layer

Sea surface temperature (SST) data from the IRI/LDEO Climate Data Library (http://iridl.ldeo.columbia.edu) were averaged over southwestern (71–74°N, 20–40°E) and southeastern (69–73°N, 42–55°E) parts of the Barents Sea. During 2012, increasing SST anomalies occurred in the Barents Sea. This increase was relatively rapid in the southeastern part, where positive anomalies increased from 0.7°C in January to 2.4°C in July (Figure 4.2.3). In the southwestern Barents Sea, positive anomalies of 0.1–1.1°C were observed throughout 2012. At the beginning of 2013, positive anomalies were close to 1.0°C, but were decreasing towards March. In April–May, small negative SST anomalies (–0.2 to –0.3°C) were observed in the southwestern Barents Sea. From May to August, significant increases in SST anomalies took place in the southern Barents Sea. The largest anomalies (up to 4.0°C) were observed in the southeastern Barents Sea, where the highest SST measurements since 1981 were taken during July, August, and September 2013. Subsequent SST anomalies decreased toward the end of the year (down to 0.5°C) due to stronger-than-usual north and northeast winds.

During August-September of 2012 and 2013, the joint Norwegian-Russian ecosystem survey of the Barents Sea was carried out. During 2012, survey measurements of surface water temperature in most areas were 0.5–2.0°C higher than the 1929-2007 long-term average (Figure 4.2.4). Large positive anomalies (greater than 2.0°C) were observed north of 76°N. Small negative anomalies (–0.1 to –0.5°C) were observed only in the central and southwestern Barents Sea, and were likely due to weaker-than-usual warming of the surface layer during the summer season. During 2013, surface temperatures were much higher (on average by 2.0–3.3°C) than the long-term average all over the Barents Sea, with the highest positive anomalies (> 3.0°C) observed mainly in the south-eastern area (south of Spitsbergen and east of Hopen Island) between 75°45' and 77°45'N (Figure 4.2.4). Surface temperatures in 2013 were much higher than in 2012 (by 1.3–2.7°C) for most of the Barents Sea, especially in its central and southern parts. Only in the north-eastern area, were temperatures lower (by 0.3–0.8°C) than in 2012. During August–September 2013, surface temperatures were the highest observed since 1951 in about 50% of the area surveyed.

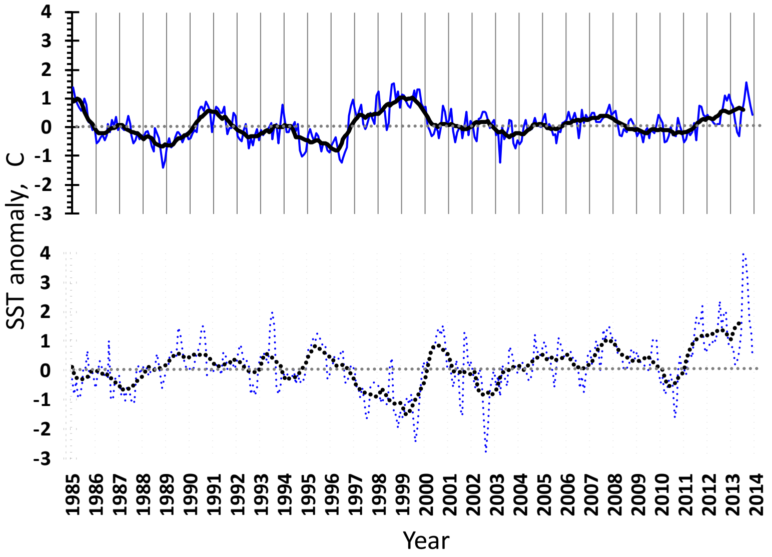

Figure 4.2.3. Sea surface temperature anomalies in the western (upper) and eastern (lower) Barents Sea in 1985–2013 (Anon., 2013).

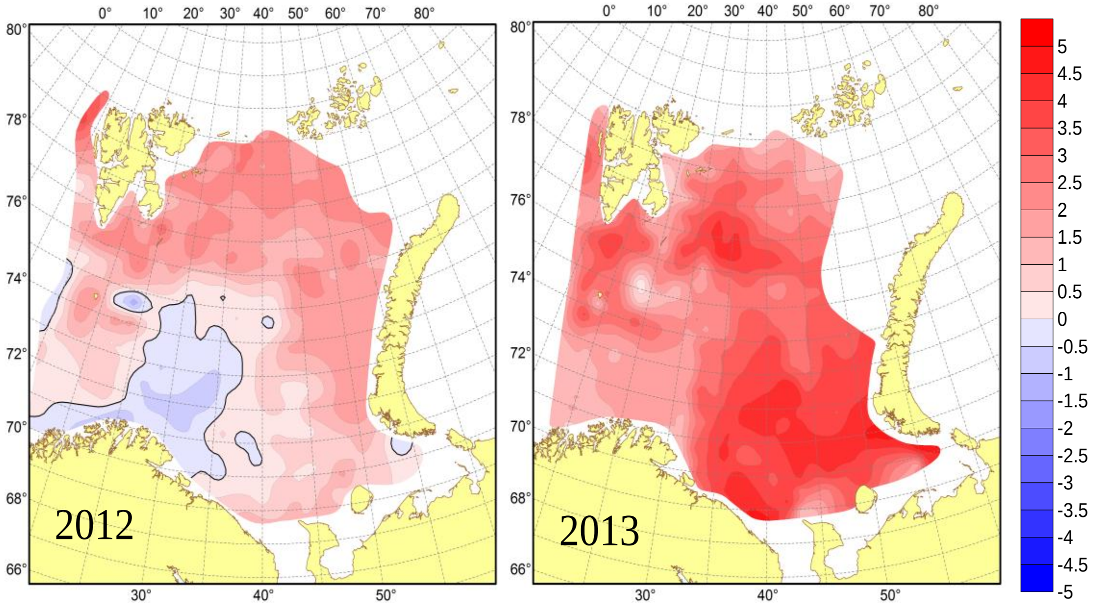

Figure 4.2.4. Surface temperature anomalies in the Barents Sea in August–September 2012 (left) and 2013 (right) (Anon., 2013).

During August–September 2012 throughout the Barents Sea, temperatures below 100-meter depths were usually 0.8–1.9°C higher than normal (Figure 4.2.5). In 2013 throughout the Barents Sea, temperatures at depths below 100m were typically above average (by 0.5–1.2°C), but lower than those observed in 2012 (by 0.5–1.2°C) (Figure 4.2.5). A larger area was covered with cold water (temperatures below zero) in 2013 than in 2012. In 2013, cold bottom waters were (as in 2012) observed in the Central Bank and in the Eastern Basin. Similarly cold waters — north of Kolguev Island in the south-eastern Barents Sea — have not been observed since 2005. Higher temperatures in the Barents Sea are mostly due to the inflow of water masses with high temperatures from the Norwegian Sea, as well as stronger-than-usual seasonal warming of the surface waters in the Barents Sea during summer.

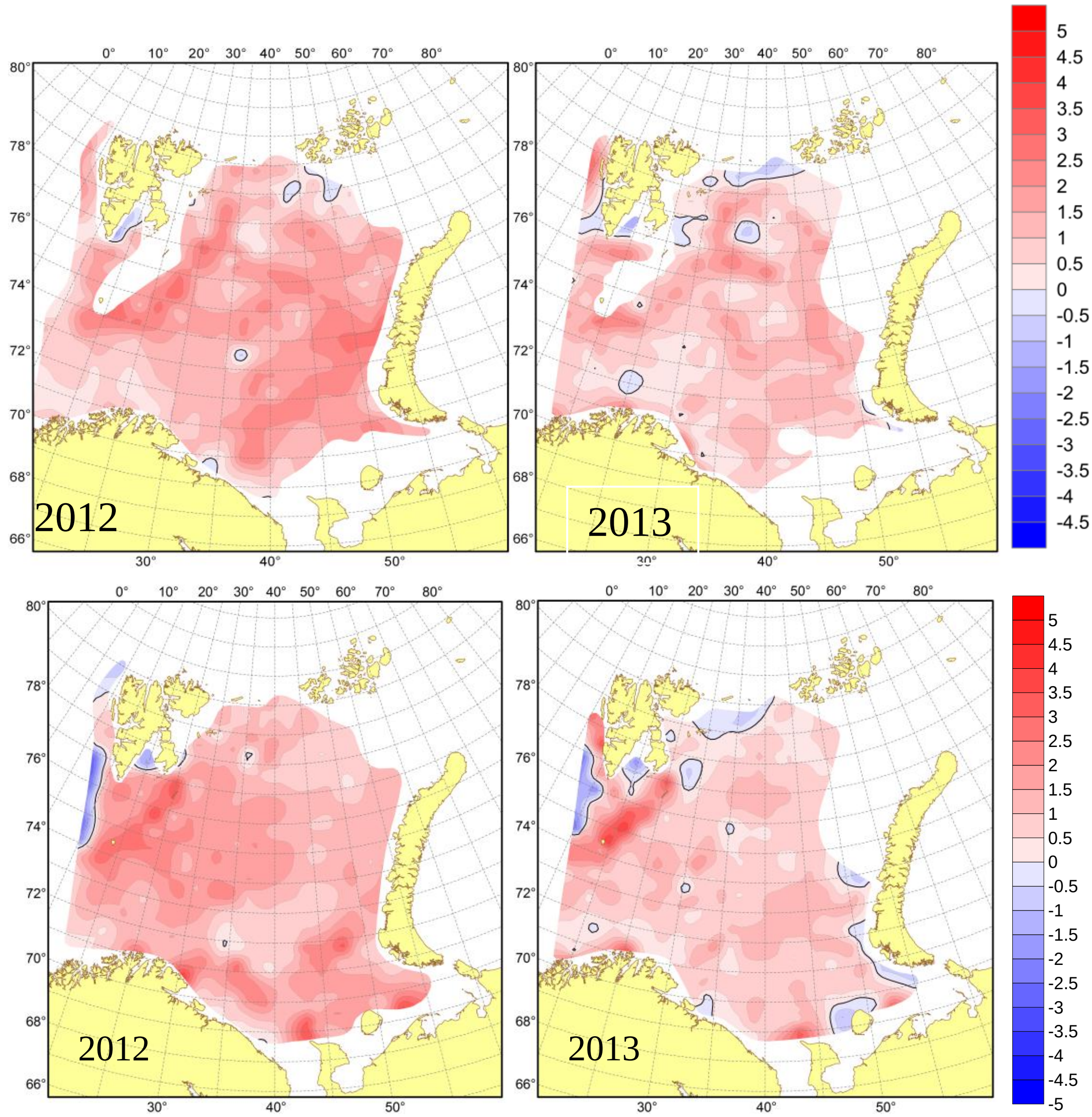

Figure 4.2.5. 100 m (upper) and near-bottom (lower) temperature anomalies in the Barents Sea in August–September 2012 (left) and 2013 (right) (Anon., 2013).

4.2.2.2 Temperature and salinity in the standard sections

The Fugløya–Bear Island section captures all Atlantic water entering the Barents Sea from the southwest. During 2011, temperatures in the southwest increased and in August were 0.5°C above the 1965-2013 long-term average (Figure 4.2.6). During 2012, temperatures in this section were 0.7°C above the 1965-2013 long-term average (Figure 4.2.7), whereas in August 2013 the temperature decreased to 0.4°C above the long-term average.

Throughout 2012, temperatures of Atlantic water within the Kola section were much higher than normal, with the largest anomalies (up to 1.8°C) occurring in the central branch of the North Cape Current (Figure 4.2.7); temperatures were also much higher than during 2011. In the Murman Current, positive anomalies had an increasing trend until June. In the central branch of the North Cape Current, a trend of decreasing positive anomalies started in May and was accompanied by stronger-than-usual northerly winds. Despite this fact, and typical of anomalously-warm years, positive temperature anomalies in the 0–200m layer in these currents exceeded 1.0°C almost throughout the year. Temperatures in the central branch of the North Cape Current during January–October were the highest observed since 1951, and were the highest observed in the Murman Current during January–August since 1951. It should be noted that Atlantic water temperatures in the 150–200m layer were 1.1–1.9°C higher than normal, and throughout the year were the highest observed since 1951. In coastal waters, positive temperature anomalies (above 1.0°C) were only observed during January-February (Figure 4.2.7). During the remainder of the year, positive temperature anomalies were 0.4–0.9°C, with the smallest values observed during August and September.

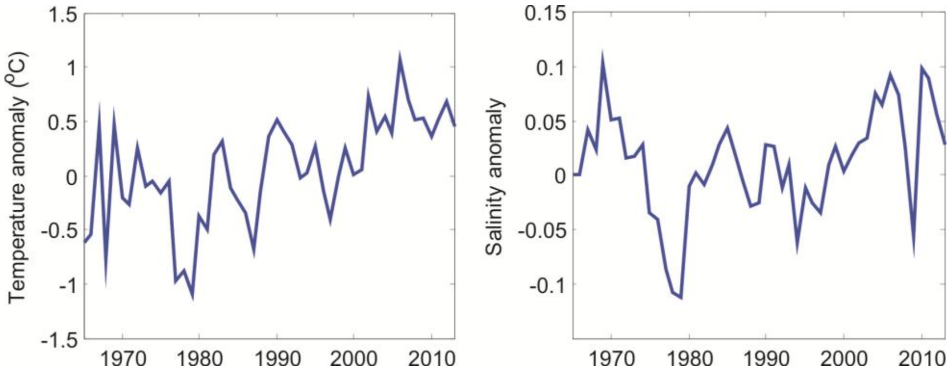

Figure 4.2.6. Temperature (left) and salinity (right) anomalies in the 50–200 m layer of the Fugløya– Bear Island section (1965-2013).

Throughout 2012, temperatures of Atlantic water within the Kola section were much higher than normal, with the largest anomalies (up to 1.8°C) occurring in the central branch of the North Cape Current (Figure 4.2.7); temperatures were also much higher than during 2011. In the Murman Current, positive anomalies had an increasing trend until June. In the central branch of the North Cape Current, a trend of decreasing positive anomalies started in May and was accompanied by stronger-than-usual northerly winds. Despite this fact, and typical of anomalously-warm years, positive temperature anomalies in the 0–200m layer in these currents exceeded 1.0°C almost throughout the year. Temperatures in the central branch of the North Cape Current during January–October were the highest observed since 1951, and were the highest observed in the Murman Current during January–August since 1951. It should be noted that Atlantic water temperatures in the 150–200m layer were 1.1–1.9°C higher than normal, and throughout the year were the highest observed since 1951. In coastal waters, positive temperature anomalies (above 1.0°C) were only observed during January-February (Figure 4.2.7). During the remainder of the year, positive temperature anomalies were 0.4–0.9°C, with the smallest values observed during August and September.

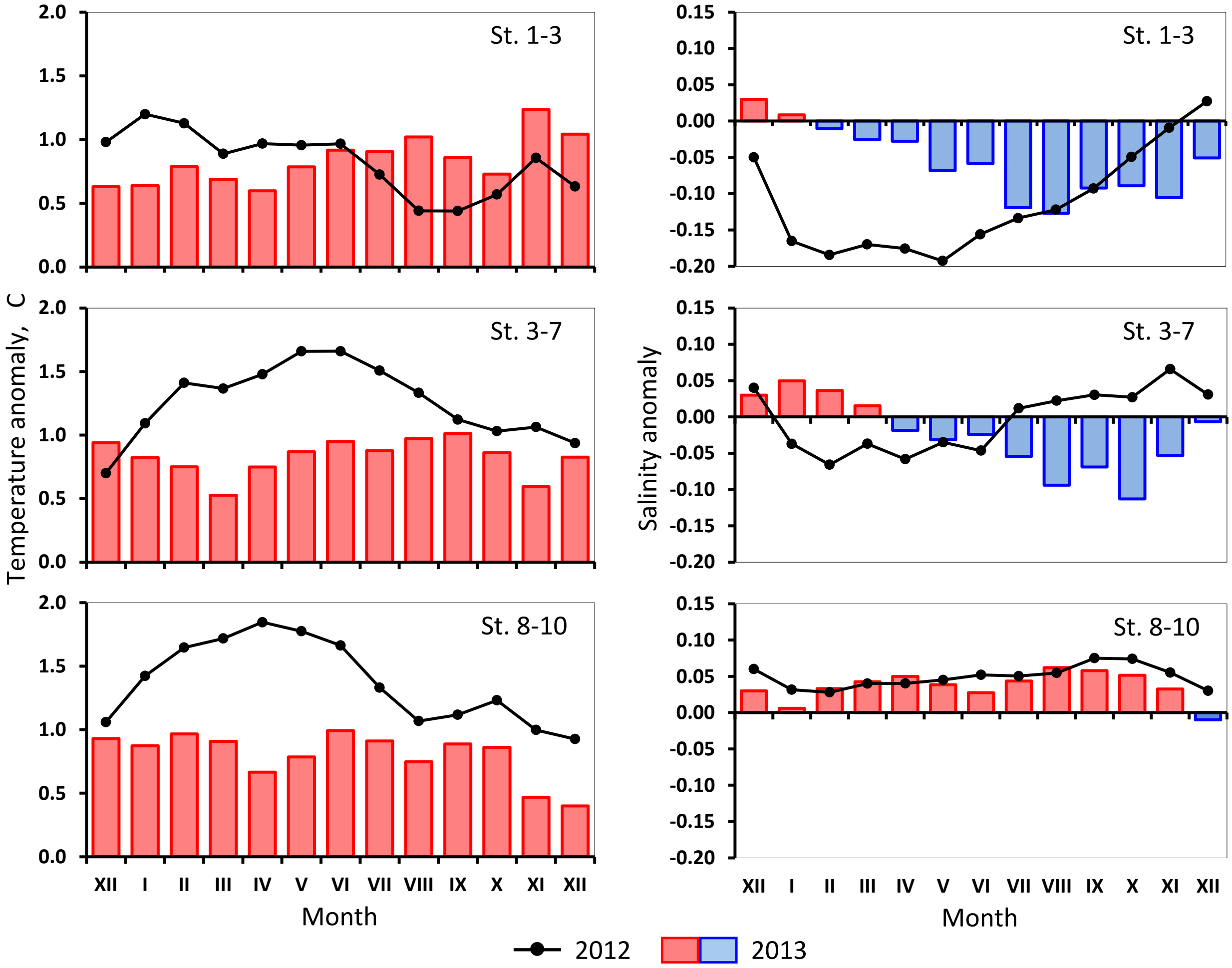

Figure 4.2.7. Monthly mean temperature (left) and salinity (right) anomalies during 2012 and 2013 in the 0–200m layer of the Kola section. St. 1–3 – Coastal waters, St. 3–7 – Murman Current, St. 8–10 – Central branch of the North Cape Current (Anon., 2013).

During 2013, Atlantic water temperatures at 0-200m depths in the Kola Section were 0.5–1.0°C higher than normal, but throughout the year they were 0.1–1.2°C lower than in 2012 (Figure 4.2.7). In coastal waters, positive temperature anomalies were 0.6–1.2°C in 2013 with the largest values (>1.0°C) observed during August, November, and December (Figure 4.2.7). During August and November, temperatures were the highest observed since 1951. The 2013 annual mean temperature in the 0–200m layer within the Kola Section was typical of anomalously warm years, but was 0.5°C lower than in 2012.

In general, lower temperatures were observed in 2013 than in 2012 for both these sections (Fugløya-Bear Island and Kola).

During 2012, salinity levels in the Kola Section were lower than in 2011 (Figure 4.2.7). In coastal waters, significant negative anomalies were observed during the first half of the year; they increased during the second half of the year, and reached positive values (>0.0°C) in December. In 2013, salinity levels in coastal waters and also in Murman Current of the Kola Section were generally lower than normal with the largest negative anomalies observed in July–November (Figure 4.2.7). In the central branch of the North Cape Current, salinity levels were on average 0.04°C higher than normal throughout 2013, and close to levels observed in 2012. Annual mean salinity during 2013 in the 0–200m layer in the Kola section was close to normal, and to levels observed in 2012.

The 2012 annual mean temperature in the 0–200m layer in the Kola section was the highest observed since 1900, but also typical of anomalously-warm years (Figure 4.2.8). The 2012 annual mean salinity in the 0–200m layer in this section was close to normal, and was less than that observed in 2011 (Figure 4.2.8). The 2013 annual mean temperature in the 0–200 m layer in the Kola Section was typical of anomalously warm years but 0.5°C lower than in 2012 (Figure 4.2.8). The 2013 annual mean salinity in the 0–200 m layer in this section was close to normal, and to that observed in 2012 (Fig. 4.2.8).

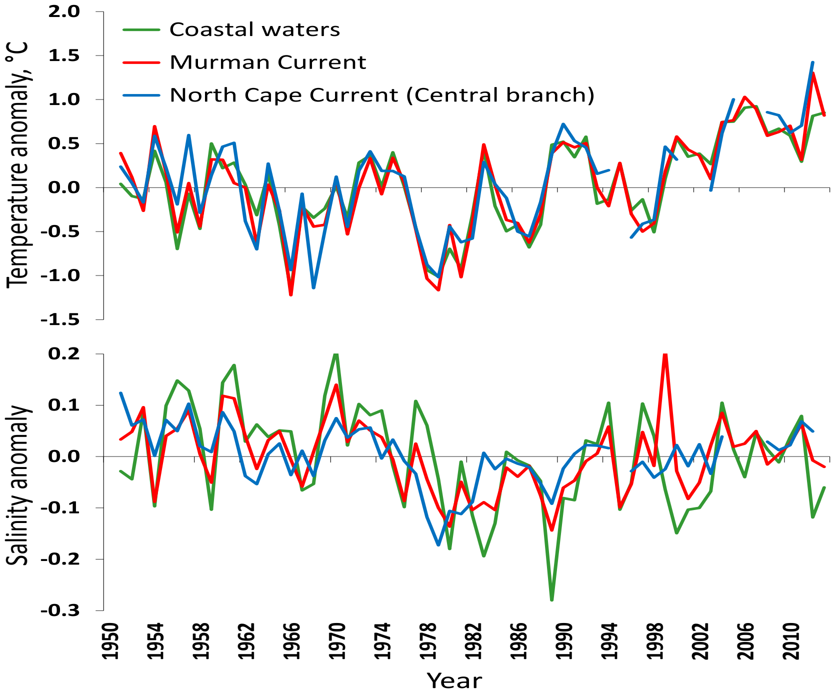

Figure 4.2.8. Annual mean temperature (upper) and salinity (lower) anomalies in the 0–200 m layer of the Kola Section in 1951–2013. Coastal waters – St. 1–3, Murman Current – St. 3–7, central branch of the North Cape Current – St. 8–10 (Anon., 2013).

The North Cape – Bear Island section, sampled in April, June, and November of 2012, had positive temperature anomalies in the 0–200m layer of the North Cape Current which decreased from 1.6°C to 0.7°C between April and November. In 2013, the North Cape – Bear Island Section was sampled in April and November. Positive temperature anomalies in the 0–200 m layer in the North Cape Current were 0.6°C.

During November 2012, the Bear Island–West section (along 74°30'N) had temperature anomalies in the 0–200m layer of the eastern branch of the Norwegian Atlantic Current (74°30'N, 13°30'–15°55'E) which were 0.7°C higher than normal. In 2013, the Bear Island – West section was only sampled in November. The temperature in the 0–200m layer in the eastern branch of the Norwegian Atlantic Current was close to the long-term average with a small positive anomaly of 0.1°C.

The Bear Island–East section (along 74°30'N) was sampled three times during 2012, and had positive temperature anomalies — in the 0–200m layer of the northern branch of the North Cape Current (74°30'N, 26°50'–31°20'E) — which decreased from 1.9°C to 1.0°C between March and November. During 2013, the Bear Island – East section was sampled in April, July, and November. Positive temperature anomalies in the 0–200 m layer in the northern branch of the North Cape Current were 0.4–0.9°C with the largest values in July.

During 2012, the Kharlov section had positive temperature anomalies in the 0–200m layer of the Murman Current, which decreased from 2.0°C to 1.4°C between May and October. In 2013, the Kharlov Section was not sampled.

The Kanin section (along 43°15'E) located in the eastern Barents Sea was sampled four times in 2012. In the 0–200m layer of the Novaya Zemlya Current (71°00'–71°40'N, 43°15'E), positive temperature anomalies (1.4–2.0°C) were observed which decreased from February to December. In August, they were as high as the historical maximum in 1954. During 2013, the Kanin section was sampled in February, August, and December. In the 0–200m layer in the Novaya Zemlya Current, positive temperature anomalies decreased from 1.5–1.6°C in February and August to 1.2°C in December.

4.2.2.3 Currents and transport

Volume flux into the Barents Sea varies in periods of several years, and was significantly lower during 1997–2002 than during 2003–2006 (Figure 4.2.9). In 2006, volume flux was at a maximum during winter, and was very low during fall. After 2006, inflow has been relatively low. During fall and winter of 2011 inflow was particularly low, but thereafter inflow increased towards spring 2013. The current data series only extends to spring 2013; thus, inflow during fall 2013 is unknown.

During 2012 and 2013, monthly and annual volume-flux anomalies were calculated using a numerical model (Trofimov, 2000) for the major currents of the Barents Sea (Figure 4.2.10). In 2012, volume fluxes were 0.7–1.9σ (Sv = Sverdrup = 1 million m^3/s) higher than the long-term average, and were 0.7–1.7σ higher than those calculated in 2011. Only in the northern branch of the North Cape Current was the 2012 annual mean volume flux close to both the long-term average and the 2011 value. Throughout 2012, large positive volume-flux anomalies (ranging between 2012 and 2011 values) were observed in the Novaya Zemlya Current; during May 2012 similar anomalies were observed in all currents. In 2013, volume fluxes in warm currents were generally higher than the long-term average but lower than in 2012. Mean annual volume fluxes in the central branch of the North Cape Current, Murman Current, and Novaya Zemlya Current were 0.5σ higher than average, while in the northern branch of the North Cape Current volume flux was lower than average, and in the North Cape and Bear Island currents volume flux was close to the long-term average. Maximum positive volume flux anomalies (1.2–1.8σ) were observed in the central branch of the North Cape Current, as well as in the Murman and Novaya Zemlya currents during June-August.

Maximum negative volume flux anomalies (1.4–1.8σ) were found in the northern branch of the North Cape Current in June and July.

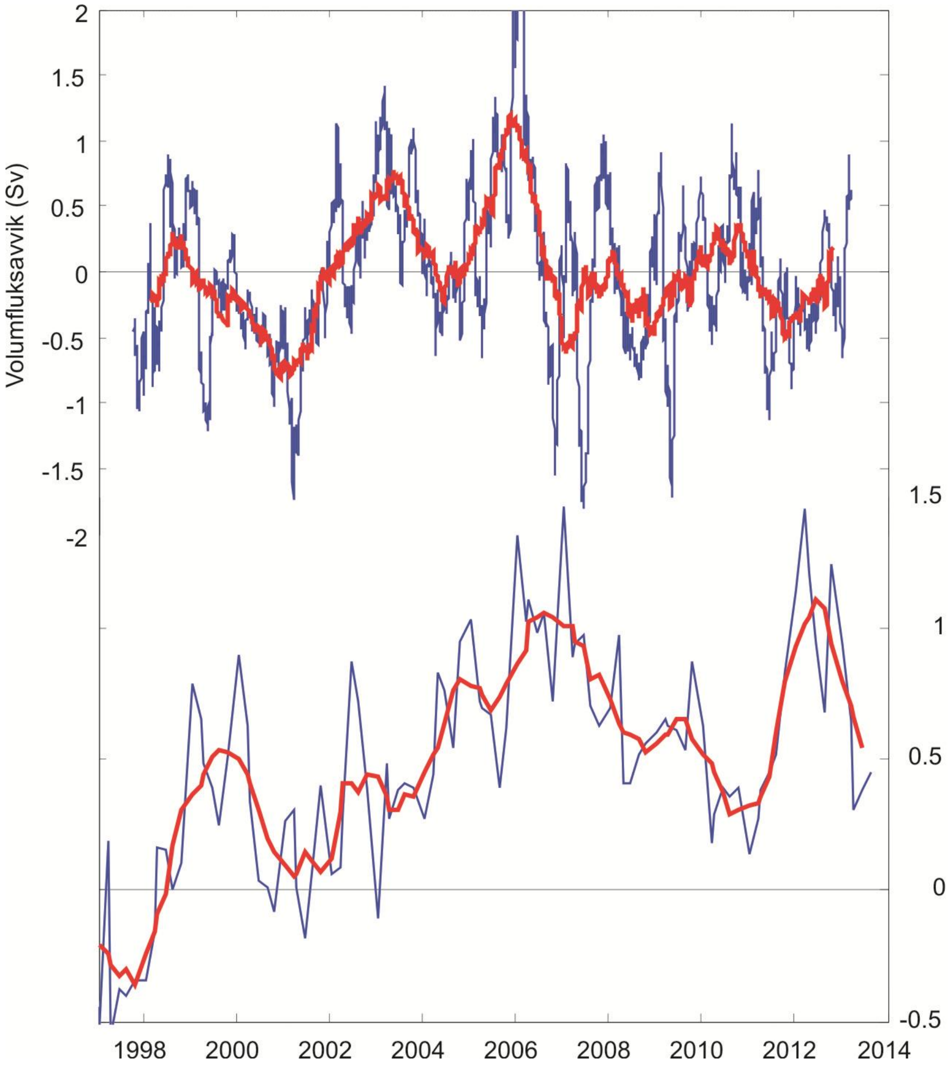

Figure 4.2.9. Observed Atlantic Water volume flux anomalies through the Fugløya–Bear Island section estimated from current meter moorings (upper) and temperature anomalies in the 50–200m layer of the water column (lower). Three-month (blue) and 12-month (red) running averages are shown.

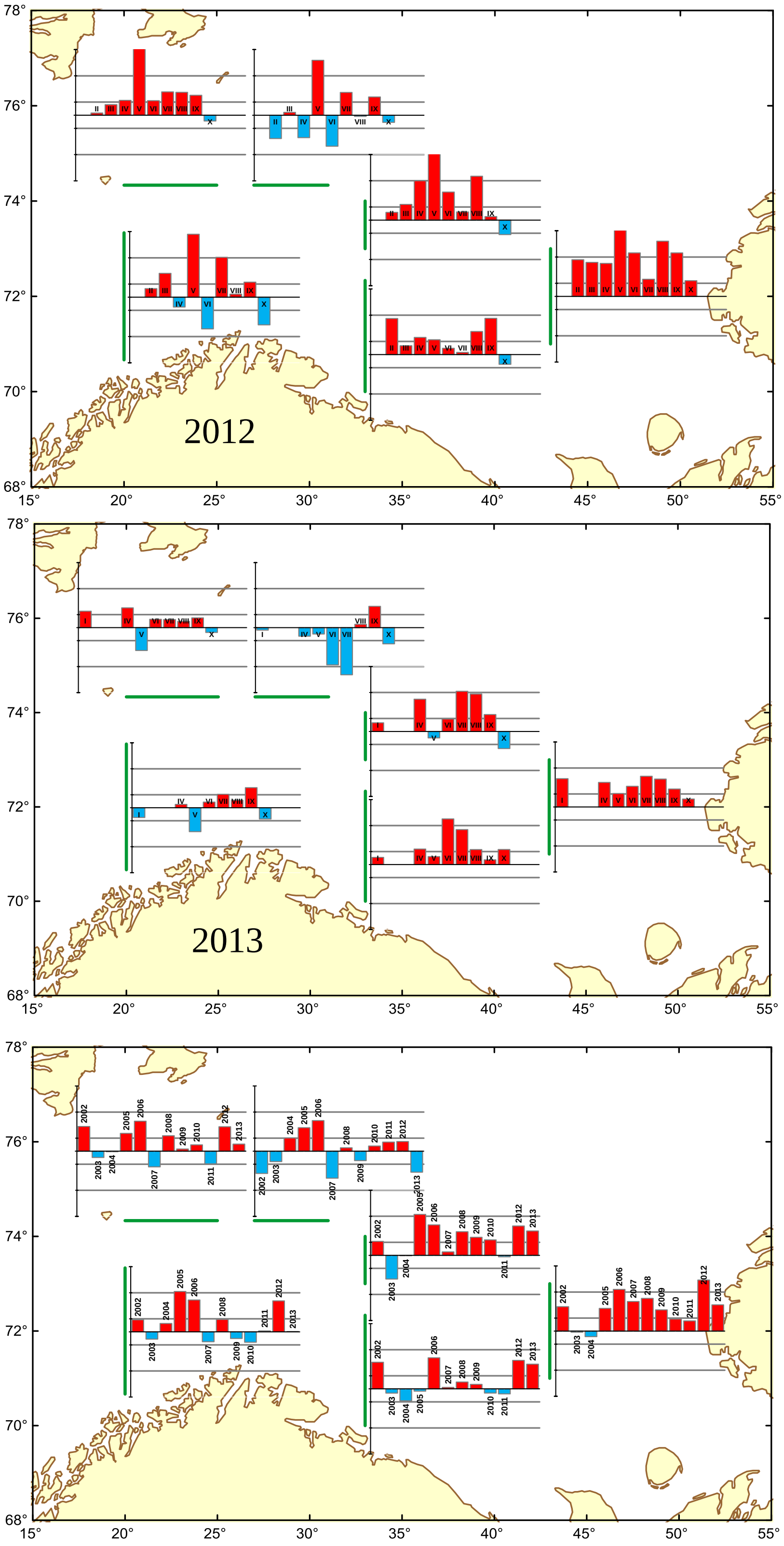

Figure 4.2.10. Calculated monthly (upper and middle) and annual (lower) volume-flux anomalies in the Barents Sea during 2012, 2013 and during the 2001–2013 period. Normalized by standard deviation (σ), the vertical scale range is 5σ and the vertical scale interval is 1σ, respectively.

4.2.2.4 Ice conditions

Meteorological conditions over the Barents Sea during winter 2011/2012, resulted in decreasing sea-ice coverage. From January through July 2012, ice coverage (expressed as a percentage of the sea area) was 17–32% below average and 7–25% less than in 2011 (Figure 4.2.11). During February and July 2012, sea-ice coverage was the smallest observed since 1951 for these months. In August and September 2012, there was no ice in the Barents Sea; the ice edge was located much farther northwards than usual, at about 83°N latitude. Also during this period, was the very rare occurrence of no ice being observed around the Spitsbergen and Franz Josef Land archipelagos. Ice formation started in the north-easternmost regions during October 2012. In the northern Barents Sea, the ice edge appeared only at the end of November. During October, November, and December, ice coverage was 14–22% less than usual, and was 1–6% less than in 2011 (Figure 4.2.12). At the end of 2012 and beginning of 2013, meteorological conditions over the Barents Sea resulted in increased sea-ice coverage. In 2013, ice coverage was still lower than normal, but higher than in 2012 (Figure 4.2.11). In January, it was only 2% higher than in the previous year. During February–June, ice coverage was 7–17% higher than in 2012, and was 5–19% lower than the long-term average. In July, ice was only observed near the Franz Josef Land archipelago. In August and September, no ice was observed in the Barents Sea. Ice formation started in the northern Barents Sea in October, when ice appeared around the Spitsbergen and Franz Josef Land archipelagos. In October, the ice coverage was 3% — an amount 12% less than usual, and 2% more than in 2012.

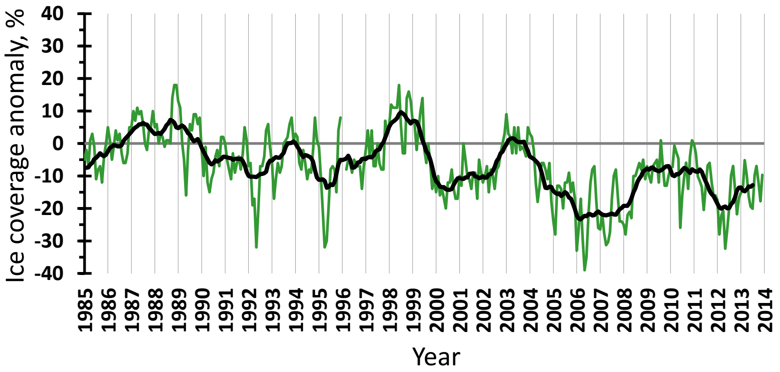

Figure 4.2.11. Ice extent anomalies in the Barents Sea during 1985–2013 (Anon., 2013): monthly values (green) and 11-month moving-average values (black).

4.2.2.5 Chemical conditions

In 2012, the oxygen saturation (dissolved oxygen) level at the bottom layer of the southern Barents Sea was much lower than the 1958-2012 long-term average, and was lower than observed in 2011. The oxygen-saturation anomaly — averaged from January to September —was –2.14% in 2012, compared to –0.79% in 2011 (Figure 4.2.12). The largest negative anomaly occurred during the first half of the year. In 2013, oxygen saturation in the Kola section increased and was slightly above normal. The average value of oxygen-saturation anomalies from January through September was 0.35%.

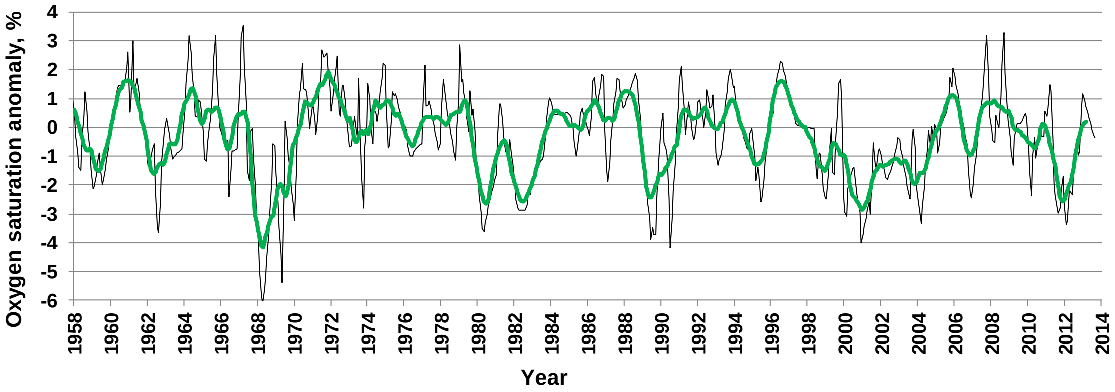

Figure 4.2.12. Monthly (black) and annual (green) oxygen-saturation anomalies at the bottom layer of the Kola section (Murman Current) over the 1958–2013 period (Anon., 2013).

4.2.2.6 Expected situation

Oceanic systems have a "longer memory" than atmospheric systems. Thus, a priori, it seems feasible to realistically predict oceanic temperatures much further ahead than atmospheric weather predictions. However, the prediction is complicated due to variations being determined by processes originating both externally and locally, which operate at different time scales. Thus, both slow-moving advective propagation and rapid barotropic responses — resulting from large-scale changes in air pressure — must be considered.

Projected temperatures for the Kola section — made using a prediction model based on harmonic analysis of data time series (Boitsov and Karsakov, 2005) — indicate that 2013 Atlantic water temperatures in the Murman Current were expected to be typical of anomalously warm years (4.9±0.5°C); 2014 temperatures are expected to decrease to values typical of warm years (4.6±0.5°C) (Table 4.2.2).

Table 4.2.2. Predicted temperature in the Kola Section (0–200 m), representing the southern Barents Sea.

	Observed	**Observed**	**Predicted**	**Predicted**
Year	2011	2012	2013	2014
Temperature	4.4	5.4	4.9	4.6

Due to high temperatures and the extreme minimum in sea-ice extent in recent years, ice cover is expected to remain well below the long-term average.

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4.3 Biotic components

4.3.1 Phytoplankton

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Among phytoplankton species in the Barents Sea, there tends to be large inter-annual and geographical variation in patterns of distribution and abundance. However, the overall annual pattern of succession is quite stabile, despite variability between years for abiotic factors such as temperature. Formation of the spring bloom varies between years, and is largely determined by the degree of stabilization in upper layers of the water column.

During the period between 2008 and 2013, no abnormalities were observed in annual patterns of succession for phytoplankton species sampled along a fixed transect of Norwegian waters extending from Vardø-North and Fugløya to Bear Island.

The production season typically proceeds with a large spring bloom during March that begins in coastal waters and fjord systems, and then spreads out into open waters. In recent years, this bloom has been dominated by species of diatoms which commonly occur during spring, such as *Chaetoceros, Skeletonema, Thalassiosira,* and the genus Phaeocystis (Prymnesiophyceae).

Up until 2012, sampling was conducted along the Vardø-North transect both before and after the spring bloom. Collected data indicate that a bloom occurred in late April/early May. Although Norwegian waters along this transect were not sampled during 2012, we can expect an increase in the occurrence of diatoms during early spring, with a subsequent decrease toward the summer. Supplementary data from nutrient samples taken along this transect indicate that an increase in primary production occurs during April/May. Again in 2013, Norwegian waters along this transect were not sampled during spring, but we assume that then also a bloom has occurred.

During summer phytoplankton are often distributed in patches consisting largely of small flagellates and dinoflagellates (*Ceratium* and *Gymnodinium*). In some years species of diatoms (mostly *Chaetoceros* spp.) can be dominant during June-August.

Coccolitophores (*Emiliania huxleyi*) occurred in blooming concentrations along the Norwegian coast during 2008-2011. Highest densities of this species were observed in western parts of the Barents Sea, in fjord systems, and close to the coast. In recent years, no large blooms or high densities of *E. huxleyi* have been observed in the open sea. During August of last two years, another species of coccolitophore (*Coccolithus pelagicus*) has also been observed.

The overall species composition of phytoplankton observed in the Barents Sea during autumn has been stable, with larger dinoflagellates dominating followed by small flagellates and cryptophyceae. During August 2012, the diatom species, *Proboscia alata* was abundant in western parts of the Fugløya-Bear Island transect; during August 2013, this same species was abundant along the entire transect (Figures 4.3.1 and 4.3.2). In recent years, the flagellate, *Dictyocha speculum*, has also been plentiful during October along the Fugløya-Bear Island Transect (Figure 4.3.3).

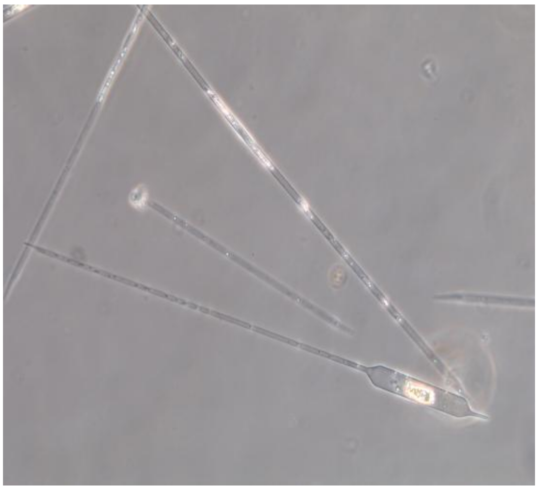

Figure 4.3.1. *Proboscia alata*

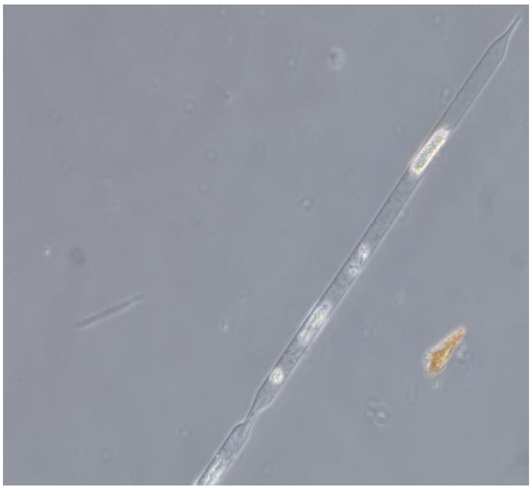

Figure 4.3.2. *Proboscia alata*

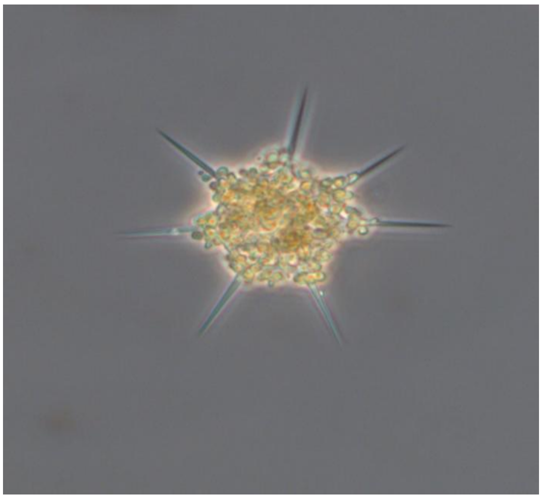

Figure 4.3.3. ***Dictyocha speculum***

4.3.2 Zooplankton

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

This chapter focuses on the current and expected state of zooplankton communities in the Barents Sea. An overview is provided of meso-, macro- and gelatinous zooplankton communities in the open sea and in coastal waters off the Kola Peninsula. Thoughts are also shared on how copepod communities are reacting to changing hydrographical condition in the Barents Sea.

4.3.2.1 Mesozooplankton

Horizontal distribution of mesozooplankton biomass in 2013 is shown in Figure 4.3.4. Patterns of distribution have been similar between years, even though the area of survey coverage may vary. Particularly low biomass was observed in central parts of the Barents Sea. In westernmost areas southeast of Bear Island, slightly higher zooplankton biomass was observed — somewhat similar to what was observed in 2009 and 2010. Another area with high mesozooplankton biomass was observed in the Russian sector of the Barents Sea, west of Novaja Zemlja and east of 25°E. Biomass levels were also high (>10 grams dry weight m^{-2}) in northern part of the Russian sector (>77°N), Franz Josef Land and northward. Regional survey coverage in 2013 was more extensive than in earlier years, and indicates that biomass in this north-eastern region is very high. Mesozooplankton in this area may have good feeding conditions, and potentially less predation from pelagic fish.

During 2013, in Norwegian waters of the Barents Sea, mesozooplankton biomass was size fractionated with results between 180-1000µm and 1000-2000µm. These were among the lowest levels recorded since the peak in 2006, and the >2000µm biomass fraction was the lowest recorded since the beginning of the time series in 1988.

Based on Norwegian data, average zooplankton biomass in 2013 was estimated to be 5.16g dry weight m^{-2} in the western-central Barents Sea. This is lower than estimated for this region in 2011 (5.88), 2008 (6.48), 2007 (7.13), and 2006 (8.63). It is also lower than the average for the period 2006-2011 (6.75g dry weight/m^2), and lower than the less certain measurements taken during 2012 (not shown). In fact, such low average biomass has not been recorded since 1992. Areal coverage for the survey was above average in 2013. Although the distribution of biomass was quite similar, the low biomass region in the central-western Barents Sea seems expanded relative to previous years.

Combined Russian and Norwegian data for the entire Barents Sea produced 7.06g dry weight m^{-2} as an estimate of average zooplankton biomass in 2013. This is less than estimated in 2008 (7.15g m^{-2} dry weight), 2007 (7.7), and 2006 (8.4); but slightly higher than in 2011 (6.7). In the Russian sector alone, average biomass in 2013 was estimated to be 9.96g dry weight m^{-2}; somewhat higher than the 2011 estimate (8.05g dry weight m^{-2}).

This was above the biomass estimate for 2011-2012 (7.7-8.8 g· m^{-2}), but lower than for 2010 (11.2 g· m^{-2}). In 2012, the high biomass area in the north greatly expanded westward to include West Spitsbergen, and extended as a wide discontinuous band stretching from the central Barents Sea all the way down to its southern bounds. High biomass areas also shifted west of the Novaya Zemlya archipelago; this resulted in low biomass near the Novaya Zemlya archipelago especially in the southeast (Figure 4.3.5). Patterns of distribution for zooplankton biomass varied between 2011 and 2012. In 2011, the highest biomass (more than 10g· m^{-2}) occurred only within a small area in northeastern Franz Josef Land; different small areas of the Barents Sea had biomass estimates ranging from 7 to 10g · m^{-2} (Figure 4.3.5).

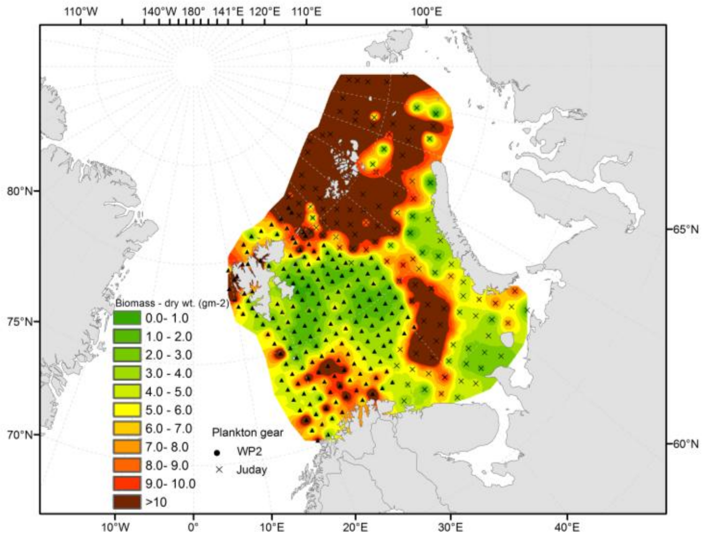

Figure 4.3.4. Distribution of zooplankton dry weight (grams dry weight m^{-2}) from bottom-0 m in 2013. Based on Norwegian WP2 and Russian Juday net-sampling data (IMR/PINRO).

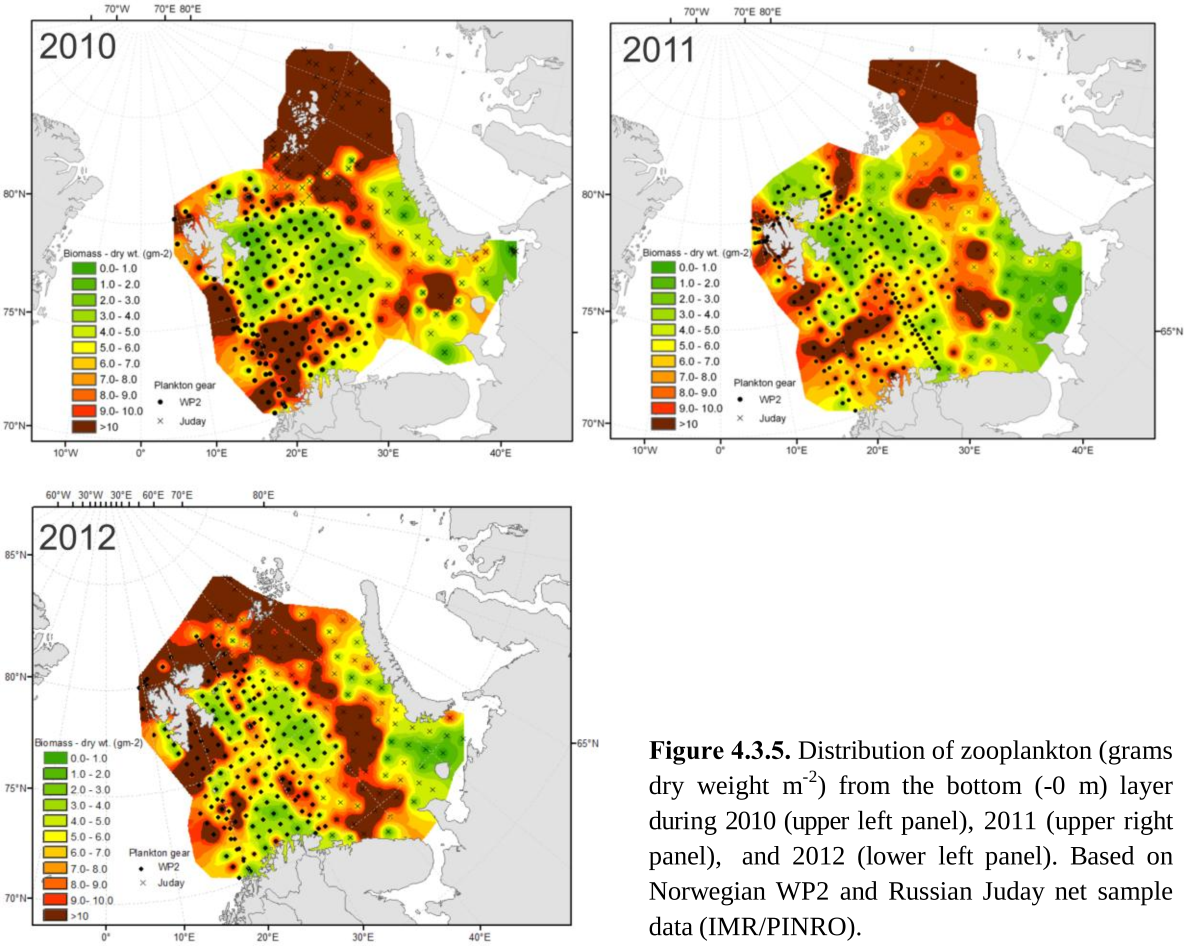

Figure 4.3.5. Distribution of zooplankton (grams dry weight m^{-2}) from the bottom (-0 m) layer during 2010 (upper left panel), 2011 (upper right panel), and 2012 (lower left panel). Based on Norwegian WP2 and Russian Juday net sample data (IMR/PINRO).

Even though distribution of biomass in 2013 was similar to previous years, it should be noted that the expanded area of survey coverage was an important factor that could significantly influence average biomass values. Hence, the locations of high and low biomass regions, and their annual fluctuations, are also important factors which allow better interpretation of mesozooplankton dynamics; they should be examined together with physical environmental factors and other biological ecosystem components.

The zooplankton community of the Barents Sea is typically dominated by the copepod species: *Calanus finmarchicus; Calanus glacialis; Calanus hyperboreus;* and *Pseudocalanus minutus*. However, euphausiids, chaetognaths, and in some cases pteropods also have high biomass. *C. finmarchicus* has the largest biomass in the western parts of the Barents Sea, whereas *C. glacialis* generally dominates in the northeastern parts (Orlova *et al*., 2009).

Northern and eastern parts of the Barents Sea

During 2011-2012, the highest zooplankton biomass levels were recorded in northern and eastern areas of the Barents Sea (Figure 4.3.5). The Arctic copepod species *C. glacialis, C. hyperboreus*, *Metridia longa*, and *P. minutus*, and the North Atlantic species, *C. finmarchicus*, were most abundant in this area (Figures 4.3.5 and 4.3.6).

Since 2010, the importance of the small Arctic species *P. minutus* in the zooplankton community, which traditionally is dominated by larger copepod species, has been gradually increasing. In 2012, abundance of *P. minutus* in some areas considerably surpassed the total abundance of all other copepod species (Figure 4.3.6). Also in 2011, and particularly in 2012, higher abundance of *M. longa* was recorded as far north as 80°N.

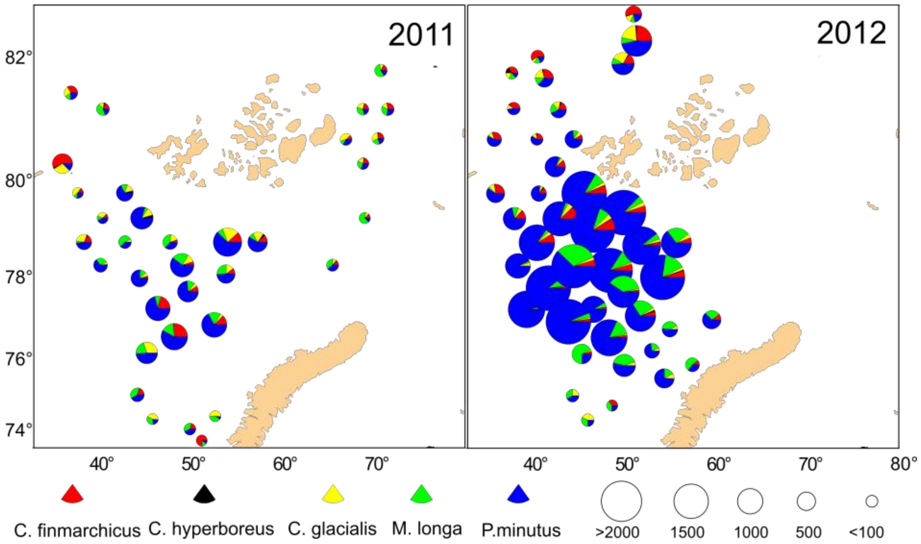

Figure 4.3.6. Relative abundance of key copepod species in the bottom-0 m layer in the Barents Sea in August-September 2011-2012 (ind. · m^{-3}).

In central and northeastern Barents Sea, estimated biomass of *P. minutus* was similar to that of *C. glacialis* and peaked at 177-212 mg · m^{-3} (Figure 4.3.7). In some areas euphausiids, chaetognaths, and hydromedusae also had high biomass estimates. *Calanus finmarchicus* was a dominant species in the western region, while *C. finmarchicus, P. minutus, M. longa*, and *C. glacialis* were dominant copepod species in the northeastern Barents Sea.

Abundance, distribution, and biomass of mesozooplankton all vary considerably from year to year in different parts of the Barents Sea. Variation in temperature, advection from the Norwegian Sea, local growth conditions, and predation pressure, along with timing of recruitment with respect to the regional coverage, are all factors that to a greater or lesser degree may contribute to such variability (Orlova *et al*., 2009).

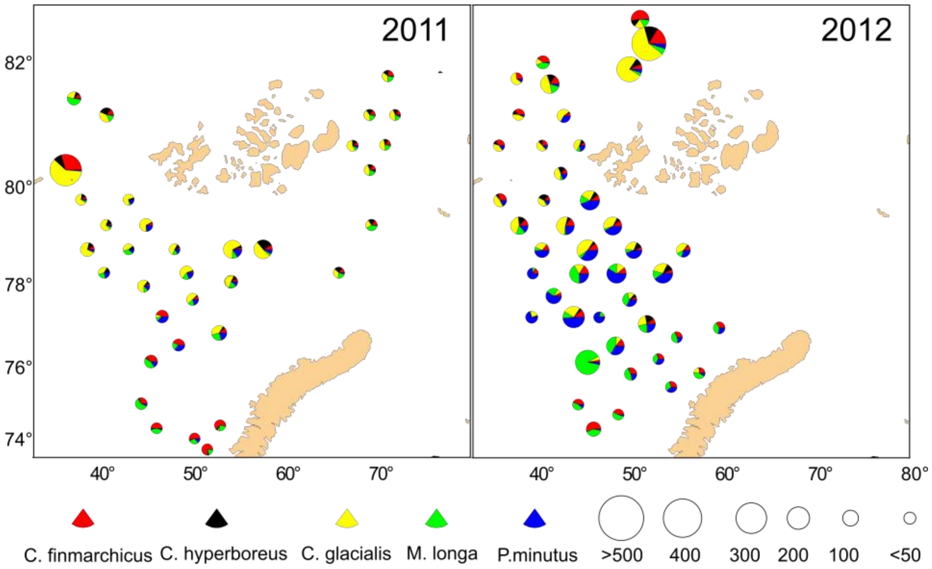

Figure 4.3.7. The biomass of key copepod species in bottom-0 m in the Barents Sea in August-September 2011-2012 (mg · m^{-3}).

The Kola section

In the Kola section, located in the southern part of the Barents Sea north of the Kola Peninsula, *C. finmarchicus* is a dominant species in terms of both abundance and biomass. Its abundance varied considerably during 2008-2012 (Figure 4.3.8). The population consisted of all developmental stages, but naupliar and copepodite (CI-CIII) stage individuals dominated in terms of abundance. During 2008-2009, abundance of *C. finmarchicus* was lowest for the period studied, and did not exceed 740 ind.·m^{-3} on average; they also declined in abundance between surface to bottom layers. Highest abundance of *C. finmarchicus* was observed in 2010 (up to 31,000 ind.·m^{-3} at one station), and its maximum abundance(8,700 ind.·m^{-3} on average) was observed at 50-100m depths. Its abundance level declined approximately by a factor of two between the 100m and bottom layer (4,570 ind.·m^{-3}). During 2011 and 2012, levels of abundance for *C. finmarchicus* were almost the same (approximately 1,300 ind.·m^{-3}). In 2011, its vertical distribution was quite similar to that observed in 2010. During the period of investigated, nauplii and copepodites CI-CIII dominated in both 0-50m and 50-100m layers. In both 2010 and 2011, they were also abundant in the 100m to bottom layer.

Abundance of late copepodite (CIV-VI) stage individuals was low, but their relative percentage was higher at depths above 100m (Figure 4.3.8). In 2012, the portion of copepodite CIV stage individuals was high at 0-50m depth in the southern half of transect. Their percentages gradually increased with increasing depth, and they were the most abundant group in the deepest layer. Results of the International Ecosystem Survey of Pelagic Fishes in the Nordic seas, conducted May-June 2012, indicated that water temperature in the Kola section corresponded to levels typical of warm and anomalously-warm years. Consequently, the development rate of *C. finmarchicus* was accelerated, and a high portion of individuals reached copepodite stage CIV, making it the dominant group forming the bulk of plankton biomass.

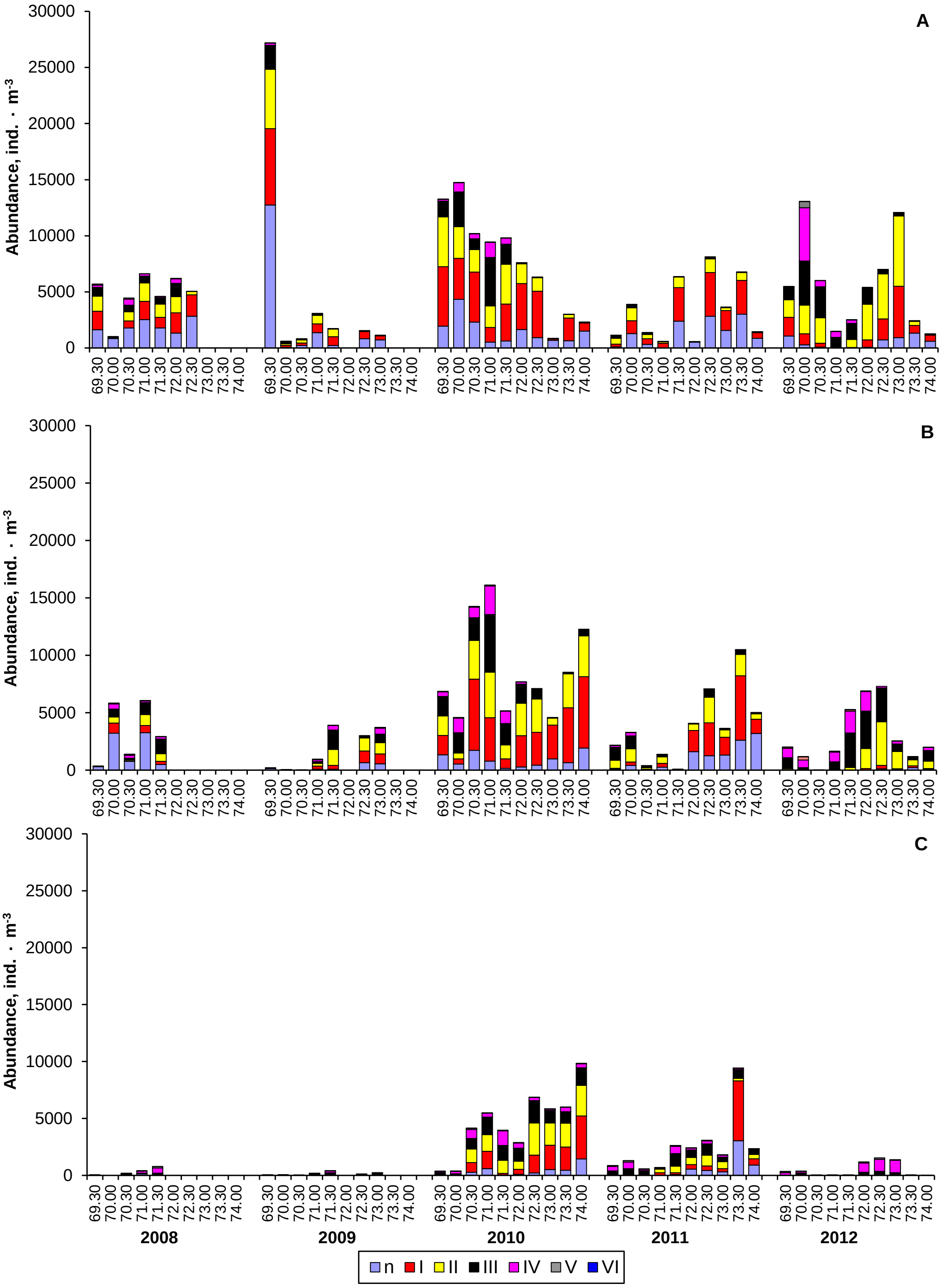

Figure 4.3.8. Abundance of *C. finmarchicus* (ind. · m^{-3}) in Juday net catches at 0-50m (A), 50-100m (B), and 100m-bottom (C) layers in the Kola section during late May-early June, 2008-2012.

The Fugløya-Bear Island (FB) transect

The Fugløya-Bear Island (FB) transect has fixed positions located at the western entrance to the Barents Sea. Normally, 5 to 8 stations are sampled depending on weather conditions. Data collected between 2004 and 2012 from four locations, representing different water masses — coastal, Atlantic, and mixed Atlantic/Arctic — were analyzed. Abundance estimates of three species (*C. finmarchicus*, *C. glacialis*, and *C. hyperboreus*) are shown in Figure 4.3.9. *C. finmarchicus* displays large inter-annual variations in abundance. The highest levels of abundances were recorded during 2010 along almost the entire transect; at the northernmost position (74º00'N), however, abundance was considerably lower. The data time series indicates that abundance of *C. finmarchicus* has been highest at the 73º30'N position. As would be expected, *C. glacialis* had highest abundance at the two northern-most positions where Atlantic and Arctic waters mix. This species is subject to large inter-annual variations. In recent years, its abundance has been considerably below the long-term average for the two northernmost positions.

Variability in the abundance of dominant *Calanus* species along the Fugløya-Bjørnøya transect (cf. Figure 4.3.9) suggests that abundance of the Arctic species (*C. glacialis and C. hyperboreus*) has decreased since 2004; while abundance of *C. finmarchicus* has increased, particularly at northern-most positions along this transect.

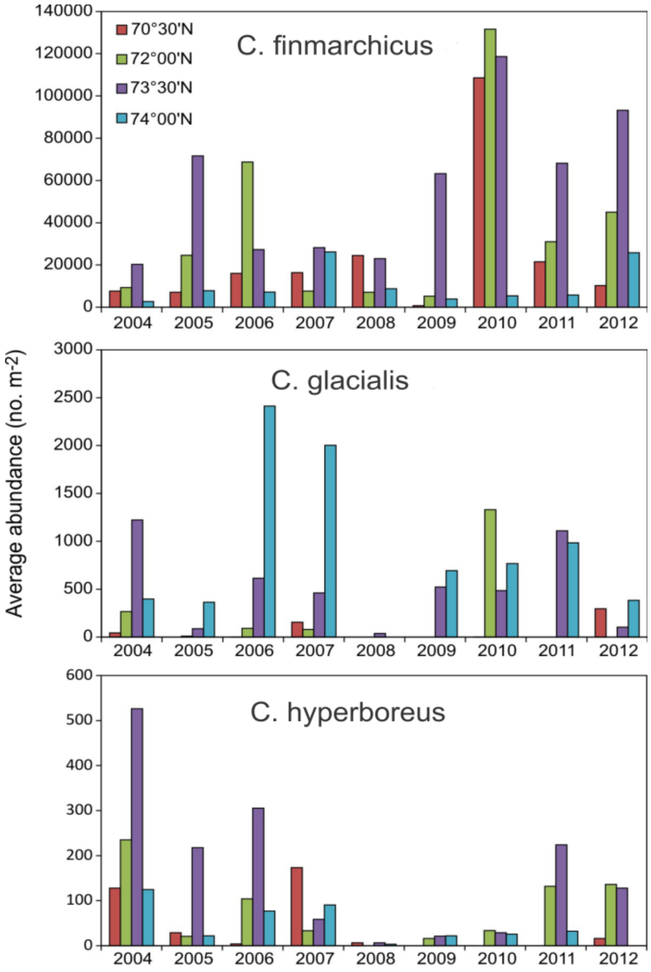

Figure 4.3.9. Calanus abundance along the transect Fugløya-Bear Island during the period 2004 - 2012. On a few occasions, when stations were lacking at a particular position, stations closest to that position were analyzed.

4.3.2.2. Macrozooplankton

Samples were collected by PINRO in the Barents Sea during the 2011-2012 autumn bottom-trawl survey to estimate pre-winter euphausiid assemblages. During 2012, further decrease in the abundance of euphausiids was recorded in some areas; at the same time their abundance increased in other areas. However, euphausiid abundance generally remained above the long-term mean in all areas of the Barents Sea (Figure 4.3.10).

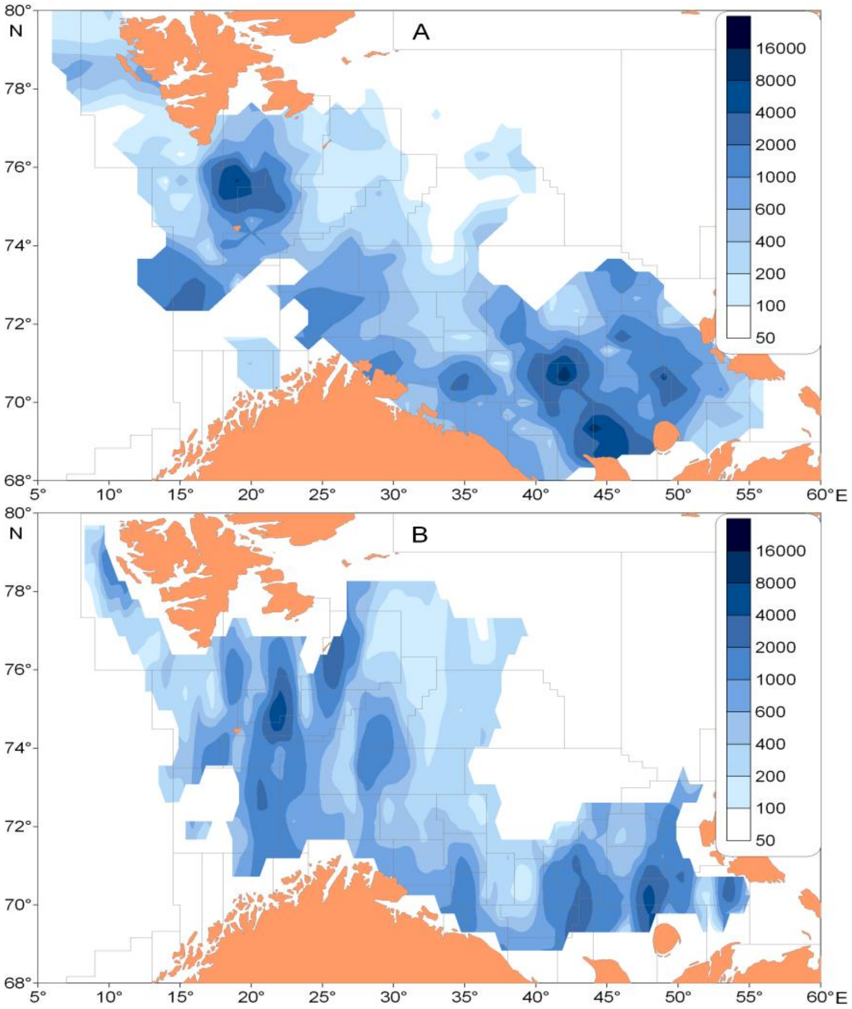

Figure 4.3.10. Distribution and abundance (ind. · 1000 m^{-3}) of euphausiids in the near-bottom layer during autumn 2011 (A) and 2012 (B).

Decreased total biomass in some local areas is indicative of the sharp decline in abundance in the eastern Barents Sea (Figure 4.3.11). The most prominent development in 2012, however, was a sharp increase in abundance of two boreal spceies, i.e., *Thysanoessa inermis* (by a factor of 7 in the northwest and by a factor of 3 in the east) and *Meganyctiphanes norvegica* (by a factor of 4 in the northwest and coastal areas, and by a factor of 2.5 - 3 in the central and eastern Barents Sea) (Figure 4.3.12). Slightly increased abundance of the *T. raschii* was observed in all exept eastern areas. Whereas, abundance of *T. longicaudana* decreased almost throughout the area of investigation.

During 2012, substantial recruitment of 0+ age group individuals was observed for: *T. inermis* (in all the areas); *M. norvegica* and *T. longicaudana* (in northwestern and western areas); *T.*

raschii (in eastern areas). Substantial recruitment of 1+ age group *T. inermis*, *T. Raschii*, and *M. norvegica* was observed in all areas.

Calanus helgolandicus, a more southerly species with a different spawning period during autumn, has regularly been observed in the Fugløya-Bjørnøya section, particularly during the period from December to February (Dalpadado *et al.*, 2012). This species is similar in appearance to *C. finmarchicus*; in recent years, it has been observed more frequently in the North Sea and southern parts of the Norwegian Sea (Svinøy transect). A report published in 2012, used the 1995-2011 data series to show intermittent high proportions of this species during winter within the Fugløya-Børnøya transect. During this same winter period, however, *C. finmarchicus* is normally inactive as it overwinters in deeper waters. There is no evidence of an increase in the relative proportion *C. helgolandicus* during this time period, which suggests that this species has not increased in absolute abundance at the entrance to the Barents Sea.

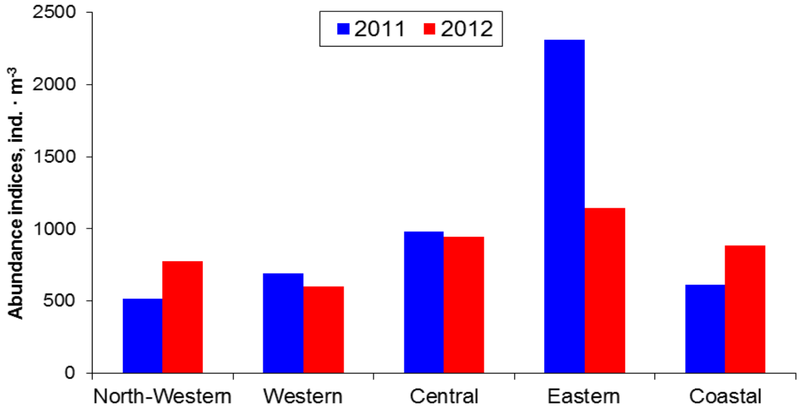

Figure 4.3.11. Mean abundance indices (ind. · 1000 m^{-3}) of euphausiids in North-Western, Western, Central, Eastern, and Coastal areas of the Barents Sea during autumn 2011 and 2012 (based on Russian trawl-net sampling data).

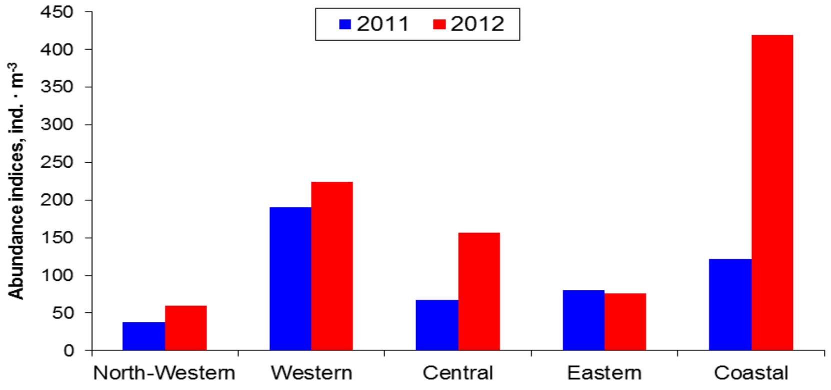

Figure 4.3.12. Mean abundance indices ind. · 1000 m^{-3}) of *Meganyctiphanes norvegica* in North-Western, Western, Central, Eastern, and Coastal areas of the Barents Sea.

4.3.2.3 Gelatinous zooplankton

Figure 4.3.13 shows the distribution of gelatinous zooplankton taken in pelagic trawls during 2012 and 2013. Estimated abundance of large gelatinous zooplankton was higher in 2013 than in 2012. The center of distribution and highest abundance was located in the central to south-western part of the Barents Sea in 2013; a quite typical pattern consistent with observations from 2008 until present. During this period, occurrence of “jellyfish” has overlapped significantly with regions of low mesozooplankton biomass. In 2013, the average gelatinous zooplankton biomass was 34.41 kg·trawldistance^{-1} near twice the average estimated for 2011 (18.6 kg·trawl distance^{-1}). It is interesting to note that mesozooplankton biomass in 2013 was the lowest recorded since 1992, which may suggest a predator-prey relationship between these two groups of plankton. The data should however be interpreted with caution since many smaller "jellyfish" species are not sampled adequately with the method currently used.

The majority of hauls taken were standardized stepwise at 40-20-0m depth intervals, but a few were taken at greater depths. The catches were adjusted for length of trawling time.

It is assumed that results mainly reflect the occurrence of larger Scyphozoan medusa as in the genus *Aurelia* and *Cyanea*. The occurrence and proportion of Ctenophora ("comb-jellies") cannot be verified; they are largely absent due to rates of escapement and rough treatment in the trawl. Proper taxonomic classification is also an issue. Both *Ctenophora* and smaller "jellyfish" are however caught in the WP2 net, but this gear type has limitations due to the small volume sampled. Initial trials using a larger vertically operated WP3 net (UNESCO, 1968) have been initiated, and will likely be used in the future.

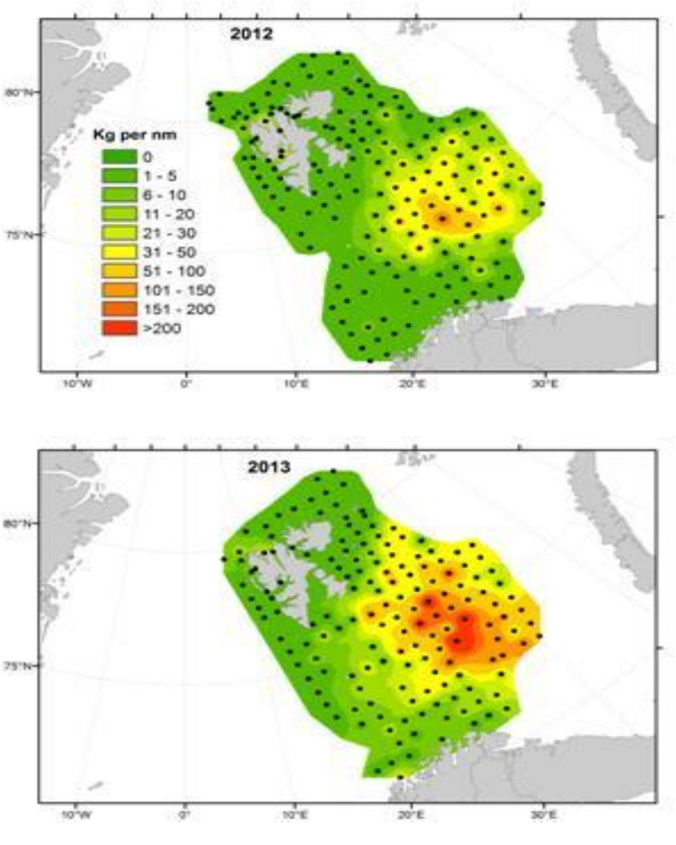

Figure 4.3.13. Distribution of gelatinous zooplankton based on pelagic Harstad trawl catches in 2012 and 2013. Numbers are standardized to kg·trawl distance^{-1}.

4.3.2.4 Expected situation

In retrospect, there was considerable decline in abundance of euphausiids in the southern Barents Sea during 2009-2010, 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. From 2011 to 2012 there has been a consistent increase in *Meganyctiphanes norvegica* in the western-, central and coastal areas, while *Thysanoessa inermis* account for most of the increase in the northwestern area. Hence, it is likely that during 2013-2014, advection and population abundance for *M. norvegica* — an Atlantic warmth-loving euphausiid species — will remain at a levels comparable to those observed during 2012. A similar pattern is predicted for the *T. inermis* population. The short term prediction for water temperatures in the Kola section is a slight decrease during 2014, which may help maintain a reasonable population level for arcto-boreal *T. raschii* in eastern areas — as this species seems to prefer shallow shelf regions and colder, less saline coastal water.

The long-term general warming trend, and further decrease in the extent of winter sea ice, will continue to facilitate expansion of warm-water species towards northern and eastern regions of the Barents Sea. Evidence of this expansion is seen in finding considerable amounts of euphausiids in the stomach contents 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 recent years. Recent findings of juvenile euphausiids north of 78ºN, and the regular occurrence of high krill biomass in north-west and south-east regions of the Barents Sea, support the belief that krill are expanding their range of in the Barents Sea, either due to local recruitment (*T. inermis* and *Thysanoessa raschii*), or due to the intrusion of Atlantic water masses and the invection of more southerly species (*M. norvegica, Thysanoessa longicaudata* and *Nematocelis megalops*). The increasing occurrence of more Atlantic krill species during the last 10 years illustrates their expansion northward into the Barents Sea. It is less certain, however, just how these species will interact with other more firmly-established species, and whether they will be able to reproduce successfully and complete their life cycles in the new areas they populate.

The current below-average level of mesozooplankton biomass in the Barents Sea is probably linked to high capelin biomass. Other plankton consumers such as 0-group herring, cod, haddock, and redfish also have an important influence on zooplankton biomass. This was likely the case during 2013 when 0-group cod, herring, and haddock all had strong year classes; whereas capelin year-class size was closer to the long-term average. Total biomass of the four most abundant 0-group fish stocks (cod, haddock, herring, and capelin) reached 2.7 million metric tons. Capelin biomass alone was estimated to be 3.9 million metric tons during August-September 2013. It follows that predation pressure on zooplankton from numerous 0-group plankton consumers was considerable during autumn 2013. It is possible that conditions for lower-trophic-level production were 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, such as medusa (jellyfish) and ctenophores (comb jellies) are also believed to be important predators on mesozooplankton in the Barents Sea, but their influence is difficult to assess quantitatively. It should be noted, however, that the low mesozooplankton abundance in the central Barents Sea during August-September to a large extent coincided with high abundance of gelatinous zooplankton; this has been observed each year from 2010 to 2013, but was particularly evident during 2013. How this may link to the distribution of capelin and its consumption of mesozooplankton is not known. Gelatinous zooplankton and capelin may prefer different size spectra of zooplankton and fish larvae as prey items. If so, their diet overlap would be smaller, and their impact on each other as competitors may be smaller. Nonetheless, for gelatinous zooplankton in the Barents Sea, there is limited information on their preferred prey or the size spectrum of organisms they prey upon. Also of note, there are a range of carnivorous zooplankton competing with pelagic fish and jellyfish to prey on the basically herbivorous mesozooplankton. Their impact is largely uncertain, but the samples from the Norwegian WP2 >2000 um size fraction during 2013 (not shown) could be useful to help indicate the biomass of this carnivorous component. Current biomass of this size fraction is the lowest in the 1988-2012 time series, most likely due to high predation from pelagic fish, poor recruitment, or unfavorable feeding conditions, i.e., low availability of preferred prey.

Based on our current understanding of hydrographic conditions and long-term dynamics of zooplankton development, we expect spawning of copepods and euphausiids to begin in mid April in the south-western areas of the Barents Sea. Having overwintered, these groups of crustaceans, along with the warm-water species which have been transported from the Norwegian Sea, will create a zone with high density of zooplankton in north-western and western parts of the Barents Sea. In recent years a region with elevated zooplankton biomass, extending north- and southward, has been observed west of Novaja Zemlja in the Russian sector. This region had high mesozooplankton biomass during 2009-2011, albeit these levels were lower than observed during 2008. Levels again increased in 2013. This seems to be an area where herbivorous zooplankton (in certain situations or during certain years) are able to sustain viable populations and avoid excessive predation during summer and autumn, making it an important area for overwintering and re-establishing the population the following spring.

The high biomass of mesozooplankton found south to south-east of Franz Josef Land in 2009 and 2010 appears to have been reduced by 2011. During 2013, however, this region regained its high biomass, extending beyond what has been observed earlier. This was caused, in part, by an extended area of survey coverage in 2013. This area partially overlaps with distributions of capelin and polar cod in the north-eastern part of the Barents Sea, suggesting that predation from these two species on zooplankton could be large. At the time of the 2013 survey, however, 2013 the effect of such predation seemed insignificant. Relatively low zooplankton biomass in central parts of the Barents Sea appears to be a recurring phenomenon. This may result from heavy predation by capelin stock and other key 0-group fish species; gelatinous zooplankton could also be important predators. Since the central Barents Sea is among the more shallow regions, mesozooplankton there have limited potential to reduce predation through vertical migration to deeper waters.

During 2013, low average mesozooplankton biomass in the central Barents Sea, the large and widely dispersed capelin stock and the additional predation from polar cod, suggests that survival and overwintering success of mesozooplankton like *Calanus* spp. will be low compared to the previous couple of years. However, import of zooplankton from the west and favorable production conditions during spring and summer 2014 could compensate for the loss of mesozooplankton from predation. Therefore, it is expected that mesozooplankton biomass in 2014 would continue to be below the long-term average, although regionally higher biomass/production could be expected as also suggested above, including areas in the western Barents Sea and the eastern edge of the Svalbard archipelago to Franz Josef Land and beyond.

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4.3.5 Fish

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4.3.5.1 Cod (*Gadus morhua*)

Based on 2013 estimates of SSB (Figure 4.3.14), ICES classifies the Barents Sea cod stock as having full reproductive capacity and being harvested sustainably. Estimated SSB has been above B_{pa} since 2002 and is now at a record high level, while total stock biomass is at a level not seen since the early 1950s. The present stock is dominated by large individuals from the very abundant 2004-2006 year classes.

Among fish species, cod is the most important predator in the Barents Sea. It feeds on a wide variety of prey, including: larger zooplankton; most available fish species, as well as juvenile cod; and shrimp. Capelin is a preferred forage fish for cod. Diet analyses indicate that the main prey items for cod in 2012-2013 were capelin, juvenile cod, shrimp, euphausiids (krill), amphipods, and haddock. Estimated total annual consumption by cod (age 1 and older) in 2012-2013 was 6-7 million metric tons.

The geographic distribution of this stock is expanding to the north and east (Figure 4.3.15). This is related to high temperatures observed in the Barents Sea during recent years as well as increased abundance.

4.3.5.2 Haddock (*Melanogrammus aeglefinus*)

Based on 2013 estimates of SSB (Figure 4.3.16), ICES classifies the Northeast Arctic haddock stock as having full reproductive capacity, but also in danger of being harvested unsustainably. Fishing mortality has fluctuated around F_{MSY} (0.35) over the last 10 years, but has increased considerably since 2010 and is now above F_{pa}. The very strong 2004-2006 year classes were recruited to the fishable stock in 2008-2010, and in 2010-2011 the stock reached the highest level observed in the 1950-2013 time series. The 2007 and later year classes appear to be of average size, nevertheless the stock now appears to be decreasing. The 2013 year class appeared to be well above average during the first year of life, but mortality in the coming years can be very high due to the high abundance of predators (particularly Northeast Arctic (NEA) cod) in the Barents Sea. Agreed-upon TACs for haddock during 2012 and 2013 were 318,000 and 200,000 metric tons, respectively.

During summer, much of the Barents Sea haddock stock is widely distributed in shallow waters to the north along the Svalbard/Spitsbergen Archipelago and to the east along the Murman Coast (Figure 4.3.17). During this same period, a significant portion of the stock is located in the central part of the sea.

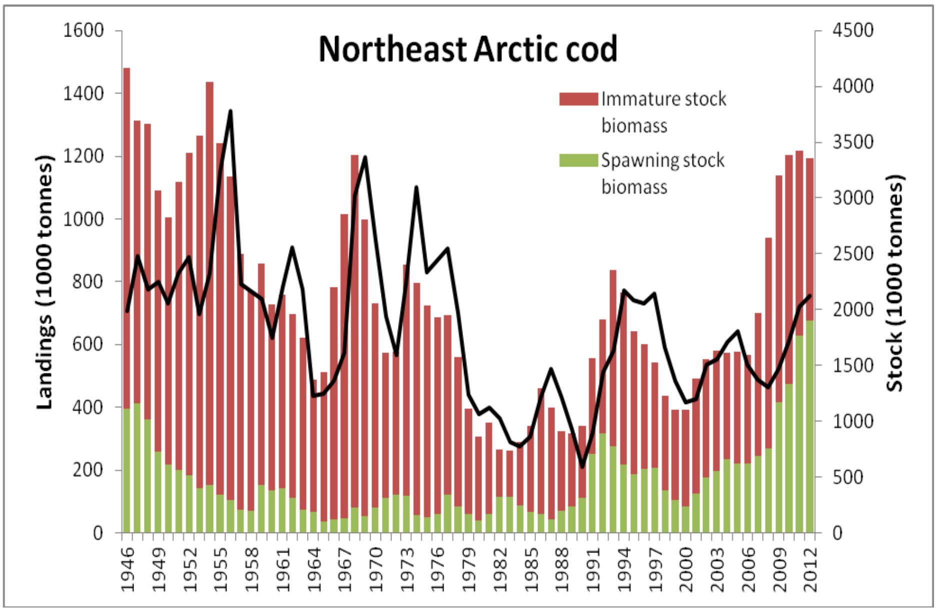


Figure 4.3.14. Northeast Arctic cod, development of spawning stock biomass (green bars), immature stock biomass (age 3 and older, red bars), and landings (black curve).

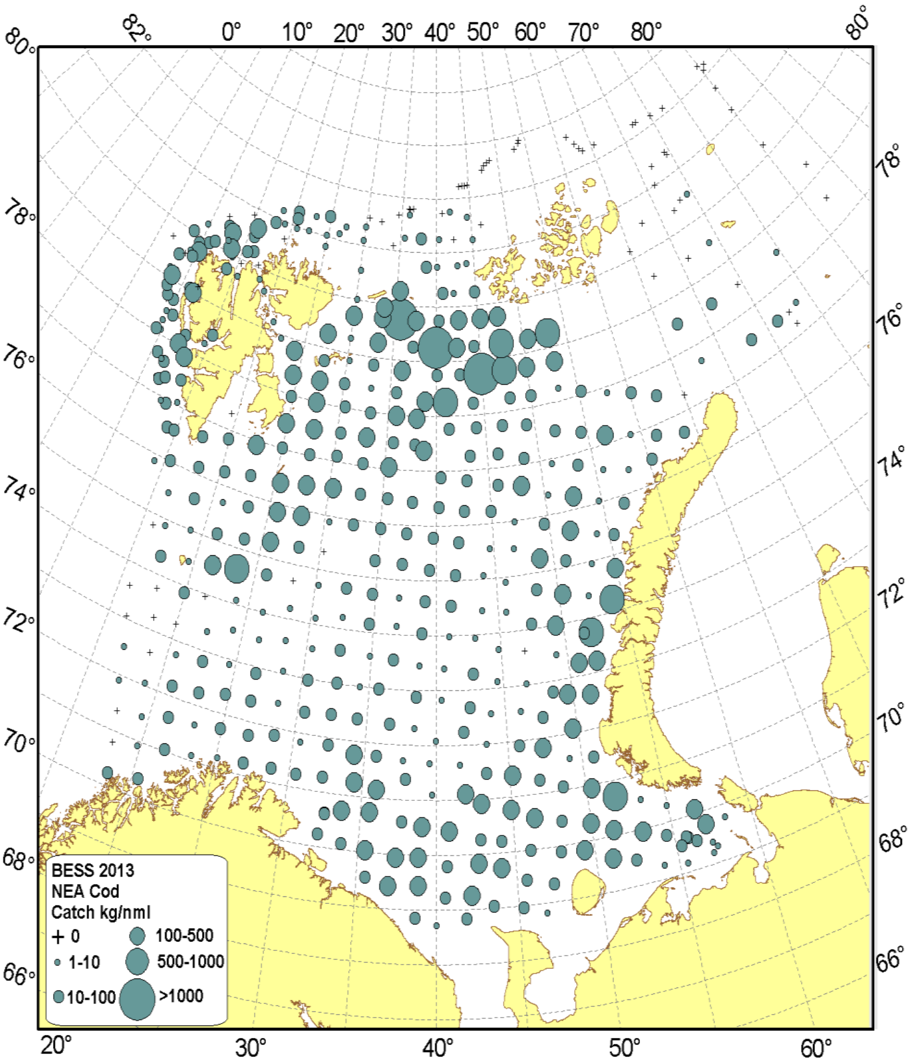


Figure 4.3.15. Distribution of Northeast Arctic cod, August-October 2013.

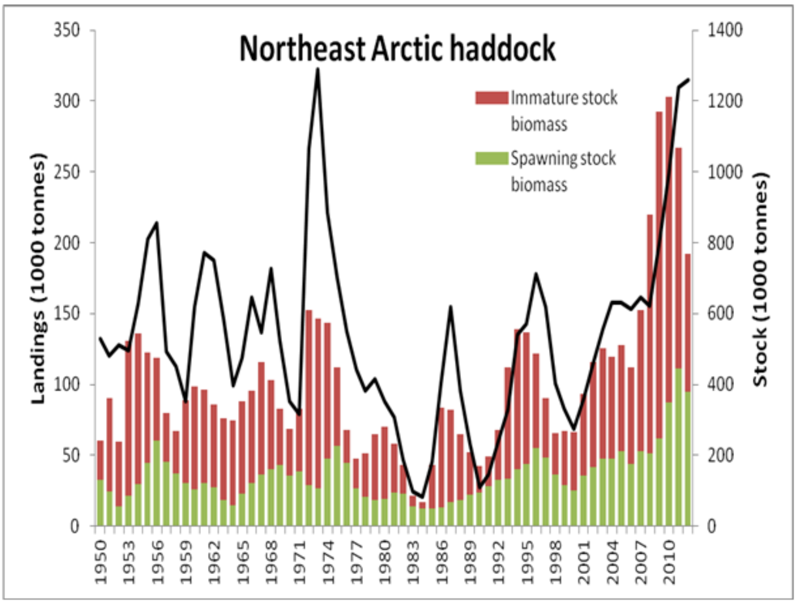


Figure 4.3.16. Northeast Arctic haddock, development of spawning stock biomass (green bars), immature stock biomass (age 3 and older, red bars) and landings (black curve).

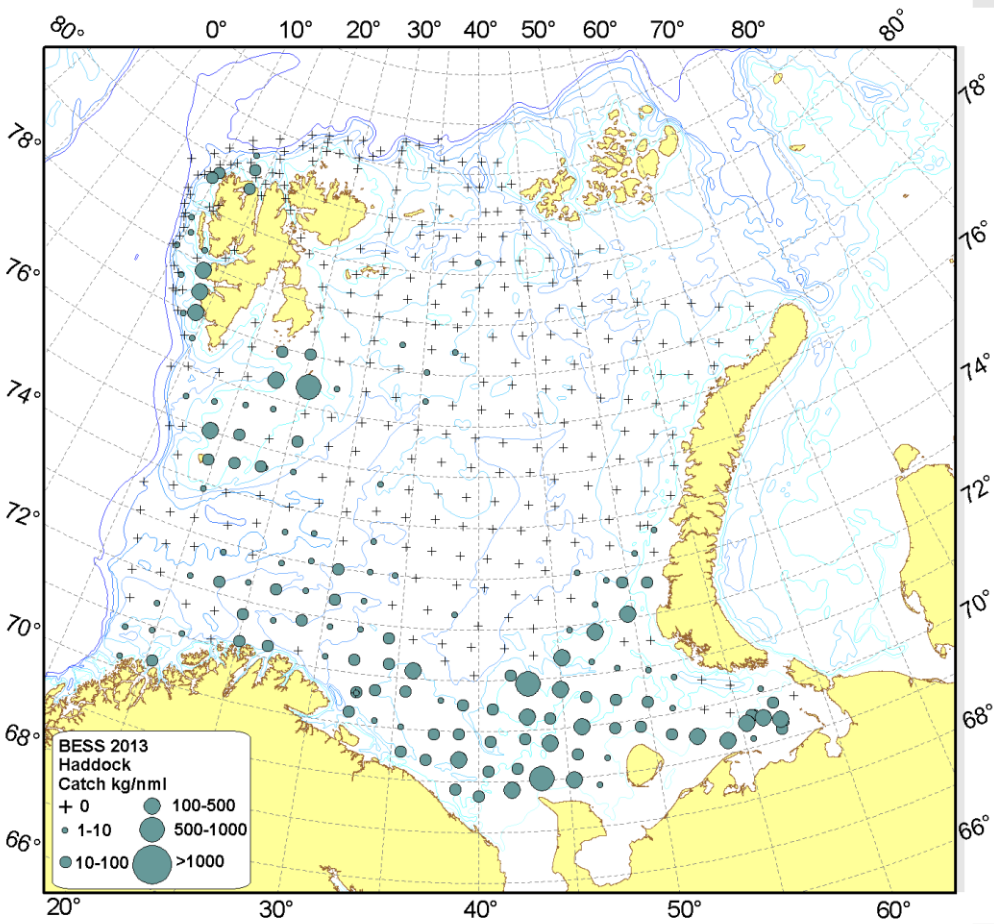


Figure 4.3.17. Distribution of Northeast Arctic haddock, August-October 2013.

4.3.5.3 Redfish (Sebastes mentella and Sebastes marinus)

Deep-Sea (or Beaked) Redfish (Sebastes mentella)

Available data indicate recruitment failure for Barents Sea deep-sea redfish (Figure 4.3.18). However, signs of improved recruitment are now apparent in the Barents Sea.

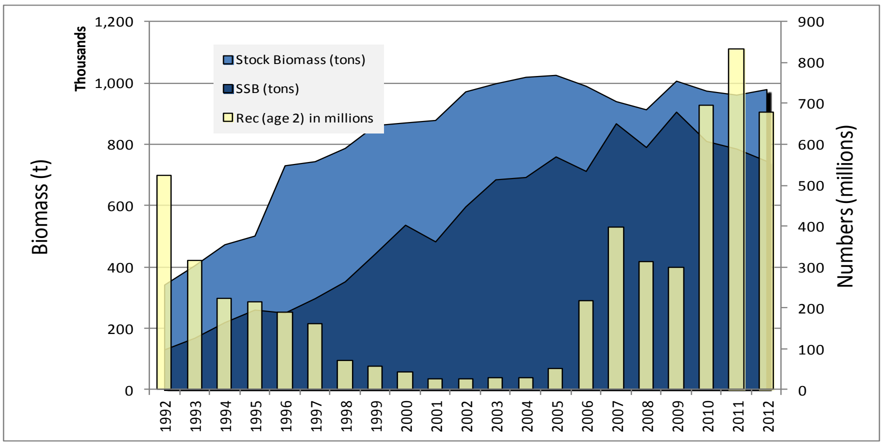


Figure 4.3.18. Results from the statistical catch-at-age model showing the development of total biomass ('000s), spawning stock biomass and recruitment at age 2 for the period 1992-2012, for *S. mentella* in subareas I and II.

For this reason, it is important that juvenile age groups are given the strongest protection from being taken as bycatch in any fishery, e.g., shrimp fisheries in the Barents Sea and Svalbard area, where significant numbers of juvenile fish are usually distributed (Figure 4.3.19).

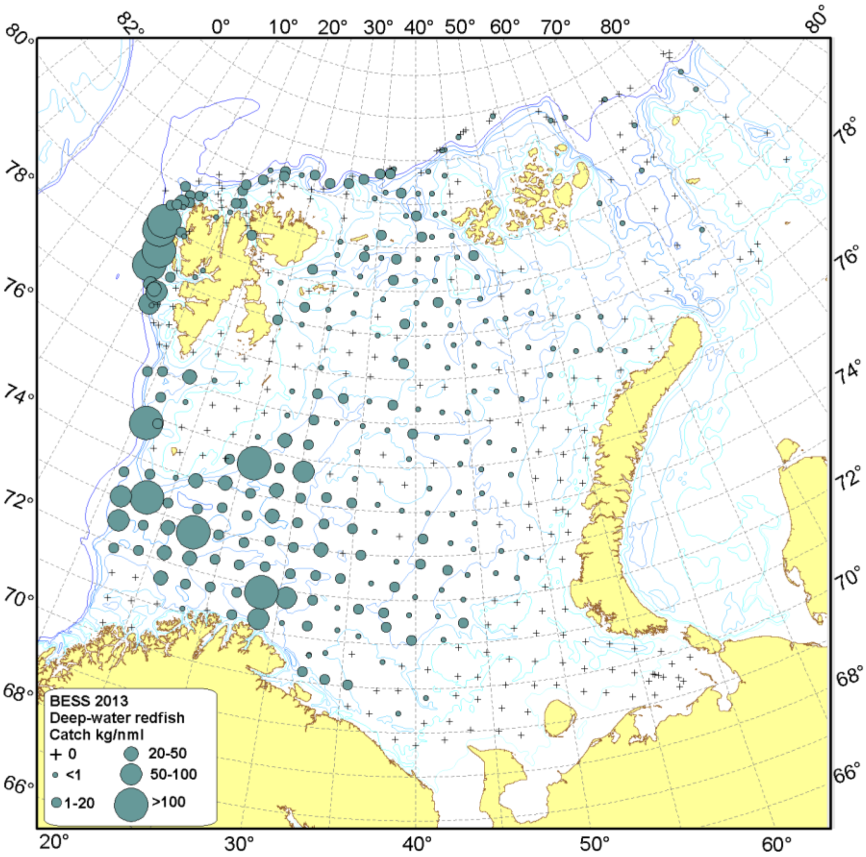


Figure 4.3.19. Distribution of deep-water redfish in August-October 2013.

This will ensure that recruiting year classes are able to contribute strongly to stock rebuilding. Year classes prior to 1995 have the best potential to contribute to the spawning stock in the coming years, as subsequent year classes (1996-2003) are extremely poor. These year classes need to be protected as they offer the opportunity to increase spawning stock size in years to come. Several years of protection to ensure growth of these year-classes may already have caused the higher levels of abundance and density recently observed along the continental slope and in pelagic waters of the Norwegian Sea.

A directed pelagic fishery for deep-sea redfish in international waters of the Norwegian Sea has developed since 2004. The size of this fishery increased to record levels in 2006, and the total catch in 2006 was 33,000 metric tons, the highest level since 1991. Total 2012 landings from demersal and pelagic catches of this species in ICES Subareas I and II amounted to 11,000 metric tons; 2013 landings were at a similar 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 provide advice on catch levels; the advice for 2014 is 24,000 metric tons.

Golden Redfish (Sebastes marinus)

In the absence of defined reference points, status of the golden redfish stock cannot be fully evaluated. The assessment indicates a substantial reduction in abundance and that the present stock level is at an historic low. During the last decade, year classes have been very weak. Presently, this stock is in very poor condition, and spawning stock biomass (SSB) is less than 20,000 metric tons (Figure 4.3.20). Given the low productivity of this species, this situation is expected to remain for a considerable period of time.

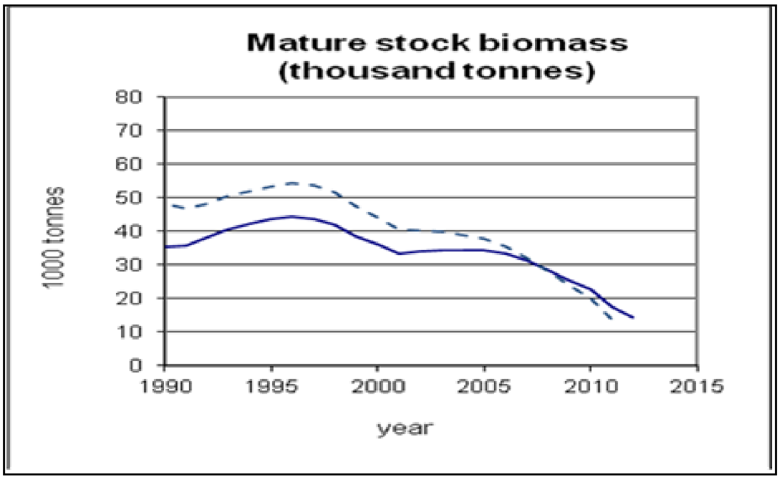


Figure 4.3.20. *Sebastes marinus*. Mature stock biomass (in thousands of metric tons). Bold line = 2013 assessment, dotted line = 2012 assessment.

Imprudently, golden redfish continue to be harvested in a directed fishery. Hence, more stringent protective measures should be implemented, such as: no directed fishing on this stock; extension of the limited moratorium implemented; and further improvement of the trawl bycatch regulations. It is also important that juvenile age groups be given strong protection from being taken as bycatch in any fishery, e.g. the shrimp fisheries in coastal and Svalbard area, and pelagic trawl fisheries for herring and blue whiting in the Norwegian Sea. This will ensure that recruiting year classes can help slow the decline of this stock. Stronger bycatch regulations and better bycatch statistics are needed to help prevent its continuation. During 2004-2010 levels of annual catch were around 7,000 metric tons; during 2011-2012 annual catch declined to below 6,000 metric tons. These catch levels further contribute to the decline of this stock.

4.3.5.4 Greenland halibut (*Reinhardtius hippoglossoides*)

Greenland halibut are widely distributed in the Barents Sea. Catches are highest along the continental slope where the main spawning grounds are located (Figure 4.3.21). The northern and north-eastern areas of the sea serve as nursery area for the stock (Figure 4.3.22). Greenland halibut are also relatively abundant in deep channels running between the shallowest fishing banks.

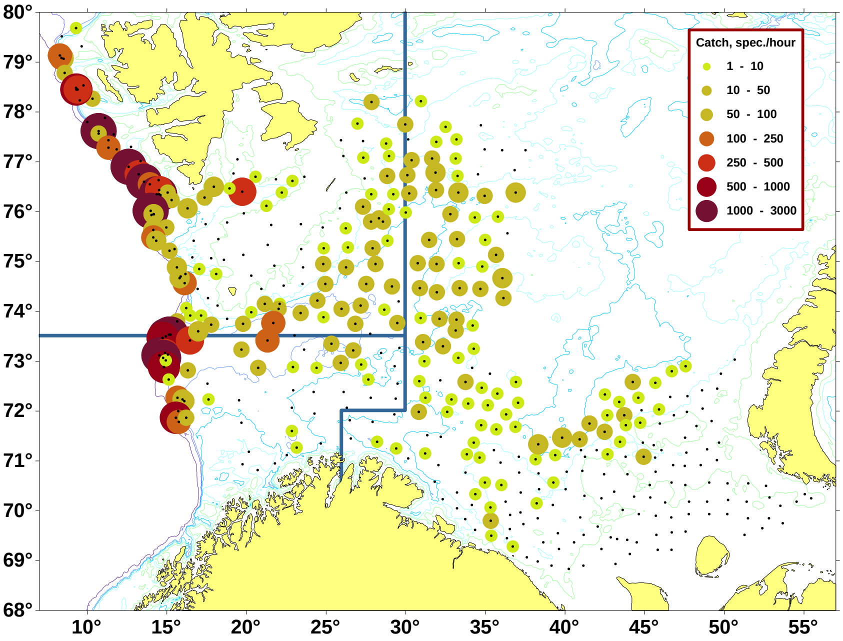


Figure 4.3.21. Greenland halibut distribution (specimens/trawling hour) in November-December 2012 based on the Russian survey.

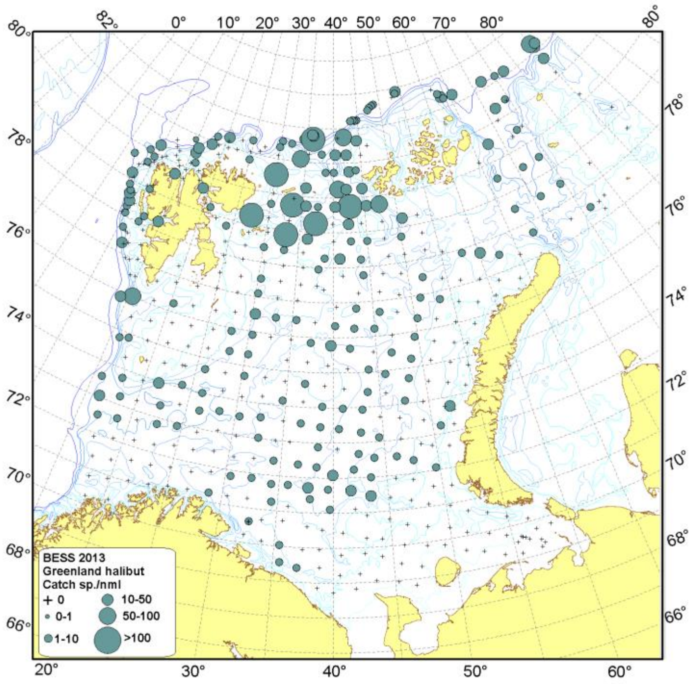


Figure 4.3.22. Greenland halibut distribution (specimens/nautical mile) during August-October 2013 based on the Joint Ecosystem Survey data.

In the absence of defined reference points and an accepted assessment, the status of the Barents Sea Greenland halibut stock cannot be fully evaluated. The stock has been at a low to intermediate level for several years and it is a long-lived species that can only sustain a low level of exploitation. Indications from fishery-independent surveys are that the stock may have increased in recent years, although results from different surveys are conflicting (Figure 4.3.23). No assessment has been accepted for this stock mainly due to age-reading problems and discrepancies between different data sources.

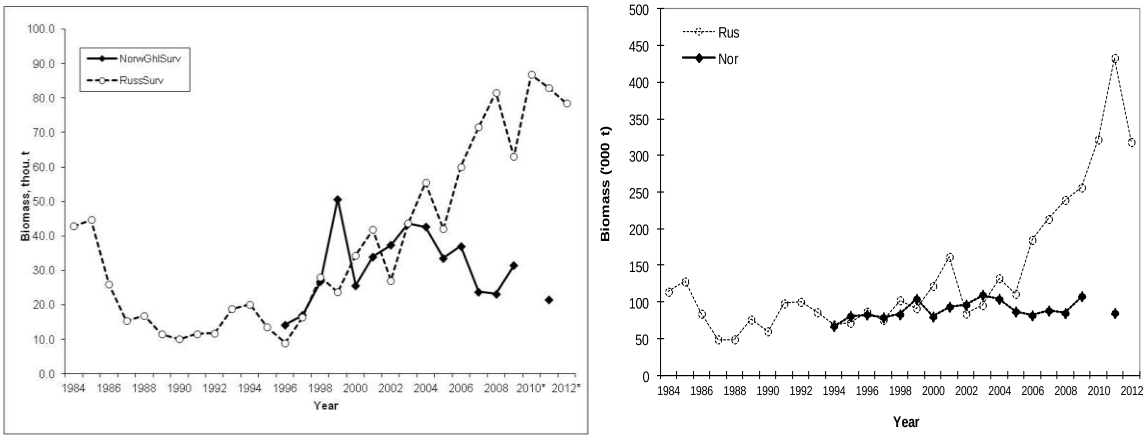


Figure 4.3.23. Northeast Arctic Greenland halibut. Left: Biomass (swept area) estimate of the mature female biomass (Norwegian Greenland halibut survey along the continental slope in August and Russian autumn trawl survey). Right: Total biomass estimates from the Norwegian Greenland halibut survey along the continental slope in August and Russian autumn trawl survey. No Norwegian survey was conducted in 2010 or 2012.

4.3.5.5. Wolffish *(Anarhichas spp.)*

Three species of wolffish: Atlantic wolffish (*Anarhichas lupus*), spotted wolffish (*Anarhichas minor*), and Northern wolffish (*Anarhichas denticulatus*) occur in the Barents Sea. Both abundance and biomass of these species is relatively small (Figure 4.3.24), but they are widely distributed.

Stock sizes for both Atlantic wolffish and spotted wolffish have been relatively stable since 2004. The size of the Northern wolffish stock has varied between 35,000 and 90,000 metric tons. Swept-area estimates of stock size were based on Joint Ecosystem Survey data.

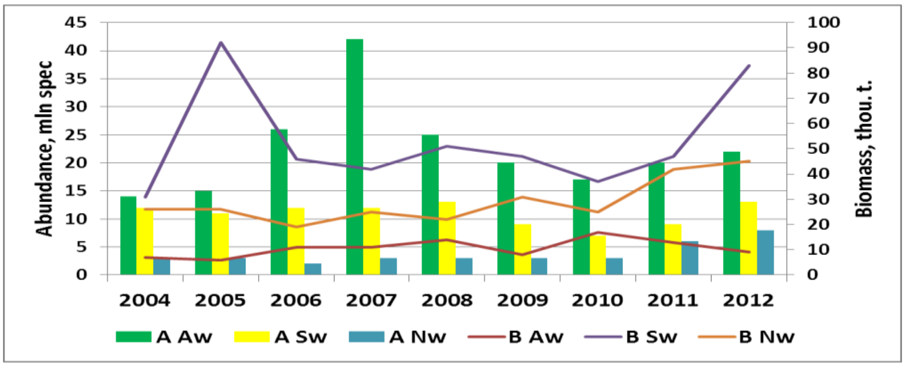


Figure 4.3.24. Stock abundance (A) and stock biomass (B) of Atlantic wolffish (Aw), spotted wolffish (Sw), and Northern wolffish (Nw) during ecosystem survey 2004-2012, calculated using bottom trawl estimates (swept area).

4.3.5.6 Capelin (*Mallotus villosus*)

The Barents Sea capelin stock size has been stable since 2008 (Figure 4.3.25). Based on 2013 estimates of SSB and recruitment, ICES classifies the Barents Sea capelin stock as having full reproductive capacity. During autumn 2013, the maturing component of the stock (individuals >14cm in length) was estimated to be 1.5 million metric tons, and 2014 SSB was predicted to be 0.4 million metric tons. The 2014 spawning stock will consist of individuals from the 2010 and 2011 year classes; but the 2010 year class is expected to be dominant. Estimated abundance of age-1 (2012 year class) capelin is above the long-term average. Observations during the international 0-group survey during August-September 2013 indicate that the 2013 year class size is average. The estimated annual consumption of capelin by cod has varied between 0.2 and 4.1 million metric tons over the period 1984-2012. Young herring also consume capelin larvae; this predation pressure is thought to be one of the causes for poor capelin year-class sizes during the periods: 1984-1986; 1992-1994; and 2002-2005.

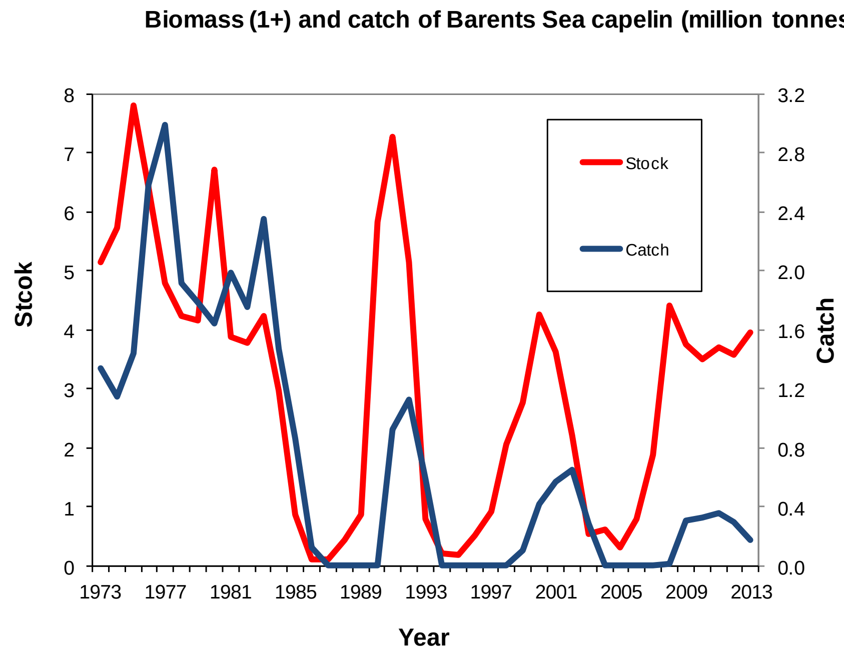


Figure 4.3.25. Barents Sea capelin. Total stock (1+) and total landings, 1973–2013.

4.3.5.7 Herring (*Clupea harengus*)

Based on 2013 estimates of SSB and fishing mortality, ICES classifies the Norwegian spring-spawning herring stock as having full reproductive capacity and being harvested sustainably. The 2002 and 2004 year classes dominate the current spawning stock that was estimated to be 5 million metric tons in 2013.

In recent years, the amount of young herring entering the Barents Sea has been low. The total abundance of herring aged 1-4 years in 2013 covered during the survey in the Barents Sea was estimated at 12.8 billion individuals (about 3 times higher than in 2012). The biomass of 0.5 million tonnes is about 80% higher than in 2012. This stock has shown a large dependency on appearance of very strong year classes (Figure 4.3.26). The 2005-2012 year classes were all below average, while the 2013 year class is approximately average. In 2014 the abundance of herring in the Barents Sea is believed to be at an intermediate level.

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 role in the Barents Sea ecosystem.

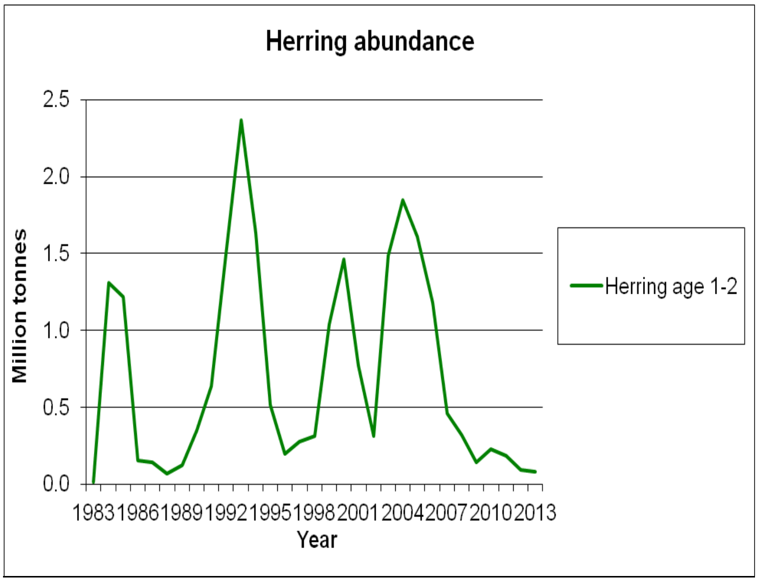


Figure 4.3.26. Abundance of age 1 and 2 Norwegian Spring-spawning herring (calculated by Virtual Population Analysis). This is a good indication of the abundance of young herring in the Barents Sea.

4.3.5.8 Polar cod (*Boreogadus saida*)

The Barents Sea polar cod stock is presently at a low level (Figure 4.3.27). Norway conducted commercial fisheries for polar cod during the 1970s, and Russia has fished this stock on more-or-less 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 stock dynamics. Stock size has been measured acoustically since 1986, and has fluctuated between 0.1-1.9 million metric tons. In 2013, stock size was estimated to be 0.5 million metric tons, which is approximately the same as estimated in 2012. The rate of natural mortality for this stock appears to be quite high. This is related to the importance of polar cod as prey for cod and different stocks of seals.

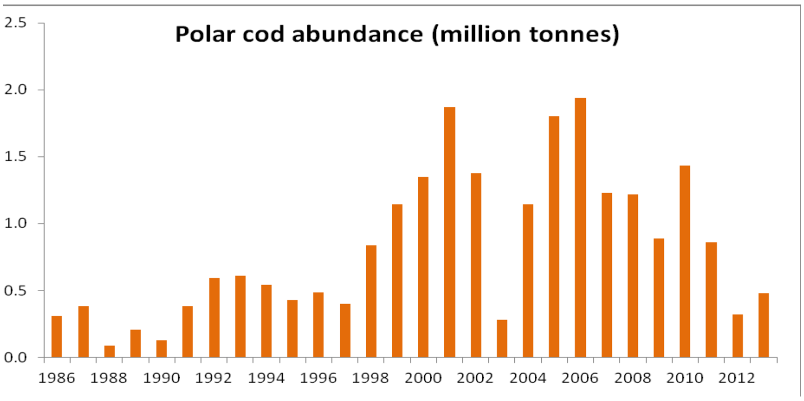


Figure 4.3.27. Polar cod stock size estimates obtained by acoustics, 1986–2013. Note: Survey coverage for polar cod was partial during 2003, and is suspected to have resulted in an unrealistically low estimate.

4.3.5.9 Blue whiting (*Micromestisius poutassou*)

Based on 2013 estimates of fishing mortality and SSB, ICES classifies the stock of blue whiting as having full reproductive capacity, and being harvested sustainably. Estimated SSB increased to an historic high in 2003, and then decreased; the stock now shows a trend of increase. Total landings in 2012 were 384,000 metric tons. The TAC for 2013 was set at

643,000 metric tons; the TAC advice for 2014 is 949,000 metric tons. Blue whiting is not fished in the Barents Sea; this ICES TAC advice applies to the Norwegian Sea and waters extending southward to Portugal.

The high abundance of blue whiting in the Barents Sea during 2004-2007 (Figure 4.3.28) may be due to increased temperature and high recruitment. Blue whiting has been observed in the western and southern Barents Sea for many years, but never in such high quantities, and never as far into eastern and northern parts of the sea as in 2004-2007. Abundance then decreased to very low levels during 2008-2011, but again increased in 2012 after the appearance of the strong 2011 year class. The estimated biomass of blue whiting in the Barents Sea in 2013 was the same as in 2012 (0.4 million metric tons) but was at a low level compared to 2004-2007. During autumn 2013, blue whiting was distributed in the western part of the Barents Sea and to the west of Svalbard/Spitsbergen, and extended eastwards to 30˚E. Most individuals observed in the Barents Sea during 2013 were 2 years of age.

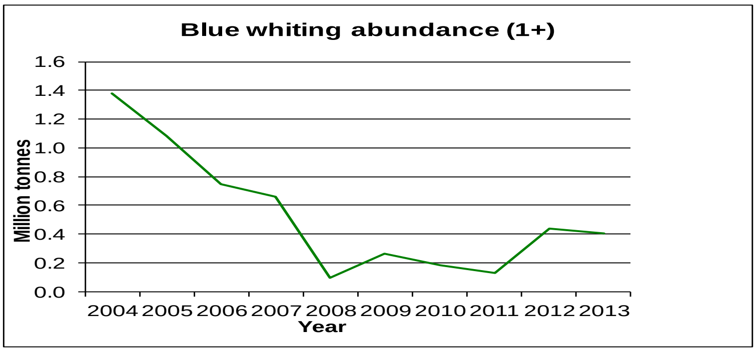


Figure 4.3.28. Acoustic abundance estimates for blue whiting from the ecosystem survey autumn 2004-2013.

4.3.5.10 Saithe (*Pollachius virens*)

Northeast Arctic saithe are found primarily along the Norwegian coast from 62^{o}N to Cape Kanin; they do not extend far northward into the Barents Sea. The 2013 stock assessment for this stock was not accepted by ICES, but national advice was provided to Norwegian authorities by IMR. SSB has decreased in recent years, and fishing mortality has increased (Figure 4.3.29). The TAC for 2014 was set to 119,000 metric tons based on national advice, a 15% reduction from 2013. However, the entire 2013 TAC was not harvested.

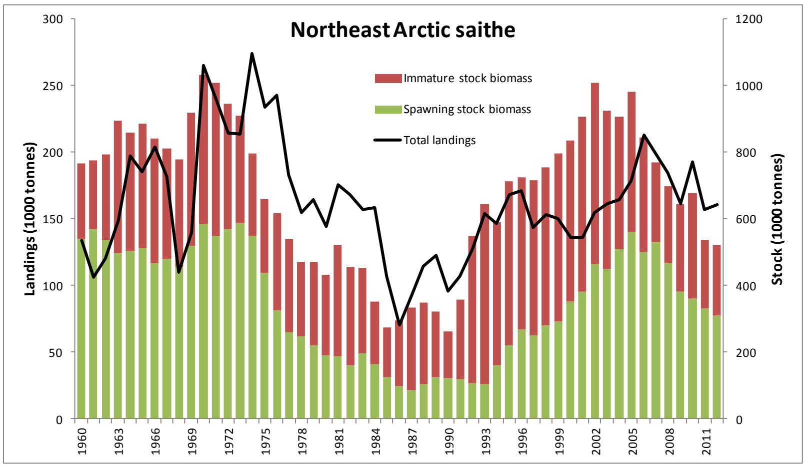


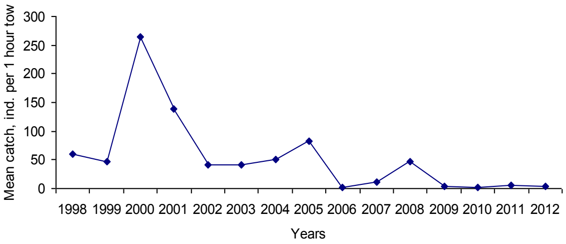
Figure 4.3.29. Northeast Arctic saithe, development of spawning stock biomass (green bars), immature stock biomass (age 3 and older, red bars) and landings (black curve).

4.3.5.11. Trends in the fish community of the Barents Sea

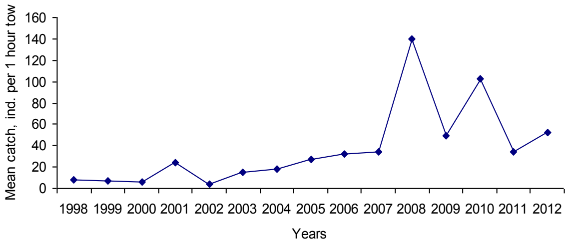
During the 1998-2012 warming period, distinct trends in abundance of fish species from different zoogeographic groups were observed (Figure 4.3.30).

Abundance of coldwater fish species (arctic, mainly arctic, and arcto-boreal groups) decreased during the period from 2000-2001 to 2012. Since 2010, however, slightly increased abundance of mainly Arctic and arcto-boreal groups has been observed.

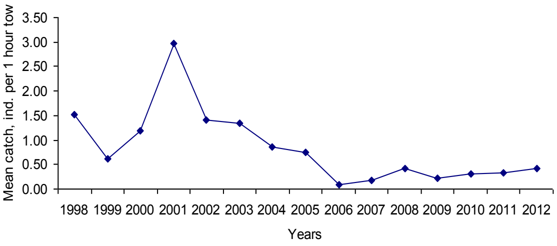
During this same period, the abundance of warm water species (boreal, mainly boreal, southern boreal, and widely distributed groups) had trends of increase. The highest abundance was observed during 2001-2004 and 2008-2010. Since 2006-2008, a clear trend of decrease has been observed for these groups.



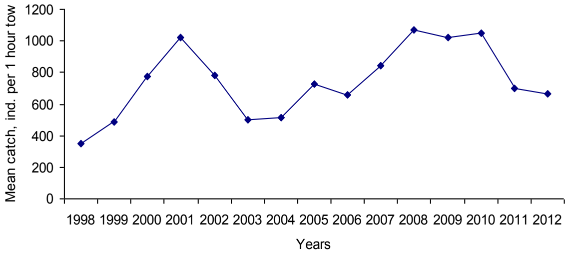
Arctic



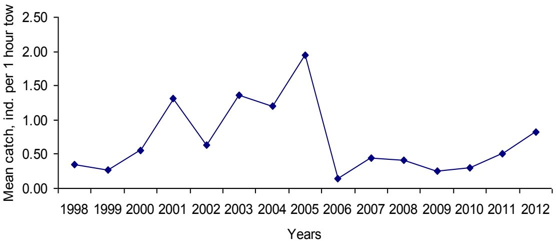
Boreal



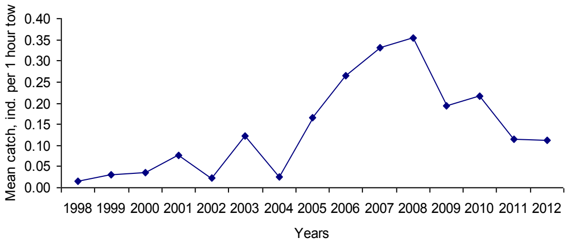
Mainly Arctic



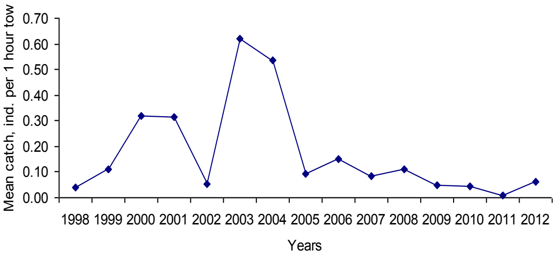
Mainly boreal



Arcto-boreal



Southern boreal



Widely distributed

Figure 4.3.30. Changes in abundance of fish species from different zoogeographic groups in the Barents Sea in 1998-2012 based on the data from Russian autumn-winter demersal survey in October-December

4.4 Human activities/impacts

4.4.1 Fisheries and other harvesting

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4.4.1.1 Fish

Due to substantial removals, fishing is the human activity that has the largest impact on fish stocks in the Barents Sea, and thereby on the functioning of the entire ecosystem. A fishery is not considered sustainable if it impairs recruitment potential of the stock. Single species management often focuses on measuring status of the fishery in relation to benchmarks called biological reference points (BRPs). BRPs for single species management are usually defined in terms of the fishing mortality rate (F) with target and limit reference points, and total- or spawning stock biomass (TSB or SSB). 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.

Fishery removals at the limit reference point for fishing mortality (F_{lim}) will eventually bring the spawning stock down to B_{lim}, below which recruitment will be impaired. Hence, F_{lim} may be used as an indicator for unsustainable exploitation representing a negative influence on both the stock and the ecosystem. Keeping F below F_{lim} and the stock above $B_{lim,}$ however, may not always be enough to ensure sustainable fisheries. Additional specific management actions may be required for each harvested stock.

In accordance with collective international guidelines, ICES aims to inform management decisions to ensure optimal yield from fisheries and maintain productive fish stocks within healthy marine ecosystems over an infinitely long period of time. The maximum sustainable yield (MSY) concept was recently implemented into ICES work, and MSY reference points have been identified and implemented into fishery management strategies for several stocks. As result, the fisheries advice provided by ICES integrates the precautionary approach, MSY, and an ecosystem approach under a single advisory framework.

In addition, 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 may result in a total yield that is less than it would be if individual fish were allowed to grow to an appropriate size. Introduction of minimum catch size and selective gears are the most common management measures to avoid growth overfishing.

The main demersal fish stocks harvested in the Barents Sea and adjacent waters (ICES areas I and II) include cod, haddock, and saithe. In addition, redfish, Greenland halibut, anglerfish, wolfish species, and flatfish species (e.g. long rough dab, plaice) are common on the shelf and at the continental slope; ling and tusk are found at the slope and in deeper waters. During 2012, approximately 1,300 thousand metric tons in total reported catch were removed from stocks of cod, haddock, saithe, redfish, Greenland halibut, and anglerfish. The total capelin catch in 2012 amounted to 296,000 metric tons. Species with relatively small landings include salmon, Atlantic halibut, hake, pollack (*Pollachius pollachius*), whiting, Norway pout, lumpsucker, argentines, grenadiers, flatfish, dogfish, and skates

The most commonly used gear in the Barents Sea is the bottom trawl, but also longlines and gillnets are used in demersal fisheries. The pelagic fisheries use purse seines and pelagic trawls. Other gears more common along the coast include hand-lines and Danish seines. Less frequently used gears are float-lines (used in a small directed fishery for haddock along the coast of Finnmark, Norway) and various pots and traps for fish and crabs. The gears used vary with time/season, area, and country. A variety of gear types are used in Norway to conduct coastal fisheries. Fishers from Russia commonly use bottom trawls, but a longline fishery largely directed at cod and wolffish is also conducted. Other countries fishing in the Barents Sea primarily use bottom trawls.

The Norwegian bottom trawl fleet accounts for about 30% of the Norwegian cod catch, about 40% of the haddock, and more than 40% of Norwegian saithe and Greenland halibut catches. The Russian bottom trawl fleet accounts for about 100% of the Russian saithe catch, about 95% of cod and haddock, 90% of the Russian Greenland halibut, and about 40% of wolfish catch. Other countries fishing groundfish in these waters use only trawls, including some pair-trawling.

For most exploited stocks, a TAC is agreed upon and a number of additional regulations are applied. Regulations differ among gear types and species targeted, and may vary between countries. Discarding is prohibited for fisheries conducted in the Barents Sea.

Northeast Arctic cod, haddock, and saithe

Annual landings of Northeast Arctic cod, haddock, and saithe for the Barents Sea are presented in Figures 4.3.14, 4.3.16 and 4.3.29 (Subchapter 4.3.5). The fishery for Northeast Arctic cod is conducted both by an international trawler fleet operating in offshore waters and by vessels using gillnets, longlines, handlines, and Danish seine operating in both offshore and coastal areas; 60-80% of annual landings are from trawlers. The regulated minimum catch size for cod is 44 cm, and the maximum proportion of undersized fish allowed is 15% of the number of cod, haddock, and saithe combined. Fisheries are controlled by inspections at sea, required reporting at catch control points when entering and leaving the EEZ, and by fish landings inspections for all commercial vessels. During 2002-2006, the rate of fishing mortality (F) ranged from 0.50 to 0.70, but decreased to 0.35 in 2007, and has remained below 0.30 since then. This F level is below that intended under the agreed management plan (0.40), but is within the range associated with high long-term yield and low risk of decreasing stock reproduction potential. For 2014, ICES advised the TAC of 993,000 metric tons as agreed in the management plan.

The haddock fishery is primarily conducted using trawl gear; haddock are also taken as bycatch in the cod fishery. In 2012, 30% of the total haddock catch was also taken using other conventional gear types, primarily longlines. The fishery is regulated through: a minimum landing size (40 cm), a minimum mesh size for trawls and Danish seines (130mm); a maximum bycatch of undersized fish (15% by number for cod, haddock, and saithe combined); closures of areas with high densities/catches of juveniles; and other seasonal and area restrictions. Historically, about half of the Russian haddock catch is taken within the Russian EEZ. In recent years, warming temperatures in the Barents Sea have influenced distribution the haddock stock, and thereby have influenced conditions to conduct this fishery. Since 2003, value of the haddock catch in Spitsbergen has increased; during 2010-2012 it peaked, and total haddock catch exceeded that from other areas of the Barents Sea.

Northeast Arctic saithe is mainly fished by Norway, accounting for more than 90% of total landings. Over the last ten years about 40% of the Norwegian catch has been taken using bottom trawls, 25% using purse seines, 20% using gill nets, and 15% using other conventional gears (longlines, Danish seines, and hand lines). The gill-net fishery is most intense during winter, purse seine during summer, while the trawl fishery takes place more evenly throughout the year.

Figure 4.4.1 shows annual fishing mortalities for gadoid stocks (Northeast Arctic cod, haddock, and saithe) relative to the critical exploitation level $F_{lim.}$

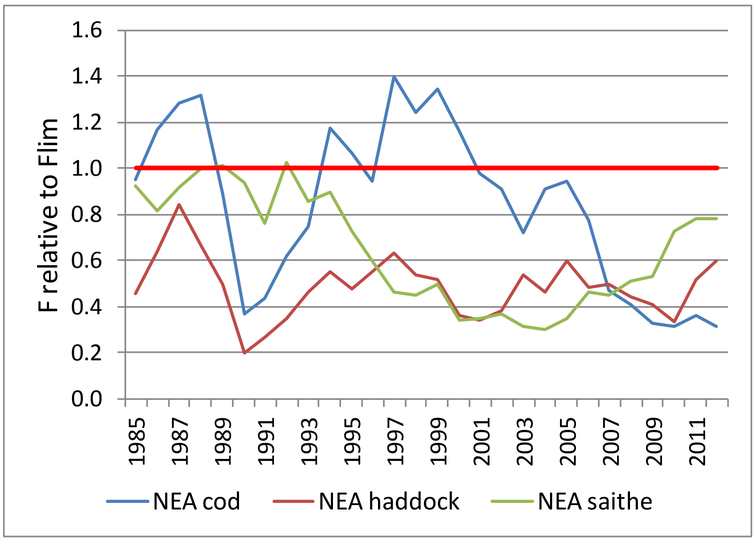

Figure 4.4.1. Annual fishing mortalities of Northeast Arctic cod, haddock, and saithe stocks relative to the limit fishing mortality reference point (F_{lim}) above which exceeds fishing at the precautionary level (F_{pa}), and may impair recruitment (ICES 2013).

Since 1985, exploitation rates have been critically high during some periods, particularly for cod; the rate was also very high for haddock before 1995. Because of the harvest control rule and better enforcement, this problem seems reduced in recent years. The recent increased exploitation rate for saithe needs to be monitored carefully. Cod and haddock are mostly taken in mixed fisheries, and optimal allowable catch for these species may be based not only on estimated F but on ratios of these species comprising the catch. Although the exploitation rate may be too high to fully reach the stock production potential, it may be concluded that since 2000 exploitation of these three stocks has been sustainable, has not impaired recruitment, and has not impacted the ecosystem negatively.

Greenland halibut

Greenland halibut is mainly fished in directed trawl and longline fisheries in slope areas of the continental shelf. This species is also taken as bycatch in other groundfish fisheries across the Barents Sea (Figure 4.4.3). During 1992-2009, directed fisheries for Greenland halibut were banned in the Barents Sea. During the last 10 years, average annual catch has been around 15,000 metric tons (Figure 4.4.2). Given the condition of the stock and lack of available information, ICES has recommended that the fishery should not exceed 15,000 metric tons until better information is available, and firm evidence of a larger stock size has been obtained.

For this species 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 the quality of input data. The preliminary assessment may nevertheless be indicative of stock trends. Although many aspects of the assessment remain uncertain, fishery-independent indices of stock size from research surveys indicate a positive trend in recent years.

The fishing mortality (F) matrix indicates that historically Greenland halibut were fully recruited to the fishery at approximately 6–7 years of age with F>0.2 for older ages, and F>0.5 in many cases. Trawl gears typically catch greater amounts of young fish compared to gillnets and longlines. Nevertheless, 6–10 year-old fish continue to represent the major age groups targeted in the fishery. Prior to decreased levels in the early 1990's, rates of fishing mortality had increased continuously for more than a decade and peaked in 1991 at F=0.64. For 2012, F was estimated at 0.04, which is the lowest level estimated for all years in the analysis. A maximum exploitation rate of 5% has been suggested to be sustainable for long-lived species when the stocks show no sign of reduced reproductive potential. This corresponds to a fishing mortality of $0.05y^{-1}$; this is shown as a reference for the maximum sustainable exploitation rate for Greenland halibut in Figure 4.4.4.

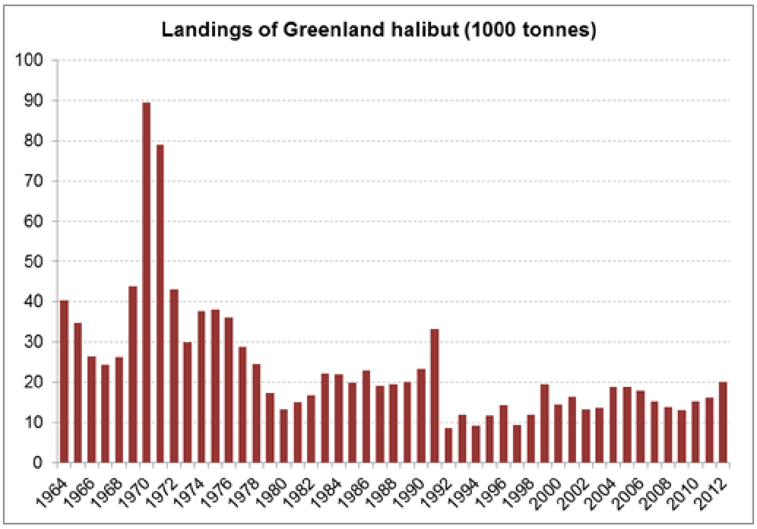

Figure 4.4.2. Northeast Arctic Greenland halibut landings (1964-2012).

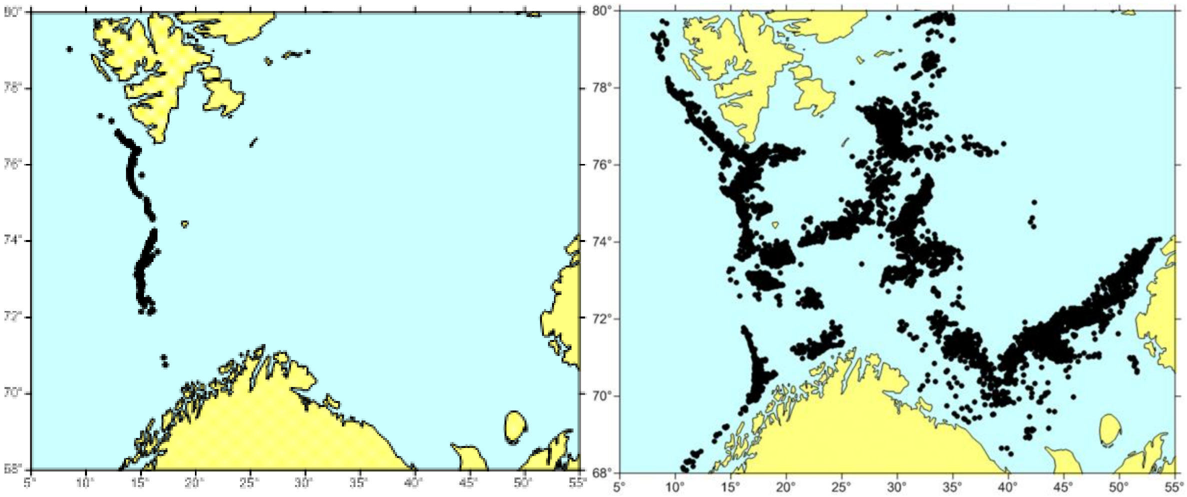

Figure 4.4.3. Locations where Greenland halibut were caught by Russian fleets in 2013 as target species (left) and as bycatch (right).

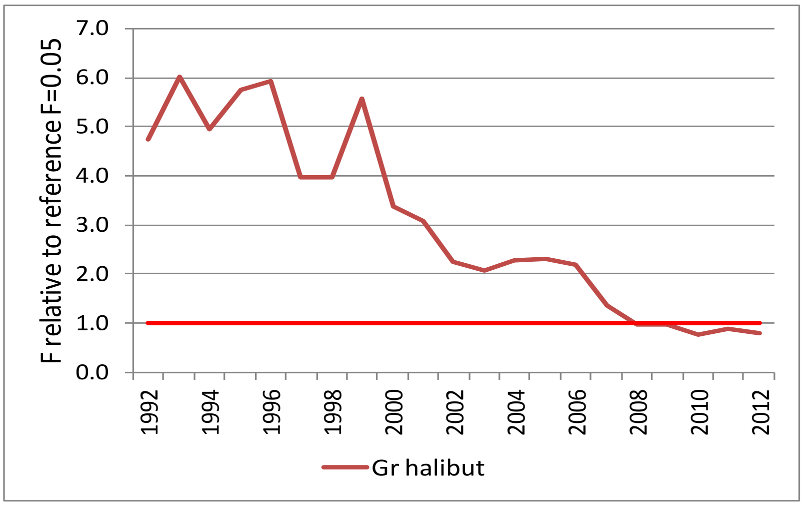

Figure 4.4.4. Annual fishing mortalities of Greenland halibut (*Reinhardtius hippoglossoides*) relative to the proposed maximum levels (i.e., 5% exploitation level) above which the fishing mortality over time probably will impair recruitment (ICES 2013).

After many years of overexploitation, tentative indications are that the Greenland halibut stock is being harvested sustainably at the current rate of exploitation. Uncertainties remain however, due to imprecision in the stock assessment.

Golden redfish (Sebastes marinus)

Annual catch of golden redfish in the Barents Sea was approximately 7,000 metric tons during 2004-2010, and decreased slightly to below 6,000 metric tons during 2011-2012. No limit reference points have been suggested or adopted for this species. Estimated SSB has been decreasing since the 1990s, and is currently at the lowest level in the time-series. Estimates of fishing mortality have been increasing since 2005; the current F is the highest level in the time-series (Figure 4.4.5). Recruitment is very low. The ICES advises that there should be no fishing on this stock, given the very low SSB (below any possible reference points) and poor recruitment.

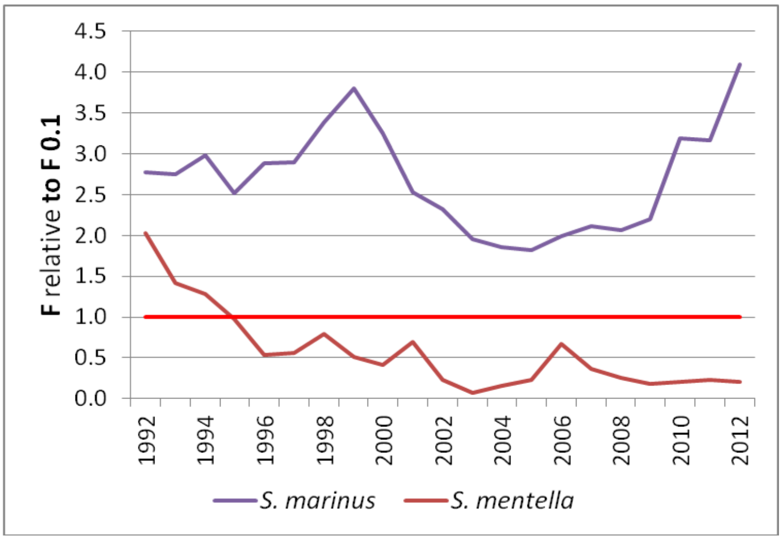

Figure 4.4.5. Annual fishing mortalities of Golden redfish (*Sebastes marinus*) and Beaked redfish (*S. mentella*) relative to the target levels ($F_{0.1}$) as a precautious proxy to FMSY at which the stocks are supposed to give the highest long term sustainable yields (ICES 2013).

Management experiences with fisheries for other *Sebastes* stocks, e.g, in the Pacific Ocean and the Irminger Sea, suggest that annual harvest rates of such slow-growing and long-lived species should not exceed 5% if the stock is recruiting normally. At times 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 for golden redfish is too intensive. Using $F_{0.1}$ as a precautionary proxy for F_{msy}, fishing at $F_{0.1}=0.08$ with 1,400 metric tons per year should produce sustainable yield at current levels of recruitment.

Beaked redfish (Sebastes mentella)

The stock of 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 4.4.6). The southern limit of its distribution is not well defined but is believed to be somewhere on the slope northwest of Shetland, and the abundance of this species decreases south of this latitude. Nonetheless, the 62º N boundary has been defined for management purposes more than a biological basis for stock separation.

The analytical assessment and management 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 authorities.

In international waters of the Barents Sea, a pelagic fishery for beaked redfish is managed by the North East Atlantic Fisheries Commission (NEAFC). In recent years, an Olympic fishery has been conducted with a set TAC that is not derived from a harvest control rule. In national waters of the Barents Sea, a demersal fishery based on bycatch is conducted 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 TAC.

Since 2004, a directed pelagic fishery for *S. mentella* in international waters beyond the EEZ of countries bordering the Norwegian Sea has developed. In 2013, this fishery had a TAC of

19,500 metric tons, of which less than 7,000 metric tons were taken. Otherwise, *S. mentella* is taken: as bycatch in demersal fisheries for cod, haddock, and Greenland halibut; as juveniles in the shrimp trawl fisheries; and occasionally in pelagic fisheries for blue whiting and herring in the Norwegian Sea.

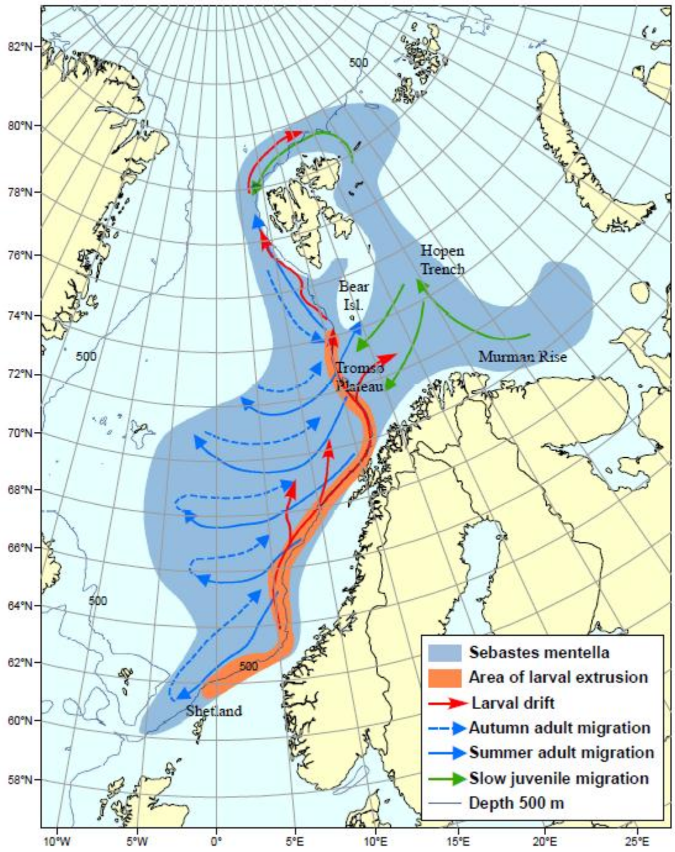

Figure. 4.4.6 Beaked redfish *(Sebastes mentella)* in Subareas I and II. Distribution, area of larval extrusion, larval drift, and migration routes.

At present, no fishing mortality or biomass reference points are defined for this stock. An $F_{0.1}$ value of 0.039 is considered a good proxy for F_{MSY} when the stock has been re-built. For 2014, ICES advised a status-quo TAC of 24,000 metric tons for *S. mentella*, and that measures currently in place to protect juveniles should be maintained.

Currently estimated fishing mortality is below the assumed natural mortality (0.05) and below the proxy for F_{MSY} ($F_{0.1}$=0.039) (see Figure 4.4.5). Fishing at $F_{0.1}$, which is close to the assumed value of natural mortality is not considered to be detrimental to the stock.

However, there have been several consecutive years (1998–2005) with very low recruitment of this long-lived, late-maturing species. This trend together with continued landings, suggests that SSB of beaked redfish may be expected to decline in the near future. The Joint Russian-Norwegian Fisheries Commission decided to avoid sharply increased quotas over the next years and to pursue a more precautionary approach. This is significant since implementation of a new analytical method may give rise to shortcomings. Because *S. mentella* is a long-lived species, there should no loss of long-term revenue by waiting for evidence of improved stock conditions before increasing the TAC. As with the management of many other long-lived species, and in keeping with responsible and precautionary strategies, TAC-increases should be made gradually, and not following a single year of perceived improvement. The Commission has requested ICES to consider and evaluate different elements of the proposed future management plan for this stock.

Wolffish (Catfish)

Three species of wolffish: Atlantic wolffish (*Anarhichas lupus*); Spotted wolffish (*Anarhichas minor*); and Northern wolffish (*Anarhichas denticulatus*) are taken mostly as bycatch in fisheries for gadoids in the Barents Sea. Although catfish are sometimes the dominant catch in longline fisheries, total catch of these species is relatively small (Figure 4.4.7).

Atlantic and Spotted wolfish comprise approximately 90% of the total catch. Northern wolfish are caught in the coastal zone; landings of this species tend not to be significant.

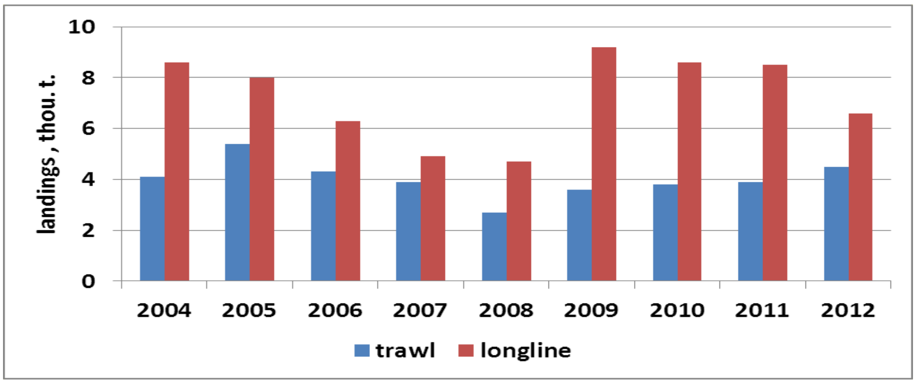

Figure 4.4.7. Annual landings of wolfish/ catfish by the Russian fleet during 2004-2012.

Capelin (Mallotus villosus)

Annual landings of Barents Sea capelin are presented in Figure 4.3.25. There was no fishery for capelin in the area during 2004-2008 due to poor stock condition, but during 2009-2013 the stock was sufficiently sound to support a quota between 200,000 and 400,000 metric tons. Since 1979, the capelin fishery has been regulated through quotas set using 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 and ecosystem approaches to fisheries management. Being a forage fish in an ecosystem where two of its predators cod and haddock are presently at high levels, the capelin stock is now under heavy predation pressure. The fishery is restricted to the pre-spawning period (mainly February-March) and the exploitation level is regulated based on a model that incorporates natural mortality, including predation from cod. A minimum landing size of 11cm has been in force since 1979. The management plan's harvest control rule is designed to ensure that SSB remains above the proposed B_{lim} of 200,000 metric tons (with 95% probability). The TAC for 2014 has been set at 65,000 metric tons.

Polar cod (Boreogadus saida)

For economic reasons, there has been little interest to develop a substantial fishery for polar cod. In recent years, the existing fishery has been conducted at a very low level relative to the stock size. Such a low level of exploitation is unlikely to influence the stock condition. Concentrations of polar cod are fished in late autumn during southward spawning migrations along the coast of Novaya Zemlya. In recent years, only Russian fishers have participated in this fishery. No fishery at all was conducted during 2012-2013, however.

Other finfish species

Information about species composition in Norwegian fisheries north of 67°N is made available through the Norwegian reference fleet (NRF), i.e., 20 high-seas vessels and 20 coastal fishing vessels which have been contracted by the Institute of Marine Research to provide fishery statistics. Table 4.4.1 shows the species composition (percent of total catch by weight) for trawl and longline fisheries conducted by the NRF during 2011. Such fishery data are now routinely collected by these vessels on a daily basis. The impact of these northern-most fisheries on non-regulated species, and the ecosystem as a whole, will be a topic for further research.

Information about total species composition in Russian bottom- and pelagic trawl fisheries in the Barents Sea and adjacent waters is available from PINRO based on 11 high-seas fishing vessels with onboard observers (Table 4.4.2). These dat were collected a total of 803 days at sea during 2012 year round in all areas fished by the Russian bottom trawl fleet, with the exception of some waters within Russian and Norwegian EEZs (Figure 4.4.8).

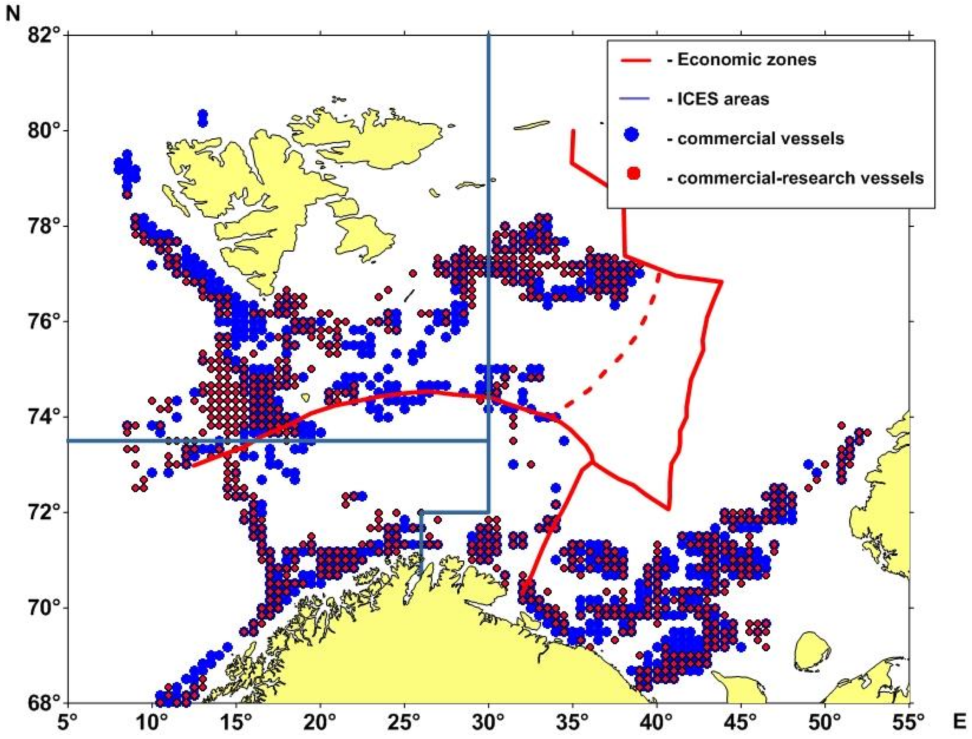

Figure 4.4.8. Location of Russian fishing and research-fishing vessels with observers on board in the Barents Sea and adjacent waters in 2012.

Table 4.4.1. Species composition (percentage of total catch by weight), 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 radiate	1,3	Wolffish - *Anarhichas dentkulatus*	0,3
Ling	0,4	Atlantic halibut	0,2
Saithe	0,2	*Amblyraja radiate*	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	+		

Table 4.4.2. Species composition (percentage of total catch by weight) of removals by Russian trawlers in the Barents Sea during 2012. Includes non-commercial species caught in bottom and pelagic trawls. Data were collected for PINRO by on-board observers.

Russian bottom trawl	
Species	**W %**
Cod	41.1
Haddock	22.0
Greenland halibut	3.1
Saithe	1.6
Wolffish - *Anarhichas minor*	0.4
Wolffish - *Anarhichas lupus*	0.4
Beaked redfish	0.2
Long rough dab	0.2
Wolffish - *Anarhichas dentikulatus*	0.2
Golden redfish	0.1
Capelin	8.7
Plaice	1.5
Polar cod	+
Herring	20.3
Amblyraja radiate	+
Ling	+
Tusk	+
Lumpsucker	+
Chimaera monstrosa	+
Anglerfish	+
Blue whiting	+
Norway pout	+
Argentina silus	+
Common sole	+

4.4.1.2 Discards

The level of discarding in Barents Sea fisheries is not known, and estimates of discard are not incorporated in fish stock assessments. Lack of discard estimates results in stock assessments which are less precise and less accurate. Hence, the impact of fisheries on the ecosystem is not fully understood. One possible approach to estimate fish discard fish is to analyze landings data, i.e., size-weight composition of landed catch relative to data collected by observers onboard commercial vessels. In 2012, Norway conducted a pilot project testing methods to estimate discard in selected fisheries, with the goal to establish methods to estimate discard on a routine basis for all Norwegian fisheries in the near future.

Since 1984, reports of redfish (primarily *S. mentella*) taken as bycatch and then discarded in the Norwegian shrimp fishery indicate that shrimp trawlers removed significant numbers of juvenile redfish at the beginning of the 1980's. This bycatch peaked in 1984, when it amounted to about 640 million individuals, a number that might equal a good year class for this stock (Figure 4.4.9). After the sorting grid became mandatory in 1993, bycatch of redfish was reduced dramatically. Reports also indicate that fishing areas closures are necessary to protect juvenile redfish, since they are not sufficiently protected using sorting grids. Cod bycatch and discard consist mainly of 1- and 2 year-old individuals, but is generally small compared to other reported sources of mortality, i.e., fisheries catch including discard, and cannibalism.

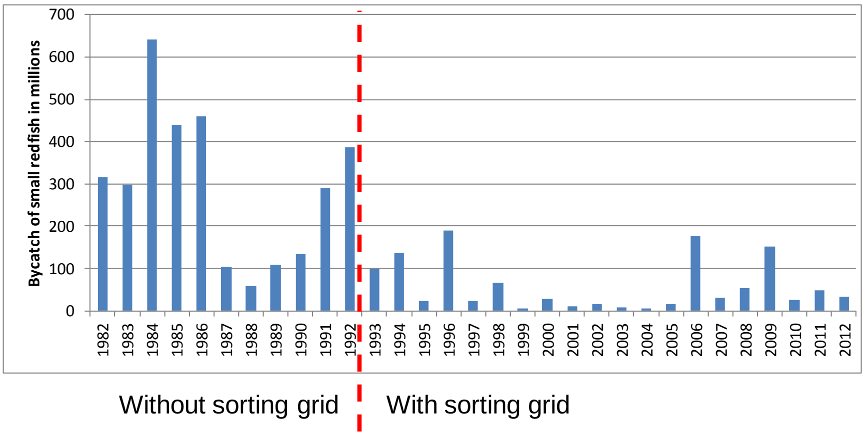

Figure 4.4.9. Revised bycatch (discards) estimates of small redfish during the Barents Sea shrimp fishery (1982-2012).

Significant discard of cod occurred in the Barents Sea shrimp fishery during 1985, 1992, and 1998. The highest number of total cod discarded was recorded in 1985 (92 million). Cod bycatch has declined in recent years to less than 3 million individuals. Discard of haddock and Greenland halibut in the Barents Sea shrimp fishery has been estimated for the period 2000-2005; results indicate the highest haddock discard in 2002 9.2 million individuals, and highest discard of Greenland halibut in 2000 at 13.2 million individuals. For both these species discard levels in the shrimp fishery have been low in recent years.

4.4.1.3 Shellfish

Northern shrimp (Pandalus borealis)

Both Norwegian and Russian vessels harvest northern shrimp in the Barents Sea over the stock's entire area of distribution. Vessels from other nations are restricted to fish this species only in the Svalbard zone. No overall TAC has been set for northern shrimp, and the fishery is regulated through effort control, licensing, and a partial TAC in the Russian zone only. The regulated minimum mesh size is 35mm. Bycatch is constrained by mandatory sorting grids, and by temporary closures in areas with high bycatch of juvenile cod, haddock, Greenland halibut, redfish, or shrimp (<15mm).

Since the mid-1990s, a major restructuring of the fleet toward fewer and larger vessels has taken place. Since 1995, average engine size of a shrimp vessel in ICES Subareas I and II increased from 1,000HP (horse power) to more than 6,000HP in the early 2010s, and the number of fishing vessels has declined markedly. Overall catch has decreased since 2000, reflecting reduced economic profitability in the fishery. In 2012, 25,000 metric tons 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. Accordingly, ICES advised that in 2014 a TAC of 60,000 metric tons should maintain the stock at its current high biomass.

In recent years, the largest shrimp biomass has been observed in eastern areas of the Barents Sea (Figure 4.4.10). Therefore, catch levels from some of the more traditional western fishing grounds have declined. Recent reports indicate lower catch rates than would be expected given the overall good stock condition. This may be related to operation costs for a relatively small fleet to move from more traditional fishing grounds, and to find new grounds with commercially viable shrimp concentrations.

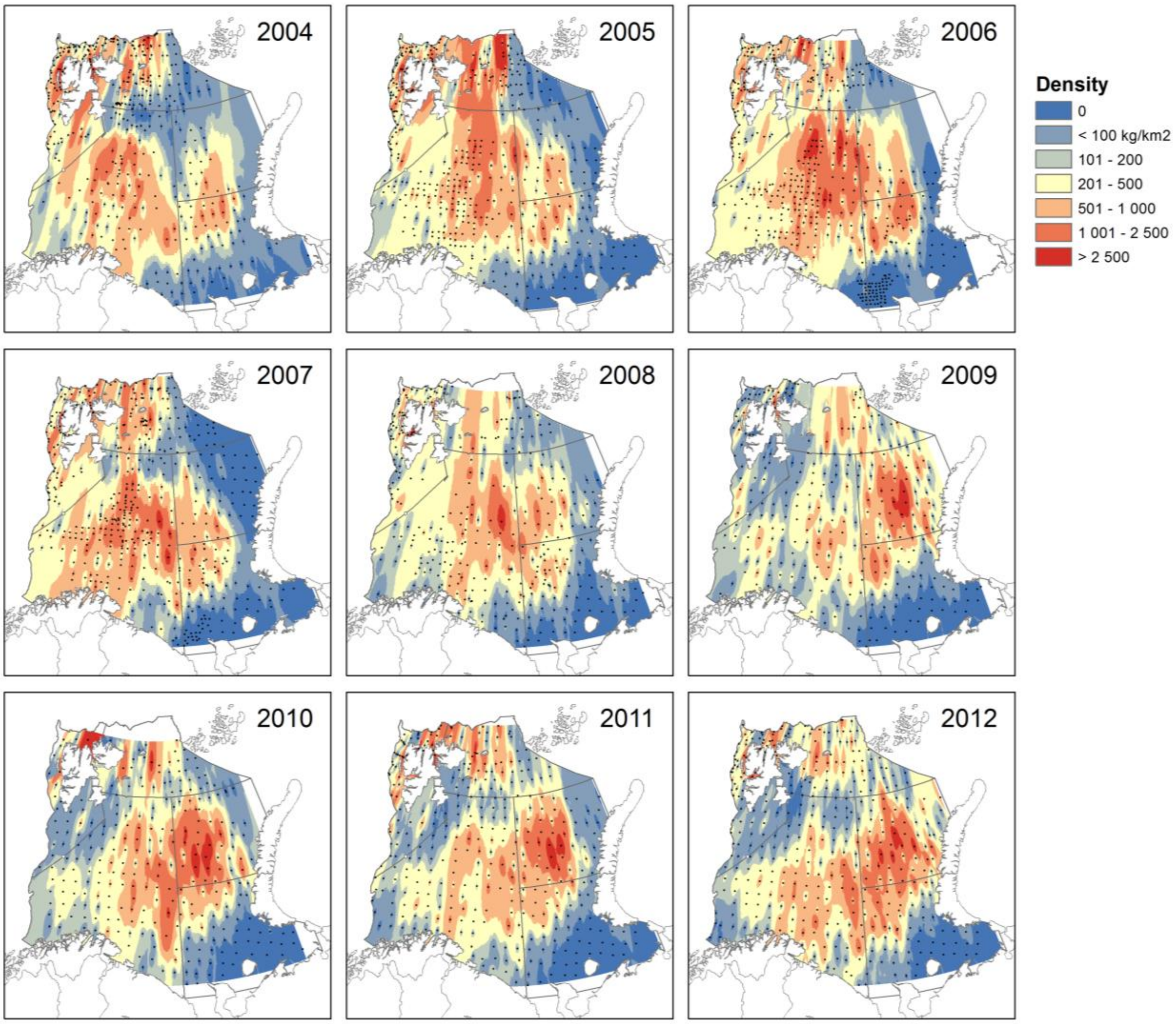

Figure. 4.4.10. Shrimp density by year from inverse distance weighted interpolation (e.g. Fisher *et al*., 1987) between trawl stations (black dots) for the Joint Russian-Norwegian Ecosystem survey (Europe Albers Equal Area Conic projection).

*Red king crab (*Paralithodes camtschaticus*)*

In the area east of 26°E and south of 71°30'N, and in Russian waters of the Barents Sea, the commercial crab fishery is managed to achieve long-term sustainability by setting annual quotas for this area. Outside this area (west of 26°E), the red king crab fishery is regarded as undesirable; a free non-legislated fishery is permitted, and release of viable crabs back into the sea is prohibited. In the Norwegian waters of the Barents Sea, the harvest rate of this species in the quota-regulated area is high; this is intended 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> 130mm) are taken in the quota-regulated fishery, and there are no seasonal catch restrictions. Hence, Norwegian management of this fishery contradicts management regimes applied in both the Bering Sea (Alaska) and in the Russian part of the Barents Sea.

4.4.1.5 Important indirect effects of fisheries on the ecosystem

Fisheries in the Barents Sea not only influence the stocks targeted. Due to strong species interactions, removal of one stock may influence the abundance of other stocks through fishery-induced changes in food supply, competition for food, and predation pressure. Reductions in stock size due to fishery removals may also lead to changes in migration pattern. Density-dependent migrations may cause fish stocks to cover greater areas and travel longer distances when abundance is relatively high. Fishing pressure may also reduce the average age and/or size of a stock, and may also reduce the average age at maturity.

Qualitative effects of trawling on benthic organisms have been studied to an extent. The challenge for management is to determine fishing levels which ensure that fisheries are both profitable and sustainable over time. The difficulty lies in the fact that both profitable fishing and sustainable fishing depend on maintaining the integrity of benthic fish habitats. To determine the total impact of trawling, extensive mapping of both fishing effort and bottom habitat would be necessary. The most serious effects of trawling have been demonstrated for hard bottom habitats dominated by large sessile fauna. Organisms which erect structures and dwell in colonies — sponges, anthozoans, and corals — have shown considerably reduced abundance in the wake of bottom trawl gear. Accordingly, hard bottom substrates in the Barents Sea providing habitat for such large epifauna should be identified and protected (Løkkeborg and Fosså, 2011).

Trawling effects on soft bottom have been less studied, and consequently there are large uncertainties associated with the effects of fisheries on these habitats. 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 sediments, and through relocation of shallow burrowing infaunal species to the surface of the seafloor.

During 2009-2012, joint research between Norway and Russia was conducted to explore the possibility of using pelagic trawls when targeting demersal fish species. Pelagic trawl should minimize the impact on bottom fauna, and reduce bycatch. During these exploratory fishery operations, it was mandatory to use sorting grids and/or trawls with square mesh in the top panel of the cod end — this more stable four-panel trawl geometry was used to avoid catching undersized fish.

After four years of exploratory fishing with pelagic trawls, use of this gear to fish for cod, haddock, and other demersal fish species is still not allowed — primarily due to smaller size fish being captured (on average), and a tendency toward large trawl hauls too big to handle without difficulty. The experiment has, however, led to advances in the design of bottom trawls, including: bigger trawl openings; better size selection; and escapement windows to avoid excessive catch sizes.

Lost gear types, such as gillnets, may continue to catch fish unintentionally 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 at depths shallower than 200m is considered not to be a significant problem due to lost, discarded, or abandoned nets having a limited fishing life: they tend to have a high rate of biofouling that causes their netting to become clogged; and, in some areas, tidal scouring speeds their erosion. Investigations conducted by the Norwegian Institute of Marine Research during 1999-2000 demonstrated that the number of gillnets lost increases with depth. Indications also were that of all Norwegian gillnet fisheries the fishery for Greenland halibut is where most nets are lost. The effects of ghost fishing in deeper waters, e.g. for Greenland halibut, may be greater since ghost fishing may continue for periods of 2–3 years or longer, largely due deeper waters have lower rates of biofouling and tidal scouring. Since 1980, the Norwegian Directorate of Fisheries conducted annual surveys to retrieve lost or abandoned fishing gear. A total of 10,784 gill nets of 30m standard length (approximately 320 km) were retrieved from Norwegian fishing grounds during1983- 2003. During the 2011 retrieval survey gears retrieved and brought back to land included: more than 1,100 gillnets; 54 red king crab traps; 13km trawl wire; 12km of ropes; 40km of longlines; and numerous trawl cod ends. These lost gears had “ghost fished” 14.0 metric tons of fish and approximately 12,000 crabs, primarily red king crab.

Other types of fishery-induced mortality include: slipping — where pelagic catch is released too late to ensure survival; burst nets; and that 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 have been demonstrated, but population-level effects are not known.

In Barents Sea trawl fisheries, harp seals occur as bycatch and often die in the trawl (Zyryanov *et al*., 2004), whereas other seal species occur only occasionally as bycatch in trawls. In addition, during years with low capelin abundance, harp seals migrate into coastal waters in search of alternative food sources; this migration coincides with the winter gillnet fishery for immature cod along Norwegian coast in the Barents Sea. The harbour porpoise is also subject to being taken as bycatch in gillnet fisheries (Bjørge and Kovacs, 2005). Despite the relatively large abundance of dolphins in the Barents Sea, they are not often caught in trawls (Haug *et al*., 2011). In 2004, Norway initiated a monitoring program for bycatch of marine mammals in fisheries.

Fisheries impact seabird populations in two different ways: 1) directly, through bycatch of seabirds in fishing equipment; and 2) indirectly, through competition with fisheries for the same food sources.

Documentation of the scale of seabird bycatch in the Barents Sea is patchy. Particular incidents such as bycatch of large numbers of guillemots during spring cod fisheries in Norwegian waters have been documented (Strann *et al*., 1991). Gillnet fishing affects primarily coastal and pelagic diving seabirds, while surface-feeding seabirds are most vulnerable to longline fishing (Furness 2003). The population impact of direct mortality through bycatch will vary with the time of year, the status of the affected population, and its sex and age structure. Even low levels of bycatch mortality may be a threat to red-listed species such as common guillemot, white-billed diver, and Steller’s eider.

Several bird scaring devices have been tested for longline fisheries; a simple bird-scaring line not only significantly reduces seabird bycatch, but also increases fish catch by reducing bait loss (Løkkeborg, 2003). This creates an economic incentive for the fishermen to use it, and often results in the bird-scaring line being used without any forced regulation when seabird bycatch is a problem.

In 2009, the Norwegian Institute for Nature Research (NINA) and the Norwegian Institute of Marine Research (IMR) began a cooperation to develop methods to estimate seabird bycatch (Fangel *et al*., 2011).

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