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Joint Norwegian-Russian environmental status 2008
Report on the Barents Sea Ecosystem
Part I - Short version

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Electronical version on internet portal

Our report is also published on internet using the URL
http://www.barentsportal.com.

The web publication is identical to the printed report, but you will in addition find ads that supplements and broadens some aspects in the contents. Furthermore, you will find a Web Map Service which gives you the opportunity to have a more geographic focus on some of the thematic presentation of environmental issues, and e.g. add other maps on top for comparison. An interesting feature is the possibility to give your comments on all text and figures. Hopefully, these comments will stimulate to debates on environmental issues, condition and future development in the Barents Sea – or bring up questions on topics that are difficult to conceive or should be broaden more. If prosperous, the web publication will be the main form for updating and developing of the Joint Norwegian-Russian environmental status reports on the Barents Sea Ecosystem.

The report may alternatively be downloaded at
http://www.imr.no/ - (publications -> IMR-Pinro reports).

Joint Norwegian-Russian environmental status 2008 Report on the Barents Sea Ecosystem

Part I – Short version

By

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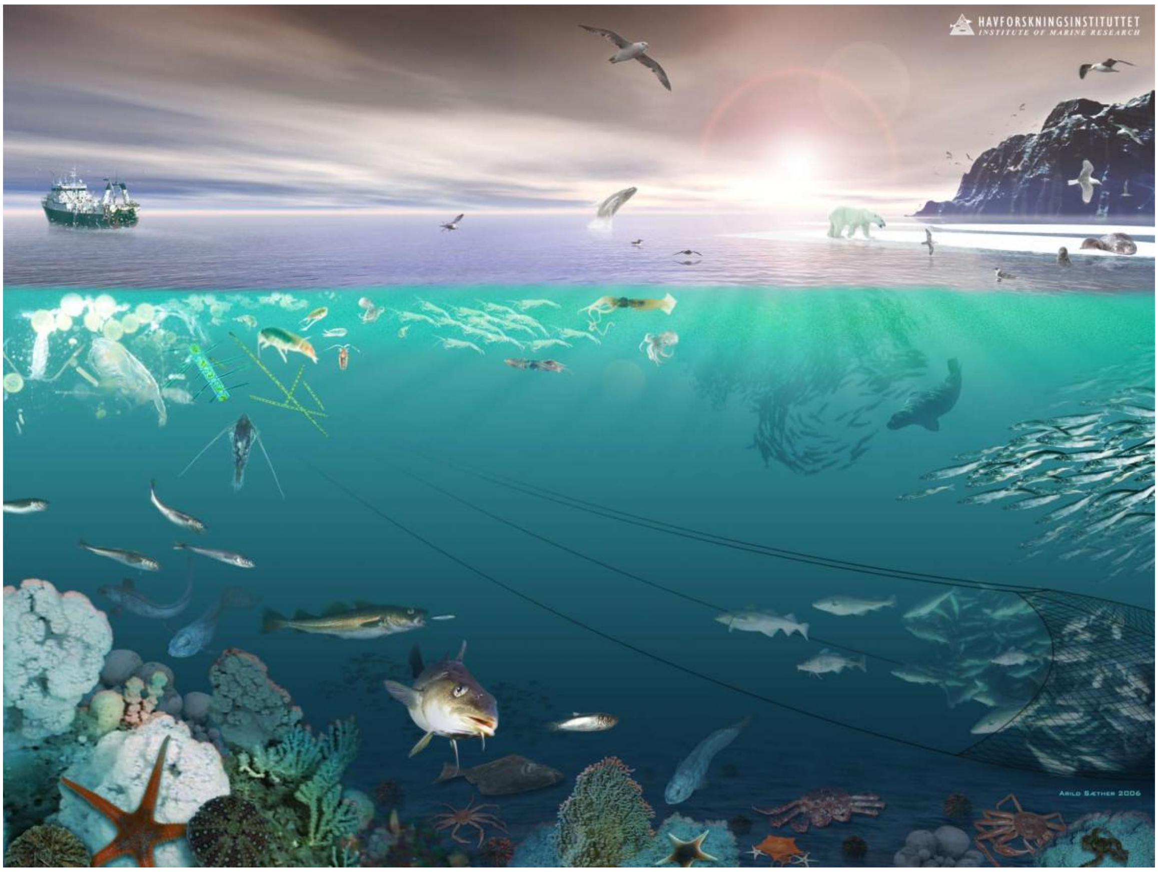

November 2009

Content

1 Introduction

This is a short version of the Joint Norwegian-Russian environmental status 2008 report on the Barents Sea Ecosystem. It is written to provide an easy accessible summary of the main findings in the full report, and is aimed at groups such as decision makers, professionals involved in developing ecosystem-based management and journalists.

The report was initiated by the Joint Russian - Norwegian Commission on Environmental Cooperation and the work has been carried out in co-operation with the Joint Russian-Norwegian Fisheries Commission. The main objective is to provide a comprehensive description of the Barents Sea ecosystem using relevant scientific knowledge from both Russian and Norwegian scientists.

The report will contribute to the scientific basis for development of an ecosystem-based management plan for the Russian part of the Barents Sea and contribute to the further development of ecosystem-based management in the Norwegian Territories within the area, via the Norwegian Barents Sea Management Plan.

Developing an ecosystem-based management plan requires broad information about the various components and dynamics of the system, as well as information about how the ecosystem is affected by anthropogenic activities. Therefore, this report provides a basic description of the major ecosystem components and their dynamics for the Barents Sea, including the physical environment. It also describes human activities and discusses their impact on the ecosystem. The status of major components of the ecosystem is described using the most recent data. Some aspects of long-term change are also discussed. In addition, examples of important issues relevant to the development of ecosystem-based management are highlighted. It should be emphasised that although core issues are highlighted, no attempt is made to give a complete list of relevant themes, but rather to point to possible directions of future work relating to ecosystem-based management for the Barents Sea. Finally, the report comments on the needs for monitoring and integrated ecosystem status reports in a situation where human impact on the Barents Sea is expected to increase in the future.

Preparation of the report has been based on the positive experiences with previous Barents Sea ecosystem status reports made jointly by PINRO (Russia) and Institute of Marine Research (Norway). The work has been carried out in 13 expert groups with more than 130 experts from a total of 9 Russian and 20 Norwegian institutions having participated. The work has been led by Sevmorgeo and PINRO on the Russian side and Institute of Marine Research and The Norwegian Polar Institute on the Norwegian side. The expert groups started their work in November 2008, and the report thus builds on data collected in 2008 and earlier.

2 General description of the Barents Sea ecosystem

The Barents Sea is a sub-Arctic shelf ecosystem located between 70° and 80°N. It connects with the Norwegian Sea to the west and the Arctic Ocean to the north. The dynamics of the system are strongly influenced by the inflow of warm Atlantic water from the west (Figure 1).

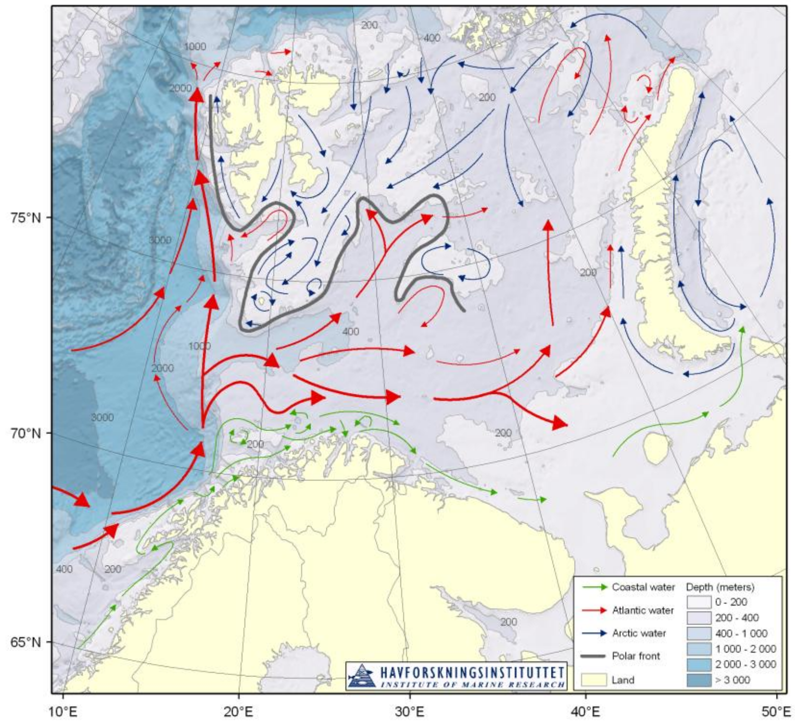

Figure 1. Main features of circulation and bathymetry in the Barents Sea.

This water mass is separated from Arctic Water by the ocean Polar Front, which is characterised by strong horizontal gradients in temperature (Figure 2A), salinity and concomitant differences in biodiversity supported within the various regions. The system is also dominated by seasonally occurring sea ice, particularly in the eastern and northern parts. A distinct assemblage of species is associated with sea ice.

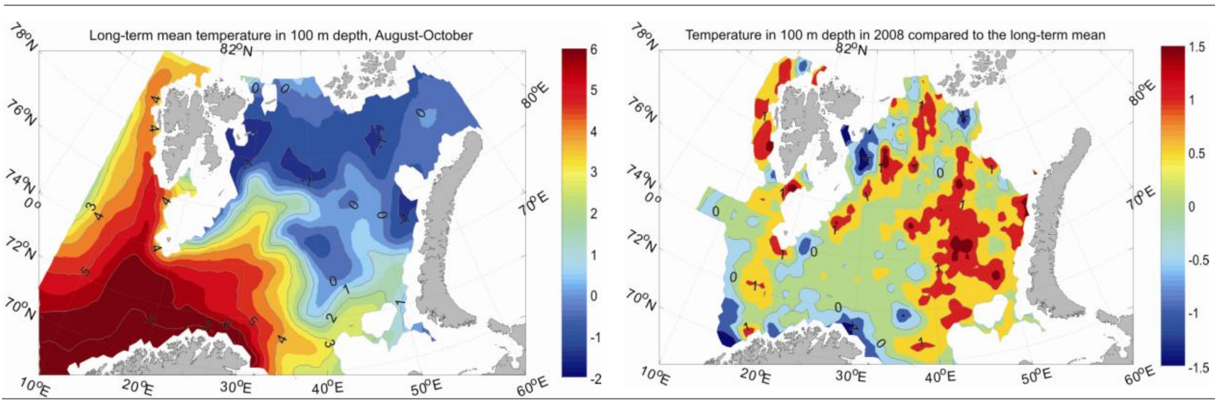

Figure 2. **A**: Average temperatures in the Barents Sea at 100 m for August-October 1977-2007. **B**: Temperature at 100 meter depth in 2008, shown as deviation from the long-term mean, where red colour indicates areas with higher than normal temperatures, green areas with normal temperatures and blue colour areas with lower than normal temperatures.

The Barents Sea is home to one of the largest concentrations of seabirds in the world, a diverse assemblage of marine mammals, including polar bears, and several commercially important fish stocks, the largest of which are Northeast Arctic cod, capelin and haddock. In addition, the Barents Sea is a nursery area for Norwegian spring spawning herring, one of the largest fish stocks in the world. There is also a rich community of benthic animals in the Barents Sea, numbering more than 3000 species, as well as a diverse community of zooplankton. Planktonic algae and algae attached to the sea ice both contribute to primary production in the region. Infectious organisms and free-living bacteria and virus may be important groups, but their role for the overall dynamics of the system has received little research attention. The ecosystem has been invaded by several alien species, such as the red king crab, the influence of which is being studied currently but is still largely unknown.

Capelin is a key species in the Barents Sea ecosystem. This fish species feeds in the marginal ice zone and spawns near the coast in the southern part of the Barents Sea and thus transports large amounts of energy from the north to the south. It is important as prey for several species of seabirds, mammals and commercially important fish stocks, in particular Northeast Arctic cod and juvenile herring. Capelin is an important predator of zooplankton that can actually suppress the biomass of zooplankton in the Barents Sea (Figure 3).

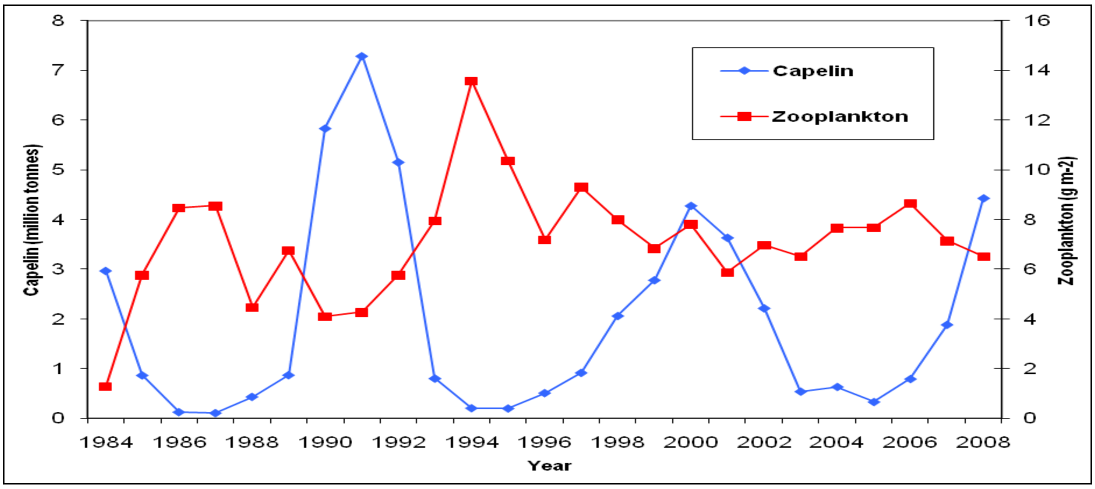

Figure 3. Annual fluctuations in zooplankton biomass and size of capelin stock in the Barents Sea.).

Capelin stock size has varied considerably in recent decades and has undergone three population collapses during the last 25 years. There is at present no consensus among scientists about the causes of the observed capelin recruitment failures leading to capelin stock collapses. While no one holds the view that the causes are all known, some suggest that the collapses are mainly a consequence of predation on capelin larvae from increased amounts of juvenile herring, others suggest several factors likely cause capelin collapses, including climatic fluctuations, predation from fish and marine mammals, and fisheries. Whatever the cause, these collapses have had far reaching consequences for other species in the ecosystem, including a severe food shortage for the Northeast Arctic cod stock, collapses of seabird populations, and food shortage causing massive migrations in seal populations. It should, however, be noted that the ecosystem consequences of the first collapse (late 1980s) was much more severe than during the two later collapses, probably because more alternative prey were available for the predators during the latter collapses.

Variations in water temperature have important effects on the Barents Sea ecosystem. In particular, periods of high temperature tend to stimulate recruitment of Northeast Arctic cod and Norwegian spring spawning herring and other fish stocks. Indirectly, recruitment of capelin may be impaired by high temperatures because of increased predation from larger amounts of juvenile herring drifting into the area from spawning grounds along the Norwegian coast. Higher water temperatures, or changes in the characteristics of the Polar Front, are often accompanied by a decrease in sea-ice cover and thereby a negative impact on ice-dependent species. Predicting the response of primary productivity to temperature variation is associated with uncertainty because the amount of light reaching the water column and supply of nutrients necessary for primary production may respond in opposite directions. When it gets warmer, the amount of light will increase because of the reduction in sea ice cover through melting. At the same time, nutrient supplies may decrease because warming and increased input of freshwater from sea ice melting can lead to increased stratification of the water column, thus reducing the mixing of nutrient rich deepwater into the surface layers where primary production occurs.

The anthropogenic driver with the largest documented effects on the Barents Sea ecosystem is currently fisheries. Negative impacts of fisheries include overfishing of several of the smaller stocks and damage to benthic communities caused by bottom trawling. In addition, climatic changes have considerable effects on the system. The climate changes likely represent both natural variations and effects of anthropogenic emissions of CO2 and other greenhouse gases. The relative importance of these two sources is not completely understood. Reproductive failure and negative population trends in ice-dependent marine mammals are possible effects of climate change. The Barents Sea is presently a relatively clean ocean with respect to pollution, however, it receives long-range transboundary transported pollution through both atmospheric and oceanic advection, in particular PCBs and other persistent organic pollutants as well as some inorganic contaminants (e.g., Hg and Pb). These substances are detectable in biota, but to date significant effects are limited to top predators, such as polar bears and glaucous gulls. Other transboundary contaminants found in the Barents Sea area are radioactive substances. Their present concentrations are too low to have any impact on marine organisms, but risk of significant contamination exists from local sources. Oil and gas activities and ship transport have thus far had no significant direct impact on the ecosystem, but this may change with the expected increase in the level of activity in the future. Ocean acidification caused by anthropogenic emission of CO2 is an emerging problem that might have a large impact on the Barents Sea ecosystem in the future.

3 Current status of the ecosystem

Current status for abiotic factors, biotic components and human activities and impact are described in separate sections below. A final section focuses on interactions between different components in the ecosystem and interactions between different human drivers. Here it is discussed how such interactions influence the current status and will potentially affect the development of central components of the ecosystem in the near future (< 5 years).

3.1 Abiotic components

Water temperatures were generally higher than average throughout 2008 (Figure 2B), but lower than the two previous years. The highest above normal levels were seen in the first and last part of 2008. A similar pattern was seen for air temperatures with higher than normal values, the highest being at the beginning and end of 2008. Average sea-ice extent has declined during the last three decades and was below average in 2008 but higher than in 2007.

The Atlantic water inflow rate in 2008 was comparable to the situation in 2007 with moderate flows during winter, a strong decrease during spring, and close to the average in early summer. The Atlantic Water temperature in 2009 is expected to decrease from the very warm year of 2008, and further decrease towards average temperatures in 2010. In the same period the ice cover is expected to increase but likely remain below average.

3.2 Biotic components

The stocks of capelin, Northeast Arctic cod and haddock are all increasing. Stocks of shrimp and saithe have decreased the recent years. According to ICES, all five stocks are harvested in a sustainable manner and have full reproductive capacity. The stock of polar cod is at a high level. The stocks of Greenland halibut, golden redfish, deep-sea redfish and coastal cod on the Norwegian coast are at low levels. There are indications that the Greenland halibut stock is increasing and signs of improved recruitment in deep-sea redfish. It is of vital importance that the juveniles of both species of redfish are protected from being caught as bycatch in any fishery. The amount of juvenile herring and blue whiting, which are not fished in the Barents Sea, has decreased during recent years and are at present at low levels. Below, variation in biomass since 1965 of Northeast Arctic cod, Haddock, Greenland Halibut and deep-sea redfish is shown in Figure 4. Variation in biomass of capelin, juvenile herring, polar cod and blue whiting since 1983 or later is shown in Figure 5.

The timing of the spring bloom of phytoplankton is monitored in the western part of the Barents Sea. In 2008 it occurred within the normal time period for this bloom.

Zooplankton biomass has dropped since 2006 and was below the long-term mean in 2008. Biomass was higher in the eastern parts of the Barents Sea, possibly as a result of low predation pressure from capelin and polar cod, which were mainly distributed in other areas in

2008. There are indications that krill, an important group of zooplankton, is expanding its distributional range towards the east and north in the Barents Sea.

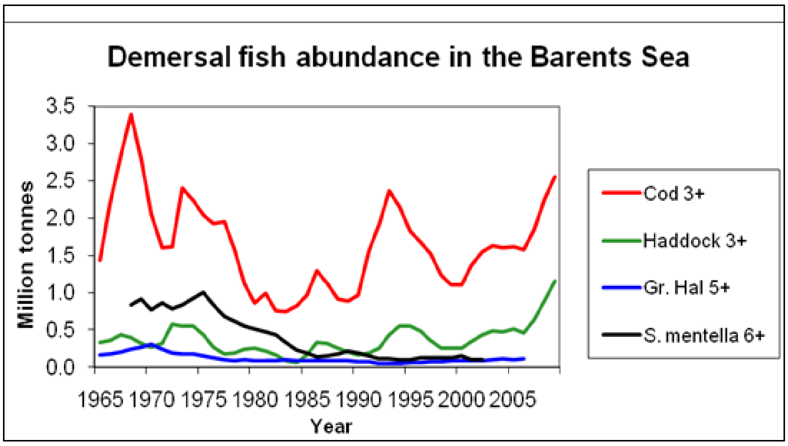

Figure 4. Biomass of demersal fish species in the Barents Sea.

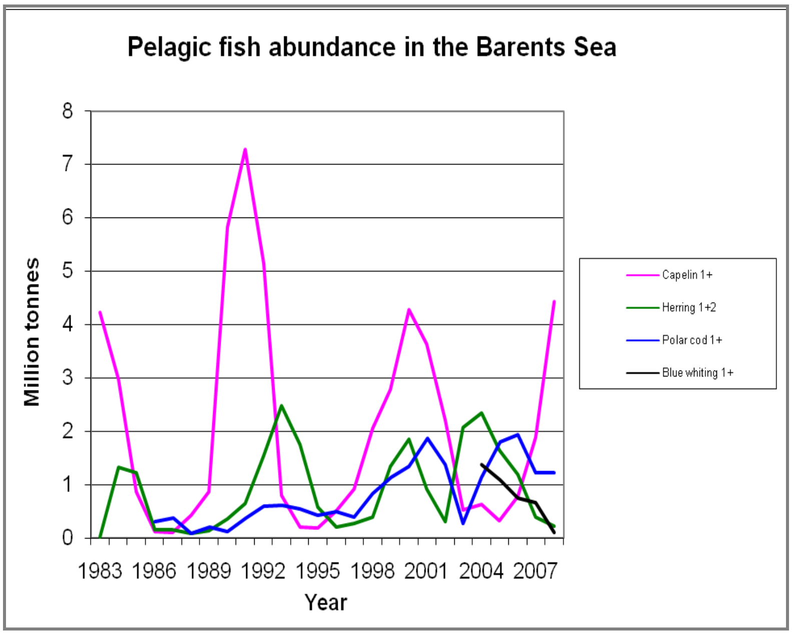

Figure 5. Biomass of pelagic fish species in the Barents Sea.

The biomass of benthic organisms has varied substantially through time and between areas in recent years . Some of this variation is due to changes in populations of snow crab and red king crab. Long-term changes in the benthic community through the 20th century (Figure 6) have been linked to temperature variability and intensity of bottom trawling, but the role these factors play in the observed variation in recent years cannot be identified with certainty. The Iceland scallop, a commercially exploited benthic species has been decreasing since 2001 in the Russian sector. The stock in the Svalbard area has probably not changed lately since there have been no fishery in the area.

Abundance data are scarce for most species of marine mammals in the Barents Sea, making it difficult to identify population trends and their possible underlying causes. For harp seals and hooded seals, existing data have shown that population size and/or pup production are probably being negatively affected by declining sea ice. Ringed seal reproduction has been negatively impacted by recent poor ice years in Svalbard (2006, 2007 and 2008), and the poor production is bound to cause declines in the adult population as these age cohorts enter into the breeding population. Stocks of harbour seals and grey seals in Norwegian sector of the Barents Sea are subject to fishery-related mortality and hunting mortality that in combination are unsustainable. Harbour porpoises are also subject to by-catch in fisheries, and in order to maintain the population at present levels given the by-catch, immigration from outside the Barents Sea is required. Population trends for polar bears in the Barents Sea are unknown.

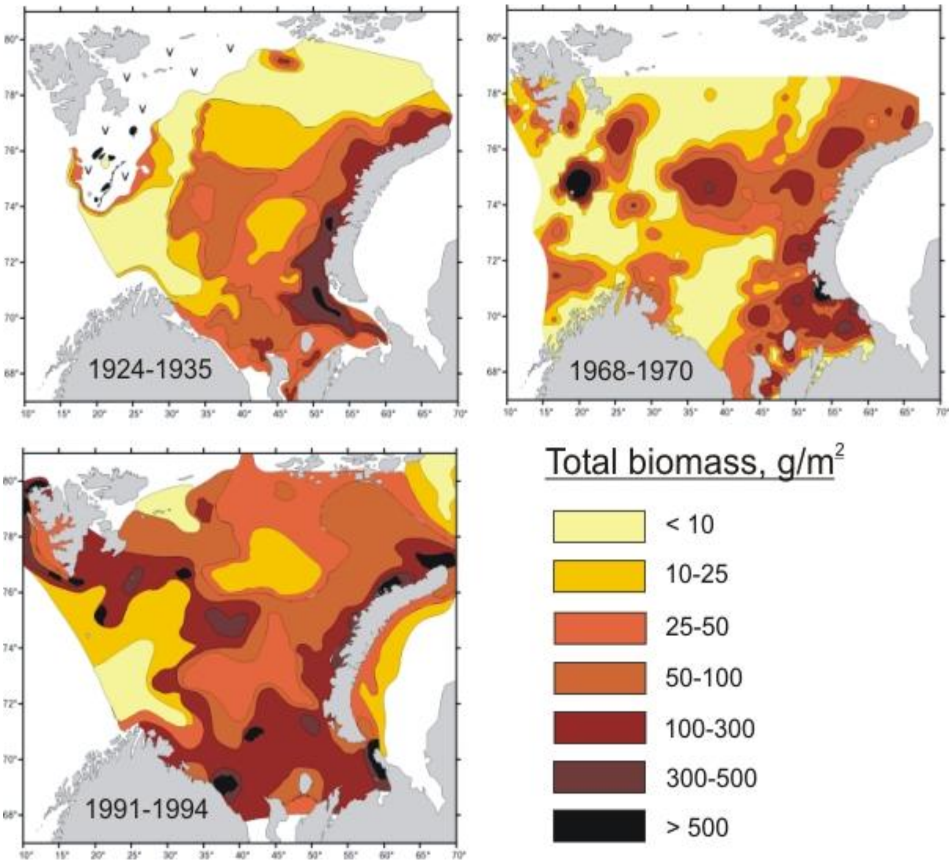

Figure 6. Distribution of the benthic biomass of the Barents Sea at different periods.

The situation for seabirds in 2008 was characterised by continued declining population trends and breeding failure of several species in the western parts of the Barents Sea, in particular the northern fulmar, black-legged kittiwake, razorbill, Atlantic puffin and common guillemot. This is similar to trends seen over much of the Northeast Atlantic in 2008, but in contrast to the situation in the eastern and northern parts of the Barents Sea, where seabird populations appear to be generally stable or increasing. The situation in the eastern Barents Sea including the Pechora Sea is however difficult to assess due to lack of monitoring data. The factors responsible for the declining trends in the western parts of the region probably involve food shortage, predation from an increasing population of white-tailed eagles and lagged effects from previous by-catch in fisheries.

The populations of the red king crab and the snow crab, which invaded the Barents Sea recently, are being followed by monitoring programs. Whereas we know that the red king crab was introduced by humans, it is unclear whether the same is the case for the snow crab or whether the species has migrated naturally into the Barents Sea. The highest concentrations of the red king crab in 2008 were observed in the southeastern part of the Barents Sea, with more than 500 individuals per square kilometre. The snow crab is recorded with increasing frequency in Norwegian waters, mainly in the northern Barents Sea and in the Svalbard Conservation Zone. An increasing number of small snow crabs have also been observed in the eastern Barents Sea. Information on other invading species is fragmentary.

Several species in the Barents Sea are on red lists of rare and threatened species. A total of 28 fish species in the area are either on the Global Red List (8 species), or on the Norwegian Red List (25 species). For 13 of these species, data are scarce and do not allow a full status evaluation, but the species would probably be on the red list if adequate information had been available. Among the 26 species of marine mammals in the Barents Sea, 11 are included in the International Red Book, 15 are included in The Red Book of Russian Federation and 9 are in the endangered-species list of Norway. More than 30 seabird species are breeding and wintering in the Barents Sea region. Among these, there are 7 Red-listed species including two from the global list, 6 from Norwegian Red List and 3 from the Red Data Book of the Russian Federation. In addition, 4 more species listed as being subject of concern in the Annex to the Red Data Book of the Russian Federation.

3.3 Human activities and impact

As described above, the major commercial fish stocks in the Barents Sea are harvested sustainably, whereas some of the smaller stocks are overfished. (Figures 7 and 8). The quota for minke whales is considered precautionary, conservative and protective, and quotas and catch rates for harp seals are considered sustainable. The harvest rate of red king crab is high and it remains to be seen how this will affect the population.

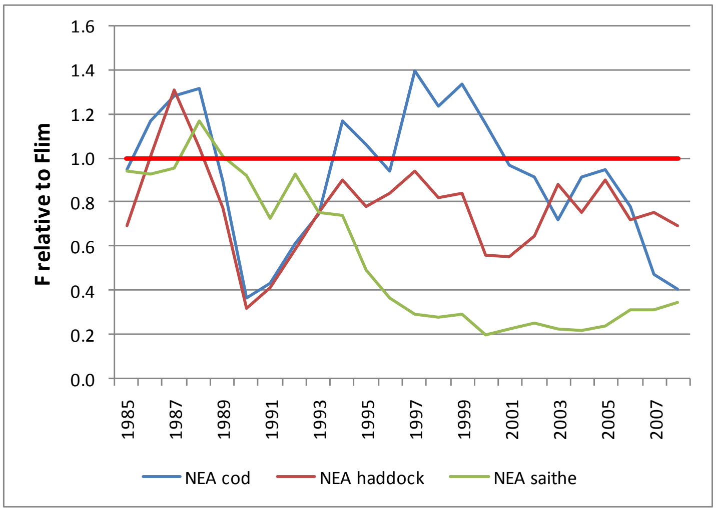

Figure 7. Annual fishing mortalities of the Northeast Arctic cod, haddock and saithe stocks relative to the critical levels above which the fishing mortality will impair the recruitment.

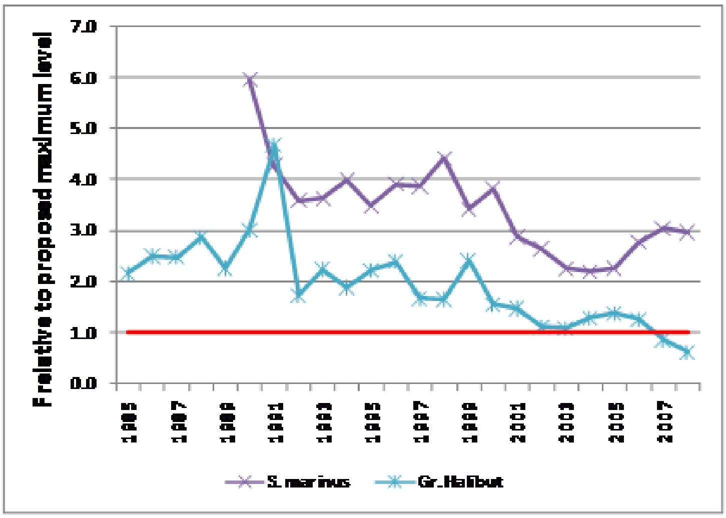

Figure 8. Annual fishing mortalities of Golden redfish (Sebastes marinus) and Greenland halibut (Reinhardtius hippoglossoides) relative to the proposed maximum levels above which the fishing mortality over time most probably will impair the recruitment.

Bottom trawling has significant impact on benthos in the Barents Sea. The most serious effects have been demonstrated for hard-bottom habitats dominated by large sessile fauna, such as corals, sponges and sea anemones. Effects on soft bottom fauna have been less studied. To avoid impact on bottom fauna, joint Russian-Norwegian work is currently exploring the possibilities of using pelagic trawls when targeting bottom living fish.

The general level of discarding from fisheries in the Barents Sea is not known. The general rate of by-catches of fish has declined during recent decades, but this issue is still a problem. Lost gear such as gillnets may continue to fish for a long time. No estimate of this impact is available. Other types of fishery-induced mortality include burst net and mortality caused by contact with active fishing gear, such as escape mortality.

The Barents Sea is relatively free of pollution. The exceptions are PCBs and other persistent organic pollutants (POPs) that are still occurring in significant concentrations in top predators like polar bears and some seabirds. Due to regulations and bans of several POPs (e.g PCB and HCB) there has been a decreasing trend in the input to the Barents Sea during the last decade. However, during the last few years, increasing trends again have been seen for some of these substances. Radioactive substances have shown a tendency to decrease over recent years in the Barents Sea, but there is still a risk of significant radioactive pollution from several local sources, such as radioactive waste containers dumped in the Barents and Kara Seas by the former Soviet Union and sunken submarines in the Norwegian Sea and the Barents Sea.

Currents status of petroleum activities are shown on the map below (Figure 9). No major accidental spills of oil from ship transport or oil and gas activities have occurred in the Barents Sea in 2008 or the recent past. Several oil and gas fields might be opened in the coming years in the Barents Sea.

Future shipping activities depend considerably on the expansion rate of the oil-and-gas related industry in the northern areas and on climate change, as climate warming and a subsequent increase of ice-free shipping routes through Arctic waters could significantly contribute to increasing ship traffic in the Barents Sea. In addition to risk from oil spills, ship traffic is also associated with the risk of introducing alien species through ballast water releases or from ship hulls.

The Arctic region is under steadily increasing pressure from tourism, but little is known about overall impact in the Barents Sea. Aquaculture may affect the ecosystem when farmed fish escape and interact with native fish, through spread of pathogens and through pollution. The total impact from such effects in the Barents Sea today is not known.

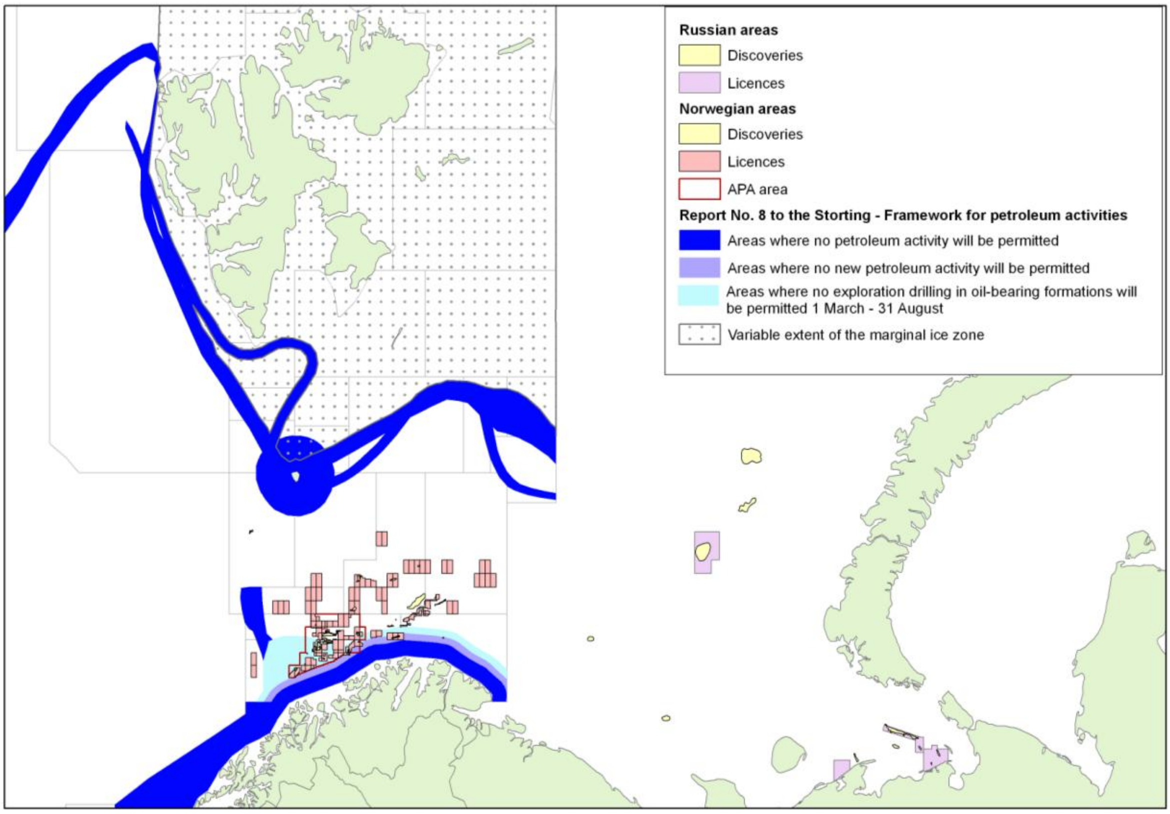

Figure 9. Map reflecting current status of petroleum activities in the Barents sea (source: the Norwegian Petroleum Directorate and Official report Sevmorgeo for Ministry of Natural Resources "Cadastre of the Russian offshore zone", 2007).

3.4 Ecosystem effects and interactions between drivers

To have a broad picture of the current status of the ecosystem and make projections about future development, it is useful to consider how different ecosystem components can affect each other and how different drivers may interact. This section discusses these issues.

As mentioned above, the drivers that currently have the largest documented effects on the Barents Sea ecosystem are fisheries and climate change. Therefore, the discussion focuses on impact of these two drivers. The climate changes in the Baremts Sea likely represent both natural variations and effects of anthropogenic emissions of CO2 and other greenhouse gases.

Northeast Arctic cod is the dominant predator in the Barents Sea ecosystem. The species probably has a stabilising effect on the ecosystem. This is because cod is an opportunistic predator that chooses the most abundant and favourable prey items and thus contributes to dampen outbreaks in prey populations. In addition, at times when prey is generally scarce, cannibalism on younger age classes quickly regulates the cod population to the availability prey.

This role of the cod as a top predator in the Barents Sea is similar to the role of cod in other North Atlantic shelf ecosystems. However, high fishing pressure has, in several of these systems, reduced the populations of cod to very low levels. There has been a subsequent increase in the populations of small pelagic forage fish species such as capelin, herring and sprat. Large stocks of these smaller fish species might be responsible for reducing cod recruitment through either predation on eggs and larvae or through competition for larval food. This mechanism might explain why cod stocks have not recovered in many of the North Atlantic shelf ecosystems despite fishing moratoria. It also suggests that the systems can shift irreversibly from a predator (cod) dominated state to a prey (capelin or herring) dominated state.

In the Barents Sea, no such shift has occurred, and the system seems to be quite resistant to current levels of anthropogenic impact. However, through a generally high fishing pressure, modern industrial fisheries have altered the Northeast Arctic cod stock significantly, resulting in on average smaller individuals than before these fisheries started. As a result, the role of cod as a top predator has been changed. This means that the Barents Sea is now likely to be more susceptible to large outbreaks and fluctuations in the stocks of small pelagic schooling fish such as capelin and herring. Thus the situation might have evolved to become more similar to that in other northern shelf ecosystems.

Fluctuations in climate have profound effects on the Barents Sea ecosystem. One of the important mechanisms is through its effect on recruitment of the major fish stocks. Recruitment of herring and cod in the Barents Sea has been shown to be positively related to sea temperature. The underlying mechanism is not completely known, but is probably related to increased abundance of food for the fish larvae during warm years. It is therefore reasonable to assume that increased sea temperature (within limits) will result in higher abundance of juvenile Norwegian spring-spawning herring and Northeast Arctic cod.

If continued warming is favourable for Norwegian spring-spawning herring, and the stock is large and harvesting low, the stock can be expected to increase further in the future. A large herring stock has a strong impact on the marine environment. In particular, herring is an important predator on eggs and larvae of several fish species. In the Barents Sea, a large stock of juvenile herring can have a strong negative effect on capelin recruitment. A continued increase in herring might therefore be expected to have long-term effects on capelin by affecting the frequency and amplitude of the capelin fluctuations, and possibly reduce the dominating role of capelin in the ecosystem. If so, this can have large effects on the ecosystem, including increasing cannibalism in cod, breeding failure in seabird populations and trophic effects on a range of other species in the ecosystem.

One may ask whether an increasing herring stock in the future may threaten the role of cod as a dominating species in the system. As long as harvesting of cod is kept below the long-term sustainable limit, and a large herring stock does not impair cod recruitment, the Northeast Arctic cod stock might continue to be relatively strong, even with capelin at low levels. However, as mentioned above, intensive fishing has probably reduced the ability of the cod to affect the large fluctuations in the stocks of capelin and juvenile herring in the Barents Sea.

In addition to effects on fish recruitment, climate variability can have significant effects on the Barents Sea ecosystem through changes in distribution of sea ice and range shifts in important species. It is expected that current trends of decreasing sea-ice cover and prolonged ice free periods in large parts of the Barents Sea will continue in a warmer climate. This is expected to have negative impact on ice-dependent flora and fauna. Of special concern are the expected negative impacts on several ice-dependent mammal species which have already been severely reduced by human over-harvesting. Some of these effects may already be visible, such as for example the poor reproduction in ringed seal populations in the recent ice poor years in Svalbard. Reduced sea-ice cover might also cause increased primary production in the Barents Sea. An expected effect of this is increased biomass of benthos in the eastern and northern parts of the Barents Sea.

Based on experience from the warm period in the Barents Sea during the 1920s and 1930s, it can be expected that the major fish species will respond to climate warming by continuing expansion north and east in the Barents Sea. This includes Northeast Arctic cod, Northeast Arctic haddock, Norwegian spring-spawning herring and capelin. Major spawning areas for Northeast Arctic cod will move northwards along the Norwegian coast from the Lofoten area to Troms and Finnmark. Boreal species, such as blue whiting, mackerel and grey gurnard might appear more regularly in the western and southern part of the Barents Sea. Similar shifts are expected for other groups of organisms, such as zooplankton, where Arctic species might be replaced by more boreal species. Benthic taxa characteristic of Arctic shelves may be displaced northward by advancing boreal taxa, and left with few refugia north of the Arctic Ocean shelf break.

Several of the responses discussed above involve long time scales. On such scales, the overall response of the ecosystem to climate change and impact from fisheries and other anthropogenic drivers are associated with large uncertainties. In addition, although a continued warming is likely in the longer term, short term cooling might occur due to natural fluctuations, and medium and long-term prospects may therefore differ. However, irrespective of temperature development and based on the present size and age composition of the main fish stocks, we have some knowledge about aspects of the short term (< 5 years) development in the ecosystem. The cod stock will stay at a stable, but high, level in the coming years. The recent growth in stock size is not likely to continue as the incoming year classes (2006-2008) are below average. The large capelin stock together with a reasonable amount of other prey should ensure enough food for the large cod stock in the coming years. The haddock stock is at a historic high level, but will probably decrease from 2010 onwards due to reduced recruitment. It is unknown whether haddock, which mainly feed on benthic organisms, will be food-limited at such high stock sizes. There are no strong year classes of herring in the Barents Sea at present, and we do not know when the next strong year class will occur. High herring abundance in the Barents Sea seems to be a necessary but not sufficient condition for a capelin collapse. Taking into account the lag between the occurrence of a strong herring year class and a capelin collapse, a capelin collapse is not likely to happen before 2012.

4 Aspects of long-term future change

Several aspects of the impact that human activities have on the ecosystem might become visible on longer time scales. Here, a short summary is given of possible long-term effects associated with climate change, ocean acidification, development towards earlier maturation in Northeast Arctic cod and changes in input of long-range transported pollution. It should be underlined that this is not a complete list of potentially important long term changes.

Although models generally project that the climate in the Barents Sea will get warmer, considerable differences exist between climate models. Predicting the magnitude and nature of the warming that is likely to occur is therefore associated with considerable uncertainty. As mentioned in the section above, it is highly likely, however, that any significant warming will cause shifts in species ranges. This means that more temperate species will become established in the area and that species already present, such as capelin and Northeast Arctic cod will tend to shift toward the north and east within the Barents Sea. In addition, sea ice extent will be reduced, and this will have a negative impact on ice-dependent flora and fauna, such as polar bears. Reduction in sea ice extent may also lead to increased primary productivity, if nutrient supply is not reduced significantly due to increased stratification in the water column. An increase in primary productivity coupled with other positive effects of increased temperature on fish growth and reproduction, may cause productivity of cod, haddock and other commercially important species to increase. However, negative effects on prey species may also occur. Thus, overall effects on fish productivity are hard to predict. Similarly, the many complex ways in which species interact creates considerable uncertainty in any set of predictions as to what the overall response of climate warming to the ecosystem will be.

Anthropogenic emissions of CO_2 are causing acidification of the world oceans because CO_2 reacts with seawater to form carbonic acid. Currently, acidity has increased by about 30% (reduction in pH by about 0,1 units). In 2100, pH reductions in the order of 0.2-0.3 units are predicted. This will significantly reduce the ability of organisms to build calcium carbonate shells and skeletons and it might also have other effects on organisms. The direct effects are expected to be most pronounced for phytoplankton, zooplankton and benthos. Fish, seabirds and marine mammals can be affected indirectly, possibly making ocean acidification one of the most important anthropogenic drivers in the Barents Sea in the future.

Age-at-maturity of Northeast Arctic cod has decreased in recent decades. If this trend continues, it could impair cod recruitment and change the role of cod as a top predator in the system.

Climate warming may increase the rate at which long range transboundary pollution makes its way into the Barents Sea Region.

5 Issues relevant for ecosystem management

An ecosystem-based management plan is typically designed to address the different types of impact human activities have on the ecosystem considered. The issues that such a plan focuses on will therefore depend on the types of anthropogenic impact that the ecosystem is subject to. Based on the description in this report of human impact on the Barents Sea ecosystem, the following issues can be highlighted as relevant when developing ecosystem-based management for the Barents Sea:

- Ocean acidification
- Mixed fisheries, undersized fish, discard of catches, bycatches and IUU fishing
- Impact of bottom trawling on benthos
- Risk of accidental discharges from oil and gas activities and ship transport
- Risk of introduction of alien species from ship traffic
- Long range transboundary pollution that is transported by air and water currents.
- Risk of radioactive pollution

It should be emphasised that although this covers many of the most relevant themes, it should not be considered a complete list. Therefore, the highlighted themes should be looked upon as both a significant part of the basis for ecosystem based management in the Barents Sea as well as important examples that illustrate how the contents of this report may be used to further develop ecosystem-based management in the area. Some issues that are clearly relevant have not been discussed, such as the concept of vulnerable and valuable areas, which is important in the management plan for the Norwegian part of the Barents Sea. The need for specific attention to risks for the loss of biodiversity and needs for protective measures for threatened species of arctic endemics within the region are examples of other relevant issues that have not been highlighted above.

The different themes described above may interact with each other. For example, if ocean acidification causes deterioration of the food base of fish stocks, this can worsen the effect that any overfishing might have on these stocks. Similarly, if both acidification and bottom trawling affect benthic communities, their effects may be additive or even amplify each other. When developing ecosystem-based management, an important challenge is therefore to conduct broad assessments of the combined impact of different types of human activities on the ecosystem.

For an ecosystem that is under considerable pressure from several anthropogenic drivers, it is particularly important to analyse whether their combined effects are so large that the ability of the system to absorb them may be exceeded, causing the ecosystem to shift into another stable state. Such changes have happened in several marine ecosystems, where collapses of cod stocks caused by overfishing, possibly exacerbated by climate variation, have triggered fundamental changes in the ecosystems that may not be possible to reverse. In the Barents Sea, impacts from climate change and ocean acidification are expected to increase in the future, while the level of fishing activities will remain high and increased oil and gas activities and ship transport are expected. To secure sustainable management of the area, it can therefore be helpful to perform the type of analyses described above that assess whether the combined impacts of all of these various anthropogenic drivers are likely to put the stability of the ecosystem at risk.

6 Future needs for monitoring and integrated status reports

The expected increases in the number and type of impacts on the ecosystem put a premium on more extensive monitoring in the future. New monitoring methodology and technology should be developed and implemented to fill the spatial and temporal gaps in current knowledge and on-going monitoring efforts. However, many ecosystem components will still depend on traditional surveys for necessary data collection for many years. During such surveys there is a strong need to capture information simultaneously from as many ecosystem components as possible to enable integrated and cost effective sampling. Developing a joint Russian-Norwegian monitoring program for the Barents Sea would be a useful measure for achieving this. Also, much of the knowledge we have today is due to the foresight of scientists that started regular long-term monitoring programs several decades ago, at a time when their usefulness in addressing current challenges from climatic change, ocean acidification and other emerging issues were unknown. Maintenance of our long-term time series should clearly remain a priority, and new technology and new programmes should be introduced to complement and expand current activities.

In addition, there is a strong need for aggregating the knowledge from observations and scientific progress in different fields. Therefore regular status reports, like this one, are essential to expose important issues and changes in the ecosystem to decision makers, as well as providing a tool for information-sharing among scientist in different fields. This sort of status report should be incorporated, as a standard product, into the pathway towards a bi-national ecosystem-based management system.

All material in this short version has been drawn from the full version of the status report (Joint Norwegian-Russian environmental status 2008, Report on the Barents Sea Ecosystem, Part II – Complete report). Below are listed the more than 130 experts from 9 Russian and 20 Norwegian institutions who have contributed to the full version.

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