030 BRIEF REPORT SERIES/KORTRAPPORT

NORSK POLARINSTITUTT 2015

Final report 2012 – 2015
Joint Russian-Norwegian Monitoring Project – Ocean 3

Oleg Korneev, Oleg Titov, Gro I. van der Meeren, Per Arneberg, Julia Tchernova, Nina Mari Jørgensen

Brief Report Series/Kortrapport no. 30

Oleg Korneev, Oleg Titov, Gro I. van der Meeren, Per Arneberg, Julia Tchernova, Nina Mari Jørgensen

Final report 2012–2015 Joint Russian-Norwegian Monitoring Project – Ocean 3

Address:
Norwegian Polar Institute
Fram Centre
NO-9296 Tromsø

Oleg Korneev, Sevmorgeo
Oleg Titov, Knipovich Polar Research Institute of Marine Fisheries and Oceanography
Gro I. van der Meeren, Institute of Marine Research
Per Arneberg, Institute of Marine Research
Julia Tchernova, Norwegian Polar Institute
Nina Mari Jørgensen, Norwegian Polar Institute

Contributors to the development of the indicator forms presented in the appendices:
J. Aars (NPI), M. Andersen (NPI), N. Anisimova (PINRO), P. Arneberg (IMR), S. Belikov (VNIIPrirody), J. Berrge (UiT), A. Bjørge (IMR), A.L. Brungot (NRPA), K.Y. Børsheim (IMR), M. Carroll (Akvaplan-niva), G. Certain (IMR), M. Chierichi (IMR), S. Cochrane (Akvaplan-niva), M. Daase (NPI), A. Dolgov (PINRO), T. Fadnes (NPD), N. Fedorova (Sevmorgeo), S. Fomin (WWF Russia), J.H. Fosså (IMR), S. Frantzen (NIFES), A. K. Frie (IMR), M. Gavrilo (NPRA), G.W. Gabrielsen (NPI), S. Gerland (NPI), H.E. Heldal (IMR), H. Hop (NPI), C. Hvingel (IMR), G. Ilyin (MMBI), R. Ingvaldsen (IMR), P.E. Iversen (Norwegian Environment Agency), A. Jelmert (IMR), L.K. Jensen (NRPA), E. Johannesen (IMR), T. Johannessen (Norwegian Environment Agency), L.L. Jorgensen (IMR), N. Kasatkina (MMBI), O. Kiyko (Ecoproject), K.M. Kovacs (NPI), O. Korneev (Sevmorgeo), A. Korosov (NERSC), T. Knutsen (IMR), V. Larionov (MMBI), S. Larsen (IMR), V. Lien (IMR), C. Lydersen (NPI), P. Lyubin (PINRO), O. Lyubina (MMBI), P. Makarevich (MMBI), M. Mauritzen (IMR), Gro I. van der Meeren (IMR), I. Melnikov (Shirshov's Institute of Oceanology), O. Mokrotovarova (Murmansk office for Hydrometeorology and Environmental Monitoring), L.B. Mortensen (IMR), B. Møller (NRPA), A. Ovsyannikov (Sevmorgeo), O. Pavlova (NPI), C.F. Pettersen (Norwegian Environment Agency), B. Planque (IMR), C.H. von Quillfeldt (NPI), F. Rey (IMR), H. Routti (NPI), A. Rybalko (Sevmorgeo), T. Shirokolobova (MMBI), H.K. Skjerdal (NRPA), G.C. Skotte (Norwegian Environment Agency), A. Smirnov (AARI), J.E. Stiansen (IMR), H. Strøm (NPI), J.H. Sundet (IMR), V. Svetochev (PINRO), A.H. Tandberg (IMR), J. Tchernova (NPI), O. Titov (PINRO), M. Tsiganova (VNIIPrirody), N. Verboven (NPI), V. Zabavnikov (PINRO), A. Zhilin (PINRO), N. Øien (IMR).

Cover photo:	Frank A. Jenssen
Printed:	March 2015
Technical editor:	Nina Mari Jørgensen and Julia Tchernova
ISBN:	978-82-7666-313-6
ISSN	1504-3215

Preface

The report is a deliverable to the Russian-Norwegian Environmental Commission represented by the Ministry of Climate and Environment (Norway) and Ministry of Natural Resources and the Environment (Russia) from the project Ocean-3, "Ecosystem based monitoring of the Barents Sea". The report summarizes the efforts of the project during 2012-2015 in establishing a set of indicators for the joint monitoring of the Barents Sea.

The project leaders and coordinators wish to thank all the contributors for their outstanding efforts in this project. Contributing institutions are: All-Russian Institute for Nature Protection (VNII Prirody), Federal State Budgetary Institution "Arctic and Antarctic Research Institute", P.P. Shirshov Institute of Oceanology of the Russian Academy of Sciences, Knipovich Polar Research Institute Of Marine Fisheries And Oceanography, Murmansk Marine Biological Institute of Russian Academy of Sciences, National park "Russian Arctic", Sevmorgeo, Ecoproject, WWF Russia, Akvaplan-niva, Institute of Marine Research, Nansen Environmental and Remote Sensing Center, National Coastal Administration, National Institute of Nutrition and Seafood Research, Norwegian Biodiversity Information Centre, Norwegian Environment Agency, Norwegian Meteorological Institute, Norwegian Institute of Nature Research, Norwegian Petroleum Directorate, Norwegian Polar Institute, and Norwegian Radiation Protection Institute.

The coordinating institutions are: Sevmorgeo and Knipovich Polar Research Institute of Marine Fisheries And Oceanography, along with Norwegian Polar Institute and Institute of Marine Research.

The report and its appendices is also available in the electronic format on the BarentsPortal (http://barentsportal.com/), a joint Norwegian - Russian environmental portal, designed for the mutual exchange and presentation of information and data relevant to the management of the Barents Sea,

13.02.2015

St. Petersburg/Murmansk/Tromsø

Oleg Korneev, Sevmorgeo

Oleg Titov, Knipovich Polar Research Institute Of Marine Fisheries And Oceanography

Nina Mari Jørgensen, Norwegian Polar Institute

Per Arneberg, Institute of Marine Research

Julia Tchernova, Norwegian Polar Institute

List of abbreviations

AARII — Arctic and Antarctic Research Institute

Arctos network — Arctic marine ecosystem research network

CBMP — Circumpolar Biodiversity Monitoring Programme

CPUE — catch per unit effort

IFE — Institute for Energy Technology

IMR — Institute of Marine Research

KSNR — Kandalaksha State Nature Reserve

MAGE — Murmansk Arctic Geological Expedition

MMBI – Murmansk Marine Biological Institute

NERSC – Nansen Environmental and Remote Sensing Center

NIFES — National Institute of Nutrition and Seafood Research

NINA — Norwegian Institute for Nature Research

NPRA — National Park Russian Arctic

NRPA — Norwegian Radiation Protection Agency

NSIDC — National Snow and Ice Data Center

NPI – Norwegian Polar Institute

PINRO — Knipovich Polar Research Institute of Marine Fisheries and Oceanography

SSNR — Solovetski State Nature Reserve

TMU — Tromsø University Museum

Contents

1 SUMMARY

1.1 INTRODUCTION

The project "Ocean-3, ecosystem monitoring in the Barents Sea" will establish the base for joint Norwegian-Russian monitoring of the Barents Sea ecosystem. The project is a part of the Work Programme for the Norwegian-Russian environmental cooperation 2013-2015 (approved in Svanhovd, 18 Sept. 2012). The main partners in this cooperation from the Norwegian side are the Norwegian Polar Institute (NPI), and the Institute of Marine Research (IMR), and from the Russian side Sevmorgeo and the Knipovich Polar Research Institute of Marine Fisheries and Oceanography (PINRO). The project's target groups are Norwegian and Russian management, research and monitoring institutions. This technical report presents results of the Norwegian–Russian effort on the development of a suite of indicators, reflecting the state of all ecosystem components and the level of anthropogenic pressure they experience, to be implemented in the joint ecosystem-based monitoring programme. The results of this project form the baseline for further development of a joint ecosystem-based monitoring programme for the Barents Sea.

1.2 THE BARENTS SEA ECOSYSTEM AND INFLUENCING FACTORS

The report presents a brief overview of the state of the environment of the Barents Sea, based on the status report published in the www.barentsportal.com. The Barents Sea is a sub-Arctic shelf (230-500 m deep) ecosystem located between 70 and 80°N. The gene ral pattern of circulation is strongly influenced by this topography. Atlantic and Arctic water masses are separated by the Polar Front, which is characterized by strong gradients in both temperature and salinity. The Barents Sea is a spring bloom system. Zooplankton forms a link between phytoplankton (primary producers) and fish, mammals and other organisms at higher trophic levels. The sea floor is inhabited by a wide range of organisms. More than 200 fish species have been registered in trawl catches during surveys of the Barents Sea, and nearly 100 of them occur regularly. Commercially important fish species include Northeast Arctic cod, Northeast Arctic haddock, Barents Sea capelin, polar cod and immature Norwegian spring-spawning herring. Marine mammals, as top predators, constitute significant components of the Barents Sea ecosystem. The Barents Sea has one of the largest concentrations of seabirds in the world. The 20 million seabirds harvest annually approximately 1.2 million tons of biomass from the area. Invasions of alien species are global in nature. The best known example of introduced species in the Barents Sea is the red king crab (*Paralithodes camtschaticus*). Another emerging species is the snow crab (*Chionoecetes opilio*). The Barents Sea is strongly influenced by human activities, historically involving fishery and hunting of marine mammals. More recently, human activities also involve transportation of goods, oil and gas, tourism and aquaculture. The Barents Sea remains relatively clean when compared to marine areas in many industrialized parts of the world. Major sources of contaminants in the Barents Sea are natural processes, long-range transport of anthropogenic pollutants, accidental releases from local activities, and ship fuel emissions.

1.3 RATIONALE BEHIND SELECTION OF INDICATORS: DESCRIPTION OF TYPES AND PRIORITIES

This list of suggested indicators resulted from a number of expert workshops, meetings and discussions. The process was built on experiences from the newly established Norwegian ecosystem-based management plan of the Barents Sea and Norwegian Sea, as well as information from the Circumpolar Biodiversity Monitoring Programme and the Marine Framework Strategic Directive (MSFD) in EU-countries.

Three types of indicators are defined here: state, pressure/activities and impact. A priority range has been set for monitoring of the suggested indicators. The priority levels used in the report are (in declining order of priority) essential (e), recommended (r) and suggested (s).

1.4 INDICATORS

The suggestions for indicators have been developed through two workshops held in Tromsø in November 2011 and March 2012. The workshops were attended by scientists and other experts from several Russian and Norwegian institutions.

The following institutions were represented from Russia: PINRO, Sevmorgeo, Murmansk Biological Institute, Arctic and Antarctic Research Institute (AARI), VNIIPrirody, Shirshov's Institute of Oceanology, WWF Russia and Ecoproject.

From Norway these institutions participated: Institute for Marine Research (IMR), Norwegian Polar Institute (NPI), The Norwegian Environment Agency (former Directorate for Nature Management and The Norwegian Climate and Pollution Authority) and Nansen Environmental and Remote Sensing Centre. The two workshops resulted in a list of suggested indicators that was sent out on a hearing to the relevant Russian and Norwegian institutions in spring 2013.

Following this, in June 2013, the final list of indicators was decided at a project leader meeting in St. Petersburg. Out of the 22 indicators, 14 are state indicators, 7 are state or impact indicators and 1 is a pressure/ activity indicator.

Most indicators have monitoring of one or more parameters (see **Table 1**). However, microbes and sea ice biota are two indicators for which neither of the two countries has initiated monitoring. On the Norwegian side, there is in addition no monitoring of bottom substrate. Sevmorgeo conducts monitoring for this indicator in Russia. The Russian side has not initiated monitoring of ocean acidification. However, there is an ongoing cooperation between the two countries within these topics.

1.5 CONCLUSIONS AND FUTURE WORK

The project has delivered a list of 22 suggested indicators, selected by experts as tools in order to assess the state of the environment of the Barents Sea. The joint official hearing of the indicators during spring 2013 has ensured an open process and good understanding in both scientific and management organs in both countries. Networking and establishment of contact between the experts within the field of environmental monitoring has been accomplished through the project period (2012-2015).

Table 1 The 22 indicators agreed upon at the St. Petersburg meeting 2013, and information regarding ongoing monitoring in Russia and Norway (*not all parameters/ sub parameters included in the existing monitoring).

Indicator	**Monitoring**	
	Russian	**Norwegian**
Sea ice cover in the Barents Sea	Yes *	Yes *
Meteorological conditions	Yes (until 2011 – AARI)	Yes
Oceanographic conditions	Yes *	Yes *
Water masses properties and volume transport in the Barents Sea	Yes *	Yes *
Ocean acidification and ocean CO_2 uptake	No	Yes *
Phytoplankton diversity, abundance and biomass	Yes *	Yes
Zooplankton diversity, abundance and biomass	Yes	Yes
Benthos diversity, abundance and biomass	Yes*	Yes *
Microbes biomass and diversity	No	No
Sea ice biota, diversity and abundance	No	No
Fish and shrimp biomass	Yes*	Yes *
Fishing pressure	No	Yes *
Introduced species	Yes *	Yes *
Seabird communities/assemblages at sea	Yes *	Yes *
Population development and demography of seabirds	No, only parameter Diet	Yes
Dynamics of non-ice associated marine mammals	Yes*	Yes
Dynamics of ice associated marine mammals	Yes *	Yes
Vulnerable and endangered species	Yes	Yes *
Pollution levels in the physical environment	Yes *	Yes *
Contaminant levels in biota	Yes *	Yes *
Bottom substrate	Yes	No
Demersal fauna biodiversity	Yes	Yes

However, in order to fulfill the intentions of Ocean-3 and proceed towards implementation of a management plan with joint monitoring of the Barents Sea, there is still work to be completed within the Ocean-3 framework. The future work includes:

- Establish environmental quality objectives.
- Link relevant toxicity reference values to indicators and parameters.
- Establish exchange programmes targeted towards specific indicators in order to allow scientists to participate on cruises, fieldwork or/and data handling.
- Suggest a plan for revision of the indicators.
- Make plans for publishing, reporting and sharing of data.

2 INTRODUCTION: NORWEGIAN-RUSSIAN ENVIRONMENTAL COOPERATION PROJECT OCEAN-3

The project "Ocean-3, ecosystem monitoring in the Barents Sea" will establish a base for the joint Norwegian -Russian monitoring of the Barents Sea ecosystem, see **Figure 1** for a map of the Barents Sea.

Figure 1 The Barents Sea with Russian and Norwegian coastal borders.

The project is a part of the Work Programme for the Norwegian-Russian environmental cooperation 2013-2015 (approved in Svanhovd, 18 Sept. 2012). This work supports the Ocean-1 project, which is a development of ecosystem-based management plan for the Russian side of the Barents Sea and which is expected to be reported within the frame of the Ocean-2 – the Barents portal – gateway for the Barents Sea environmental status update.

The main partners in this cooperation from the Norwegian side are the Norwegian Polar Institute (NPI), and the Institute of Marine Research (IMR), and from the Russian side Sevmorgeo and the Knipovich Polar Research Institute of Marine Fisheries and Oceanography (PINRO). The target groups of the project are Norwegian and Russian management, research and monitoring institutions. This technical report presents results of the Norwegian–Russian effort on the development of a suite of indicators, reflecting the state of all ecosystem components and the level of anthropogenic pressure they experience, to be implemented in the joint ecosystem-based monitoring programme. The results of this project form the baseline for further development of such programme.

The project was initiated in 2010 and completed in 2014. The process included the following milestones:

- Two workshops with broad participation of experts from Norwegian and Russian side took place in 2011 and 2012. The workshops provided an overview of existing monitoring activities and a draft of common indicators list was prepared. The following institutions were represented from Russia at the workshops: PINRO, Sevmorgeo, Murmansk Biological Institute, Arctic and Antarctic Research Institute (AARI), VNIIPrirody; Shirshov's Institute of Oceanology, WWF Russia and Ecoproject. From Norway these institutions participated: Institute for Marine Research (IMR), Norwegian Polar Institute (NPI), The Norwegian Environment Agency (former Directorate for Nature Management and The Norwegian Climate and Pollution Authority) and Nansen Environmental and Remote Sensing Centre.
- A hearing of the proposed indicators list was held in spring 2013 among key Norwegian and Russian institutions.
- Conclusion on the final list of suggested indicators for joint Norwegian-Russian monitoring of the Barents Sea was reached at the project leaders meeting in St. Petersburg in June 2013.
- Workshop in Murmansk in April of 2014, where some of the indicators were further developed and possibilities for joint monitoring activities were assessed. The following tasks were partially addressed in Murmansk:

1. Pointing out gaps in current monitoring.
2. Defining how these gaps can be filled.
3. Defining environmental objectives where relevant.
4. Initiating processes for the development of joint monitoring methodology.
5. Initiating joint monitoring activities.

The project has concluded on remaining work, and some suggestions for future work.

3 OVERVIEW OF THE ECOSYSTEM

This chapter is based on the Barents Sea ecosystem status report published at the www.barentsportal.com

3.1 THE STATE OF THE BARENTS SEA ECOSYSTEM

The Barents Sea is a sub-Arctic ecosystem located between 70 and 80°N. It connects with the Norwegian Sea to the west and the Arctic Ocean to the north, all water masses with different characteristics when it comes to salinity, temperature and origin. The average depth is 230 m and the maximum depth is approximately 500 m at the western entrance. The general pattern of circulation is strongly influenced by topography. Atlantic and Arctic water masses are separated by the Polar Front, which is characterized by strong gradients in both temperature and salinity. There is large inter-annual variability in ocean climate related to variable strength of the Atlantic water inflow, and exchange of cold Arctic water. Thus, seasonal variations in hydrographic conditions can be quite large.

The Barents Sea is a spring bloom system. During winter, primary production is close to zero. Timing of the phytoplankton bloom varies throughout the Barents Sea, with the retracting ice, and there may also be a high inter-annual variability. By early spring, the water is mixed from surface to bottom. Despite adequate nutrient and light conditions for production, the main bloom does not occur until the water becomes stratified. Stratification of water masses in different areas of the Barents Sea may occur in several different ways:

1) Fresh surface water from melting ice along the marginal ice zone.

2) Solar heating of surface layers in Atlantic water masses.

3) Lateral dispersion of waters in the southern coastal region (Rey, 1981).

Same as in other areas, diatoms are also the dominant phytoplankton groups in the Barents Sea (Rey, 1993).

In the Barents Sea ecosystem, zooplankton forms a link between phytoplankton (primary producers) and fish, mammals and other organisms at higher trophic levels. Zooplankton biomass in the Barents Sea can vary significantly between years and crustaceans are important. The calanoid copepods of the genus *Calanus* play a key role in this ecosystem. *Calanus finmarchicus*, is most abundant in Atlantic waters and *C. glacialis* is most abundant in Arctic waters. Both form the largest component of zooplankton biomass. Calanoid copepods are largely herbivorous, and feed particularly on diatoms (Mauchline, 1998). Krill (euphausiids), another group of crustaceans, also play a significant role in the Barents Sea ecosystem as food for fish, seabirds, and marine mammals. Krill species are believed to be omnivorous: filter-feeding on phytoplankton during the spring bloom; while feeding on smaller zooplankton during other times of the year (Melle et al., 2004). Several amphipod species were found abundant in the Barents Sea. The term "jellyfish" is commonly used in reference to marine invertebrates belonging to the class *Scyphozoa*, phylum *Cnidaria*. Both comb-jellies (*Ctenophora sp.*) and "true" jellyfish are predators, and they compete with plankton-eating fish, because copepods often are significant prey items.

The sea floor is inhabited by a wide range of organisms. The high diversity among bottom animals is presumed to be due to the abundance of microhabitats that organisms can adapt to. More than 3050 species of benthic invertebrates inhabit the Barents Sea (Sirenko, 2001). The benthic ecosystems in the Barents Sea have considerable value, both in direct economic terms and in their ecosystem functions. Scallops, shrimp, king crab, and snow crab are benthic residents which are harvested in the region. Many species of benthos are also interesting for bio-prospecting or as a future food resource, such as sea cucumber, snails and bivalves. Several of them are crucial to the ecosystem. Important fish species such as haddock, catfish and most flatfishes primarily feed on benthos.

More than 200 fish species are registered in trawl catches during surveys of the Barents Sea, and nearly 100 of them occur regularly. Even so, the Barents Sea is a relatively simple ecosystem, with few fish species of potentially high abundance. Commercially important fish species include Northeast Arctic cod, Northeast Arctic haddock, Barents Sea capelin, polar cod and immature Norwegian spring-spawning herring. Species distribution largely depends on positioning of the Polar Front. Variation in recruitment of species, including cod and herring, has been linked to changes in influx of Atlantic waters. Cod, capelin, and herring are key species in the Barents Sea trophic system. Cod prey on capelin, herring, and smaller cod; while herring prey on capelin larvae. Cod is the most important predator fish species in the Barents Sea, and feeds on a wide range of prey, including larger zooplankton, most available fish species and shrimp. Capelin feed on zooplankton produced near the ice edge. Further south, capelin is the most important prey species in the Barents Sea as it transports biomass from northern to southern regions (von Quillfeldt and Dommasnes, 2005). Herring, another prey species for cod, has similar abundance, and high energy content. Herring is also a major predator on zooplankton.

Marine mammals, as top predators, are keystone species, significant components of the Barents Sea ecosystem. About 25 species of marine mammals regularly occur in the Barents Sea, including: 7 pinnipeds (seals and walruses); 12 large cetaceans (large whales); 5 small cetaceans (porpoises and dolphins); and the polar bear (*Ursus maritimus*). Some of these species are not full-time residents in the Barents Sea, and migrate between temperate areas and the Polar Regions. Others reside in the Barents Sea all year round (e.g. white-beaked dolphin *Lagenorhynchus albirostris*, and harbour porpoise *Phocoena phocoena*). Some marine mammals are naturally rare, such as the beluga whale *Delphinapterus leucas*. Others are rare due to historic high exploitation, such as bowhead whale *Balaena mysticetus* and blue whale *Balaenoptera musculus*. Marine mammals may consume up to 1.5 times the amount of fish caught in fisheries. Minke whales and harp seals may each year consume 1.8 million and 3-5 million tons of prey of crustaceans, capelin, herring, polar cod, and gadoid fish respectively (Folkow et al., 2000; Nilssen et al., 2000). Functional relationships between marine mammals and their prey seem closely related to fluctuations in marine ecosystems. Both minke whales and harp seals are thought to switch between krill, capelin and herring depending on availability of the different prey species (Lindstrøm et al., 1998; Haug et al., 1995; Nilssen et al., 2000). Fish and mammals have seasonal feeding migrations so that the stocks in the area will have their most northern and eastern distribution in August-September and be concentrated in the southern and south-western areas in February-March.

The Barents Sea has one of the largest concentrations of seabirds in the world (Norderhaug et al., 1977; Anker-Nilssen et al., 2000; Gabrielsen, 2009); its 20 million seabirds harvest annually approximately 1.2 million tons of biomass from the area (Barrett et al., 2002). Nearly 40 species are thought to breed regularly in northern regions of the Norwegian Sea and the Barents Sea. Abundant species belong to the auk and gull families. Seabirds play an important role in transporting organic matter and nutrients from the sea to the land (Ellis, 2005). This transport is of great importance especially in the Arctic, where lack of nutrients is an important limiting factor.

3.2 FACTORS INFLUENCING THE BARENTS SEA ECOSYSTEM

Invasions of alien species – spread of the representatives of various groups of living organisms beyond their primary habitats – are global in nature. Their introduction and further spread often leads to the undesirable environmental, economic and social consequences. Different modes of biological invasions include a natural movement associated with the population dynamics and climatic changes, intentional introduction and reintroduction, and accidental introduction with the ballast waters or along with the intentionally introduced species, etc. The best known examples of introduced species in the Barents Sea are red king crab (*Paralithodes camtschaticus*) and snow crab (*Chionoecetes opilio*).

The Barents Sea is strongly influenced by human activity historically involving the fishing and hunting of marine mammals. More recently, human activities also include transportation of goods, oil and gas, tourism and aquaculture. Industrial development in the Arctic demands a closer look at its impact on the ecosystem. During the last years there has been a growing interest in evaluation of ecosystem response to anthropogenic impact in light of the climate change. Fisheries are considered to be the strongest human impact on the fish stocks in the Barents Sea, and thereby for the functioning of the whole ecosystem. However, the observed variation in both fish species and ecosystem is also influenced by other factors such as climate and predation.

The Barents Sea remains relatively clean when compared to marine areas in many industrialized parts of the world. Major sources of contaminants in the Barents Sea are natural processes, long-range transport, accidental releases from local activities, and ship fuel emissions. Results of recent studies indicate low level of contaminants in the Barents Sea marine environment and confirm results of earlier studies on bottom sediments in the same areas. In the near-term, observed levels of contaminants in the marine environment should not have any significant impact on commercially important stocks or on the Barents Sea ecosystem.

The Barents Sea holds a large potential as an important region for oil and gas development. Currently, offshore development is limited both in the Russian and Norwegian economic zones but it is gradually increasing with the discoveries and development of new oil- and gas fields. In the Norwegian zone production is limited to the Snøhvit field (as of 2009 when the status report was finished, ref www.barentsportal.com). There is however increasing petroleum activity in the Barents Sea, related to among other things exploration drilling. Transport of oil and other petroleum products from ports and terminals in NW-Russia have been increasing over the last decade. In 2002, about 4 million tons of Russian oil was exported along the Norwegian coastline, in 2004, the volume reached almost 12 million tons, but the year after it dropped, and from 2005 to 2008 was on the levels between 9,5 and 11,5 million tons per year (Bambulyak and Frantsen, 2009).

The environmental risk of oil and gas development in the region has been evaluated several times, and is a key environmental question facing the region. The risk of large accidents with oil tankers will increase in the years to come, unless considerable measures are imposed to reduce such risk.

The high biodiversity of the oceans represents a correspondingly rich source of chemical diversity, and there is a growing scientific and commercial interest in the biotechnology potential of Arctic biodiversity. Scientists from several nations are currently engaged in research that can be characterized as bio-prospecting (systematic search for interesting and unique genes, molecules and organisms from the marine environment with features that may be of value for commercial development).

Ocean acidification is greater and happening faster than at any other time during the entire period of observation. The absorption of CO_2 seems to generally go faster in colder waters and thus might affect the Barents Sea ecosystem.

4 THE SELECTION PROCESS FOR THE SUITE OF INDICATORS

4.1 ECOSYSTEM-BASED MANAGEMENT AS A GOAL

The purpose of integrated management is to provide a framework for the sustainable use of natural resources and goods derived from the ecosystem and at the same time maintain the structure, functioning and productivity of the ecosystems of the area, in this case the Barents Sea. Several international agreements, such as the Oslo convention (1972), the Paris convention (1974), the Convention for Biodiversity (CBD, since 1992), conclude that the ecosystems are to be managed in ways that provide sustainable use and maintenance of the ecosystem functions. Therefore all international collaborative institutions, like the North-East Atlantic Fisheries Commission, the International Council for the Exploration of the Sea (ICES), the Arctic Council, and the EU-countries are now moving towards monitoring, analysis and advisories for marine ecosystems instead of single species. Indicators based on measurable parameters of the ecosystem are being suggested, tested and tried out in most of new management plans and directives.

4.2 ROLE OF INDICATORS AND ENVIRONMENTAL OBJECTIVES

The role of indicators is to provide data on the state of ecosystem components for the evaluation of the state and trends of the ecosystem as a unit. The present suite of indicators is meant to offer a wide range of information for all components of the Barents Sea ecosystem, including physical conditions and human activities and to help fill knowledge gaps.

To be valuable for the management, the indicators must have relevant environmental objectives where appropriate, to allow for evaluations of the registered trends and states. In this report, the aim is to present the indicators, selected for the joint Norwegian-Russian monitoring project within cooperation on environmental protection.

4.3 RATIONALE BEHIND SELECTION OF INDICATORS: DESCRIPTION OF TYPES AND PRIORITIES

This list of suggested indicators resulted from two expert workshops and other meetings and discussions. Organization of the two workshops is described below. The process was built on experiences from the newly established ecosystem-based management plan of the Barents Sea and Norwegian Sea, as well as information from the Marine Framework Strategic Directive (MSFD) in EU-countries.

The first sets of Norwegian indicators for the Barents Sea and the Norwegian Sea were mainly state indicators describing climatic and biological states and trends. For the North Sea, as well as the MSFD process, it was realized that also pressure and impact indicators are needed to inform the sector managers on important drivers and pressures on the ecosystem. It is particularly important for the Barents Sea where there is a great potential for further industrial development and growing anthropogenic pressure.

Based on these experiences, it is suggested that this suite of common indicators for the Russian-Norwegian cooperation should have all three types of indicators:

- **(E)** State indicator which describes the state (“the quality”) of part of the ecosystem.

A state indicator for the ecosystem component should provide a set of values along a timeline. Depending on the component, a reference level must be set, allowing the registration of deviations from the desirable level or state.

For management purposes this indicator should reflect the changes due to the anthropogenic influence, experienced by the ecosystem component in question. It is, therefore, important to obtain indicators that describe the state of species that are harvested, species that are dependent upon them, and by-catch species, because changes in the state of such species are likely to be partly or wholly caused by human activities. A state indicator used frequently in fishery management is the weight of the spawning stock ("the spawning biomass") for commercial fish stocks, with a threshold value placed so that an enhanced risk of poor recruitment can be expected for spawning stocks below that level.

The physical part of the ecosystem (temperatures, salinity and currents) normally cannot be influenced by management responses, but indicators that describe the physical part of the ecosystem can give early warning of changes that will probably result in changes in the productive ability of the ecosystem and may also change the sensitivity of the organisms for other pressures. Early adaptation to such changes may be an important element in ecosystem-based management in the future.

As a clean ocean is a precondition for consumers to have confidence in products harvested from the sea, it is important to have indicators that show whether the ocean is clean enough to permit production and harvesting of food and can provide warning of changes that put the quality of the harvested products at risk.

- **(A)** Pressure indicator which describes the level and changes of human activities that affect the ecosystem

Human activities are what we are able to change through management responses. Such indicators typically used in fisheries management are catches and by-catch statistics. Indicators of this kind may give early warning of possible negative changes for a population, before the effects have had time to accumulate and they can be detected, in turn, in the state indicators.

- **(I)** Impact indicator which describes changes that can be traced back to human activities in part of the ecosystem

However, serious changes in the ecosystem frequently are not caused by human activities alone – more often, they are a result of human activities together with changes in the physical part of the ecosystem (temperatures, currents, etc.). This type of indicator is therefore often difficult to interpret, but it is useful in combination with other types.

A priority range has been set for the suggested indicators. The priority levels used in the report are:

- Essential

These are indicators considered as absolutely essential for monitoring state of the ecosystem. These indicators are necessary to be able to evaluate changes within the ecosystem components and experienced pressures and impacts.

- Recommended

Expert advice implies that these indicators will highlight some additional connections or influences, or will help to gain a better picture of the state of the ecosystem.

- Suggested

These are indicators or parameters that are not monitored now but should be, in expert opinion. However, in light of financial or personnel shortages they are presented as suggested – to be included and monitored if possible.

4.4 Role of and rationale for the selected indicators

The main expectation of any indicator is that it is meant to show important changes over time in the ecosystem, and the main purpose of initiating the project was to develop a joint monitoring programme that reflects the level of anthropogenic impact on ecosystem due to the increasing level of human activity. There are in general four basic elements making up for the ecosystem-based management that are the underlying base for the selection of indicators. These four elements are:

- Defining the environmental objectives and goals
- Collecting data
- Evaluating the relationship of the state of ecosystem components
- Mitigating the failure to reach environmental objectives

These four elements are discussed in more detail below:

- Defining the environmental objectives and goals

The environmental goals should be based on defining anthropologically related pressures. Management is directed towards human activities and therefore the goals must be related to what it is possible to actually manage through regulations of such activities. Indicators need to be selected in order to actually show how anthropological activities have impacts and how these impacts change with the level of these activities. It has been found difficult to separate between natural and anthropogenic pressures. Still, the series of suggested indicators are expected to reflect, at least partially, ecosystem responses due to changes in levels of human activity.

Some indicators included in the list had environmental objectives defined earlier, but for some newly adopted indicators, the environmental objectives remain to be established. This topic was partially addressed during the Murmansk workshop in the spring of 2014.

- Collection of data to describe the state of a particular ecosystem component

In order to collect time series for the developments of ecosystem related indicators, data need to be collected in a coordinated, comparable and systematic manner to achieve data series that are clearly related to the environmental goal to be achieved.

The data collected must be comparable between sampling crews, locations, seasons and years. It takes decades to build data time series long enough to minimize for the noise of natural variation and gain sufficient limitation in uncertainty in the trends shown by the data series. For many of the suggested indicators, long time series are already available.

However, in some instances sampling techniques differ between the Norwegian and Russian practices and possibilities for coordination and standardization of methods will have to be further addressed.

Developments in survey technology and improved equipment for monitoring lead to continuous considerations for improvements of data collection methodology. For instance, satellite technology should be wider implemented for monitoring and as such will be used in this joint project to provide valuable information.

- Evaluate the relationship of the state of ecosystem components

With sufficient data series collected in space and time, the actual state of each component can be analysed and compared to the environmental goal. This can be done through mathematical assessments of the trends and variations of the indicators, by themselves and in relationship to each other, and over time. Additionally development of a range of models are being done world-wide with the aim to provide the assessed state with reliable model calculations on how these states may develop in selected scenarios predicting future states.

Once the joint programme is in place and operates with the standardized data collection practices, it will be possible to utilize models for assessments, predictions and sustainable management of the Barents Sea resources.

- Mitigation of failure to reach environmental objectives

An important element of management plans should be implementations of measures to be taken if and when the state of the components does not reach the objectives. However, at this stage this issue is not relevant.

The best scientific knowledge has been used when preparing the following list of indicators.

The indicator can be one set of data time series, a selection of parameters which together will make up for one indicator or each parameter can further include sub parameters where necessary. Our understanding of the integrated ecosystem process and trends as well as pressures and impacts from anthropogenic activities is still limited.

4.5 Organisation of the expert workshops

The two expert workshops for selection of indicators were held in Tromsø in November 2011 and March 2012, respectively. Both workshops were attended by several institutions from both the Russian and Norwegian side. The following institutions were represented at the two workshops (number of persons from each institution in brackets):

- November 2011: PINRO (2), Sevmorgeo (2), MMBI (1), AARI (1), VNIIPrirody (1), WWF Russia (1), IMR (5), NPI (6), DN (1), KLIF (1), NERSC (1).
- March 2012: PINRO (2), Sevmorgeo (3), AARI (3), MMBI (1), VNIIPrirody (1), RAS Shirshov's Institute of Oceanology (1), Ecoproject (1), WWF Russia (1), IMR (8), NPI (8), Klif (1), NERSC (1).

At the first workshop, the group of experts worked with identifying suggestions for indicators that could be included. In the time period leading up to the second workshop, the expert group worked with these indicators, identifying in more detail how each indicator should be developed, the type of data that would be required and data sources. At the second workshop, the expert group selected the indicators that should be included in the further process and also suggested how each indicator, parameter and sub parameter should be prioritised. This list was then sent out a hearing to relevant Russian and Norwegian institutions.

5 INDICATORS

At the St. Petersburg meeting in June 2013, the joint indicators list for monitoring of the Barents Sea was established, see **Table 2**. The indicators were set based on the suggestions from scientists attending two joint Norwegian-Russian workshops previously. The priorities of the indicators are mostly at the highest level, «-E- essential”. One indicator, “Seabirds at sea” is listed as “R-recommended”. However, the indicators have multiple parameters and some even sub parameters, which in turn give details in the direction of the monitoring. Many of these are not highly prioritized.

The 22 indicators are divided into:

- State indicators: 14
- State/impact indicators: 7
- Pressure indicators: 1

Table 2 The 22 suggested indicators, type of indicator, priority and the number of associated parameters and sub parameters.

Indicator	Type of indicator	Priority (e- essential, r-recommended, s-suggested)	Number of parameters and sub parameters
Sea ice cover in the Barents Sea	State (E)	e	5/20
Meteorological conditions	State (E)	e	3/6
Oceanographic conditions	State (E)	e	4/20
Watermasses properties and volume transport	State (E)	e	4/9
Ocean acidification and ocean CO_2 uptake	State/impact (E/I)	e	5/11
Phytoplankton diversity, abundance and biomass	State (E)	e	11/33
Zooplankton diversity, abundance and biomass	State (E)	e	7/15
Benthos diversity, abundance and biomass	State (E)	e	2/7
Microbes biomass and diversity	State (E)	e	7
Sea ice biota, diversity, biomass and production	State (E)	e	6/0
Fish and shrimp biomass	State (E/I)	e	11/0
Fishing pressure	Pressure (A)	e	5/4
Introduced species	State/impact (E/I)	e	5/10

Indicator	Type of indicator	Priority (e- essential, r-recommended, s-suggested)	Number of parameters and sub parameters
Sea bird communities/assemblages at sea	State (E)	r	1/1
Population development and demography of seabirds	State (E)	e	4/40
Dynamics of non-ice associated marine mammals	State/impact (E/I)	e	1/3
Dynamics of ice associated marine mammals	State/impact (E/I)	e	4/12
Vulnerable and endangered species	State/impact (E/I)	e	4/7
Pollution levels in the physical environment	State/impact (E/I)	e	4/14
Contaminant levels in biota	State/impact (E/I)	e	6/24
Bottom substrate	State (E)	e	4/2
Demersal fauna biodiversity	State (E)	e	1/3

In the following, each indicator is presented on one page, with main information in order to give a brief overview of the contents. More comprehensive, detailed information is available in the appendices.

5.1 Sea ice cover in the Barent Sea

Indicator: Sea Ice Cover in the Barents Sea

Type of indicator: E, state of the ecosystem.

Priority of indicator: e, essential.

Rationale: Sea ice is one of the most important components of the Barents Sea climate system. It plays a crucial role for many species and ecosystem processes and has a strong impact on regional economies and local communities.

Parameters:

- Sea Ice area (NPI)
- Ice thickness (NPI)
- Snow thickness on sea ice cover (NPI)
- Ice age (NPI)
- Iceberg occurrence (Sevmorgeo)

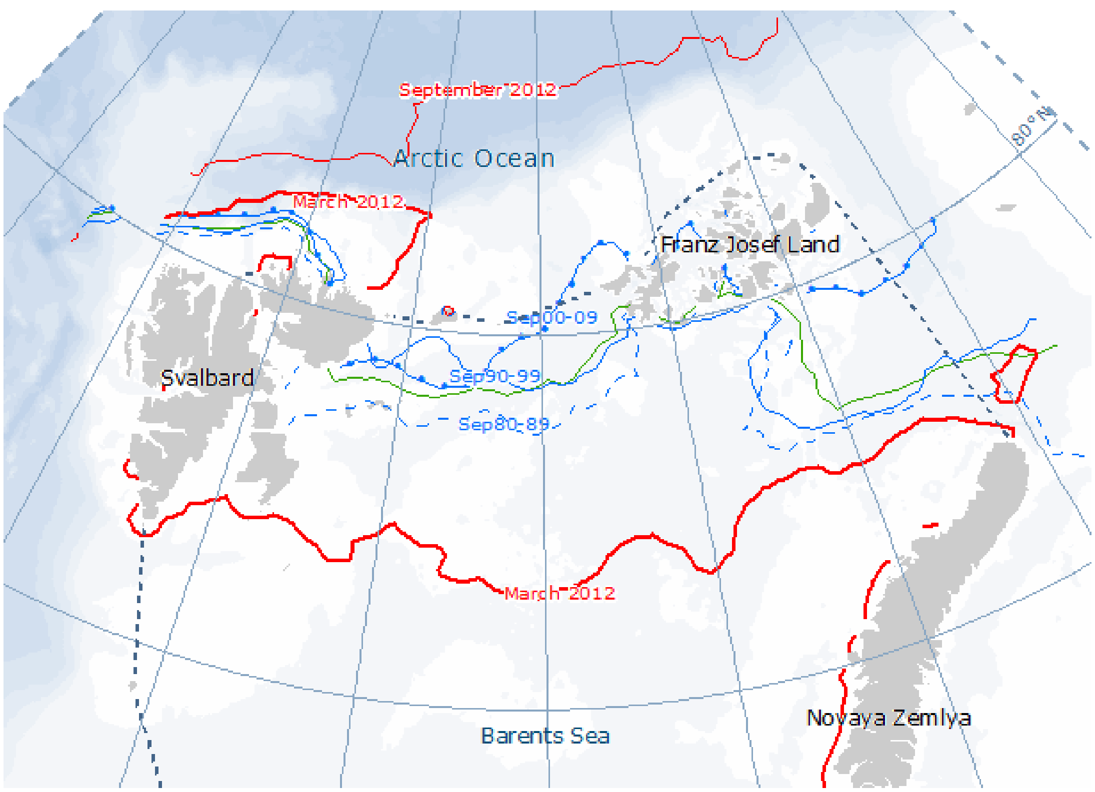


Figure 2 Sea ice in the Barents Sea. Source: www.barentsportal.com, NPI.

5.2 Meteorological conditions

Indicator: Meteorological conditions

Type of indicator: E, state of the ecosystem.

Priority of indicator: e, essential.

Rationale: The air temperature influences ice conditions and shows the warming and the cooling in the region. The summer Barents Sea air temperature correlates to the ice conditions in the region. The winter temperature correlates to the sea surface temperature (SST).

Parameters:

- Air temperature (AARI)
- Meteorological pressure indices (AARI)
- Precipitation (AARI)

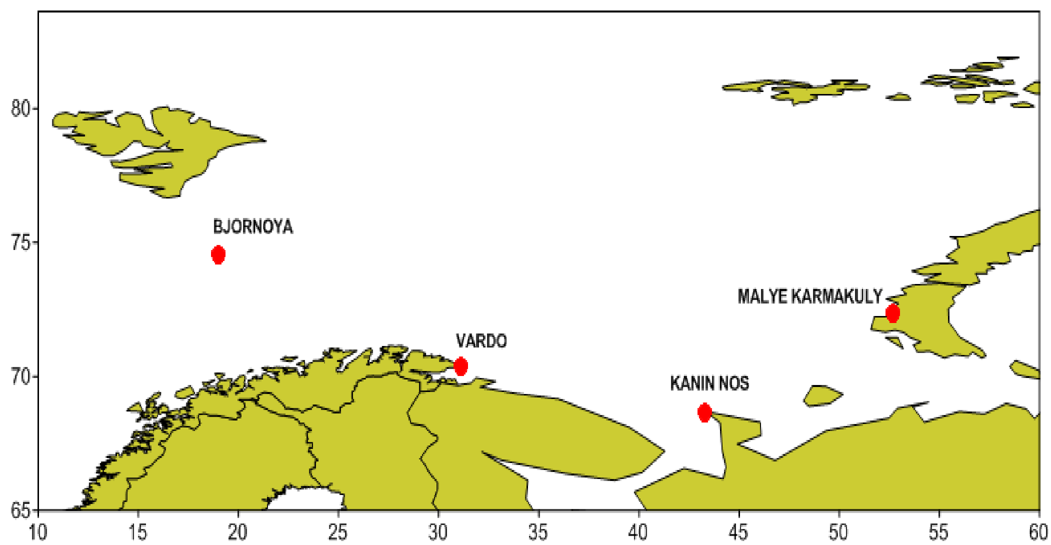


Figure 3 Four meteorological stations around the Barents Sea. Source: AARI.

5.3 OCEANOGRAPHIC CONDITIONS IN THE BARENTS SEA

Indicator: Oceanographic conditions in the Barents Sea

Type of indicator: E, state of the ecosystem.

Priority of indicator: e, essential.

Rationale: Oceanographic conditions play a key role in the functioning of the Barents Sea ecosystem. The temperature in the Barents Sea is dependent on the advection of heat through the southwestern opening and defines the distribution of various important species as well as the extent of the seasonal sea-ice cover. Hence, monitoring oceanographic properties is important for the management of the ecosystem of the Sea.

Parameters:

- Water temperatures (IMR, PINRO, NIVA, NERSC, ECMWF)
- Salinity (IMR, PINRO, ECMWF)
- Nutrients (IMR, PINRO)
- Oxygen (PINRO)

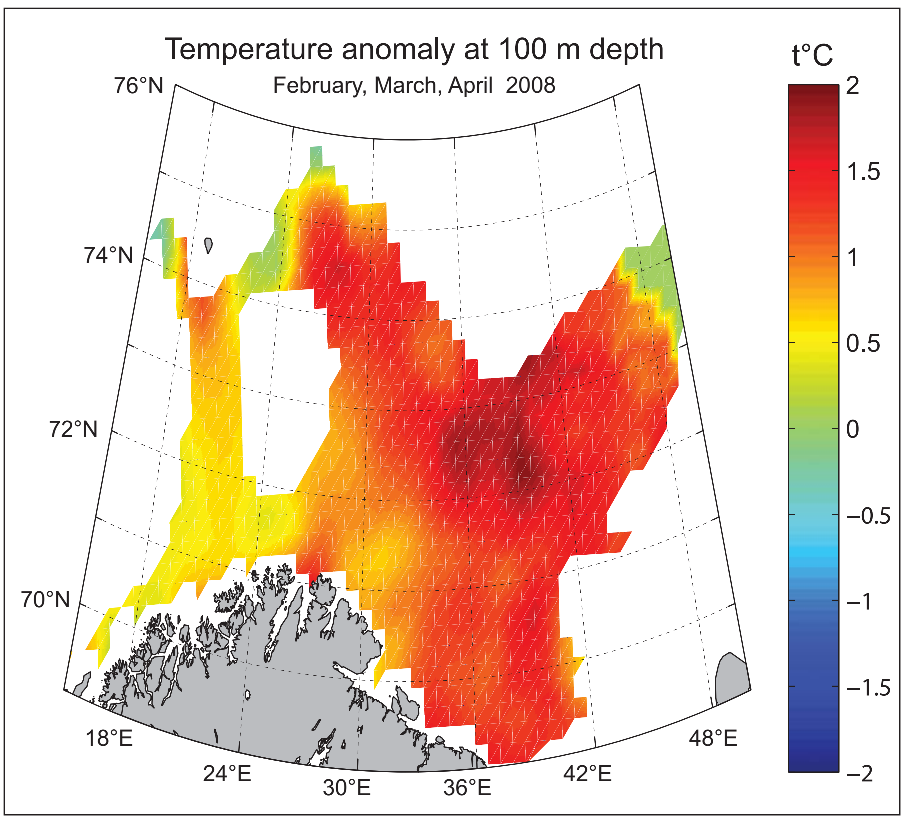


Figure 4 Temperature anomaly at 100 meter depth in the Barents Sea in Feb-Mar-Apr 2008 relative to 1970-2008 average. Source: IMR.

5.4 WATER MASSES PROPERTIES AND VOLUME TRANSPORT IN THE BARENTS SEA

Indicator: Water masses properties and volume transport in the Barents Sea

Type of indicator: E, state of the ecosystem.

Priority of indicator: e, essential.

Rationale: Water masses properties and volume transports play a key role in the functioning of the Barents Sea ecosystem. Due to unique properties of water masses, the Barents Sea is rich in marine life, being one of the most productive fishing grounds in the world. Monitoring of water mass properties and volume fluxes is of major importance for management and sustainable use of resources of the Sea.

Parameters:

- Frontal zones (NERSC, PINRO)
- Area of water masses (PINRO, IMR)
- Volume transport - BSO and BSX) (IMR, PINRO)
- Volume transport - other sections (IMR)

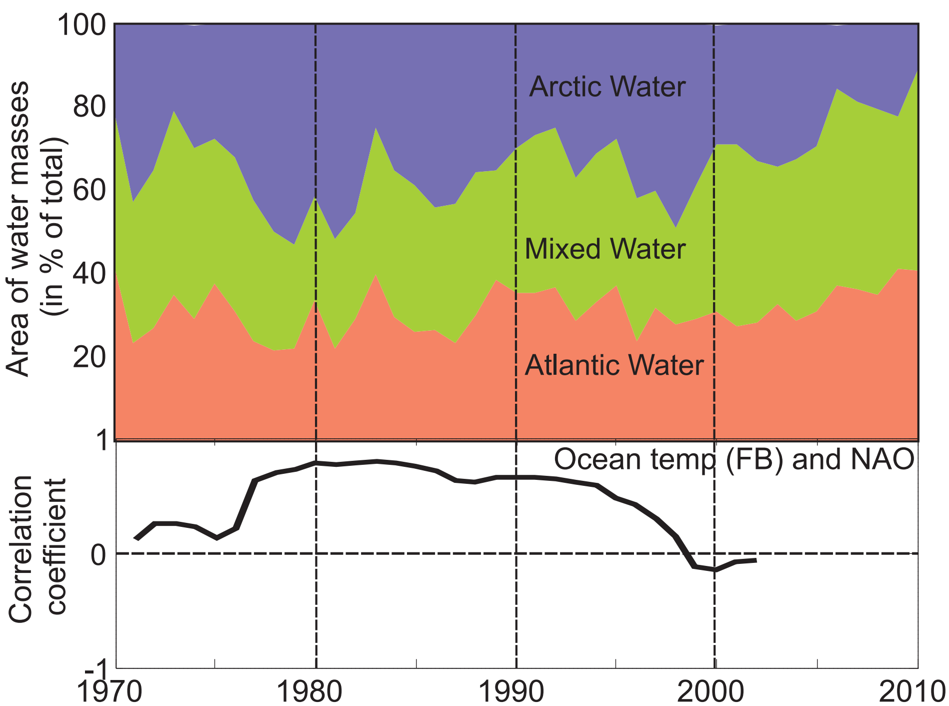


Figure 5 The expansion of the warm and saline Atlantic water at the expense of the colder and fresher Arctic water. (The correlation coefficient figure is not relevant, but is kept so that the year axis can be seen.) Source: IMR

5.5 OCEAN ACIDIFICATION AND OCEAN CO2 UPTAKE

Indicator: Ocean Acidification and ocean CO2 uptake

Type of indicator: E/I, describes state of the ecosystem but is impacted by human activities.

Priority of indicator: e, essential.

Rationale: The ocean has taken up between 30 to 50% of the human induced CO_2. This has led to a pH decrease and a decrease in carbonate ion concentration ($[CO_3^{2-}]$). There is a large natural seasonal and interannual variability. Long-term monitoring is required to discern the change due to increased CO_2 and its impact on OA state.

Parameters:

- Total Alkalinity (AT) (IMR)
- Total Inorganic Carbon (CT) (IMR)
- Calcium carbonate saturation (Ω) (IMR)
- pH in situ (IMR)
- Partial pressure of CO_2 (pCO2) (IMR)

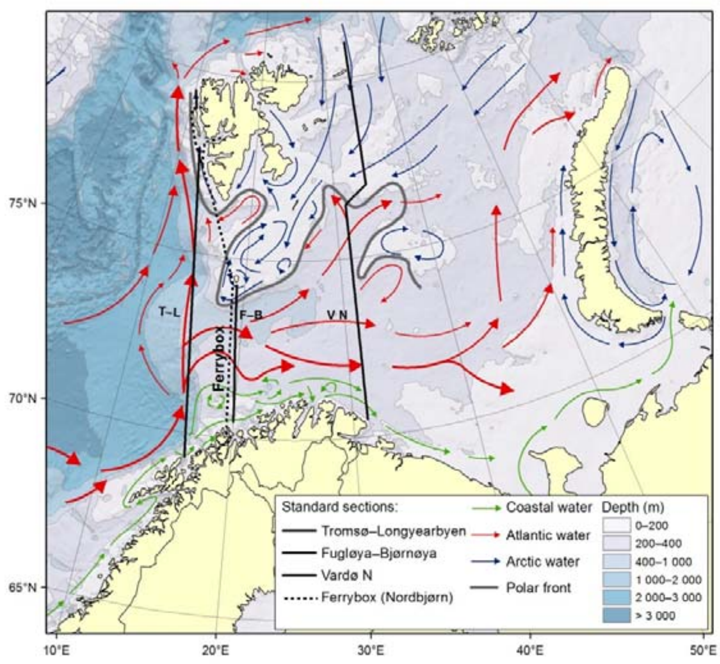


Figure 6 Schematic overview of the circulation pattern and different water masses in the Barents Sea. The black lines show the repeated transects that IMR have initiated sampling and measurements for OA studies and oceanic CO_2 uptake. The dotted line show the repeated Ferrybox route with the cargo ship Norbjørn operated by NIVA for ocean acidification studies. Source: IMR and NIVA.

5.6 Phytoplankton diversity, abundance and biomass

Indicator: Phytoplankton diversity, abundance and biomass

Type of indicator: E, state of the ecosystem.

Priority of indicator: e, essential.

Rationale: Phytoplankton is the first link of all trophic chains in marine ecosystems and only the primary producer in the open water. Its diversity, abundance, biomass and production will be important for how much energy is available for other trophic levels.

Parameters:

- Species composition (CBMP, Arctos network/NPI, IMR, PINRO)
- Species abundance (CBMP, Arctos network/NPI, IMR, PINRO)
- Group abundance Dinoflagellates, Diatoms and Coccolithophorids (CBMP, Arctos network/NPI, IMR, PINRO)
- CDOM, satellite (NERSC)
- PIC, satellites' (NERSC) and benthic samples
- Diversity indices (CBMP, Arctos network/NPI, IMR, PINRO)
- Start, duration and intensity of the spring bloom (NERSC)
- Start, duration and intensity of the late summer bloom (NERSC)
- Chlorophyll (NPI, MMBI, PINRO)
- Total biomass (IMR, PINRO)
- Net primary productivity (NERSC)

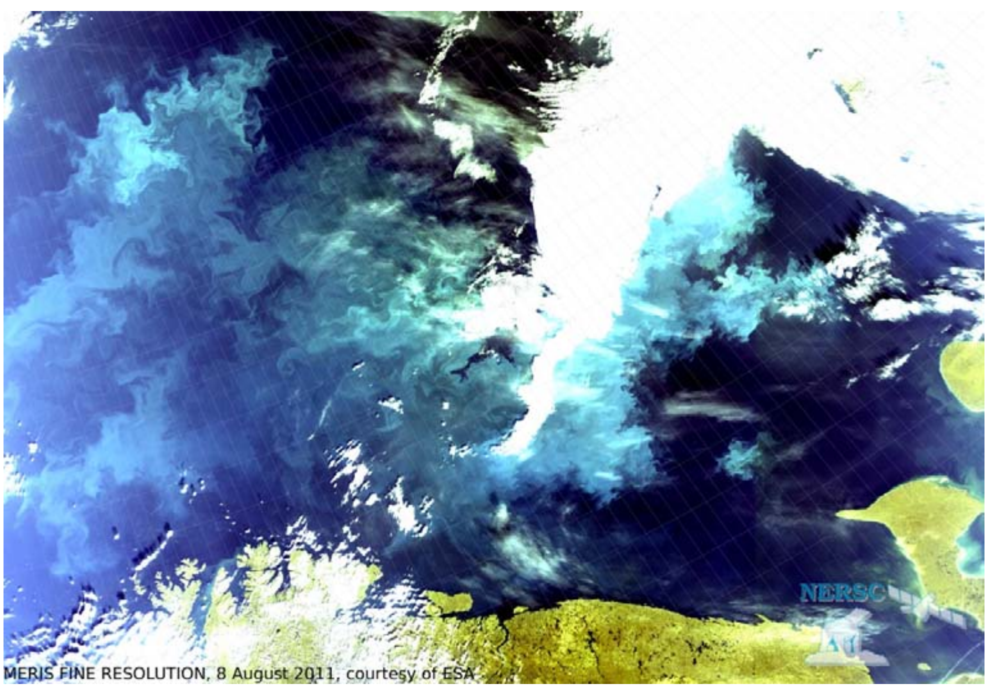


Figure 7 Satelite photo of spring bloom in the Barents Sea, the green areas are coccolithophoride in the Barents Sea. Photo: ©ESA/Nansen centre (NERSC).

5.7 Zooplankton diversity, abundance and biomass

Indicator: Zooplankton diversity, abundance and biomass

Type of indicator: E, state of the ecosystem.

Priority of indicator: e, essential.

Rationale: In the Barents Sea ecosystem, zooplankton forms a link between phytoplankton (primary producers) and fish, mammals and other organisms at higher trophic levels. It is thus important to monitor this group to better understand ecosystem dynamics.

Parameters:

- Species composition of zooplankton (IMR, PINRO)
- Average zooplankton biomass (3 size classes) in autumn survey of the entire Barents Sea (IMR, PINRO)
- Species abundance of zooplankton (IMR, PINRO)
- Relative abundance of Calanus species (IMR, PINRO)
- Spatial distribution of total zooplankton biomass in autumn survey of the entire Barents Sea (IMR, PINRO)
- Species composition of krill (IMR, PINRO)
- Krill abundance (IMR, PINRO)
- Jelly fish biomass (IMR, PINRO)

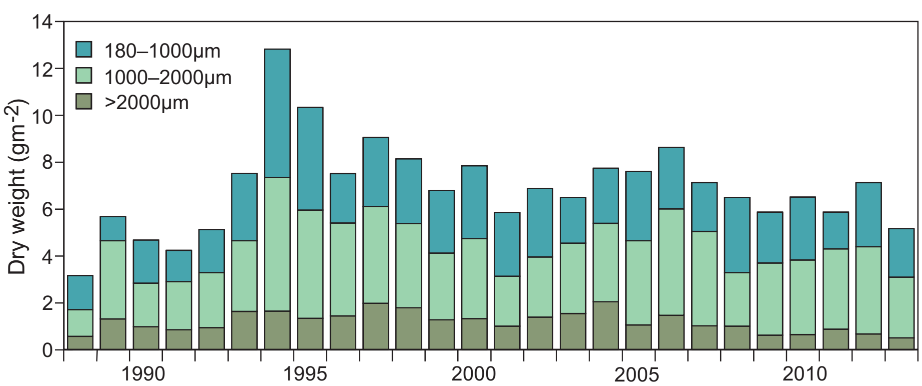


Figure 8 Size fraction of zooplankton in the Barents Sea. Source: IMR.

5.8 BENTHOS DIVERSITY, ABUNDANCE AND BIOMASS

Indicator: Benthos diversity, abundance and biomass

Type of indicator: E, state of the ecosystem.

Priority of indicator: e, essential.

Rationale: Benthos is one of the main components of marine ecosystems. It is stable in time, characterizes local situation, and is able to show the ecosystem dynamics in retrospective. The changes in community structure and composition reflect natural and anthropogenic factors.

Parameters:

- Benthos diversity, abundance and biomass (species and total) (MMBI, PINRO, VNIIOkeangeologia, Akvaplan-niva, IMR)
- Megafauna (trawl collections, video and photographs) (IMR, PINRO, IMR, Akvaplan-niva)

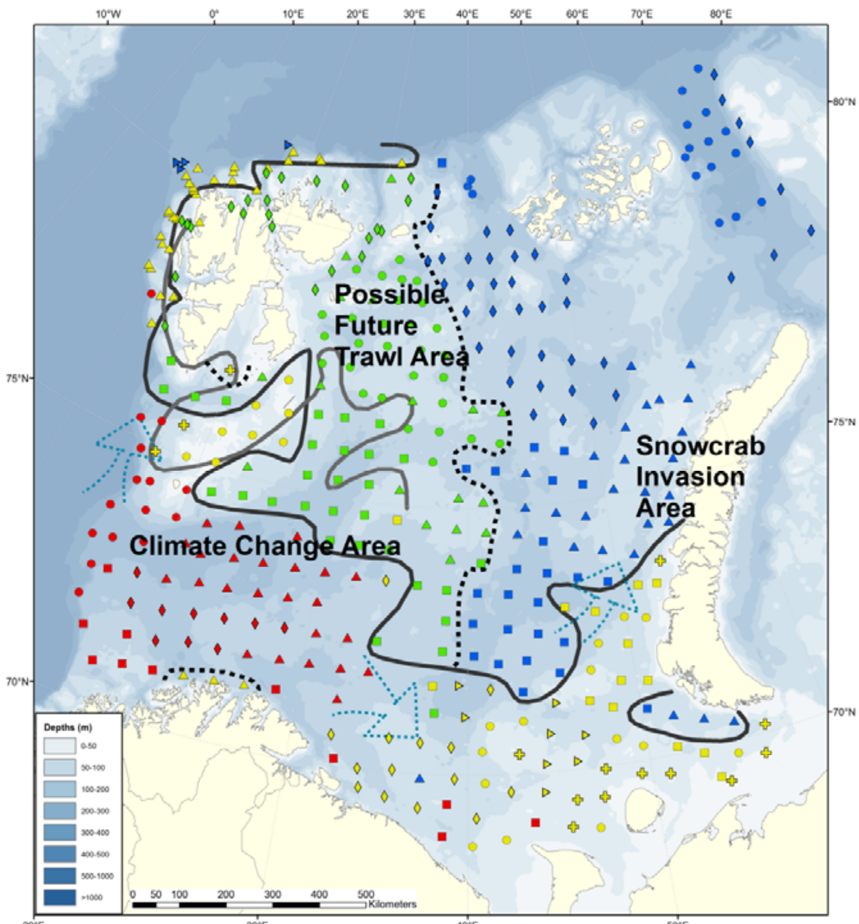


Figure 9 The baseline map of the Barents Sea mega-benthic communities in 2011, based on fauna similarity (see Jørgensen et al 2014 for methodology, results and discussion) with the northern (green and blue) and southern (yellow and red) region where the black full line is illustrating the "benthic polar front" in 2011. The grey full line is the approximately oceanographic Polar Front. Dotted line: Is partly illustrating a west-east division. Red: South West sub-region (SW) Yellow: Southeast, banks and Svalbard coast (SEW). Green: North West and Svalbard fjords (NW). Blue: North East (NE). Source: IMR.

5.9 MICROBES, BIOMASS AND DIVERSITY

Indicator: <u>Microbes (archaea and bacteria) biomass and diversity</u>

Type of indicator: E, state of the ecosystem.

Priority of indicator: e, essential

Rationale: The procaryotic bacteria and archaea, as a result of their diversity and unique types of metabolism, are involved in the cycles of virtually all essential elements. Bacteria play an important role in for example the microbial loop, i.e. a trophic pathway in the marine microbial food web where dissolved organic carbon (DOC) is returned to higher trophic levels via the incorporation into bacterial biomass, and coupled with the classic food chain formed by phytoplankton-zooplankton-nekton. This indicator must be further developed. The work is carried out by IMR and MMBI.

Parameters:

- Total bacterial cell number
- Average cell volume
- Bacterial biomass
- Morphological structure
- Live – dead count
- Production rate
- Genetic structure

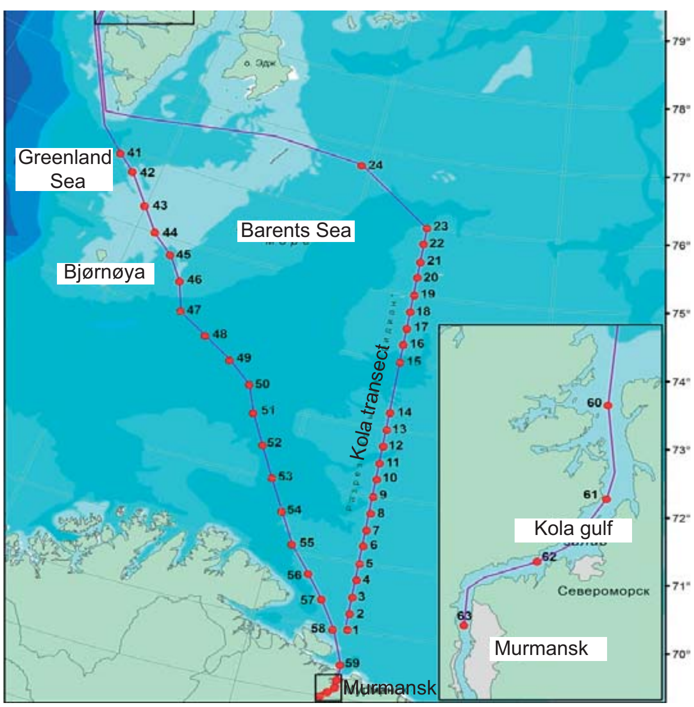


Figure 10 Sections and complex stations (MMBI map) made in the outfit 9-23 November 2013 on the research vessel "Dalnye Zelentsy": Kola transect – stations 1-23; random transects from Svalbard to the Kola Bay – stations 41-59; transect along the Kola Bay – stations 60-63. Source: MMBI.

5.10 Sea ice biota; diversity, biomass and production

Indicator: Sea ice biota diversity, biomass and production

Type of indicator: E, state of the ecosystem.

Priority of indicator: e, essential

Rationale: The importance of ice-related ecosystems is significant. Ice algae is the prime food source for the majority of the ice fauna, thus fuelling the ice-related part of the ecosystem, and the significance increases further north due to lower pelagic production. The sympagic–pelagic–benthic coupling is of great importance in the Arctic. Reduced sea ice, especially a shift towards less multiyear sea ice, will affect species composition as well as biomass and production.

Parameters

- Ice algae biomass (CBMP)
- Ice algae species composition (CBMP)
- Ice algae chlorophyll-a concentration (CBMP)
- Ice algae diversity indices (CBMP)
- Macrofauna species composition (CBMP)
- Macrofauna abundance and biomass (CBMP)

Figure 11 *Melosira arctica* – key diatom species in the Arctic. Photo: Józef Wiktor. Source: www.marbef.org.

5.11 Fish and shrimp biomass

Indicator: Fish and shrimp biomass

Type of indicator: E/I, describes state of the ecosystem but is impacted by human activities.

Priority of indicator: e, essential.

Rationale: The rationale between the use of fish and shrimp biomass is to include sub parameters that are important parts of the Barents Sea ecosystem. The stock developments of keystone species as capelin and cod and young herring are tightly connected and important for the dynamics between these stocks on each other as well as zooplankton, other fish stocks, sea mammals and sea birds.

Parameters

- Blue whiting (IMR and PINRO)
- Beaked red fish (IMR and PINRO)
- BS capelin (IMR and PINRO)
- NEA cod (IMR and PINRO)
- NEA haddock (IMR and PINRO)
- Long rough dab (IMR and PINRO)
- Polar cod (IMR and PINRO)
- Greenland halibut (IMR and PINRO)
- NSS herring (IMR and PINRO)
- Shrimp (IMR and PINRO)
- Biomass of 0-group fish (IMR and PINRO)

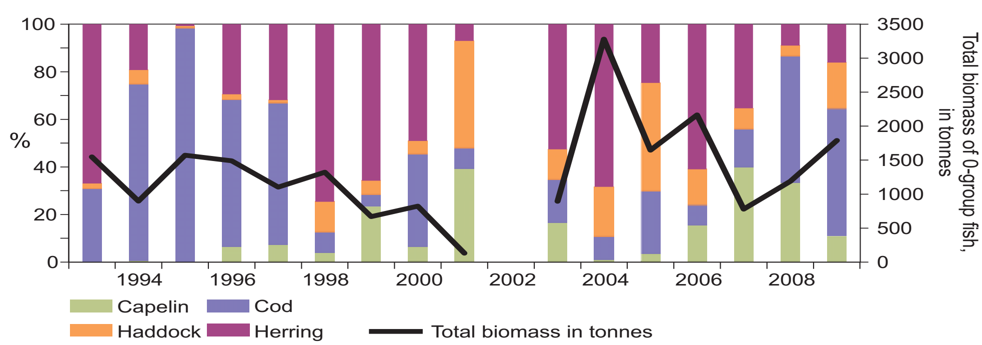


Figure 12 Biomass of four Barents Sea fish species. Source: IMR.

5.12 Fishing pressure

Indicator: Fishing pressure

Type of indicator: A, pressure indicator, describes anthropogenic impact.

Priority of indicator: e, essential.

Rationale: Fishing can remove large part of key commercial stock from the ecosystem, thereby influencing directly and indirectly the other ecosystem components. Normalized fishing mortalities shows if a stock is harvested sustainable (according to given international reference levels). Landings show how much biomass is removed and IUU fishing, Ghost fishing and dumping show unwanted human harvest of key ecosystem components.

Parameters:

- Normalized fishing mortalities (ICES)
- Fishing landings/catches by commercial fleets (ICES)
- IUU fishing
- Ghost fishing
- Dumping

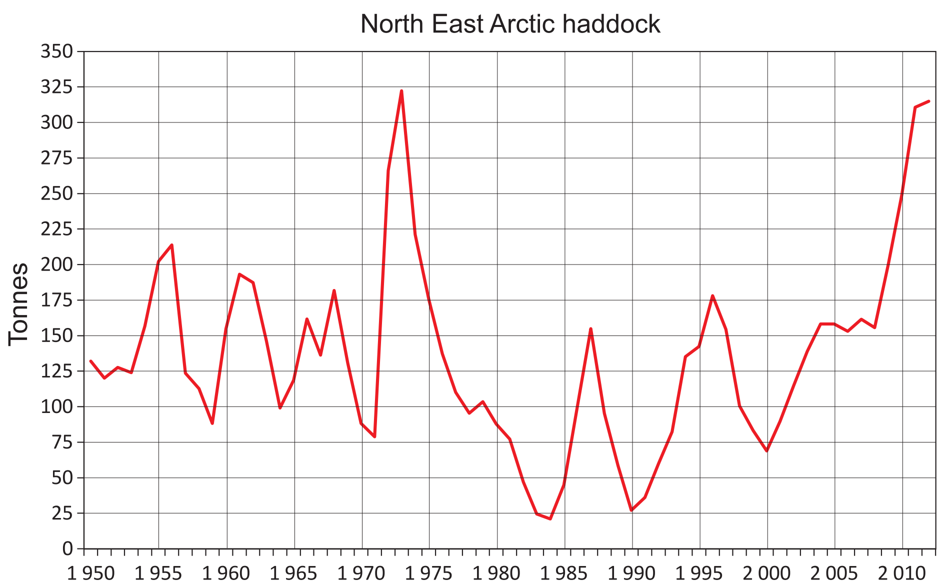


Figure 13 Landings of North-East Arctic haddock. Source: AFWG report 2012 Table 4.18/IMR.

5.13 INTRODUCED SPECIES

Indicator: Introduced species

Type of indicator: E/I, describes state of the ecosystem but is impacted by human activities.

Priority of indicator: e, essential.

Rationale: Next to climate changes, introduced species represent the largest threat to biodiversity and habitat destruction in the world. Alien species may expel native fauna and cause serious changes in the ecosystem functionality. Exotic species are commonly dispersed by human activities, and ballast water and biofouling are thought to be the most important vectors in the marine environment.

Parameters:

- Distribution and biomass of king and snow crabs (IMR, PINRO)
- Species composition in ballast waters and hull fouling (IMR)
- Impact of king crab (IMR, PINRO)
- Impact of snow crab (IMR,PINRO)
- Door step species (IMR)

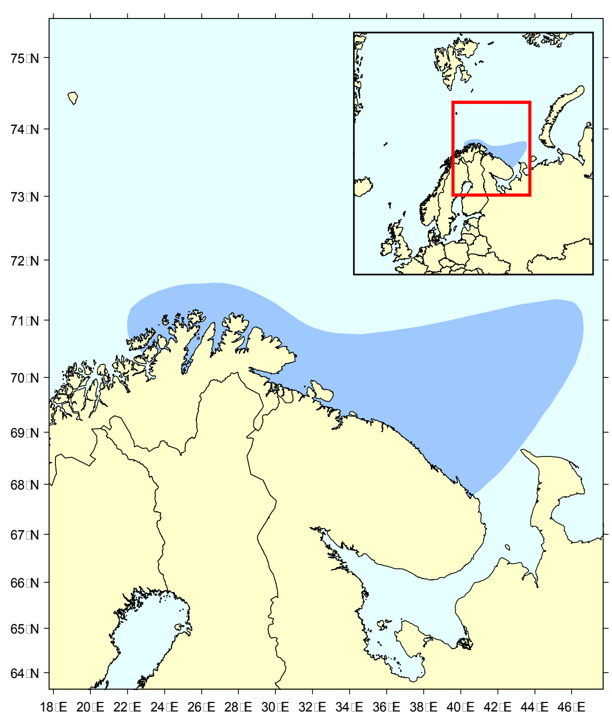


Figure 14 Approximate distribution of red king crab in the Barents Sea. Source: IMR.

5.14 Seabird communities/assemblages at sea

Indicator: Seabird communities/assemblages at sea

Type of indicator: E, state of the ecosystem.

Priority of indicator: e, essential.

Rationale: The purpose of the indicator is to identify changes in the seabird community in the Barents Sea. Distribution and abundance of seabirds at sea is sensitive to changes in the ecosystem in open waters. The indicator reflects both changes in population size and changes in habitat use.

Parameters:

- Spatial-seasonal distribution of seabird communities (NINA, IMR).

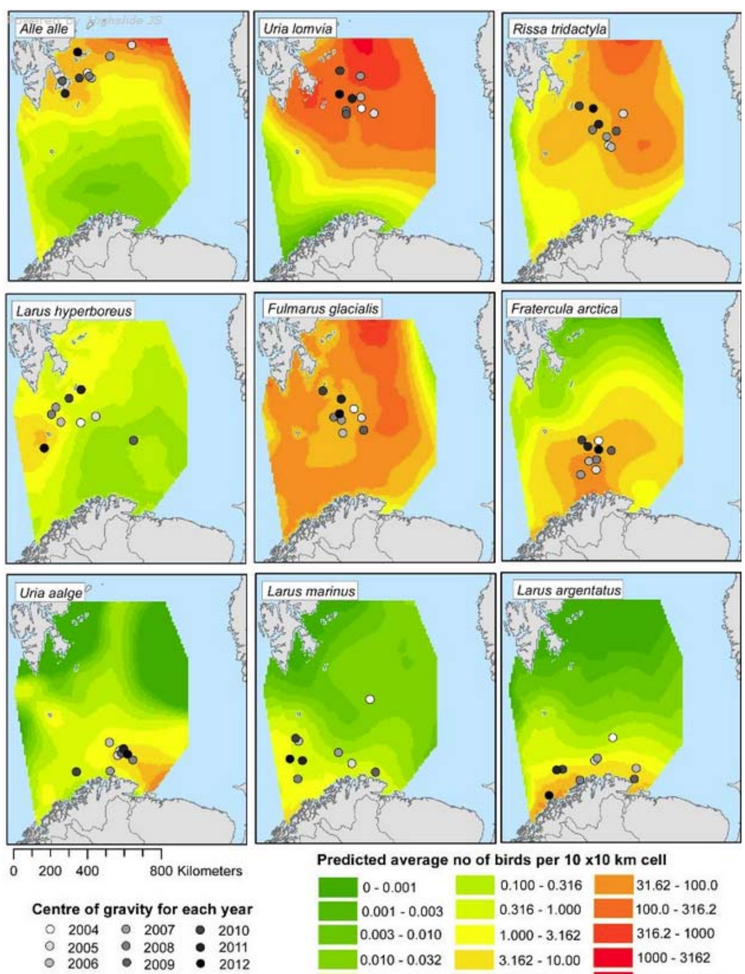


Figure 15 Density distribution for nine seabird species in the Barents Sea. Source: www.seapop.no.

5.15 POPULATION DEVELOPMENT AND DEMOGRAPHY OF SEABIRDS

Indicator: Population development and demography of seabirds

Type of indicator: E, state of the ecosystem.

Priority of indicator: e, essential.

Rationale: Seabirds constitute important components of the Barents Sea ecosystem. They form an important link between the marine and terrestrial ecosystems by bringing nutrients from sea to land. As predators covering many niches, seabirds can be used as indicators of health of the marine ecosystem at large.

Parameters

- Breeding population numbers in selected colonies (NPI, NINA, KSNR, SSNR, NP, NPRA, AARI, TMU)
- Adult survival (NPI, NINA, KSNR, SSNR, NP, NPRA, AARI, TMU)
- Reproductive success (NPI, NINA, KSNR, SSNR, NPRA, AARI, TMU)
- Diet (NPI, NINA, KSNR, SSNR, NPRA, AARI, TMU, PINRO)

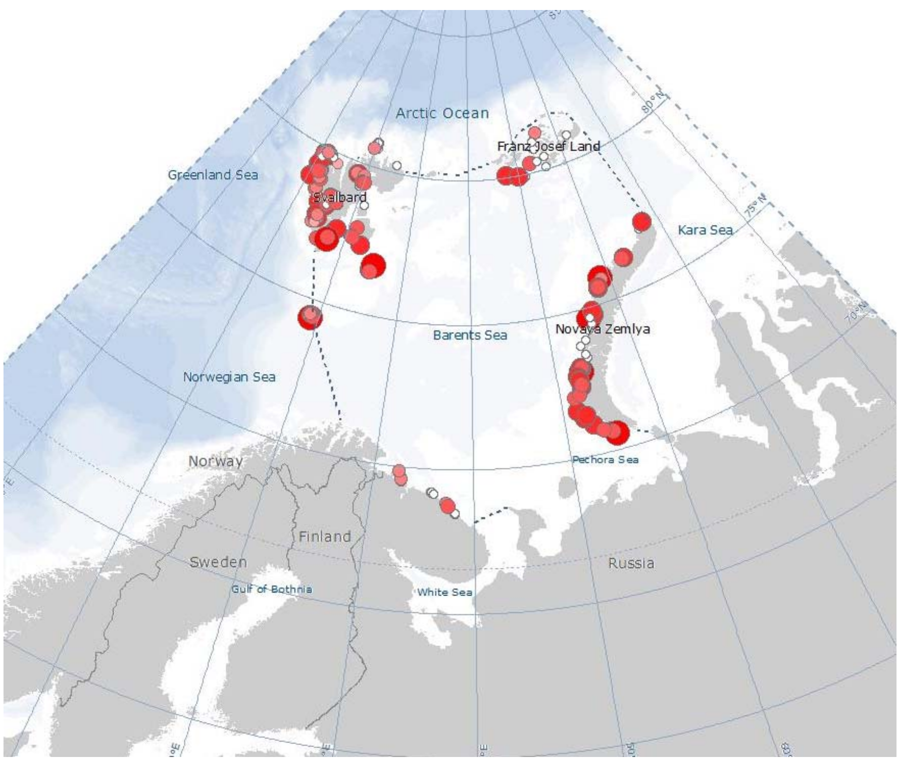


Figure 16 Brunnichs guillemot in the Barents Sea. Source: www.barentsportal.com.

5.16 Dynamics of non-ice associated marine mammals

Indicator: Dynamics of non-ice associated marine mammals

Type of indicator: E/I, describes state of the ecosystem but is impacted by human activities.

Priority of indicator: e, essential.

Rationale: Monitoring the dynamics of non-ice associated marine mammals in the Barents Sea area is essential for understanding overall ecosystem dynamics and as a basis for assessing and mitigating impacts of human activities on the marine fauna.

Parameters

- Abundance and spatial distribution of marine mammals (PINRO, MMBI, IMR)

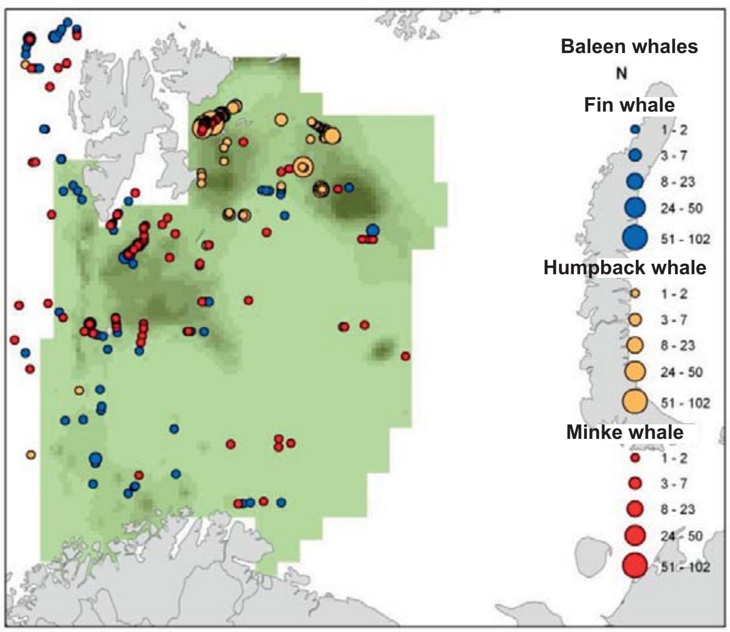


Figure 17 Balaenopterid distributions as observed in the western Barents Sea during the ecosystem survey. Green shades: Averaged densities of baleen whales (fin, minke and humpback whales) in the years 2003-2007. Dots: observations of fin (blue), humpback (yellow) and minke (red) whales during the 2010 ecosystem survey. Russian observations are not included in the figure. Source: IMR.

5.17 Dynamics of ice associated marine mammals

Indicator: Dynamics of ice associated marine mammals

Type of indicator: E/I, describes state of the ecosystem but is impacted by human activities.

Priority of indicator: e, essential.

Rationale: Ice associated marine mammals are expected to be severely affected by declining sea ice extent. It is thus of great importance to monitor their population dynamics.

Parameters:

- Polar bear population (NPI)
- The Barents Sea/White Sea harp seal population, distribution, abundance and biological state (IMR, PINRO, MMBI)
- Walrus population in the Barents Sea, distribution and abundance (NPI, PINRO, VNIIPrirody)
- Ringed seal population in the Barents Sea, distribution and abundance (NPI, PINRO)

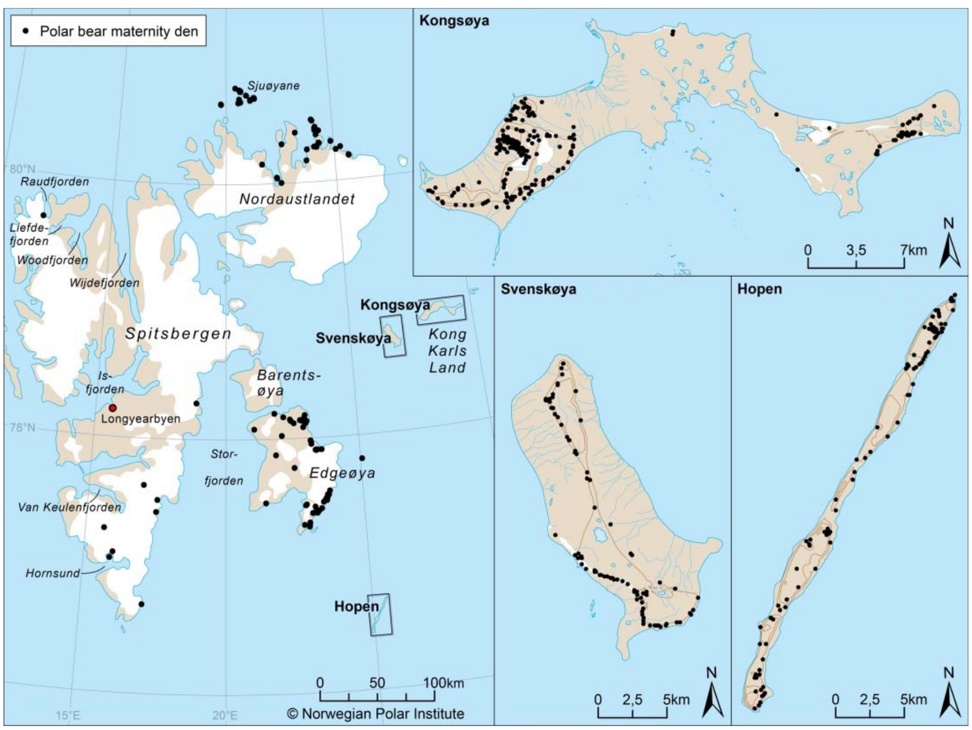


Figure 18 Distribution of polar bear maternity dens in Svalbard. Source: NPI.

5.18 Vulnerable and endangered species

Indicator: Vulnerable and endangered species (VES)

Type of indicator: E/I, describes state of the ecosystem but is impacted by human activities.

Priority of indicator: e, essential

Rationale: A healthy ecosystem is based on biodiversity. To maintain it, vulnerable and endangered species must be consistently monitored. They are important in terms of genetic, scientific, educational and esthetic value. They experience direct impact from anthropogenic activity as well as from the changing environmental conditions that affect their distribution and population numbers.

Parameters:

- Total number of VES and number for the main categories: mammals, birds, fish (Norwegian Biodiversity Information Centre, NPI, VNIIPRirody, MMBI, IMR, PINRO)
- Territorial distribution of VES (IMR ecosystem cruise, NPI, MMBI, PINRO, VNIIPrirody)
- By-catch of VES (PINRO,IMR)
- Species of special interest (IMR, MMBI, PINRO, NPI)

Figure 19 Golden redfish, species of special interest. Source: IMR.

5.19 POLLUTION LEVELS IN THE PHYSICAL ENVIRONMENT

Indicator: Pollution levels in in the physical environment

Type of indicator: E/I, describes state of the ecosystem but is impacted by human activities.

Priority of indicator: e, essential.

Rationale: POPs, heavy metals (in particular Hg is of concern) and radionuclides are transported on a regional/ hemispheric/global scale. The Arctic is a sink region for these pollutants, where they may accumulate in biota and affect other parts of the ecosystems.

Parameters:

- Pollution levels in air (Norwegian Institute for Air Research, NRPA)
- Pollution levels in the sea water (Norwegian Environment Agency, NRPA, PINRO, MMBI)
- Oil in water from regular discharges (NPD, Norwegian Environment Agency)
- Pollution levels in sediments (IMR, NIVA, NGU, NRPA, PINRO)

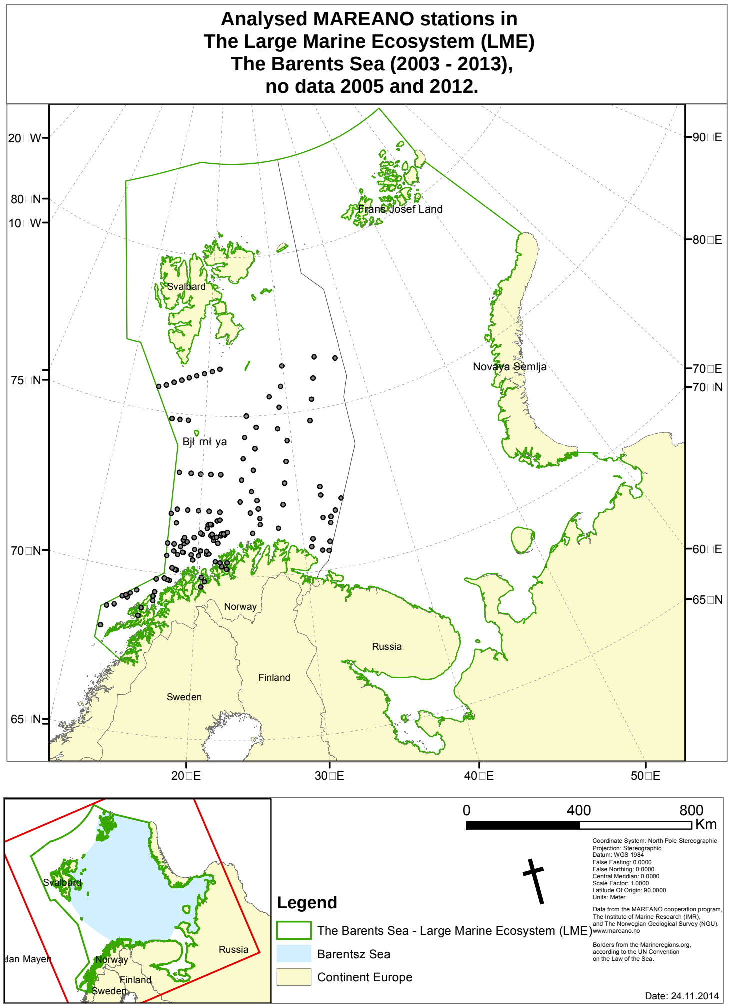


Figure 20 Sediment stations sampled by the Mareano programme in the period 2006-2009. Source: www.mareno.no.

5.20 CONTAMINANTS IN BIOTA

Indicator: Contaminant levels in biota

Type of indicator: E/I, describes state of the ecosystem but is impacted by human activities.

Priority of indicator: e, essential.

Rationale: Contaminant levels in biota show the levels of contaminants (radionuclides, heavy metals and POPs) at different trophic levels in marine food webs. When monitored over several years it would also be possible to determine spatial and temporal trends.

Parameters:

- Contaminants in Brünnich's guillemots (NPI, NRPA)
- Contaminants in polar bears (NPI)
- Contaminants in Atlantic Cod (NIFES, PINRO)
- Contaminants in king crab (NIFES, PINRO)
- Contaminants in Greenland halibut (IMR, PINRO)
- Radioactivity in seaweed (*Fucus vesiculosus*) (NRPA, MMBI)

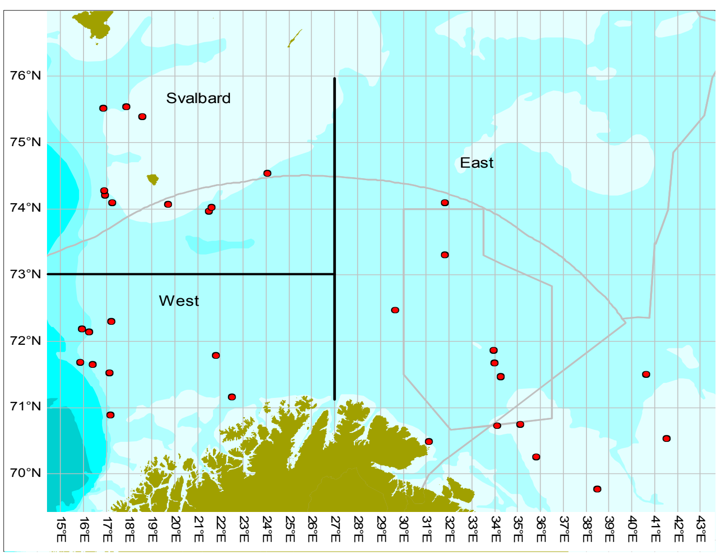


Figure 21 Sampling positions for the baseline study of Northeast Arctic cod (*Gadus morhua*) sampled from February 2009 to May 2010. 25 fishes were sampled at each position. Source: NIFES.

5.21 Bottom substrate

Indicator: Bottom substrate

Type of indicator: E, state of the ecosystem.

Priority of indicator: e, essential.

Rationale: State of the bottom substrate defines he quality of the benthic community life as well as the levels of pollutants such as heavy metals, oil etc. which are important in the planning of environmental research and security measures to ensure the safety of oil rigs.

Parameters:

- Grain size (gravel, sand, silt and mud) (Sevmorgeo, MMBI, MAGE)
- Boulder bed (Sevmorgeo, MAGE)
- Organic matter (Sevmorgeo, Okeangeologiya)
- Colour of bottom sediment (Sevmorgeo)

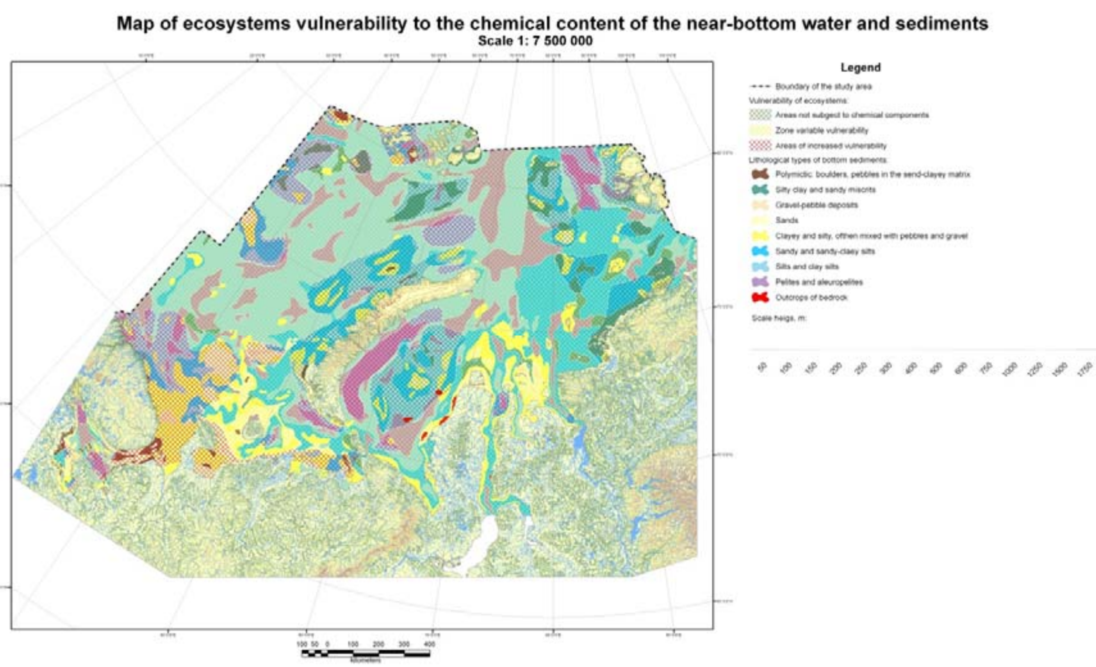


Figure 22 Map of ecosystems vulnerability to the chemical content of the near-bottom water and sediments. Source: Sevmorgeo.

5.22 Demersal fauna biodiversity

Indicator: Demersal fauna biodiversity

Type of indicator: E, state of the ecosystem.

Priority of indicator: e, essential

Rationale*:* This indicator is based on the vector of biomasses of the demersal species caught during the ecosystem survey in the demersal trawl. Following the widely accepted paradigm that diverse communities are more stable through time, and therefore more able to sustain either human or climate driven change, our approach can classify these sub-areas along a “resilience-to-change” gradient.

Parameter:

- Biomass per species of the demersal fauna (IMR).

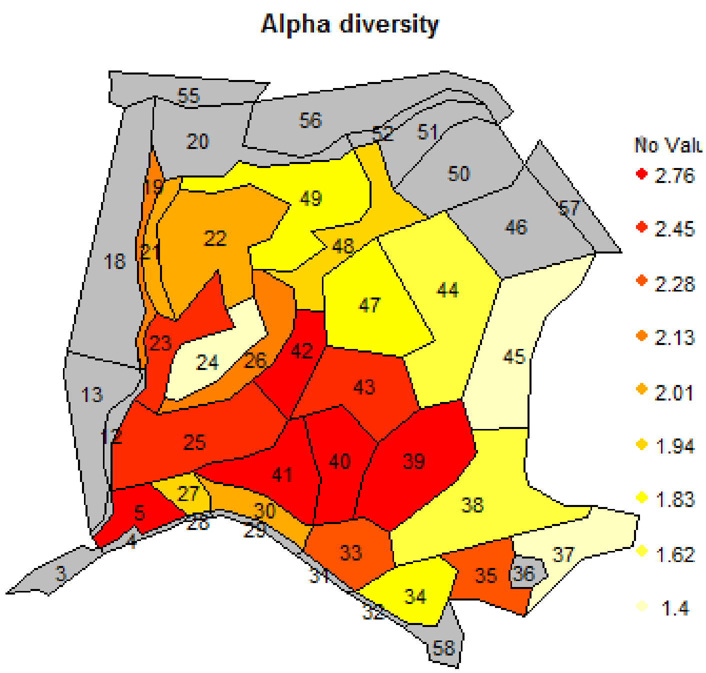


Figure 23 The α-diversity can be viewed as a measure of species diversity at a local (trawl) scale α-diversity is higher in areas corresponding to the Atlantic waters and the polar front. Source: IMR.

6 EXISTING MONITORING PLATFORMS AND GAPS

The table below, **Table 3**, presents the current status of monitoring of each indicator. The information is based on expert submitted information following the workshops. Most indicators have ongoing monitoring of one or more parameters. However, microbes and sea ice biota are two indicators neither of the two countries have initiated monitoring of, but scientists find these mandatory in order to assess the state of the environment of the Barents Sea.

The Norwegian side has in addition to the two indicators mentioned above not initiated monitoring of bottom substrate, whilst the performing institution of the ongoing monitoring in Russia is Sevmorgeo. However, there is ongoing cooperation between the two countries within this topic. The Russians have in addition to the two indicators mentioned above not initiated monitoring of ocean acidification.

Table 3 Comprehensive overview of ongoing monitoring of indicators, parameters and sub parameters based upon submitted expert information. The following information is included: Indicator – name of indicator. Type – E, state, A, pressure, I, impact. Priority – e, essential, r, recommended, s, suggested. Parameter – name of parameter. Sub parameter – name of sub parameter. Monitoring – ongoing monitoring or not, and performing institutions/year.

Indicator (type and priority)	Rationale	Parameter (type and priority)	Sub parameter (priority)	Monitoring	
				Russian	**Norwegian**
Sea Ice cover in the Barents Sea (E,e)	Sea ice is one of the most important components of the Barents Sea climate system. It plays a crucial role for many species and ecosystem processes and has a strong impact on regional economies and local communities.			yes	yes
		Sea ice area (E ,e)		NSIDC, AARI, NERSC	NSIDC, AARI,NERSC
			Sea ice area (satellite) (e)	yes	since 1979
			Extent (satellite) (e)	yes	since 1979
			Concentration (satellite) (e)	yes	since 1979
			Concentration (airborne) (r)	yes	no
			Concentration (in situ) (r)	yes	no
			Timing of ice formation (r)	yes	since 1979
			Timing of ice retreat (r)	yes	since 1979
		Sea-ice thickness (E, e)		yes	yes
			Altimeter (satellite) (s)	no	tbv
			In situ (e)	yes	since 1966
			Airborne (s)	no	no

			Moored upward looking sonars (s)	no	no
		Snow thickness on sea ice cover (E,e)		yes	yes
			In situ (e)	no	since 1966
			Airborne (r)	no	no
		Sea-ice age (E,s)		yes	yes
			Satellite (s)	yes	since 1988
			In situ (s)	no	no
		Iceberg occurrence (E,s)		1950-1990	no
			Number of icebergs observed (A) (e)	yes	no
			Number of months in which episodes of observation were recorded (M) (r)	yes	no
			Number of episodes (E) defined by the dates of observation, during which icebergs were recorded (e)	yes	no
			A calculated value (D) determining the average number of fixations of icebergs in one episode of observations (e)	yes	no
			Iceberg shape (s)	yes	no
Meteorological	The air temperature influences ice conditions and shows the warming			yes	yes

conditions (E,e)	and the cooling in the region. The summer Barents Sea air temperature correlates to the ice conditions in the region. The winter temperature correlates to the sea surface temperature (SST).	**Air temperature (E,e)**		yes	yes
			Individual times series (s)	1926-2011 - AARI	yes MET
			Aggregated air temp product from met stations surrounding the Barents Sea (e)	1926-2011 - AARI	yes MET
		Meteorological pressure indices (E,e)		yes	yes
			NAO (s)	1950-2011 - AARI	yes MET
			AO (s)	1899-2011- AARI	yes MET
			Barents Sea Atm. Circ index (e)	1976-2011- AARI	yes MET
		Precipitation (E,s)		yes	yes
			Rain+snow (e)	1926-2011- AARI	yes MET
Oceanographic conditions in the Barents Sea (E,e)	Oceanographic conditions play a key role in the functioning of the Barents Sea ecosystem. The temperature in the Barents Sea is dependent on the advection of heat through the southwestern opening and defines the distribution of various important species as well as the extent of the			yes	yes
		Water temperatures (E,e)		yes	yes
			Fixed transects (FB, VN, Kola, Kanin) (e)	Joint monitoring: PINRO, Kola, 1900 – present, Kanin, 1959–present	Joint monitoring: IMR and PINRO, 1900 – present 1977 – present

	seasonal sea-ice cover. Hence, monitoring hydrological properties is important for the management of the ecosystem of the Sea.		Northern Barents Sea (defined Arctic water box, scientific surveys) (e)	Joint monitoring: IMR and PINRO	Joint monitoring: IMR and PINRO
			Whole area (maps). Depth: 50 m and bottom (r)	PINRO, 1951 – present	IMR, 1970 – 2008
			Fixed stations in coastal waters (e)	PINRO 1936–	IMR (Ingøy), 1936 – present, gaps:- 1945–1968, 1977–1978
			SST in situ, (ferry box) (s)	no	NIVA and IMR, 1998 – present
			SST (sea surface temperature from satellite) (s)	PINRO, 1982 – present	NERSC, 1981 – present
			SST (reanalysed data) (e)	PINRO, 1950 – present	ECMWF, 1958 – present
		Salinity (E,e)		yes	yes
			Fixed transects (FB, VN, Kola, Kanin) (e)	Joint monitoring: PINRO, Kola, 1900 – present, Kanin, 1959–present	Joint monitoring: IMR and PINRO, 1900 – present; 1977 – present
			Northern Barents Sea (defined Arctic water box, scientific surveys) (e)	Joint monitoring: IMR and PINRO	Joint monitoring: IMR and PINRO
			Whole area (maps). Depth: 50 m and bottom (r)	PINRO, 1951 – present	IMR, 1970 – 2008

			Fixed stations in coastal waters (Ingøy, 50, 200 m, others) (e)	PINRO, 1936 – present	IMR (Ingøy),1936–present, gaps in 1945–1968, 1977–78
			SSS (sea surface salinity from reanalysed data) (s)	no	ECMWF, 1958 – present
		Nutrients (E,e)		yes	yes
			Fixed transects (FB, VN, Kola, Kanin) (e)	PINRO (phosphates), Kola, 1959 – present	FB & VN: IMR
			Northern Barents Sea (defined Arctic water box, scientific surveys) (e)	no	IMR, Ecosystem cruise 1980->
			Whole area (maps). Depth: 50 m and bottom (r)	no	IMR, 1980->
		Oxygen (E,e)		yes	no
			Fixed transects (Kola) (e)	PINRO, Kola, 1959 – present (biochemical oxygen demand, 2008 – present)	no
			New sections (Kanin, FB, VN) (e)	PINRO, Kanin 1959 – present	needs to be developed
			Northern Barents Sea (defined Arctic water box, scientific surveys) (r)	no	needs to be developed

			New: whole area (maps). Depth: 50 m and bottom (r)	PINRO, 1959 – present	needs to be developed
			New: Oxygen (surface; e.g. Ferry box) (s)	no	needs to be developed
Water masses properties and volume transport in the Barents Sea (E,e)	Water masses properties and volume transports play a key role in the functioning of the Barents Sea ecosystem. Due to unique properties of water masses, the Barents Sea is rich in marine life. Monitoring of water mass properties and volume fluxes is of major importance for management and sustainable use of resources of the sea.			yes	yes
		Frontal zones (E,e)		Need to be further developed	Need to be further developed
			Sharpness and location from satellite (e)	no	1980 – present
			New: use in situ S and T (calculation from PINRO/IMR) from ecosystem surveys (r)	PINRO, 1964 – present	IMR
		Area of water masses (E,e)		yes	yes
			Use in situ S and T (calculation from PINRO/IMR) from ecosystem surveys (e)	no	Joint monitoring: PINRO and IMR; 1970 – present
		Volume flux across the south-western (Norway-Bjørnøya) and north-eastern boundaries (Novaya Zemlya-Frans Josef Land) (E,e)		yes	yes
			Current meters (LADCP, ship transects (e)	no	IMR Data are available, but need

					post processing
			Current meters/ADCP on mooring SW Barents Sea (e)	no	IMR, 1997 — present
			New current meter and ADCP mooring in NE Barents Sea (e)	PINRO, 1991/92, 2007/08	No existing plans
			Numerical modelling (r)	PINRO, 1960–- present	IMR, 1960 – present
		Volume flux across the other boundaries and transects (E,r)		yes	yes
			Current meters and ADCP: mooring Bjørnøya-Svalbard (e)	no	No existing plans
			Numerical models (r)	PINRO, 1960 - present	IMR, 1960 — present
Ocean Acidification and ocean CO_2 uptake (E/I,e)	The ocean has taken up between 30 and 50% of the human induced CO_2. This has led to a pH decrease and a decrease in carbonate ion concentration ([CO32-]). There is a large natural seasonal and interannual variability. Long-term monitoring is required to discern the change due to increased CO_2			no	Developed for the Norwegian Sea, coming for the Barents Sea
		Total Alkalinity (AT) (E,e)		no	
			In fixed transects (FB, VN, Kola, Kanin) (e)	no	IMR (FB, VN), IMR started repeated transect FB in 2010

	and its impact on OA state.		from northern Barents Sea (defined Arctic water box, scientific surveys) (e)	no	IMR
		Total inorganic carbon (CT) (E,e)		no	
			In fixed transects (FB, VN, Kola, Kanin) (e)	no	IMR (FB, VN), IMR started repeated transect FB in 2010
			From northern Barents Sea (defined Arctic water box, scientific surveys) (e)	no	IMR
		Calcium carbonate saturation (Ω) (E,e)		no	
			Calculated from AT and CT FB, VN, Kola, Kanin) (e)	PINRO	IMR (FB, VN), IMR started repeated transect FB in 2010
			Calculated from AT and CT northern Barents Sea (defined Arctic water box, scientific surveys) (e)	PINRO	IMR
			Calculated from pH and pCO_2 on mooring (s)	no	IMR investigate possibilities
		pH in situ (E,r)		no	yes
			In fixed transects (FB, VN, Kola, Kanin) (r)	no	IMR (FB, VN). Not started
			From northern Barents Sea (defined Arctic water box, scientific surveys) (r)	no	IMR

			pH sensor on moorings (s)	no	IMR
		Partial pressure of CO2 (pCO2) (E,s)		no	
			pCO2 sensor on mooring (s)	no	To be developed
Phytoplankton diversity, abundance and biomass (E,e)	Phytoplankton is the first link of all trophic chains in marine ecosystems and the primary producer in the open water. Its diversity, abundance, biomass and production will be important for how much energy is available for other trophic levels.			yes	yes
		Species composition (E,e)			Data are not comprehensive, data collection started in 2009
			Rijpfjorden transect (e)	no	NPI, UNIS
			Kongsfjorden-section (e)	no	NPI (MOSJ)
			Fugløya-Bjørnøya (e)	no	IMR
			Vardø-N (e)		IMR
			Kola (e)	MMBI, PINRO	no
			ES, Barents Sea (e)	To be developed	To be developed

		Diversity indices (E,e)			
			Kongsfjorden-section (e)	no	NPI (MOSJ)
			Fugløya-Bjørnøya (e)	no	IMR
			Vardø-N (e)	no	IMR
			Kola (e)	MMBI, PINRO	no
		Species abundance (E,s)			
			Kongsfjorden-section (s)	no	NPI
			Fugløya-Bjørnøya (s)	no	IMR
			Vardø-N (s)	no	IMR
			Kola (s)	MMBI, PINRO	no
		Group abundance (E,e)			
			Kongsfjorden-section (e)		NPI (MOSJ)
			Fugløya-Bjørnøya (e)		IMR
			Vardø-N (e)		IMR

			Kola (e)	MMBI, PINRO	
		Total biomass (E,e)			IMR use the Chl a as a ”total biomass” indicator
			Kongsfjorden-section (e)	no	no
			Fugløya-Bjørnøya (e)	no	no
			Vardø-N (e)	no	no
			Kola (e)	MMBI, PINRO	no
		Chlorophyll (E,e)			
			Kongsfjorden-section (e)	no	NPI (AEM/MOSJ) , IMR
			Fugløya-Bjørnøya (e)	no	IMR
			Vardø-N (e)	no	IMR
			Kola (e)	MMBI, PINRO	no
			Lidar, at fixed polygon (to some depth) (s)	No present activities	To be developed
			Satellite,Barents Sea, surface (e)	no	IMR/Monitoring group (Norwegian Management Plan), NERSC. Spring/early summer as a minimum,

					preferable longer. 1998 – present Only summer data available
		Net primary productivity (E,e)			
			Barents Sea, surface (e)	no	NERSC, 1998–present, gaps: winter time
		CDOM, satellite (E,e)			
			Barents Sea, surface (e)	no	NERSC, 1998–present, gaps: winter time
		PIC, satellites (E,e)			
			Barents Sea, surface (e)	no	NERSC, 2002 – present
		Start, duration and intensity of the spring bloom (E,e)			
			Barents Sea, surface (e)	no	NERSC, 1998–present, gaps: winter time
		Start, duration and intensity of the late summer bloom (E,e)			

			Barents Sea, surface (e)	no	NERSC, 1981 – present
Zooplankton diversity, abundance and biomass (E,e)	In the Barents Sea ecosystem, zooplankton forms a link between phytoplankton (primary producers) and fish, mammals and other organisms at higher trophic levels. It is thus important to monitor this group to understand the ecosystem dynamics.				
		Species composition (E,e)			
			Kongsfjorden-section (e)	no	NPI, 1996 – present, gaps: 1998, 2005
			Vardø-N (e)	no	IMR, data collection started in 2012
			Rijpfjorden transect (e)	no	NPI, 2004 – present, gaps: 2005,2009
			Kola (e)	copepods only so far, PINRO, 1959 – present, gaps:1994–2007	no
			Fugløya-Bjørnøya (e)	no	IMR, 1995 – present
		Species abundance (E,e)			
			Kongsfjorden-section (e)	no	NPI, 1996 – present,

					gaps:1998-2005
			Fugløya-Bjørnøya (e)	no	IMR, 1995 – present
			Vardø-N (e)	no	IMR, 2012 – *No samples analyzed for species composition*
			Kola (e)	PINRO, 1959 – present, gaps:1994–2007	no
			Rijpfjorden transect (e)	no	NPI, 2004 – present, gaps:2005, 2009
		Krill abundance (E,e)		October-December, Barents sea, PINRO, 1952 – present	no
		Spatial distribution of total zooplankton biomass in the entire Barents Sea (E,e)		Joint monitoring: PINRO and IMR, 2004 – present	Joint monitoring: PINRO and IMR, 2004 – present
		Average zooplankton biomass (3 size classes) in autumn survey of the entire Barents Sea (E,e)		Joint monitoring: PINRO and IMR, 2004 – present	Joint monitoring: PINRO and IMR, 2004 – present
		Jelly fish biomass (E,s)		PINRO and IMR	IMR and PINRO, 1980 – present

		Relative abundance of calanus species (E,e)			
			Kongsfjorden-section (e)		NPI, 1996 – present, gaps: 1998, 2005
			Fugløya-Bjørnøya (e)		IMR, 1995 –
			Vardø-N (e)		IMR, 2012 –, *No samples analyzed for species composition*
			Kola (e)	PINRO, 1959 – present, gaps: 1994–2007	no
			Rijpfjorden transect (e)	No	NPI, 2004 – present, gaps: 2005, 2009
Benthos diversity, abundance and biomass (E,e)	Benthos is one of the main components of marine ecosystems. It is stable in time, characterizes local situation, and is able to show the ecosystem dynamics in retrospective. The changes in community structure and composition reflect natural and anthropogenic factors.				
		Benthos (quantitative collections or sampled by grab) – Diversity, abundance and biomass (species and total) (E,e)			

			Kola section (e)	PINRO – 1930, 1935, 1950, 1968, 1969, 1970, 2003. PINRO and MMBI – 2010 –present.	no
			Pechora sea (e)	VNIIOkeangeologia, 1991–1995s and 2000 –2003s, 2005, 2006, published data of 1920 –30s and 1960s. PINRO – benthos data 1924 –1928, 1968 –1970, 2004 – 2006, macrobenthos – since 2010	no
			Barents Sea Polar Front transect (e)	PINRO – 1968, 1970, 2003, 2006	Akvaplan-niva, 1992, 2005, 2007, 2008, 2009
			Norwegian coast – sampled by grab (e)	no	IMR, MAREANO every 5-10 years
		Megafauna (trawl collections, video and photographs) (E,e)			
			Barents Sea (trawl collection) (e)	PINRO and IMR – 2006 -present.	IMR

			Norwegian coast a) Corals, megafauna b) Northward migrating species c) Bottom trawling (e)	no	IMR, MAREANO every 5-10 years
			Svalbard point photographs (e)	no	UiT, more than 30 years (point localities, photographs each year)
Microbes biomass and diversity (E,e)	The procaryotic bacteria and archaea, as a result of their diversity and unique types of metabolism, are involved in the cycles of virtually all essential elements. Bacteria play an important role in for example the microbial loop, i.e. a trophic pathway in the marine microbial food web where dissolved organic carbon (DOC) is returned to higher trophic levels via the incorporation into bacterial biomass, and coupled with the classic food chain formed by phytoplankton-zooplankton-nekton.			To be further developed, suggested areas for monitoring The Kola Section, Franz-Josef Land, Novaya Zemlya – opening of the White Sea to the Barents Sea, Spitsbergen archipelago – the northern part, highly touristic	To be further developed, suggested areas for monitoring The Kola Section, Franz-Josef Land, Novaya Zemlya – opening of the White Sea to the Barents Sea, Spitsbergen archipelago – the northern part, highly touristic
		Total bacterial cell number (E,s)			
		Average cell volume (E,s)			

		Bacterial biomass (E,s)			
		Morphological structure (E,s)			
		Live-dead count (E,s)			
		Production rate (E,s)			
		Genetic structure (E,s)			
Sea ice biota diversity, and abundance (E,e)	The importance of ice-related ecosystems is significant. Ice algae is the prime food source for the majority of the ice fauna, thus fuelling the ice-related part of the ecosystem, and the significance increases further north due to lower pelagic production. The sympagic-pelagic-benthic coupling is of great importance in the Arctic. Reduced sea ice, especially a shift towards less multiyear sea ice, will affect species composition as well as biomass and production.			Regular measurements need to be planned; no monitoring going on for ice biota	Regular measurements need to be planned; no monitoring going on for ice biota
		Ice algae biomass (E,e)		no	no
		Ice algae species composition (E,e)		no	no
		Ice algae chlorophyll-a concentration (E,e)		no	no
		Ice algae diversity indices (E,e)		no	no

		Macrofauna species composition (E,e)		no	no
		Macrofauna abundance and biomass (E,e)		no	no
Fish and shrimp biomass (E/I,e)	The rationale between the use of fish and shrimp biomass is to include sub parameters that are important parts of the Barents Sea ecosystem. The stock developments of keystone species as capelin and cod and young herring are tightly connected and important for the dynamics between these stocks on each other as well as zooplankton, other fish stocks, sea mammals and sea birds.				
		Blue whiting (E/I,s)		IMR and PINRO, 2004-	IMR and PINRO, 2004-
		Beaked redfish (E/I,s)		Distribution. Indices of abundance and biomass for immature part of population. PINRO,IMR, Joint Ecosystem survey 2004-present, Joint Winter survey 2004-present, Russian autumn-winter survey 2000-present	Joint monitoring: IMR and PINRO, 2004-

		NEA capelin (E/I,e)		Joint monitoring: Total biomass, maturing biomass and recruitment, IMR and PINRO, 1972 - present	Joint monitoring: Total biomass, maturing biomass and recruitment, IMR and PINRO, 1972 - present
		NEA cod (E/I,e)		Joint monitoring: Total biomass, spawning stock biomass and recruitment , IMR and PINRO, 1946 – present	Joint monitoring: Total biomass, spawning stock biomass and recruitment , IMR and PINRO, 1946 - present
		NEA haddock (E/I,e)		Joint monitoring: Total biomass, spawning stock biomass and recruitment, IMR, PINRO, 1951 - present	Joint monitoring: Total biomass, spawning stock biomass and recruitment, IMR, PINRO, 1951 - present
		Long rough dab (E/I,r)		Monitoring not started. Abundance by length group) are taken annually during the ecosystem survey.	Monitoring not started.Abundance by length group) are taken annually during the ecosystem survey.
		Polar cod (E/I,r)		Joint monitoring: Total biomass, spawning stock biomass and recruitment , IMR and PINRO, 1986 -	Joint monitoring: Total biomass, spawning stock biomass and recruitment , IMR and PINRO, 1986 -

				present	present
		Greenland halibut (E/I,r)		Joint monitoring. Total biomass, spawning stock biomass and recruitment IMR, PINRO, 1964-2011 Russian autumn-winter survey 2000-present Norwegian slope survey.	Joint monitoring: Total biomass, spawning stock biomass and recruitment IMR, PINRO, 1964-2011,
		NSS herring (E/I,r)		Joint monitoring: Total biomass of young in the Barents Sea, IMR,PINRO, 1973 - present	Joint monitoring: Total biomass of young in the Barents Sea, IMR,PINRO, 1973 - present
		Shrimp (E/I,r)		Joint monitoring: Total biomass, spawning stock biomass and recruitment, IMR, PINRO, Norwegian trawl survey 1982-2005 Russian trawl survey 1984-2005 Joint Ecosystem survey 2004-	Joint monitoring: Total biomass, spawning stock biomass and recruitment, IMR, PINRO, Norwegian trawl survey 1982-2005 Russian trawl survey 1984-2005 Joint Ecosystem survey 2004-

		Biomass of 0-group fish (E/I,e)		IMR,PINRO, 1980-	IMR,PINRO, 1980-
Fishing pressure (A,e)	Fishing can remove large part of key commercial stock from the ecosystem, thereby influencing directly and indirectly the other ecosystem components. Normalized fishing mortalities shows if a stock is harvested sustainable (according to given international reference levels). Landings shows the how much biomass that is removed and IUU fishing, Ghost fishing and dumping shows unwanted human harvest of key ecosystem components.				
		Normalized fishing mortalities (A,e)		yes	1985 - present
		Fishing landings/catches by commercial fleets (A,e)		yes	yes
			Landings NEA capelin (e)	ICES 1972 – present	ICES 1972 – present
			Landings NEA cod (e)	ICES, 1949- present	ICES, 1949- present
			Landings NEA haddock (e)	ICES, 1960-present	ICES, 1960-present
			Landings NEA saithe (s)	ICES, 1950 - present	ICES, 1950 - present
		IUU fishing (A,s)		yes	Some data exists in the Barents Sea for the cod fisheries, based on vessel satellite tracking of the activity of fishing vessels.
		Ghost fishing (A,s)		needs to be developed	no
		Dumping (A,s)		yes	no

Introduced species (E/I,e)	Next to climate changes, introduced species represent the largest threat to biodiversity and habitat destruction in the world. Alien species may expel native fauna and cause serious changes in the ecosystem functionality. Exotic species are commonly dispersed by human activities, and ballast water and biofouling are thought to be the most important vectors in the marine environment.				
		Distribution and biomass of king and snow crabs (E/I,e)			
			Red king crab distribution in NEZ (e)		IMR, 1993 - present
			Snow crab distribution in NEZ (e)		IMR, 2004 - present
			Red king crab in REZ (e)	Annual trawl and pot survey PINRO on stock assessment	
			Snow crab distribution in REZ (e)	Annual trawl and pot survey PINRO on stock assessment	
		Species composition in ballast waters and hull fouling (E/I,r)			
			Monitoring ballastwater and hull foulingto Svalbard (r)	no	UiT, IMR
			Monitoring ballastwater and hull fouling from the Far East (r)	no	no

		Impact of king crab (E/I,e)			
			Monitoring impact on the Barents Sea benthos (e)	PINRO - 1930-1931, 1996, 2003, 2011.	IMR and PINRO, 2008 - present
			Monitoring spread of the red king crab (e)	PINRO, trawl and trap surveys 1996-present	IMR and PINRO, 1994 - present
		Impact of snow crab (E/I,e)			
			Monitoring impact on the Barents Sea benthos (e)	PINRO - 1968-1970, 2004-2006.	IMR and PINRO, 2004-present
			Monitoring spread of the snow crab (e)	PINRO, trawl and trap surveys 2007-present	IMR and PINRO, 1996-2004. IMR and PINRO, 2004-present
		Door step species (E/I,e)		No, to be further developed	No, to be further developed
Seabird communities/assemblages at sea (E,r)	The purpose of the indicator is to identify changes in the seabird community in the Barents Sea. Distribution and abundance of seabirds at sea is sensitive to changes in the ecosystem in open waters The indicator reflects both changes in population size and changes in habitat use.			yes	yes
		Spatial-seasonal distribution of seabird communities (E,r)		Methods to be further agreed / developed	Methods to be further agreed / developed
			Aerial / ship-based surveys / maps of seabird assemblages at sea (r)	PINRO, 2002-present, does not fit relevant methods , methodology	IMR, NINA

				should be developed	
Population development and demography of seabirds (E,e)	Seabirds constitute important components of the Barents Sea ecosystem. They form an important link between the marine and terrestrial ecosystems by bringing nutrients from sea to land. As predators covering many niches, seabirds can be used as indicators of health of the marine ecosystem at large.				
		Breeding population numbers in selected colonies (E,e)		yes	yes
			European shag (e)	KSNR, 1960-present	NINA, 1960-present
			Common eider (e)	KSNR/SSNR, 1960-present	NPI/NINA 1960-present
			Herring gull (e)	KSNR/SSNR, 1960-present	NINA, 1960-present
			Glaucous gull (e)	NPRA, 1992-present	NPI, 1986-present
			Black-legged kittiwake (e)	KSNR/NPRA, 1930 present	NPI/NINA, 1930-present
			Ivory gull (e)	NPRA 2006 - present	NPI, 2006-present
			Brünnich's guillemot (e)	KSNR/NPRA, 1930 - present	NPI/NINA/TMU, 1960-present
			Common guillemot (e)	KSNR 1930 – present	NPI, 1960-present

			Little auk (e)	no	NPI, 2004-present
			Atlantic puffin (e)	KSNR 1930 - present	NINA, 1960-present
		Adult survival (E,e)		to be spread/developed into Russian side	
			European shag (e)		NINA/KSNR, 1960-present
			Common eider (e)		NPI/NINA/KSNR/SSNR, 1960-present
			Herring gull (e)		NINA/KSNR/SSNR, 1960-present
			Glaucous gull (e)	no	NPI, 1986-present
			Black-legged kittiwake (e)	no	NPI/NINA/KSNR, 1930-present
			Ivory gull (e)	no	NPI, 2006-present
			Brünnich's guillemot (e)	no	NPI/NINA/TMU, 1960-present
			Common guillemot (e)	no	NPI/KSNR/NPRA, 1960-present
			Little auk (e)	no	NPI/NPRA, 2004-present
			Atlantic puffin (e)	no	NINA/KSNR, 1960-present

		Reproductive success (E,e)		To be spread/developed into Russian side	
			European shag (e)		NINA/KSNR, 1960-present
			Common eider (e)		NPI/NINA/KSNR/SSNR, 1960-present
			Herring gull (e)		NINA/KSNR/SSNR, 1960-present
			Glaucous gull (e)	no	NPI, 1986-present
			Black-legged kittiwake (e)		NPI/NINA/KSNR, 1930-present
			Ivory gull (e)	NPRA 2006 – present	NPI, 2006-present
			Brünnich's guillemot (e)		NPI/NINA/TMU/KSNR, 2006-present
			Common guillemot (e)		NPI/KSNR, 1960-present
			Little auk (e)	no	NPI, 2004-present
			Atlantic puffin (e)		NINA/KSNR, 1960-present
		Diet (E,e)		To be spread/developed into Russian side	
			European shag (e)		NINA/KSNR, 1960-

					present
			Common eider (e)		NPI/NINA/KSNR/SSNR, 1960-present
			Herring gull (e)		NINA/KSNR/SSNR, 1960-present
			Glaucous gull (e)		NPI, 1986-present
			Black-legged kittiwake (e)		NP/NINA/KSNR, 1930-present
			Ivory gull (e)		NPI, 2006-present
			Brünnich's guillemot (e)		NPI/NINA/TMU/KSNR, 1960-present
			Common guillemot (e)		NPI/KSNR, 1960-present
			Little auk (e)		NPI, 2004-present
			Atlantic puffin (e)		NINA/KSNR, 1960-present
Dynamics of non-ice associated marine mammals (E/I,e)	Monitoring the dynamics of non ice associated marine mammals in the Barents Sea area is essential for understanding overall ecosystem dynamics and as a basis for assessing and mitigating impacts of human activities on the marine				
		Abundance and spatial distribution of marine mammals (E/I,e)			Need to standardize Norwegian and Russian observation

	fauna.				protocols
			Distribution of balaenopterid (minke, fin and humpback whales) and white beaked dolphins (e)	PINRO, 2002-present	IMR, PINRO, 2003 – present
			Abundance of Minke whales (e)	no	Including CPUE and sighting surveys data, IMR, CPUE:1938-83 Sighting surveys: 1988/89-prent
			By-catches of common porpoises (s)	no	IMR - Harbour porpoises in Northern Russia most likely belong to the same stock as harbour porpoises in Finnmark and may therefore be affected by Norwegian bycatches.
Dynamics of ice associated marine mammals (E/I,e)	Ice associated marine mammals are expected to be severely affected by declining sea ice extent. It is thus of great importance to monitor their				
		Polar bear population			

	population dynamics.	**(E/I,e)**			
			Number of dens in important denning areas in Svalbard and Russia (e)	no	NPI, since 1978. Present data mainly from Svalbard –needs to be developed for Russia
			Average number of cubs per female in reproductive age (e)	no	NPI, since 1992. Present data mainly from Svalbard –needs to be developed for Russia
			Average body condition for males (r)	no	NPI, since 1987. Present data mainly from Svalbard –needs to be developed for Russia
		The Barents Sea/White Sea harp seal population (E/I,e)			Based on pup production
			Population size (e)	PINRO, 1998—present Catch based model: 1945-present	Joint monitoring: PINRO, IMR, Pup production estimates: 1998-2010. Catch based model: 1945-present

			Distribution of harp seals in connection with reproduction	PINRO, 2009, 2010	no
			Reproductive rates of female harp seals (s)	PINRO, 1963-72; 1976-85; 1990-93; 2006; 2011 1962-64; 1988	Joint monitoring: PINRO, IMR, 1963-72; 1976-85; 1990-93; 2006; 2011 1962-64; 1988
			Diet shifts in harp seals (s)	no	IMR, NPI and others. Stomachs and intestines: 1987-2011 (intermittently) Blubber: 1995, 2006, 2011
			Length at age and body condition parameters of harp seals (r)	PINRO (only length) 1963-72 1990, 1991, 1992, 1995-1998, 2000, 2004-2006, 2011	IMR, 1963-72 (only length), 1990 (only length), 1991, 1992, 1995, 1996, 1997,1998, 2000, 2004, 2005, 2006, 2011
		Walrus population in the Barents Sea (E/I,e)		Haul out location analysis from satellite data done by WWF	
			Population size (e)	no	NPI, 2006 - present, planned 5 year intervals (some variance expected due to

					weather and ice conditions in individual seasons.
			Remote camera monitoring of tourist visitation (s)	no	NPI, 2007
		Ringed seal population in the Barents Sea (E/I,e)			
			Population size (e)	PINRO, 1998-present	NPI, needs to be developed. Surveys done in 2001 and 2002, not repeated after this because of ice condition deterioration.
			Reproductive rates of ringed seals (e)	no	NPI, collections 2002 and 2012
Vulnerable and endangered species (VES) (E/I,e)	Healthy ecosystem is based on biodiversity. To maintain it, vulnerable and endangered species must be consistently monitored. They are important in terms of genetic, scientific, educational and esthetic value. They experience direct impact from anthropogenic			To be further developed	To be further developed
		Total number of VES and number for the main categories: mammals, birds, fish (E/I,e)			

	activity as well as from the changing environmental conditions that affect their distribution and population numbers.		Number of VES in mammals, their relative abundance and population trend (e)	PINRO, 2006-present	Norwegian Biodiversity Information Center, NPI, VNIIPrirody, MMBI
			Number of VES in birds, their relative abundance and population trend (e)	PINRO, 2006-present	Norwegian Biodiversity Information Center, NPI, VNIIPrirody
			Number of VES in fish, their relative abundance and population trend (e)	PINRO	Norwegian Biodiversity Information Center, IMR, PINRO
		Territorial distribution of VES (E/I,e)		PINRO and IMR, 2006 – present, MMBI, PINRO, VNIIPrirody	IMR ecosystem cruise, NPI
		By-catch of VES (E/I,e)		unclear	IMR
		Species of special interest (E/I,e)			
			Relative abundance of Bowhead whales (e)	PINRO, 2002-present	NPI, 2008. Relative abundance measured using passive acoustic recorders (only monitored in the Fram strait);

					Summer distribution (and relative abundance) measured from sighting reports
			Golden redfish (e)	Joint IMR and PINRO	IMR, abundance estimates
			Abundance of harbour seals on the Barents Sea coast (e)	IMR, MMBI, PINRO, NPI PINRO, 2003-present	IMR, MMBI, PINRO, NPI (Svalbard), Norway: 1994-8; 2003-2006 Russia: 1990-2007; Svalbard – intermittent 5-yr intervals
			Abundance of grey seals on the Barents Sea coast (e)	IMR, PINRO, MMBI,	IMR, PINRO, MMBI, Norway: 1990-1991; 1998-2003; 2006 Murmansk Obl.:1986-1992
Pollution levels in the physical environment (E/I,e)	POPs, heavy metals (in particular Hg is of concern) and radionuclides are transported on a regional/ hemispheric/global scale. The Arctic is a sink region for these pollutants, where they may				
		Pollution levels in air (E/I,e)			NILU. Methods in Russia and Norway need to be the

	accumulate in biota and affect other parts of the ecosystems.				same
			Halogenated compounds (HCH, HCB, Chlordanes, DDTs; PCBs [minimum 28, 52, 101, 118, 138, 153,180]; PBDEs [47, 153, 154, 183, 196, 206]; HBCDD ; PFCs [PFOSA, PFOS, PFOA] (e)		NILU
			HG (e)	no	NILU
			PAH [16] (r)	no	NILU
			Other heavy metals (Cd, Pb, As, Ni, V, Cu, Cr, Zn) (r)	Murmansk subdivision of Roshydromet	NILU
			Radioactivity - gamma emitters (s)	no	NRPA
		Pollution levels in sea water (E/I,e)		Measured in same positions as sediments (Sevmorgeo MMBI)- Sub parameters to be further discussed/ developed	
			Polycyclic aromatic hydrocarbons PAH (r)	State Company "Sevmorgeo". Barents Sea – 2001 – 2009	The Norwegian Environment Agency, Petroleum Directorate

				MMBI - 2000-2012	
			Heavy metals (Cd, Pb, As, Ni, Cu, Cr, Hg, Zn) (e)	SC "Sevmorgeo", Barents Sea – 1997 – 2009. MMBI -1989-2014	
			Radionuclides (r)	MMBI 1995-2014	NRPA
			THC (s)	SC "Sevmorgeo" 1999-2012 MMBI 1989-2013	
		Oil in water from regular discharges (E/I,r)			
			Presence and distribution of oil spills (e)	Murmansk municipal water cleaning system	The Norwegian Environment Agency, Norwegian Petroleum Directorate, 2005 - present
		Pollution levels in sediments (E/I,e)			
			Metals (As, Pb, Cd, Cu, Cr, Hg, Ni, Zn) (e)	Sevmorgeo 2001-2009,	Institute of Marine Research (IMR), Norwegian Institute for Water

				MMBI 1989-2014	Research (NIVA) - 1995-2010, Geological Survey of Norway (NGU),
			THC, PAH (e)	Sevmorgeo, PINRO	IMR, NIVA - 1995-2010
			Organic pollutants (PCB, HCH, DDT, HCB) (r)	Sevmorgeo 2001-2009, MMBI 1989-2014	IMR, NIVA- 1995-2010
			Radioactivity (Gamma emitting isotopes) (e)	Sevmorgeo 2001-2009, MMBI 1989-2014	NRPA - 1999-2012, IMR - 1995-2010,
Contaminant levels in biota (E/I,e)	The rationale of using contaminant levels in biota is that it shows the levels of contaminants (radionuclides, heavy metals and POPs) at different trophic levels in marine food webs. When monitored over several years it would also be possible to determine spatial and temporal trends.				
		Contaminants in Brünnich's guillemots (E/I,e)			
			Organic contaminants in eggs (Chlorinated Pesticides (DDT, HCB, HCH, Chlordanes, mirex, etc); PCBs; PBDE; HBCDD; Toxaphene; PFAS) (e)	no	NPI, 1993- present
			Hg in eggs (e)	no	NPI - 1993 - present

			Other heavy metals in eggs (r)	no	no
			Gamma emitting isotopes, polonium-210, in adults (s)	no	Very little data and coverage, NRPA - 2005
		Contaminants in polar bears (E/I,e)			
			Organic contaminants and metabolites in blood (DDT, HCB, HCH, Chlordanes, mirex, PCB, PBDE,HBCDD,Toxafene, PFAS) (e)	no	NPI, 1989 - present
			Hg in hair (e)	no	NPI, 1995- present
			Other heavy metals in hair (s)	no	no
		Contaminants in Atlantic Cod (E/I,e)			
			Fish health (e)	To be developed, PINRO	To be developed, IMR
			Hg in fillet (e)		NIFES, 1995 -
			Other heavy metals in fillet and liver (r)	PINRO	PCB 6/7, pesticides, brominated flame ret., PFOS) NIFES, 2006-present
			Organic contaminants in liver (e)		NIFES, 2006-present

			Cesium-137 (s)	MMBI	NRPA, IMR, 1991-2012
			^{90}Sr (s)		
		Contaminants in king crab (E/I,s)		To be developed	To be developed
			Hg (e)	no	no
			Other heavy metals (r)	no	no
			Organic contaminants (e)	PINRO and Akvaplan niva: Aliphatic hydrocarbons, PAH, PCB, pesticides	Akvaplan-niva and PINRO : PCB 6/7, pesticides, brominated flame ret., PFOS)
			Cesium-137 (s)		
		Contaminants in Greenland halibut (E/I,e)		To be developed	To be developed
			Hg in fillet (e)		
			Other heavy metals in fillet and liver (r)		
			Organic contaminants in liver (e)		

			Cesium-137 (s)		
			^{90}Sr (s)		
		Radioactivity in seaweed (Fucus vesiculosus) (E/I,r)			
			Radioactivity (Cesium-137, Technetium-99, Plutonium 239/240) (r)		Norwegian Radiation Protection Authority and Institute for Energy Technology
			Technetium-99 (r)		NRPA/IFE, 1995
			Caesium-137 (r)	MMBI,1992-present (different locations)	IFE, 1999
Bottom substrate (E,e)	State of the bottom substrate defines the quality of the benthic community life as well as the levels of pollutants such as heavy metals, oil etc. which are important in the planning of environmental research and security measures to ensure the environmental safety of oil rigs.				MAREANO
		Grain size (gravel, sand, silt and mud) (E,e)			
			Fraction <0,01mm (e)	Sevmorgeo	
			The median diameter (s)	Sevmorgeo	
		Boulder bed (E,s)		under development	
		Organic matter (E,r)		Sevmorgeo	

		Color (E,e)		Sevmorgeo	
Demersal fauna biodiversity indicator (E/I,e)	This indicator is based on the vector of biomasses of the demersal species caught during the ecosystem survey in the demersal trawl. Following the widely accepted paradigm that diverse communities are more stable through time, and therefore more able to sustain either human or climate driven change, our approach can classify these sub-areas along a "resilience-to-change" gradient.				
		Biomass per species of the demersal fauna (E/I,e)			
			α-diversity per subarea (e)	IMR/PINRO, 2004-present	IMR/PINRO, 2004-present
			β-diversity per subarea (e)	IMR/PINRO, 2004-present	IMR/PINRO, 2004-present
			+++ any other relevant community metric (e)	IMR/PINRO, 2004-present	IMR/PINRO, 2004-present

7 THE MURMANSK WORKSHOP – COORDINATION OF ONGOING MONITORING

7.1 BACKGROUND

Bringing Russian and Norwegian experts together has been the preferred method throughout this project, as described in chapter 2. The work was initiated through the initial workshops for preparing the indicators in 2011 and 2012. The outcome of these meetings was good, as bringing the experts on the various topics together for a designated time and purpose was effective and productive.

Topics that needed further attention and that would benefit from joint discussions were selected prior to the Murmansk workshop. Out of the original 22 indicators, 18 were targeted at the workshop for further specification and focus on methods, see **Table 4** below. Out of these 18 targeted indicators, 10 indicators are already covered or related to the ongoing IMR and PINRO work within the Joint Russian Norwegian Fisheries Commission.

The purpose for this workshop was to discuss methods and coordination in order to prepare for joint monitoring. Prior to the workshop, additional information was prepared for most topics in order to facilitate discussions. This information was technical and practical and was related to timing, duration, and cost of fieldwork related to monitoring of each indicator. Thus, the experts could discuss actual framework conditions related to performing monitoring tasks.

7.2 THE WORKSHOP

The Murmansk workshop took place at PINRO headquarters in Murmansk, from 31 March to 2 April 2014. There were 12 participants from Norway and 20 from Russia, in addition to interpreting services. Working groups, targeted indicators and participants are shown in **Table 4**.

Following the introductory plenary sessions, all focus was on intensive work among designated experts in eight groups on the following four prioritized tasks:

1) Are the parameters developed sufficiently?

2) Are the environmental objectives listed?

3) Methods – compatibility between Russian and Norwegian monitoring activities

4) Possible joint cruises

Later, the results were presented to all groups, and the presentations and updated indicator forms submitted to Ocean-3 project leaders.

In addition to the workshop in Murmansk, a separate meeting was organized on the topic “Sea Ice Biota”, when Igor Melnikov (P.P. Shirshov Institute of Oceanography) visited NPI scientist Haakon Hop at the end of March 2014.

Table 4 Overview of working groups, targeted indicators and participants at the Murmansk workshop in 2014.

Group	Indicator(s)	Participants in the group	Instittition	Contact information
1	• Benthos • Demersal fauna biodiversity	1. Lis Lindal Jørgensen 2. Olga Lyubina 3. Pavel Lyubin 4. Nataliya Anisimova	1. IMR 2. MMBI 3. PINRO 4. PINRO	lis.lindal.joergensen@imr.no lubina@mmbi.info plubin@mail.ru n_anisim@pinro.ru
2	• Bottom substrate • Pollution levels in physical environment • Contaminants in biota	1. Alexander Rybalko 2. Oleg Korneev 3. Andrey Zhilin 4. Nadezhda Kasatkina 5. Tor Johannessen 6. Louise Kiel Jensen 7. Gennady Ilyin	1. Sevmorgeo 2. Sevmorgeo 3. PINRO 4. MMBI 5. MD 6. NRPA 7. MMBI	rybalko@sevmorgeo.com korneev@sevmorgeo.com zhilin@pinro.ru kasatkina@mmbi.info tor.johannessen@miljodir.no Louise.Kiel.Jensen@nrpa.no ilyin@mmbi.info
3	• Dynamics of non-ice-associated marine mammals • Vulnerable and endangered species (VES) • Introduced species	1. Nikolay Kavtzevich 2. Anne Kirstine Frie 3. Maria Tsiganova 4. Anders Jelmert	1. MMBI 2. IMR 3. VNIIPrirody 4. IMR	kavtsevich@mmbi.info anne.kirstine@imr.no shamshin99@mail.ru anders.jelmert@imr.no
4	• Fish and shrimp biomass • Fishing pressure	1. Evgeniy A. Shamray 2. Edda Johannessen	1. PINRO 2. IMR	shamray@pinro.ru edda.johannesen@imr.no
5	• Hydrological conditions in the Barents Sea • Sea Ice cover in the Barents Sea • Meteorological conditions • Water masses properties and volume transport in the Barents Sea	1. Oleg Titov 2. Aleksey Karsakov 3. Vidar Lien	1. PINRO 2. PINRO 3. IMR	titov@pinro.ru karsakov@pinro.ru vidar.lien@imr.no;
6	• Microbes • Ocean acidification and CO_2 uptake	1. Tatiana Shirokolobova 2. Knut Yngve Børsheim 3. Marina Venger 4. Marina Pavlova 5. Oleg Titov	1. MMBI 2. IMR 3. MMBI 4. MMBI 5. PINRO	shirokolobova@mmbi.info yngve.borsheim@imr.no venger@mmbi.info pamarka@mail.ru titov@pinro.ru
7	• Phytoplankton diversity, abundance and biomass	1. Pavel Makarevich 2. Viktor Larionov 3. Stuart Larsen	1. MMBI 2. MMBI 3. IMR	makarevich@mmbi.info larionov@mmbi.info stuart.larsen@imr.no
8	• Zooplankton diversity, abundance and biomass	1. Andrey Dolgov 2. Igor' Berchenko 3. Tor Knutsen	1. PINRO 2. MMBI 3. IMR	dolgov@pinro.ru berchenko@mmbi.info tor.knutsen@imr.no

7.3 Results and outcome

The overall outcome of the workshop was good, in that most groups worked efficiently and presented their results afterwards. However, the outcome was strongly dependent on the level of participation in the groups and to which degree the work had been prepared by the experts prior to the workshop.

All results on the four tasks mentioned previously have been incorporated into the indicator forms, see the attachments.

The discussions on the topic "Sea Ice Biota" in (which took place separately in Tromsø) were varied, and included focus on the lack of financing rather than the possibilities to initiate joint monitoring. Thus, the discussions were not fruitful in the direction of joint monitoring. However, the contact between the experts has been established and the scientific discussions regarding the indicator itself has been initiated.

8 CONCLUSIONS

The main goal of Ocean-3 as described in the Work Programme for the Norwegian-Russian environmental cooperation 2013-2015 (approved in Svanhovd, 18 Sept. 2012), is to provide the framework for ecosystem based monitoring in the Barents Sea through, among other things, development of indicators. The project is based on the work done during the last period, 2010-2012. Ocean-3 is, along with Ocean-2, part of the fundament for joint Russian-Norwegian management of the Barents Sea.

8.1 RESULTS

The main outcome of Ocean-3 this period is the suggested 22 joint indicators for monitoring of the Barents Sea. The indicators will cover the most important indicative environmental factors necessary to assess the environmental state of the Barents Sea. Most indicators consist of both parameters and sub parameters. The work comprises of 22 indicators, consisting of 99 parameters with associated sub parameters.

The selected indicators are the result of joint efforts of Russian and Norwegian experts, in assessing the most relevant indicators and parameters needed in order to investigate the state of the environment of the Barents Sea. Both sides have to a large extent incorporated indicators, parameters or sub parameters from ongoing national monitoring. The joint official hearing of the indicators spring 2013 has ensured an open process and good understanding in both scientific and management organs in both countries. Networking and establishment of contact between the experts within the field of environmental monitoring has been accomplished through the three workshops that took place through Ocean-3 during the period (2012-2015).

A goal of the project is to work towards increased operational joint monitoring of the Barents Sea. This remains to be done for most of these indicators. An important aspect in this context is to work towards achieving harmonized methods and also, where it may be feasible, joint cruises. Both aspects have been addressed through this project. However, 12 indicators have parameters that are originating from the work underlying the Joint Russian-Norwegian Fishery Commission. These include the indicators on fish and shrimp biomass, fisheries, both indicators on marine mammals (apart from polar bear and walrus), indicators on phytoplankton and zooplankton. The monitoring for these indicators and parameters, are either coordinated already, or there are ongoing processes in order to ensure harmonized methods and joint cruises. As for the remaining indicators, many of them related to meteorological conditions, sea ice cover, sea ice biota and seabirds in addition to contamination in air and other biota then commercial species, there is still a need to work on harmonizing of methods, networking and joint cruises.

8.2 REMAINING WORK

In order to ensure sound management of the environment of the Barents Sea, the indicators and parameters need to be assessed related to environmental quality objectives. Ocean-3 did not succeed in establishing such objectives during this project period. It was clear at an early stage that in order to reach some of the initial milestones of the project, the indicators were prioritized. However, several indicators have already ongoing processes in other international fora, such as ICES. It seems reasonable to incorporate the results of these processes into Ocean-3, and remain in contact with these organizations through our established network to ensure updated information about their work.

International work on contaminants and threshold values in biota is challenging. As of now, toxicity reference values for contaminants in biota or in the physical environment are not linked to indicators or parameters. This is a larger work that requires high level expert participation in the working groups and specific Arctic perspective.

8.3 FUTURE PLANS

In order to fulfill the intentions of Ocean-3 and proceed towards implementation of a management plan with joint monitoring of the Barents Sea, there is still work to be completed within the Ocean-3 framework.

Environmental quality objectives should be developed through a scientific process, and in understanding with other relevant processes. Ocean-3 should decide on which indicators and related environmental objectives that should prioritized. As for indicators related to the Joint Russian-Norwegian Fishery Commission, management objectives have already been set through the work in this commission and the underlying work done in ICES. As mentioned above, toxicity reference values should be linked to indicators and parameters.

Harmonizing methods requires knowledge on the background for existing methods, and such knowledge is best obtained through hands-on experience. Ocean-3 wish to initiate exchange programmes between Norway and Russia targeted towards specific indicators in order to allow scientists to participate on cruises, fieldwork or/and data handling.

Following the Russian-Norwegian Environmental Commissions admission of the suggested 22 indicators, it is anticipated that it will be necessary to revise the defined indicators maximum 3-5 years in the future as new knowledge of the Barents Sea ecosystem and new methods for monitoring develop. Thus a plan for revision of the indicators should be established.

At the joint Russian-Norwegian Ocean-3 project leader meeting in St. Petersburg in June 2013, initial discussions on publishing, reporting and sharing of data took place. Final plans of these aspects must be drawn up. The BarentsPortal (www.barentsportal.com) is the existing portal for publishing Barents Sea status reports, resulting from the Joint Russian-Norwegian work, as well as from the national ecosystem surveys, utilizing the developed suit of indicators and from subsequent joint monitoring programme.

9 REFERENCES

Anker-Nilssen T., Bakken V., Strøm H., Golovkin A., Bianki, V., and Tatarinkova, I.P. (eds.). 2000. The Status of Marine Birds Breeding in the Barents Sea Region. Norwegian Polar Institute Report Series No. 113. Tromsø.

Bambulyak, A., and Frantzen, B. 2009. Oil transport from the Russian part of the Barent Region. Status per January 2009. The Norwegian Barents Secreatariat and Akvaplan-niva. 97 pp.

Barrett R.T. 2002. Atlantic puffin Fratercula arctica and common guillemot Uria aalge chick diet and growth as indicators of fish stocks in the Barents Sea. Marine Ecology-Progress Series, 230: 275-287.

Ellis, J.C. 2005. Marine birds on land: a review of plant biomass, species richness, and community composition in seabird colonies. Plant Ecology 181: 227–241.

Folkow, L.P., Haug, T., Nilssen, K.T., and Nordøy, E.S. 2000. Estimated food consumption of minke whales (Balaenoptera acutorostrata) in northeast Atlantic waters in 1992-1995. NAMMCO Scientific Publication Series, 2: 65-80

Gabrielsen, G.W. 2009. Seabirds in the Barents Sea. In: E. Sakshaug, G. Johnsen, K. Kovacs (eds) Ecosystem Barents Sea, Tapir Academic Press, Trondheim 2009: pp 415-452.

Haug, T., Gjøsæter, H., Lindstrøm, U. and Nilssen, K.T., (1995). Diet and food availability for northeast Atlantic minke whales (Balaenoptera acutorostrata), during the summer of 1992, ICES Journal of Marine Science, 52: 77-86. Lindstrøm et al., 1998.

Lindstrøm, U., Harbitz, A, Haug T. and Nilssen, K. 1998. Do harp seals Phoca groenlandica exhibit particular prey prefences? ICES Journal of Marine Science, 55, 941-953.

Mauchline, J. 1998. The biology of calanoid copepods. Advances in Marin Biology 33, Academic Press, London. 710 pp.

Melle, W., Ellertsen, B., and Skjoldal, H.R. 2004. Zooplankton: The link to higher trophic levels. In Skjoldal, H.R. (ed.), The Norwegian Sea Ecosystem. Tapir Academic Press, Trondheim.

Nilssen, K.T., Pedersen, O-P., Folkow, L., and Haug, T. 2000. Food consumption estimates of Barents Sea harp seals. The North Atlantic Marine Mammal Commission Scientific Publication Series, 2: 9–28.

Norderhaug, M. , Bruun, E., and Møllen, G. U. 1977. Barentshavet sjøfuglressurser. Norsk Polarinstitutts Medd., 104, 119 s. (In Norwegian with English summary).

von Quilfeldt, C., Dommasnes, A. 2005. Proposals for indicators and environmental quality objectives for the Barents Sea. Report from a sub-project under the management plan for the Barents Sea.

Rey, F. 1981. The development of the spring phytoplankton outburst at selected sites off the Norwegian coast. In Sætre, R. and Mork, M. (eds.) The Norwegian Coastal Current, pp. 649- 680. Bergen, University of Bergen.

Rey, F. 1993. Planteplanktonet og dets primærproduksjon i det nordlige Barentshavet. Fisken og Havet, 1993(10), 39 pp.

Sirenko, B.I. 2001. List of species of free-living invertebrates of Eurasian Arctic seas and adjacent deep waters. Explorations of the fauna of the seas, 51(59). 131 pp.

Internet:

www.barentsportal.com

www.imr.no

www.npolar.no

www.sevmorgeo.com

www.pinro.ru

www.mareano.no

www.nifes.no

www.seapop.no

www.marbef.org

www.niva.no

www.aari.nw.ru

10 APPENDICES

Overview of all indicators and parameters are available in the CD attached.

10.1 LIST OF TABLES

10.2 LIST OF FIGURES

Title: Benthos diversity, abundance and biomass

About the indicator

- ***Type of indicator: E***
- ***Priority of indicator: e***
- ***Rationale:*** Benthos is one of the main components of marine ecosystems and represents the original "integrated" characteristic of their conditions. Benthos is stable in time, characterizes local situation, and is able to show the ecosystem dynamics in retrospective. The community structure and composition is determined by natural and anthropogenic factors. Thus, changes in the balance of organisms of different biogeographic groups may be indicative of climate change; changes in the balance of organisms of different trophic groups may be indicative of anthropogenic impact.

Overview of Parameters

Parameters (name)	***Type (“E”, “A”, or “I”)***	***Priority (“e”, “r” or “s”)***
1) Benthos (quantitative collections or sampled by grab) - Diversity, abundance and biomass (species and total)	*E*	e
2) Mega fauna (trawl collections, video and photographs)	*E*	e

Contact person/responsible person: Olga Kiyko, Ecoproject

Title: Benthos diversity, abundance and biomass

Parameter: Benthos — Diversity, Abundance and Biomass (species and total)

About the parameter

- ***Type of parameter: E***
- ***Priority of parameter: e***
- ***Rationale :*** Benthos is one of the main components of marine ecosystems and represents the original "integrated" characteristic of their conditions. Macrobenthos is stable in time, characterizes local situation, and is able to show the ecosystem dynamics in retrospective. Many benthic species have been shown to have a relatively narrow temperature/ecological niche, and will thus have to shift geographic range with changes in sea-climate. Benthic communities are described in terms of species composition, abundance (ind/m^2) and biomass (g/m^2). These parameters are further determined by the following indices: species dominating by biomass, ratio of epifauna and infauna, dominating trophic groups, balance of organisms of different biogeographic groups etc. The structure of macrobenthos is determined by natural and anthropogenic factors. Thus, changes in the balance of organisms of different biogeographic groups may be indicative of climate change; changes in the balance of organisms of different trophic groups may be indicative of anthropogenic impact.

Overview of the subparameters

	Subparameters (name)	*Institution responsible for monitoring*	*Time series period*	*Gaps in monitoring*	*Priority (“e”, “r” or “s”)*
1	Kola section	*MMBI, PINRO*	*Annually*	*Shortage of specialists for sample processing*	e
2	Pechora sea (did not meet in April 2014 was in Murmansk/PINRO)	*VNIIO keangeologia*	*1991-1995s and 2000-2003s, 2005, 2006, published data of 1920-30s and 1960s*		e
3	Barents Sea Polar Front transect (did not meet in April 2014 was in Murmansk/PINRO)	*Akvaplan-niva*	*1992, 2005, 2007, 2008, 2009*		e
4	Norwegian coast - sampled by grab	*IMR*	*MAREANO every 5-10 years*		e

*Subparameter 1 – **Kola section***

- **Short facts about the subparameter:** Kola section – area of the Barents Sea near Kola bay.
- **Why this is a key subparameter:** Kola section – It is the most accessible and frequently studied area (annual expeditions from PINRO and MMBI). Composition of macrozoobenthos (changing the balance of organisms of different biogeographic groups) in this part of the Barents Sea plays an important role in assessing climate change.
- **Monitoring:** Conducted annual once per year quantitative collections ("grab samples") of macrozoobenthos. The following parameters are assessed: the species composition, the number (abundance) of each species and the total number (abundance) (ind/m^2), and the biomass of each species and the total biomass (g/m^2), the ratio of the Boreal and Arctic species, biodiversity indexes, stress situation in community by the ABC method, Denisenko index.
- **Current status of the subparameter:** studies were conducted in 1927, 1930, 1931, 1933, 1934, 1935, 1947, 1948, 1950, 1968, 1968, 1969, 1995, 1997, 1999, 2000, 2001, 2003, 2003, 2005, 2006, 2007, 2010, 2011, 2012, 2013. Studies are under way and scheduled to be performed in the future.
- **Quality objectives:** Currently, monitoring of macrobenthos in the Kola section is carried out only by Russian organizations PINRO and MMBI. Since 1995 this is done in accordance with international standards. List of objectives:
  - Diversity indexes
  - Trophic traits (ecosystem function)
  - Vulnerability (trawling)
  - Biogeographical structur (climate)
  - Community structure and distribution
- **Environmental objectives:** Species change and new species. Change in index. Change in community and biographical distribution based on biomass and abundance.
- **Reference level:** MMBI and PINRO regularly conduct research in the Kola section. This work includes hydrobiological and hydrological studies. Thus, there is an archival database, which will allow for a correlation between changes in the composition and the structure of the macrozoobenthos and changes in hydrological parameters.
- **Gaps in data coverage:** Additional funding is required to connect the work of specialists.
- **Other issues about the subparameter:** This subparpameter is the longest time series in the history of the benthic fauna observations in the Arctic.

Contact person/responsible person: Pavel Lyubin, PINRO, Olga Lyubina, MMBI

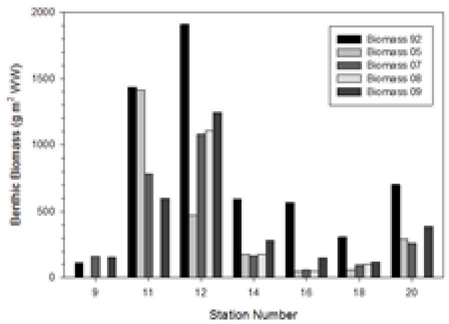
*Subparameter 2 – **Pechora Sea***

- **Short facts about the subparameter:** Pechora Sea is a south-eastern area of the Barents Sea.
- **Why this is a key subparameter:** It is a very important area. This is an area of the planned development of oil fields. The Pechora Sea is also characterized by high biological productivity. Complex monitoring studies have been conducted in this area and planned for the future (expeditions Sevmorgeo, VNIIOkeangeologia, MMBI, published data). Composition of macrozoobenthic community can serve as indicators of anthropogenic impact.
- **Monitoring:** Conducted annual once a year quantitative collections ("grab samples") of macrozoobenthos. The following parameters are assessed: the species composition, the number (abundance) of each species and the total number (abundance) (ind/m^2), and the biomass of each species and the total biomass (g/m^2).
- **Current status of the subparameter:** studies were conducted in 1920-30s, 1960s, 1991-1995, 2000-2003, 2005, 2006. Studies are under way and scheduled to be performed in the future.
- **Quality objectives:** Currently, monitoring of macrobenthos in the Pechora Sea is carried out by Russian organizations as part of engineering and environmental studies for environmental impact assessments for planning of the oil fields development.
- **Reference level:** Scientific and environmental research in the Pechora Sea is carried out more frequently than in other parts of the Barents Sea. For the Pechora Sea long-term changes of macrozoobenthic composition and biomass were investigated. The total benthic biomass in the 1991-1994 years has no significant differences compared to that registered in 1920–1930 years. The total biomass, obtained during the surveys at the end of 1960s, significantly differs both from the values of 1920–1930s and from the values of 1991–1994. For 1968–1970 years notes significant reduction in benthic biomass all over the Barents Sea. The richest in the south-eastern part of the Barents Sea (Pechora Sea) the biomass decreased by 40-60%. Decrease in abundance has affected primarily arctic-boreal species.
- **Gaps in data coverage:** Further studies carried out in the southeastern segment of the Barents Sea in 2000–2002 had revealed a decrease in the benthic biomass as compared to the 1991–1994 data. The average biomass decrease was two-fold and in some areas 3–5-fold. At the same time, benthos composition and structure of both survey periods were quite similar. All the results published. Input data can be provided by the author for further use in comparing the new data.
- Work in the area is carried out by different organizations. There is no single database.
- **Other issues about the subparameter: -**

Contact person/responsible person: Olga Kiyko

Subparameter 3 - ***Barents Sea Polar Front transect***

- **Short facts about the subparameter:** 7 station transect of benthic macrofauna and associated parameters from Storfjord, Spitsbergenbanken, Hopedjupet to Sentralbanken.
- **Why this is a key subparameter:** This sampling transect is ideal for monitoring changes in the distribution of Atlantic and Arctic water masses, because it spans the current position of the polar front, covering both Arctic and Atlantic water, as well as Spitsbergen Bank Water. Quantitative assessment of benthic community faunal and sedimentary parameters further covers a range of depths and habitat types (erosion to deposition areas).
- **Monitoring:** See map for locations of stations. Sampling on ships of opportunity. Sampling points of time series: 1992, 2005, 2007, 2008, 2009. Parameters measured: Benthic Macrofauna via van Veen Grab (Abundance, biomass, species composition), Sediment Grain Size Distribution, Sediment TOC, Oceanographic parameters (CTD).



- **Current status of the subparameter:**
- Structure and function of the benthic faunal communities are strongly influenced by depth, water mass, and sediment grain size. Some marked changes have occurred over the monitoring period. There was a large decrease in benthic biomass between the mid-1990s and 2000s. Biomass was stable in the 2000s and perhaps increased in the late 2000s (see plot). Abundance and species richness patterns at individual stations also varied with time at individual stations.
- **Quality objectives:** National and international Sediment Quality Objectives are usually set to detect impacts of specific human pressures (aquaculture, eutrophication etc.). These quality objectives do not directly apply to this transect, although comparisons may be made between naturally low- and high productive areas along this transect, and anthropogenically influenced areas.
- **Reference level:** Because this transect is free of direct human influence, reference values for this indicator represent the sliding baseline of natural, climate-induced changes.
- **Gaps in data coverage:** At present, the data set is restricted to benthic macrofauna. However, new parameters have been suggested for this transect of stations via Svalbard Integrated Arctic Earth Observing System (SIOS). Particularly, monitoring of pelagic biological components (e.g. zooplankton) has been proposed. In addition, a moored instrument array has also been suggested through SIOS. However, it is unsure whether and when these additions will be realized.
- Results from this subparameter are presented in Carroll et al. (*in prep*) and Cochrane et al. (2012).

References:
Carroll, M.L. and others. Title to come.
Cochrane, S.K.J., Pearson, T.H., Greenacre, M., Costelloe, J., Ellingsen, I.H., Dahle, S., Gulliksen, B. 2012. Benthic fauna and functional traits along a Polar Front transect in the Barents Sea – Advancing tools for ecosystem-scale assessments. J. Mar. Sys. doi:10.1016/j.jmarsys.2011.12.001

Contact person/responsible person: Michael Carroll, Sabine Cochrane, Akvaplan-niva

*Subparameter 4 – **Norwegian coast - sampled by grab***

- **Short facts about the subparameter:** Investigation of quantitative indices of macrozoobenthic communities (infauna and epifauna) along the Norwegian coast (species composition, abundance (ind/m^2) and biomass (g/m^2).
- **Why this is a key subparameter:** Benthic communities and organisms are especially suited for long-term comparative investigations since many of the constituent species are sessile or have low mobility, are relatively long lived and integrate effects of environmental change over time. There are good baseline data available through the MAREANO-programme. It is also an ecosystem component that below the tidal zone shows low year to year variability.
- **Monitoring:** Monitor selected stations from MAREANO every 5-10 years. Comparison of quantitative characteristics (abundance and biomass) of benthic communities - compare with historic/MAREANO data (sampled by grab).
- **Current status of the subparameter:** Species-lists (including number of specimens) are available for all marked stations, this can be used to calculate indexes comparable to those used by i.e. EU water framework directive.
- **Quality objectives:**
- **Reference level:**
- **Gaps in data coverage:**
- **Other issues about the subparameter:**

Contact person/responsible person: Lene Buhl Mortensen IMR, MAREANO

Title: Benthos diversity, abundance and biomass

Parameter: Megafauna (trawl collections, video and photographs)

About the parameter

- ***Type of parameter: E***
- ***Priority of parameter: e***
- ***Rationale :*** Megafauna – are the largest benthic organisms. Megafauna (e.g. sponges and corals) provide habitats to other species through habitat engineering. Due to their size they are the easiest to survey and count. Photo and video recording can be used to monitor their abundance and distribution. Annual trawl collection is carried out in the Barents Sea.

Overview of the subparameters

	Subparameters (name)	***Institution responsible for monitoring***	***Time series period***	***Gaps in monitoring***	***Priority (“e”, “r” or “s”)***
1	Barents Sea (trawl collection)	*IMR(Lis Lindal Jørgensen)* *PINRO (Pavel Lubin)*	*Annually since 2006, and continuing*	*-Need improving the taxonomic skills of staff.* *-Need to develop Species Atlas for standardized identification in time and space.*	E
2	Norwegian coast a) Corals, megafauna OK b) Northward migrating species c) Bottom trawling	*IMR (Jan Helge Fosså)* *See link*	*MAREANO every 5-10 years*		E
3	Svalbard point photographs (published)	*University of Tromsø v. Jørgen Berge*	*More than 30 years (point localities, photographs each year)*		E

Subparameter 1 – ***Barents Sea long term monitoring*** (under development)

- **Short facts about subparameter:** Consider all benthic megafauna invertebrate species taken annually with conventional trawl surveys conducted for annual fish stock assessments (the IMR-PINRO Ecosystem Surveys "BEES", Michalsen et al 2013) in Russian and Norwegian side of the entire Barents Sea (see Anisimova et al 2012). This routine should be a global permanent part of the long term assessment, implementing ecosystem management of marine resources.
- **Why this is a key subparameter:** Benthic organisms, having limited mobility, are well known integrators of the environmental condition. The degradation steps from a stable community with ecosystem services and goods, towards a disturbed end-community with large variation, are used as indicators of the environmental status (Pearson and Rosenberg 1979). Monitoring across gradients will account for spatial and biological heterogeneity and the difference of sensitivity of the fauna to anthropogenic and natural perturbations.
- **Role in the ecosystem:** The benthic fauna of the Barents Sea provides ecosystem functions of substrata space and structure and refuge from predation for a wide variety of small fishes and invertebrates of all life stages. Changing climate, ocean acidification, increased trawling activity and invasive predators are all expected to have impact on the Barents Sea benthic mega-faunal communities. It is therefore urgent to document biological changes in this part of the benthic ecosystem.
- **Monitoring:** The BEES annual monitoring will describe variation in community structure and diversity among and within areas in the Barents Sea and evaluates vulnerability. Areas expected to be exposed to external forcing are used as case studies on how resilience are measured in the field. Within these areas, stations along gradients of increasing natural (temperate, invasive species) and/or anthropogenic (bottom trawling) perturbations are evaluated. Changes include turnover in the species composition and frequency, the community structure and functions along the gradients are used to identify and understand thresholds of resilience within the benthos subjected to different depth and oceanographic regimes. The natural history of the benthic species and their functions are combined with theoretical considerations to provide measures of resilience in marine systems. The output of this research will use the resilience* concept within a management context. (*resilience of ecosystems is the amount of disturbance that an ecosystem can absorb while still maintaining its function).
- **Current status:** Preliminary studies suggest few and widely distributed faunal assemblages in the central and northern part of the Barents Sea and several spatially restricted assemblages in the southern and coastal areas. Depth, temperature, sediment and ice cover are found to be structuring these communities. Separate monitoring plans are under the process of being developed for the distinct species assemblages. Subparameters are also under development but will include:

Local and general biomass distribution	IMR – PINRO	2006 – present
Local and general abundance distribution	IMR – PINRO	2006 – present
Local species richness	IMR – PINRO	2006 – present
Local and general indexes	IMR – PINRO	2006 – present
Temporal community change	IMR – PINRO	2009 – present

Anisimova NA, Jørgensen LL, Lubin P, Manushin I, (2010) Mapping and monitoring of benthos in the Barents Sea and Svalbard waters: Results of the join Russian Norwegian Benthic program 2006-2008. IMR/PINRO Joint Report Series 2009(1), 114 pp. ISSN 1502-8828.

Anisimova NA, Jørgensen LL., Lubin P., Manushin I. (2011) Benthos. *In* The Barents Sea. Ecosystem, resources, management. Half a century of Russian-Norwegian cooperation, pp. 315-328. Ed. by T. Jakobsen. and V.K. Ozhigin. Tapir Academic Press, Trondheim. Chapter 4.1.2.

Jørgensen LL., Ljubin P, Skjoldal HR, Ingvaldsen RB, Anisimova N, Manushin I (in ms) Distribution of epibenthic megafauna in the Barents Sea: baseline for an ecosystem approach to management.

Johannesen E, Jørgensen LL, Dolgov A, Fossheim M, Greenacre M, , Ingvaldsen R, Lubin P, Primicerio R, (in prep) The response of mega-benthos and demersal fish to environmental gradients in the Barents Sea

Jørgensen L.L, Anisimova NA., Lubin P (2009). Dyreliv på havbunnen: langtidsovervåkning og jakten på miljø- indikatorer. In: Mortensen LB, Hodnesdal H., Thorsnes T. (Eds.) Til Bunns i Barentshavet og havområdene utenfor Lofoten. Norges Geologiske Undersøkelse 2010. ISBN: 978-82-7385-142-0

Jørgensen L.L. (2008) Artssammensetning og mengde av bunndyr og fisk i forskningstrål in: Knut Sunnanå og Maria Fossheim. Forvaltningsplan Barentshavet -rapport fra overvåkingsgruppen 2008 Fisken og havet, særnummer 1 b–2008

Jørgensen L.L, Anisimova N., Ljubin P. Benthic investigations (2008) in: Stiansen, J.E. and A.A. Filin (editors) Joint PINRO/IMR report on the state of the Barents Sea ecosystem in 2006, with expected situation and considerations for management. IMR/PINRO Joint Report Series No. 2/2007. ISSN 1502-8828. 209 pp.

Jørgensen L.L, Anisimova N., Ljubin P. Benthic investigations (2007) in: Stiansen, J.E. and A.A. Filin (editors) Joint PINRO/IMR report on the state of the Barents Sea ecosystem in 2006, with expected situation and considerations for management. IMR/PINRO Joint Report Series No. 2/2007. ISSN 1502-8828. 209 pp.

Lubin P., Jørgensen L.L., Anisimova N. (2009) Benthos. In: Stiansen, J.E., Korneev, O., Titov, O., Arneberg, P. (Eds.), Filin, A., Hansen, J.R., Høines, Å.,Marasaev, S. (Co-eds.) 2009. Joint Norwegian-Russian environmental status 2008. Report on the Barents Sea Ecosystem. Part II – Complete report. IMR/PINRO Joint Report Series, 2009(3), 375 pp. ISSN 1502-8828.

Michalsen K, Dalpadado P, Eriksen E, Gjøsæter H, Ingvaldsen R.B., Johannesen E, Jørgensen L.L, Knutsen T, Prozorkevich D, Skern-Mauritzen M (2013): Marine living resources of the Barents Sea – Ecosystem understanding and monitoring in a climate change perspective, Marine Biology Research, 9:9, 932-947

Pearson TH, Rosenberg R (1978) Macrobenthic succession in relation to organic enrichment and pollution of the marine environment. Oceanogr Mar Biol Annu Rev 16:229-311

Contact person/responsible person: Lis Lindal Jørgensen, IMR

Subparameter 2a – ***Norwegian coast: Corals, megafauna*** *(needs update)*

- **Short facts about the subparameter:** Megafauna - coral reefs in the coastal waters of Norway.
- **Why this is a key subparameter:** Mega fauna (e.g. sponges and corals) provides habitats to other species through habitat engineering species. Furthermore habitat forming mega fauna is especially suited for long-term comparative investigations since they are relatively long lived and integrate effects of environmental change over time.
- **Monitoring:** Monitor selected coral stations from MAREANO every 5-10 years.
- **Current status of the subparameter:**
- **Quality objectives:**
- **Reference level:** Distribution analysis to determine north/south boundaries of mega fauna documented by video in the arctic part of the Barents Sea. Visual observations of the seabed represent an efficient way of surveying the distribution of megafauna in large areas. Larger anthozoans, such as ***Lophelia pertusa***, and several gorgonians are long lived and relatively slow growing species, implying that annual surveys of selected monitoring locations would not be relevant for detecting distribution expansion. However, many mobile species within the groups Echinodermata (except many Ophiuroidea), and Decapoda are possible to identify on videorecords and may respond faster to climate changes than slow growing sessile species. Locations mapped by MAREANO represents candidates for monitoring locations with respect to the identifiable mobile megafauna. The results from

MAREANO are quantitative, and future video surveys should be performed in agreement with Norsk standard (NS 9435) and be analysed to provide data on number of individual per 100 m^2.
- **Gaps in data coverage:**
- **Other issues about the subparameter:**

Contact person/responsible person: Jan Helge Fosså, IMR

Subparameter 2b – ***Norwegian coast: Northward migrating species***

- **Short facts about the subparameter:** Comparison of north/south boundaries of species composition.
- **Why this is a key subparameter:**
- Many benthic species have been shown to have a relatively narrow temperature/ecological niche, and will thus have to shift geographic range with changes in sea-climate. Thus changes of the areal boundaries of species distribution, its shifting in the northern /southern direction may mark changes in the temperature regime (warming/cooling trends). The baseline-monitoring that is represented by MAREANO will be possible to use to compare further shifts in north/south boundaries.
- **Monitoring:** Comparison of north/south boundaries (of species) with historic data/MAREANO data (both video and trawl sampling), Comparison of distribution of large (conspicuous) megafauna with historic/MAREANO data (video).
- **Current status of the subparameter:** Species-lists (including number of specimens) are available for all marked stations, this can be used to calculate indexes comparable to those used by i.e. EU water framework directive. Distribution analysis to determine north/south boundaries of bottom fauna species of infauna (sampled by grab), epifauna (sampled by beamtrawl) and hyperfauna (sampled with epibenthic sled) in the arctic part of the Barents Sea. The baseline-monitoring that is represented by MAREANO will be possible to use to compare further shifts in north/south boundaries. Species-lists from all stations are available through www.mareano.no
- **Quality objectives:**
- **Reference level:**
- **Gaps in data coverage:**
- **Other issues about the subparameter:**

Contact person/responsible person: Ann Helene Tandberg, IMR, MAREANO

Subparameter 2c – ***Norwegian coast: Bottom trawling***

- **Short facts about the subparameter:** Composition of mega-epifauna and hyperfauna (sampled by beamtrawl and sampled with epibenthic sled) in the coastal waters of Norway.
- **Why this is a key subparameter:** Benthic communities and organisms are especially suited for long-term comparative investigations since many of the constituent species are sessile or have low mobility, are relatively long lived and integrate effects of environmental change over time. There are good baseline data available through the MAREANO-programme. It is also an ecosystem component that below the tidal zone shows low year to year variability.
- **Monitoring:** Monitor selected stations from MAREANO every 5-10 years, Comparison of distribution of benthic communities- compare with historic/MAREANO data (beamtrawl, rp-

sled), comparison of distribution of large (conspicuous) megafauna with historic/MAREANO data (video).

- **Current status of the subparameter:** Species-lists (including number of specimens) are available for all marked stations, this can be used to calculate indexes comparable to those used by i.e. EU water framework directive.
- **Quality objectives:**
- **Reference level:**
- **Gaps in data coverage:**
- **Other issues about the subparameter:**

Contact person/responsible person: Lene Buhl Mortensen, IMR, MAREANO

*Subparameter 3 – **Svalbard point photographs** (needs update)*

- **Short facts about the subparameter:** Long-term monitoring of hard-bottom macrobenthic organisms and algae at three localities in northern Svalbard. There are permanent photographic monitoring stations established in 1980 on the west coast of Svalbard, and on the east side in Hinlopenstrait in depths of 15 -20m.
- **Why this is a key subparameter:** Benthic hard bottom communities and organisms are especially suited for long-term comparative investigations since many of the constituent species are sessile or have low mobility, are relatively long lived and integrate effects of environmental change over time. Some of the longest photographic time-series (>30yrs) that have been conducted.
- **Monitoring:** An array of 2x5 squares of 0.5x0.5m each is photographed in exactly the same position every year in autumn. All organisms have been removed from half of the squares in order to study recolonisation and succession of epibenthic organisms. There are to stations along the Svalbard west-coast (entrance of Kongsfjorden and in Smeerenburgfjorden) and one in Hinlopenstrait near Tommelpynten. The pictures are analysed using a semi-automatic method in Adobe Photoshop. Pictures are taken annually, during UNIS- cruise activities.
- **Current status of the subparameter:** The stations are continuously monitored. All pictures and data from previous years have been analysed and published/ are available.
- **Quality objectives**
- **Reference level:**
- **Gaps in data coverage:** There has been only monitoring of these communities along the Svalbard west coast, now a new station on the east coast in Hinlopenstrait is established. It fills the gap of monitoring in different type of arctic habitats that are connected to different water masses.
- **Other issues about the subparameter:**

Contact person/responsible person: Jørgen Berge University of Tromsø

Title: Bottom substrate

About the indicator

- ***Type of indicator: E***

  Priority of indicator: e

- ***Rationale***: State of the bottom substrate defines the quality of the benthic community life as well as the levels of pollutants such as heavy metals, oil, etc. which are important in the planning of environmental research and security measures to ensure the environmental safety of oil rigs. This parameter is very important, because it defines the area of long-term accumulation of chemical elements, direction of geochemical processes on the border of the «seabed-water», and also allows to predict the emergence of possible zones of contamination by the inflow of pollutants as a result of the destruction of technogenic objects. The possibility of early deployment of security tools for action in the face of dangerous situations is created this way. This indicator is influenced by lithodynamic processes, transportation of clastic products by bottom currents and gravitational processes, slow sedimentation of suspended mineral and biogenic particles as well as the erosion of the seabed and forming the "residual" or "relict" sediments. It also reflects the conditions of the infiltration of the gas emanation in the zones of modern faults buried under the modern sediments. This indicator influences the distribution of pollutants such as heavy metals, hydrocarbons, radionuclides, etc.

Overview of Parameters

Parameters (name)	***Type ("E", "A", or "I")***	***Time series period***	***Institution responsible for monitoring***	***Priority ("e", "r" or "s")***
Grain size (gravel, sand, silt and mud)	*I*	*1997-2010*	*Russia: "Sevmorgeo", MMBI MAGE*	e
Boulder bed	*I*	*1990 - 2010*	*Russia: "Sevmorgeo", MAGE*	e
Organic matter	*I*	*2003 - 2010*	*Russia: "Sevmorgeo", VNIIOkeangeologia*	e
Color of the sediment	*I*	*2003 - 2010*	*Russia: "Sevmorgeo"*	e

Contact person/responsible person: Aleksandr Rybalko and Oleg Korneev, Sevmorgeo.

Title: Bottom substrate

Parameter: Boulder bed

About the parameter

- ***Type of parameter: E***
- ***Priority of parameter: s***
- ***Rationale:*** Boulder bed presents an important ecological parameter as it defines environmental conditions for benthic organisms. This is a zone with clean water due to the absence of seabed erosion. In the boulder bed areas no accumulation of pollutants occurs, as there is no accumulation of fine sediments.

- **Short facts about the parameter:** Boulder bed ("hard bottom") occurs near raised areas of the sea bottom containing boulders and pebbles forming solid bedrock. This type of bottom sediments is typical for the Polar regions with glaciers or areas of development of the folded bedrock.
- **Why this is a key parameter:** This sub-parameter is a key to determine the areas of long-term erosion or transit of debris, as well as to optimize monitoring network, mapping the distribution of communities of benthic organisms.
- **Monitoring:** Provided by the results of geophysical research, and verified by visual (diving) and video observations. Typical for the polar regions with glacial sedimentation type. Here monitoring stations can be sparse and observation intervals are long (1 time in 3-5 years)
- **Current status of the parameter**: Under development.
- **Quality objectives:** Russian monitoring program of the boulder bed can only be the subject of hydro-biological monitoring, mainly for benthic sedentary organisms. Monitoring of the chemical composition of the sediment is usually lacking. Hydrochemical monitoring can be conducted to determine the content of nutrients and pollutants in the bottom water
- **Reference level:** Typically, the geochemical monitoring for areas of the boulder bottom is missing. Hydrobiological monitoring data series allow estimation changes in environmental conditions for benthic organisms in the areas of anthropogenic pressure.
- **Gaps in data coverage:** There are shortcomings that are linked to the technical difficulties in sampling in the boulder bed areas, including hydrobiological sampling. The most successful observations are those performed by divers, but that type of work is labour-intensive and unsuitable for very deep water.
- **Other issues about the subparameter:** Main purpose of the boulder bed monitoring at this time is optimization of monitoring network via exclusion of stations of continuous monitoring in those areas.

Contact person/responsible person: A.Rybalko and O.KorneevSevmorgeo,

Title: Bottom substrate

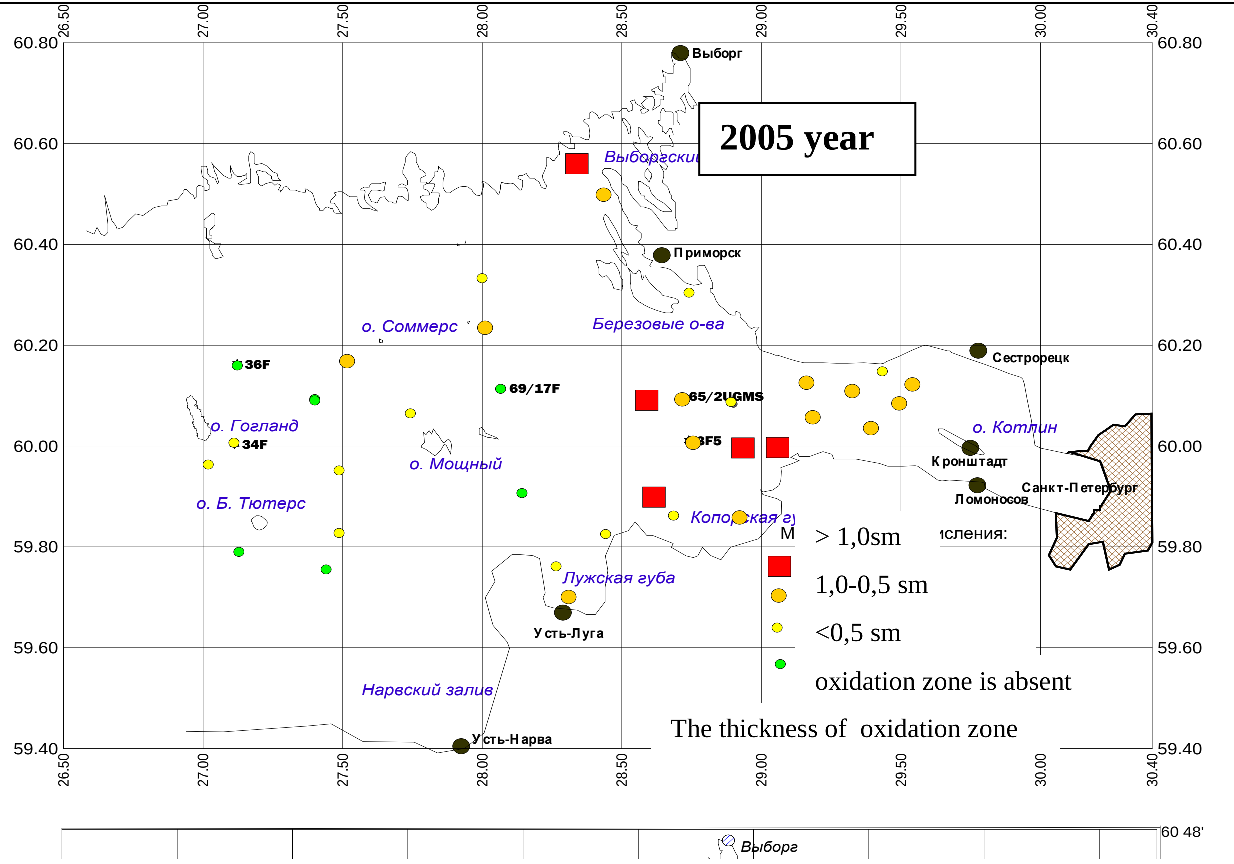
Parameter: Color of bottom sediments

About the parameter

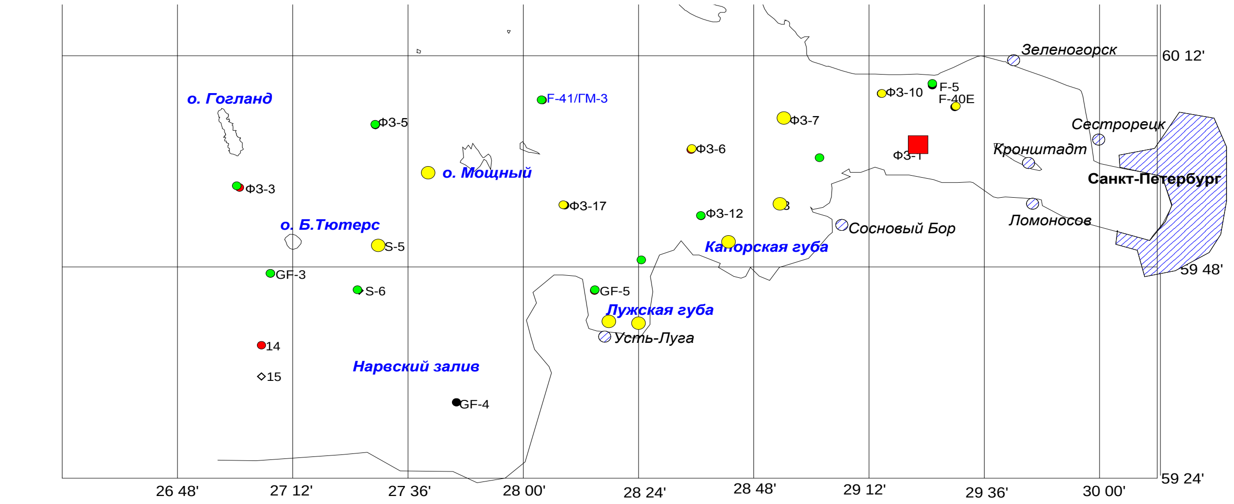
- ***Type of parameter: I***
- ***Priority of parameter: e***

Rationale: Color of the upper layer of the bottom sediments (liquid mud) reflects amount of the dissolved oxygen in the near-bottom water. Redox potential reflects character and direction of chemical compounds and elements migration from the near bottom layer to the sediment or from the sediment to the near bottom water (as well as absence or decreased speed of such migration)

- **Short facts about the parameter:** Color (redox-potential) of upper layer of bottom sediments.
- **Why this is a key parameter:** This parameter plays an important role in estimation of direction of geochemical processes and possibility of secondary contamination of near-bottom water and sediments.
- **Monitoring:** can be monitored in 2 ways: 1) visual or by application of color swatches directly in samples, collected in special tubes or by sediment grabs ; 2) by measuring redox potential in specially collected samples or directly in the sampler. Measurements must be done within 2 hrs after retrieving the samples.
- **Current status of the parameter:** Such measurements take place since the beginning of monitoring in the Barents and White seas, and particularly in the Finsky Gulf, where cyclical changes in physical and chemical parameters are being observed.



Enclosed maps demonstrate how oxidation conditions in the Finsky Gulf have shifted to reduction conditionsover significant number of stations, which led to infiltration of near bottom waters by the ground waters and increase in concentration of heavy metals in the bottom sediment on stations in the eastern part. These were naturally occurring changes. But this can also have an anthropogenic origin, when dissolved oxygen is used for oxidation of contaminants, particularly organic compounds.



Distribution of oxidation conditions has direct influence on distribution of such elements as iron and manganese, which determine sorption capacity of sediments. Sevmorgeo' database has data on sediments color, supported by redox-potential changes from 2001 to 2010.

Direct correlation is observed between the intensity of the oxidized layer (brown coloration) and quantitative content of benthos.

Presence of oxidized layer and its intensity (integrated indicator of length of period with anaerobic conditions) was identified as the most significant indicator during estimation of the bottom sediment development in the Nevskiy guba.

- **Quality objectives:** Description of coloration of the top sediment layer, particular attention paid to the areas of brown coloration on the sea bed, required estimation of its intensity and mapping of gathered data are noted in instructing documents for the state monitoring in Russia.
- **Reference level:** data can be presented in cartographic format (i.e. pillar diagram reflecting the time trend) for each monitoring station , or in a linear function graph time vs intensity of oxidized layer (or changes in redox-potential or both)
- **Gaps in data coverage:** Main issue is selective application of this index. The only document requesting to include this indicator as a part of mandatory monitoring - methodic guidelines for the conduct of state monitoring of the Western Arctic Shelf seas. Therefore, inclusion of this indicator as a mandatory part of the monitoring activities should be discussed.
- **Other issues about the subparameter:**

Contact person/responsible person: Oleg Korneev and Alexander Rybalko, Sevmorgeo

Title: Bottom substrate

Parameter: Grain size

About the parameter

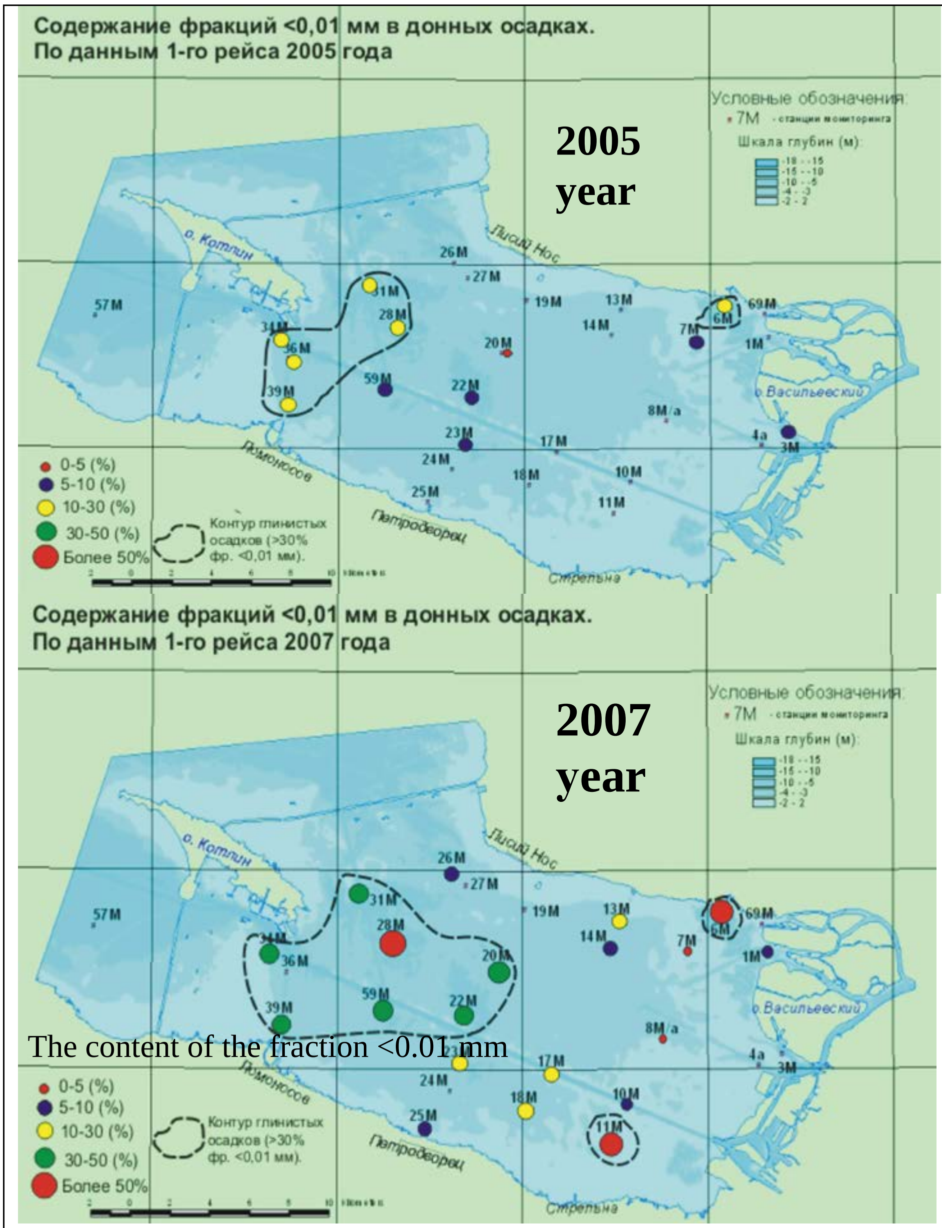
- ***Type of parameter: E***
- ***Priority of parameter: e (essential)***
- ***Rationale :*** This parameter is important because granulometric composition of bottom sediments directly affects concentration of heavy metals, hydrocarbons, etc. The allocation of anomalies may not be correct without comparison of granulometric composition of bottom deposits. Mapping the types of granulometric composition directly on the bottom sediments map gives the opportunity to forecast concentrations of heavy metals. Granulometric composition is also an important parameter for the characteristics of the spawning grounds of fish

Overview of the subparameters

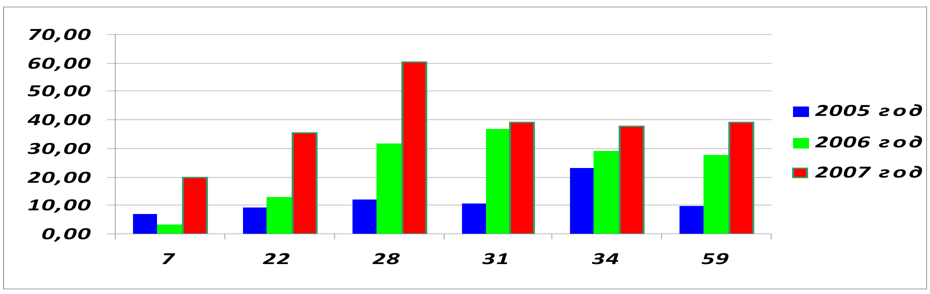
Subparameters (name)	*Institution responsible for monitoring*	*Time series period*	*Gaps in monitoring*	*Priority (“e”, “r” or “s”)*
Fraction <0,01mm	*Russia - Sevmorgeo*	*All station*		e
The median diameter	*Russia - Sevmorgeo*	*All station*		s

Subparameter 1 - Clay fraction

- **Short facts about the subparameter:** Clay fraction.
- **Why this is a key subparameter:** This subparameter is a key to interpretation of the geochemical analysis data since the correct comparison of data on concentrations of heavy metals and hydrocarbons can only be made for sediments, similar in granulomethric content. An increase or a decrease of clay fraction over time can also signal a change in conditions of sedimentation.
- **Current status of the subparameter:** This subparameter is widely used in Russia to assess the changes of conditions of deposition and subsequent interpretation of geochemical data.



Figures show a comparison of the change in the content of clay fraction in the Neva Bay in 2005 and 2007. You can see an expansion of clay sediments and increase in the content of clay fraction in 2007 as a result of the intensive use of dredger for the development of new port areas.



Changes of the content of clay fraction are showed in the figure by the stations, and by years. Accordingly, increase in the concentrations of heavy metals and hydrocarbons will be connected with this factor, and not with the increased pollution.
The advantage of this parameter is that on one hand, it is quantitative and can be used in different calculations, and on the other hand the computation of it simple and objective (50% of the particles are smaller and 50% of the particles are greater) and does not depend on the type of particle size distributions and other statistical limitations.

- **Quality objectives:** Performance of granulometric analysis in Russia is regulated by special methodological documents. The normative documents also regulate borders of particle size classes, types of bottom sediments and determination of this parameter for the mapping of the bottom sediments.
- **Reference level:** Currently, normative documents on the geochemical works on land and at sea point to the need of utilizing this subparameter. The same provision is noted in the manual for monitoring of different levels for marine basins, when an exploration or extraction of oil and gas resources is taking place.
- **Gaps in data coverage:** The main problem is a semi-quantitative type of analysis. That is why we have a great dispersion of data in monitoring of the same stations. It is necessary to integrate data from several stations. In addition, the methodology of particle size analysis and classification of the bottom sediments according to the results differ significantly in Russia and the Western countries .
- **Other issues about the subparameter:** Data on the granulometric composition of bottom sediments of the Barents and White seas obtained by monitoring of the geological environment during the period 2001 -2010 from the Kandalaksha Bay of the White sea (including 2011-2012) are contained in the databases of the JSC «Sevmorgeo» and in the Central Fund storage of materials on Geology of seas and oceans in the Gelendzhik. Coordinates and the type of particle size analysis are presented at the joint Russian-Norwegian geoportal.

Subparameter 2 - Median diameter

- **Short facts about the subparameter:** Median diameter.
- **Why this is a key subparameter:** This subparameter allows to show a collapsed granulometric information. The calculation of this index is simple (50-50%). The obtained values are correct, as it does not depend on the type of distribution and other factors, determining the calculation of statistical coefficients.
  Many maps of the bottom sediments In the Western countries are based just on the mapping of this subparameter. At the same time, this is a specific quantitative parameter, which allows to use it in data processing monitoring, including the use of multivariate statistics.
- **Current status of the subparameter**: At present time there is a large number of maps of the bottom sediments, drawn up on the basis of the calculation of the median size. Such maps as a subsidiary are included in the structure of sheet compiled by the State geological survey of Norway. These maps are a convenient base for large sections of the water area.
- **Quality objectives:** Specific recommendations for mapping on median are absent. However, the simplicity of calculation of median, its objectivity and mathematical correctness makes it popular among sedimentologists both in the East and in the West.

- **Reference level:** Although the need for the development of the bottom sediments maps on the basis of the median diameter is not specified in the methodological documents in Russia, they still remain popular, likely because they are easy to create from the technical aspect. Probably the same reasons lie in the basis of these maps in the Western countries.
- **Gaps in data coverage:** The main weakness of such maps has long been known. The values of the median of particle size composition of bottom sediments depends little on the content of the most fine and coarse fractions, which are the most responsive to the changes of lithodynamic processes. Because of that the connection of index "median size" with geochemistry of bottom sediments is significantly lower than when you use the «content of clay fraction».

Contact person/responsible person: Oleg Korneev, Alexander Rybalko, Sevmorgeo"

Title: Bottom substrate

Parameter: Organic matter

About the parameter

- ***Type of parameter: I***
- ***Priority of parameter: r***

Rationale : Organic matter is a key parameter to estimate intensity and direction of geochemical processes. Large amount of organic matter leads to the uptake of free oxygen for its oxidation and thus decreases concentration of free oxygen in water, up to formation of anaerobic zones. Organic matter is an excellent sorbent and determines sharp increase in concentration of most chemical elements and their compounds, including pollutants, in sediments. Presence of large amount of organic matter in water makes possible formation of cancerogenic organochlorine compounds.

- **Short facts about the parameter:** Organic matter. Detected by burning of sediment and estimation of weight change of the sample.
- **Why this is a key subparameter:** Organic matter is a key parameter for understanding of occuring geochemical processes , estimation of its concentration and techniques for removing organic content from the sample are necessary for obtaining correct concentrations of most heavy metals and other inorganic pollutants in the bottom sediments .
- **Monitoring:** Content of organic matter is determined by laboratory techniques in samples collected during the monitoring efforts. All collected data for heavy metals in sediments must be recalculated accounting for the actual content of organic matter if its amount exceeds 3%. Increased amount of organic matter can be found near industrial and communal water discharge points, in local depressions with poor water exchange.
- **Current status of the subparameter:**
- **Quality objectives:** Requirement for organic content analysis is included in the most of the programs of environmental monitoring programs on different levels in Russia and Norway alike. Use of this parameter for the Artctic seas is limited due to the low concentrations (usually less than 1%) and lack of reliable techniques for determination.
- **Reference level:** In Russia, organic matter is determined in sediments (organic carbon, C org) and in the water column (BPK5). State monitoring program as well as local monitoring programs requires this analysis in the areas of active oil and gas extraction facilities. Results are usually presented in form of the annual or seasonal trendlines. Monitoring program also includes multi factor correlation analysis that includes data on concentration changes of organic matter.
- **Gaps in data coverage:** Main drawback is a lack of reliable techniques and large discrepancies between methods of organic matter content analysis in the bottom sediments. This makes re-calculated results of obtained concentrations of heavy metals and other pollutants over organic matter hard to interpret and compare.

- **Other issues about the subparameter:** Although organic matter itself is not a pollutant, it is one of the key indicators of the state of marine geological environment.

Contact person/responsible person: Oleg Korneev, Alexander Rybalko, Sevmorgeo

Title: Contaminant levels in biota (E,I)

About the indicator

- ***Type of indicator: E,I***
- ***Priority of indicator: e***
- ***Rationale:*** The rationale of using contaminant levels in biota is that it shows the levels of contaminants (radionuclides, heavy metals and POPs) at different trophic levels in marine food webs. When monitored over several years it would also be possible to determine spatial and temporal trends.

Overview of Parameters

Parameters (name)	***Type (“E”, “A”, or “I”)***	***Priority (“e”, “r” or “s”)***
Radioactivity in seaweed *(Fucus vesiculosus)* (E,I)	*E,I*	r
Contaminants in Brünnich’s guillemots	*E,I*	e
Pollution in polar bears	*E,I*	e
Contaminants in Atlantic cod	*E,I*	e
Contaminant in king crab (currently no available data)	*E,I*	s
Contaminants in Greenland halibut	*E,I*	s

Contact person/responsible person: Geir W. Gabrielsen, NPI

Title: Contaminant levels in biota (E)

Parameter: Contaminants in king crab (E)

About the parameter

- ***Type of parameter: E***
- ***Priority of parameter: s***
- ***Rationale :*** Measurements of contaminants in king crab are important as this species is fished for human consumption. In addition, they have a potential to accumulate chemical compounds (organic and inorganic) and might serve as an indicator of environmental pollution. At present no data are available, but NIFES will have some results of the recent study available in spring of 2013.

  This parameter needs to be developed.

Overview of the subparameters

Subparameters (name)	*Institution responsible for monitoring*	*Time series period*	*Gaps in monitoring*	*Priority (“e”, “r” or “s”)*
Hg				e
Other heavy metals				r
Organic contaminants				e
Cesium-137				s

Subparameter 1 - name

- **Short facts about the subparameter:**
- **Why this is a key subparameter:**
- **Monitoring:**
- **Current status of the subparameter:**
- **Quality objectives:**
- **Reference level:**
- **Gaps in data coverage:**
- **Other issues about the subparameter:**

Contact person/responsible person:

Title: Contaminant levels in biota (E,I)

Parameter: Radioactivity in seaweed (*Fucus vesiculosus*)

About the parameter

- ***Type of parameter: E,I***
- ***Priority of parameter: r***
- ***Rationale:*** Measurements of seaweed along the Norwegian coast show a relatively high uptake of technetium (^{99}Tc). The main source of this radioactive substance is discharges from Sellafield to the Irish Sea. The concentration of ^{99}Tc in seaweed along the Norwegian coast has decreased since Sellafield reduced these emissions. Cs-137 is also monitored on both Russian and Norwegian side.

Overview of the subparameters

Subparameters (name)	***Institution responsible for monitoring***	***Time series period***	***Gaps in monitoring***	***Priority ("e", "r" or "s")***
Technetium-99	*NRI and IFE*	*1995->*		r
Caesium-137	*NRPA/IFE* *Murmansk Marine Biological Institute (MMBI)*	*1999->* *1992->*		r

- **Short facts about the parameter**: The seaweed Bladderwrack (*Fucus vesiculosus*) is geographically distributed along the coastline of Norway and Northwest Russia*. F. vesiculosus* provides a canopy and shelter for many small animals, and it also act as a chemical defense against the marine herbivorous snail *Littorina littorea*. *F. vesiculosus* show a relatively high uptake of ^{99}Tc and some uptake of ^{137}Cs. The main source of ^{137}Cs in the Barents Sea is from the global fall out in the 60s, from the Chernobyl accident in 1986 and from the reprocessing plants La Hague and Sellafield, while ^{99}Tc originates from discharges from the reprocessing plant at Sellafield.
- **Why this is a key parameter:** Seaweed is sessile and by the continuous uptake integrates the water concentration of radionuclides over time. It has a high affinity for ^{99}Tc and *F. vesiculosus* has also been widely used as a bio-indicator for ^{137}Cs. The accumulation of ^{137}Cs in brown algae is, however, not as pronounced as for ^{99}Tc. The uptake of ^{137}Cs also depends on the salinity of the surrounding sea water, with higher uptake at lower salinities.
- **Monitoring:**

<u>Norwegian side:</u>

Norwegian Radiation Protection Authority and Institute for Energy Technology are responsible for the measuring programme. NRPA collects seaweed (*F. vesiculosus*) samples from four stations along the Norwegian coastline. On Hillesøy in northern Norway, seaweed is collected every month and at the other locations once per year. In addition, IFE performs monthly or annual seaweed sampling at eleven locations along the coastline, from the Russian border in the north to the Swedish border in the south. Monthly ^{99}Tc-analysis of seaweed from Hillesøy in Troms and Utsira in Rogaland has been conducted since the mid-1990s.

Russian side:

Murmansk Marine Biological Institute has been studying artificial radioactivity in seaweed of the Barents Sea since 1992. The most part of investigations were carried out in different places of the Kola Peninsula coast (not in regular monitoring stations). In spring 2005 and 2011 activity concentrations of radionuclides in seaweed were investigated in the same places of the Barents Sea coastal zone (see Figure 1 of sampling stations).

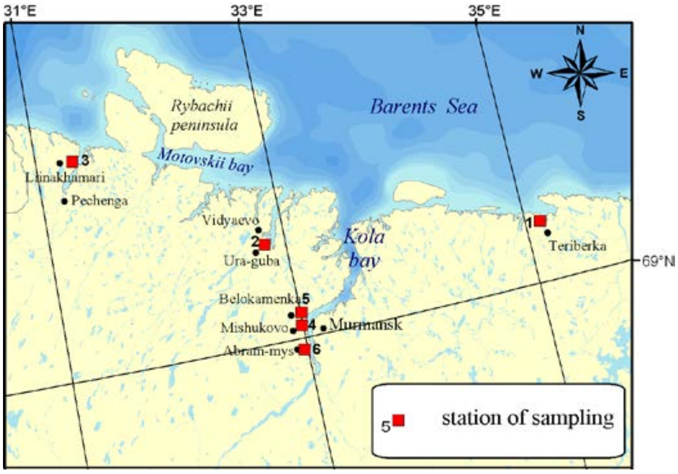


Figure 1: Map of seaweed sampling in 2005 and 2011

- **Current status of the parameter:**

Norwegian side:

Example from the Norwegian monitoring data is shown in the figure (2) below. The trends in discharges are very well reflected in concentration measured in Norwegian seaweed a few years later.

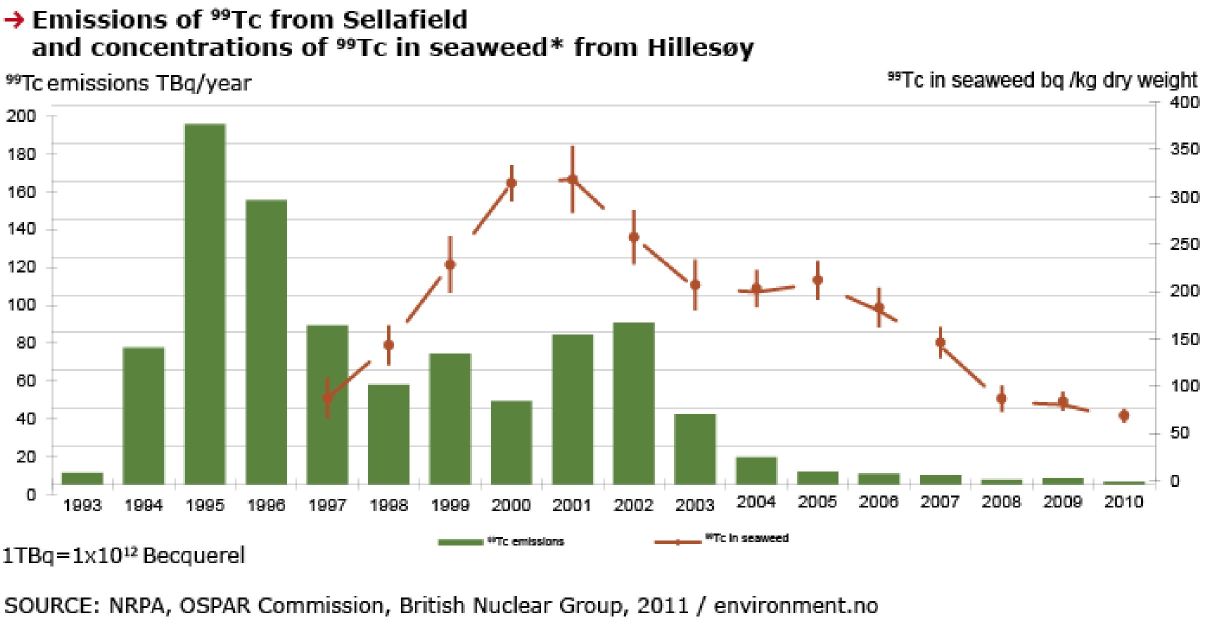


Figure 2: Annual liquid discharge of ^{99}Tc from Sellafield (primary axis) and annual average (with 95 % confidence limits) ^{99}Tc activity concentration in brown algae (Fucus vesiculosus) sampled at

Hillesøy in the period 1997-2010 (secondary axis). The reduction is caused by reducing emissions from Sellafield.

In addition, we have annual monitoring of the ^{137}Cs concentrations in seaweed along the Norwegian coastline. Data from 2010 are shown below.

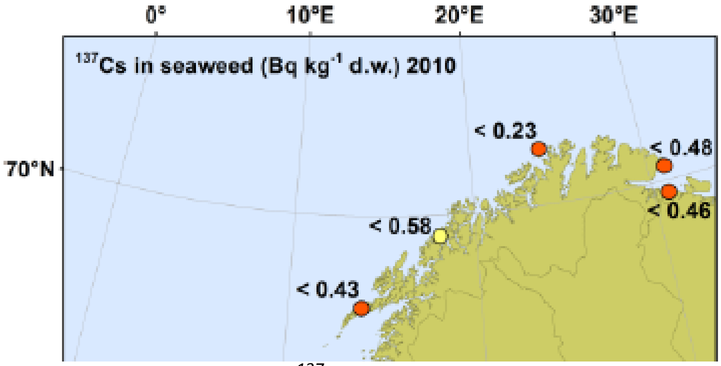


Figure 3: Concentration of ^{137}Cs in F. vesiculosus *from the Norwegian coastline in 2010.*

Russian side:

Specific activities of ^{137}Cs, ^{40}K, ^{90}Sr in the Barents Sea algae in 2011 are summarized in Table 1. There were no significant differences in ^{137}Cs accumulation by different species of macrophytes. In most cases, the specific activity of ^{137}Cs in algae was lower than the apparatus sensitivity. *Laminaria* from the area of Mishukovo had trace amounts of ^{152}Eu (0.05 Bq/kg, dry weight) indicating possible minor emission of radioactive isotopes from the "Atomflot" enterprise to the Kola Bay.

Table 1: Activity concentrations of gamma-emitting radionuclides and ^{90}Sr in the Barents Sea algae, April 2011

Station	*Region*	*Species*	*^{137}Cs, Bq/kg d.w.*	*^{40}K, Bq/kg d.w.*	*^{152}Eu, Bq/kg d.w.*	*^{90}Sr, Bq/kg d.w.*
1	Teriberka	*Fucus vesiculosus*	<0,6	769±170		
		Fucus serratus	<0,7	1026±228		0.4±0.1
		Fucus distichus	<0,3	224±63		3.9±0.7
2	Ura-guba	*Fucus distichus*	0.4±0.2	506±122		4.1±0.6
3	Liinakhamari	*Fucus vesiculosus*	0.3±0.2	82±18		1.0±0.2
		Fucus distichus	<0.2	896±200		0.5±0.1
		Fucus serratus	<0.7	638±84		0.7±0.1
4	Mishukovo	*Fucus distichus*	<0.5	1006±221		0.0±0.0
		Ascophillum nodosum	<0.6	558±119		2.7±0.4
		Laminaria saccharina	<0.1	137±18	0.05±0.03	2.0±0.3
5	Belokamenka	*Fucus vesiculosus*	<0.8	368±87		0.9±0.1
		Ascophillum nodosum	<0.2	626±152		1.0±0.2
6	Abram-mys	*Ascophiillum nodosum*	<1.1	692±155		0.4±0.1
		Fucus distichus	<1.7	1197±271		1.2±0.3
		Laminaria saccharina	<0.4	417±190		1.7±0.1

- **Reference level:** A reference level must be established. The action level is defined as a steady increase in the level of pollutants over a certain number of years, or a sudden increase from one sampling to the next in an area.
- **Gaps in data coverage:** With the combined stations on the mainland of Norway and

Northwest Russia, the monitoring of radionuclides in seaweed is very well covered. Any expansions of the monitoring should be on the islands of the Barents Sea.

Contact person/responsible persons: Nadezhda Kasatkina, Murmansk Marine Biological Institute,
Louise Kiel Jensen, Norwegian radiation protection authority, Louise.Kiel.Jensen@nrpa.no

Title: Contaminant levels in biota (E)

Parameter: Contaminants in Atlantic Cod (E)

About the parameter

- ***Type of parameter: E***
- ***Priority of parameter: e***
- ***Rationale:*** The North East Atlantic cod is omnivorous fish species studied for longest time with regards to contaminants and a long time trend is available for most of the parameters. In open seas it has been studied since early 90-ties. The lipid rich liver is suitable both as human food and as an indicator of fat soluble POPs where there are also good basic data to compare with. The species is fished in large volume and is an important food species for humans.

Overview of the subparameters

Subparameters (name)	***Institution responsible for monitoring***	***Time series period***	***Gaps in monitoring***	***Priority ("e", "r" or "s")***
Hg in fillet	*NIFES*	*1995 -*		e
Other heavy metals in fillet and liver	*NIFES*	*2006-*		r
Organic contaminants in liver	*NIFES*	*2006-*		e
Cesium-137	*Norwegian radiation Protection Authority (NRPA) and the Institute of Marine Research (IMR)*	*1991-2012*		s
Strontium -90 in the skeleton				s

Subparameter 1 – Mercury in fillet

- **Short facts about the parameter:** *Gadus morhua* contaminants is generally a key parameter for evaluating seafood safety in this area.
- **Monitoring:** NIFES has monitored mercury in cod fillet since 1995. Sampling positions were not recorded during the period from 1995 to 2006. Mercury has been determined in individual cod fillets using inductively coupled plasma-mass spectrometry (ICPMS). Since the releaset of the Management Plan of the Barents Sea in 2007, the monitoring has been extended to include POPs and also heavy metals in the liver.
  Sampling is normally done by the Institute of Marine Research. This is also the case for the extended baseline study (Fig.1) perfprmed in the period 2009 to 2011.

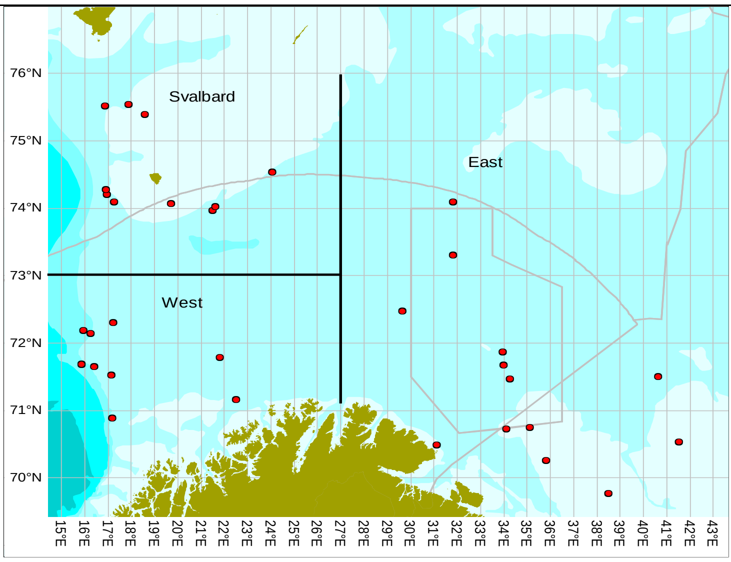


Figure 1. Sampling positions for the baseline study of Northeast Arctic cod (*Gadus morhua*) sampled from February 2009 to May 2010. 25 fish was sampled at each position.

- **Current status of the parameter:** NIFES has finalized a major baseline study of cod (2009-2011), including North East arctic cod, the data are given in the Table 1. The sampling undertaken for the baseline study was extensive, and covered the entire area of distribution of cod over a full year. Mercury concentration in cod fillets sampled from 1995 to 2010 is given in Table 1.

Table 1 Mercury concentrations (mean and range) in cod fillets obtained in the period (1995-2010). (www.NIFES.no/seafood)

Year	Number of fish	Mean (mg/kg ww)	Range (mg/kg ww)
2009-2010	800 (baseline)	0.036	0.01-0.16
2007	99		<0.01-0.14
2006	75	0.04	<0.01-0.25
2003	20	0.02	0.01-0.03
2002	100	0.04	0.01-0.45
2000	50	0.03	0.01-0.08
1998	50	0.04	0.01-0.08
1996	25	0.03	0.01-0.08
1995	75	0.04	0.01-0.08

The concentration levels of mercury in cod fillet are generally low (Table 1). All concentration levels were well below EU's maximum level of mercury in cod fillet set at 0.5 mg/kg wet weight for human consumption (EC, 2006. Commission regulation No 1881/2006 of 19 December 2006 setting maximum levels for certain contaminants in foodstuffs.

The mercury concentrations in cod fillet seem to be stable in the time period from 1995 to 2010.

- **Reference level:** The mercury concentrations are highly related to the weight of the fish.
- **Quality objectives:** Maximum level of mercury in cod fillet is set at 0.5 mg/kg wet weight for human consumption (EC 1881/2006).

Subparameter 2 - Other heavy metals in fillet and liver

- **Short facts about the parameter:**
  Gadus morhua contaminants is a key parameter for evaluating seafood safety in this area.
- **Monitoring:**
  NIFES has monitored arsenic, cadmium and lead in cod fillet since 1995. Sampling positions of cod were not recorded in the period from 1995 to 2006. The elements have been determined in individual cod fillets using inductively coupled plasma-mass spectrometry (ICPMS). Since the start of the Management Plan of the Barents Sea in 2007, the monitoring has been extended to include POPs and also heavy metals in the liver.

  Sampling is normally done by the Institute of Marine Research. This is also the case for the baseline study (Fig.1).

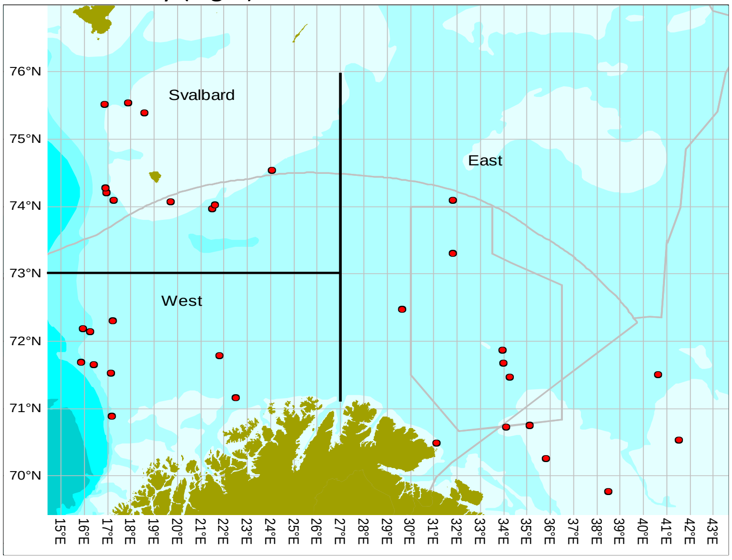


Figure 1. Sampling positions for the baseline study of Northeast Arctic cod (*Gadus morhua*) sampled from February 2009 to May 2010. 25 fish were sampled at each position.

- **Current status of the parameter:** NIFES has finalized a major baseline study of cod (2009-2011a), including Northeast arctic cod, the data are given in the Table 1. The sampling undertaken for the baseline study was extensive, and covered the entire area of distribution of cod and a full year. The concentrations of arsenic, cadmium and lead in fillet of cod sampled from 1995 to 2010 are given in Table 1.

Table 1 Concentration levels of arsenic, cadmium and lead (mean and range) in fillets of Northeast arctic cod caught in the period (1995-2010). (www.NIFES.no/seafood)

Year	Number (N)	Arsenic (mg/kg ww)	Cadmium (mg/kg ww)	Lead (mg/kg ww)
2009-2010	800 (baseline)	12 (0.3-170)	<0.002	<0.01-0.06
2007	99	7.5 (0.1-60)	<0.001-0.03	<0.01-0.04
2006	75	7.2 (0.5-79)	<0.001-0.009	<0.01
2003	20	9.0 (2.9-17)	<0.002	<0.01
2002	100	16 (0.5-222)	<0.002-0.009	<0.01-0.09
2000	50	4.0 (0.5-22)	<0.001	<0.01
1998	50	9.6 (0.4-52)	<0.001	<0.01
1996	25	10 (0.4-50)	<0.001	<0.01-0.05

1995	75	6.0 (0.4-30)	<0.001-0.001	<0.01-0.02

The concentration levels of cadmium and lead in cod fillet are generally low (Table 1). All concentration levels were well below EU's maximum level of cadmium and lead in cod fillet set at 0.05 and 0.3 mg/kg wet weight, respectively, for human consumption (EC, 2006. Commission regulation No 1881/2006 of 19 December 2006 setting maximum levels for certain contaminants in foodstuffs. The concentration levels of cadmium and lead in cod fillet seem not to have changed in the period from 1995 to 2010. There is no max level for neither total arsenic nor inorganic arsenic in fish fillet set by EU. Arsenic in seafood is usually found in the organic form, and not in the inorganic toxic form.

The concentration levels of cadmium and lead in cod fillet seem not to have changed in the period from 1995 to 2010.

- **Reference level:**
- **Quality objectives:** EU has set a maximum level of cadmium and lead in cod fillet at 0.05 and 0.3 mg/kg wet weight, respectively, for human consumption (EU 1881/2006).

Table 2. Concentration levels of arsenic, cadmium and lead (mean and range) in livers of Northeast arctic cod caught in the period (2005-2010). (www.NIFES.no/seafood)

Year	Number (N)	Arsenic (mg/kg ww)	Cadmium (mg/kg ww)	Lead (mg/kg ww)
2009-2010	800	13 (1.8-240)	0.19 (0.02-1.3)	<0.01
2007	49	13 (2.4-110)	0.15 (0.04-0.41)	<0.04-0.2
2006	52	6.5 (2.4-42)	0.20 (<0.03-0.46)	<0.04-0.07
2005	25	8.8 (3.3-44)	0.29 (0.09-1.4)	<0.04

The concentration levels of cadmium and lead in cod liver are generally low (Table 2). So far, no maximum levels of cadmium and lead in fish liver are set by EU.

Subparameter 3 - Organic contaminants in liver

- **Short facts about the parameter:** *Gadus morhua* contaminants is a key parameters in evaluating seafood safety in this area. POPs in liver of cod is also a much used parameter in environmental quality due to its high lipid content.
- **Monitoring:** NIFES has monitored polychlorinated dibenzo-p-dioxins and polychlorinated dibenzofurans (PCDD/Fs), non-orto- and mono-orto PCBs (DL-PCBs), non-dioxin-like PCBs (NDL-PCBs) and polybrominated diphenyl ethers (PBDE) in cod liver since 2006. The organic contaminants were determined in individual cod liver using high resolution gas chromatography – high resolution mass spectrometry (HRGC-HRMS).
  Sampling of Northeast arctic cod is normally done by the Institute of Marine Research. This is also the case for the baseline study (Fig.1).

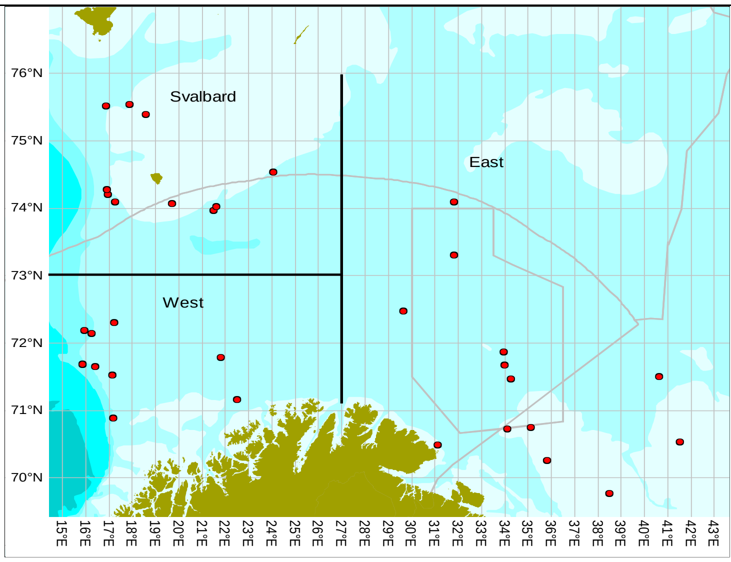


Figure 1. Sampling positions for the baseline study of Northeast Arctic cod (*Gadus morhua*) sampled from February 2009 to May 2010. 25 fish was sampled at each position.

- **Current status of the parameter:** NIFES has finalized a major baseline study of cod (2009-2011), including Northeast arctic cod, the data for the organic contaminants are given in the Table 1. The sampling undertaken for the baseline study was extensive, and covered the entire area of distribution of cod and a full year. Concentration of sum PCDD/Fs and DL-PCBs, NDL-PCBs and PBDEs in liver of cod sampled from 2006 to 2010 are given in Table 1.

Table 1 Concentrations of sum PCDD/Fs + dl-PCBs (ng TEQ/kg ww), NDL-PCBs (PCB_6) and $PBDE_7$ are given as means and range (minima-maxima) in liver of Northeast Artic cod caught during 2006 and 2010. (www.NIFES.no/seafood)

Year	Number of fish	Sum PCDD/Fs + DL-PCBs (ng TEQ/kg ww)	PCB_6 (µg/kg ww)	$PBDE_7$ (µg/kg ww)
2009-2010	780 (baseline)	14.2 (1.0-151)	92 (10-510)	4.5 (0.2-37)
2008	99	12.5 (3.4-56)[a)]	92 (23-575)[b)]	3.8 (1.1-15)
2007	75	22.8 (1.8-110)[a)]	165 (15-650)[b)]	6.1 (1.5-18)
2006	20	18.1 (2.1-57)[a)]	113 (11-389)[b)]	9.4 (7.0-40)

[a)] TEQ-WHO-1998 used for samples 2006-2008. TEQ-WHO-2005 used for the baseline samples.
[b)] PCB_7 used for samples 2006-2008. PCB_6 used for the baseline samples.

Totally, 166 samples of individual livers out of 784 livers from the baseline study (i.e. 21 %) had a concentration of PCDD/Fs+dl-PCBs higher than 20 ng TEQ kg^{-1}ww, that is the maximum level of sum PCDD/Fs and dl-PCBs set for fish liver by EU intended for human consumption (European Commission, 2011. Commission regulation (EC) No 1259/2011 of 2 December 2011 amending Regulation (EC) No 1881/2006 as regards maximum levels for dioxins, dioxin-like PCBs and non dioxin-like PCBs in foodstuffs. Official Journal of the European Union L 320/18, 03.12.2011).

Totally, 58 samples of individual livers out of 784 livers from the baseline study had concentrations of PCB_6 higher than 200 µg kg^{-1} ww that is the maximum level for PCB_6 in fish liver set by EU for human consumption (EC, 2011).

The mercury concentrations in cod fillet seem not to have changed in the period from 1995 to 2010.

- **Reference level:**
- **Quality objectives:** After 2012, maximum level of sum PCDD/Fs and DL-PCBs in cod liver is set at 20 ng $TEQ_{WHO-2005}$/kg wet weight for human consumption (EC 1259/2011). Before 2012, maximum level of sum PCDD/Fs and DL-PCBs in cod liver is set at 25 ng $TEQ_{WHO-1998}$/kg wet weight for human consumption (European Commission (2006), Commission regulation (EC) No 199/2006 amending Regulation (EC) No 466/2001. After 2012 a new maximum level was set also for NDL-PCBs (PCB_6) in fish liver at 200 µg/kg wet weight.

Subparameter 4 – Cesium -137

(same as for subparameter 1)

Subparameter 5 - Strontium -90 in the skeleton

to be developed

Contact person/responsible person: NIFES, Sylvia Frantzen.

Title: Contaminant levels in biota (E)

Parameter: Contaminants in Brünnich's guillemots (E)

About the parameter

- ***Type of parameter: E***
- ***Priority of parameter: e***
- ***Rationale:*** The Brünnich's guillemot is a high Arctic species that mainly feeds on fish and crustaceans. It plays an important role in the Arctic food web, because it occurs in high numbers. Its wide distribution makes it a useful species for monitoring environmental contamination.

Overview of the subparameters

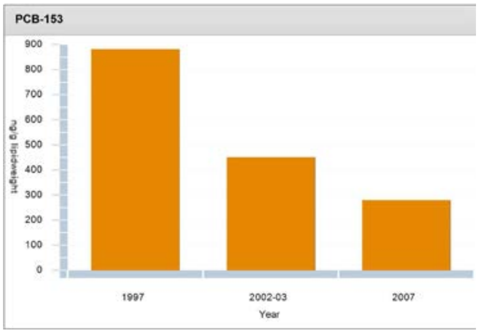
Subparameters (name)	*Institution responsible for monitoring*	*Time series period*	*Gaps in monitoring*	*Priority ("e", "r" or "s")*
Organic contaminants in eggs (Chlorinated Pesticides (DDT, HCB, HCH, Chlordanes, mirex, etc); PCBs; PBDE; HBCDD; Toxaphene; PFAS)	*NPI*	*1993-*		e
Mercury in eggs	*NPI*	*1993-*		e
Other heavy metals in eggs	*Not monitored*			r
Gamma emitting isotopes, polonium-210, in adults (r/s)	*NRPA*	*2005*		s

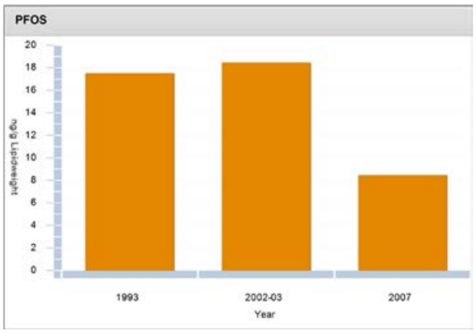
Subparameter 1 – Organic contaminants in eggs

Short facts about the subparameter: Organic contaminants (OCs) comprise a diverse group of chemical compounds that are transported from industrialised areas to the Arctic by air and ocean currents. While the concentrations of DDT and PCBs have decreased during the past 10-20 years as a result of restrictions on their use, other OCs have increased. Among these are the perfluoroalkylated substances (PFASs). Arctic organisms are exposed to OCs via different routes, e.g. dietary absorption, transport across the respiratory surface, dermal absorption and inhalation. Many OCs are lipid soluble and resistant to biodegradation. As a result, they bio-accumulate through Arctic food web. Besides trophic position the concentration of OCs in Arctic animals also depends on the ability to metabolise and excrete contaminants, gender, age and seasonal variation in body mass. OC concentrations found in seabird eggs are thought to reflect those in female birds.

- **Why this is a key subparameter:** Reported effects of OCs include damage to enzyme, immune and vitamin systems. Of particular concern are contaminants that can have an impact on the reproductive system and those that disrupt hormone function.

- **Monitoring:** Brünnich's guillemot eggs were collected by the Norwegian Polar Institute during in the spring of 1993, 2002/2003 and 2007. Sample areas included Bjørnøya and Kongsfjorden. OC concentrations were measured in homogenised whole eggs at Norwegian School of Veterinary Science (Oslo, Norway).
- **Current status of the subparameter:** The available data seem to confirm the temporal trend of decreasing concentrations of 'traditional' OCs, such as PCBs. The 'newer' contaminants, such as PFOS do not show this trend.





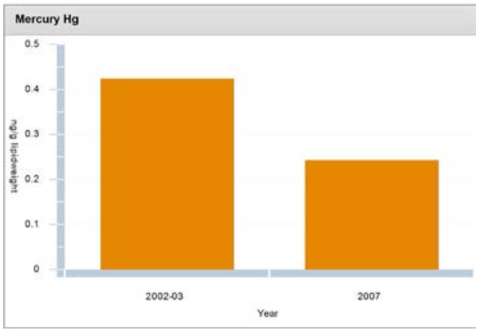
More information and other graphs can be found at the MOSJ website: http://mosj.npolar.no/en/influence/pollution/indicators/pollution_brunnichsguillemot.html and in Miljeteig and Gabrielsen (kortrapport no.16, Norsk Polarinstitutt, 2010).

- **Quality objectives:** Measurements of OC concentrations in eggs of Brünnich's guillemots from Svalbard are part of MOSJ.
- **Reference level:** There is no reference level. For man-made chemicals that do not occur naturally in the environment, the reference level can be said to be zero.
- **Gaps in data coverage:** At present monitoring of Brünnich's guillemots' eggs takes place once every five years (MOSJ).

Subparameter 2 – Mercury in eggs

- **Short facts about the subparameter:** Coal burning, waste incineration and industrial processes are the main sources of mercury in the atmosphere. In spring, atmospheric mercury is deposited on the ground or snow under the influence photochemical processes and bromine. After deposition it is partly converted to methylmercury through microbial activity. Methylmercury released from sea ice can be taken up by marine organisms. It bio-accumulates in the Arctic food web and is highly toxic.
- **Why this is a key subparameter:** Mercury is readily absorbed through the skin and mucous membranes. It binds to proteins and is freely transported throughout the body. Because mercury crosses the blood-brain barrier, it may disrupt the central nervous system causing problems such as numbness, tingling, lack of coordination and memory loss. Mercury in birds' eggs can cause embryo deformity and reduce hatching success.
- **Monitoring:** Brünnich's guillemot eggs were collected from breeding colonies in Kongsfjorden (1993, 2002/2003, and 2007) and Bjørnøya (2002/2003 and 2007) by the Norwegian Polar Institute. Mercury concentrations were measured in homogenised whole eggs at the Norwegian University for Science and Technology (Trondheim, Norway).
- **Current status of the subparameter:** Mercury concentrations in eggs of Brünnich's guillemots from Kongsfjorden were higher than mercury concentrations in eggs of Brün-

nich's guillemots from Bjørnøya. Based on the available data conclusions on temporal trends cannot be drawn. Mercury concentrations in eggs of Brünnich's guillemots from the Barents Sea were similar to those from the Canadian Arctic.

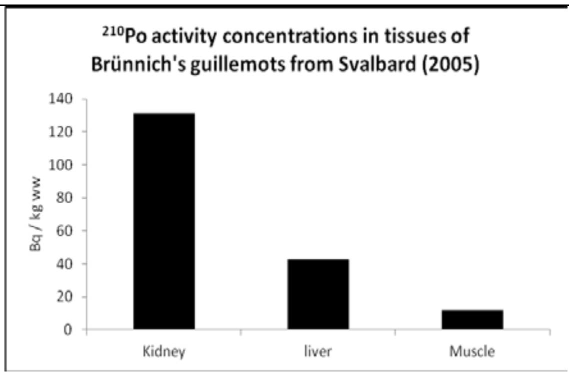


More information can be found at the MOSJ website: http://mosj.npolar.no/en/influence/pollution/indicators/pollution_brunnichsguillemot.html and in Miljeteig and Gabrielsen (kortrapport no.16, Norsk Polarinstitutt, 2010).

- **Quality objectives:** Measurements of mercury concentrations in eggs of Brünnich's guillemots from Svalbard are part of MOSJ.
- **Reference level:** Mercury concentrations in most pelagic seabirds breeding in the Arctic do not appear to be high enough to affect reproduction and survival. However, recent reports demonstrate that methylmercury in the eggs of a number of marine birds (ivory gull and black guillemot) may exceed the effects thresholds.
- **Gaps in data coverage:** At present monitoring of Brünnich's guillemots' eggs takes place once every five years (MOSJ).

Subparameter 4 – Polonium-210, in adults

- **Short facts about the subparameter:** Polonium-210 (^{210}Po) is a highly radioactive and chemically toxic element that is naturally present in the environment in extremely low concentrations (e.g. in uranium ores).
- **Why this is a key subparameter:** ^{210}Po is known to concentrate in marine organisms to a higher extent than other naturally-occurring alpha emitters. ^{210}Po levels in humans vary geographically and culturally; relatively high levels have been found in Arctic residents. Observed variation in ^{210}Po activity in seabirds probably reflects differences in diet, but little is known about trophic transfer.
- **Monitoring:** ^{210}Po activity was measured in different organs of Brünnich's guillemots from Svalbard. The study was carried out by the Norwegian Radiation Protection Agency in 2005.
- **Current status of the subparameter:** Activity concentrations of ^{210}Po in Brünnich's guillemots were comparable to those of other seabird species. Tissue-specific ^{210}Po activity decreased in the order kidney > liver > muscle.



More information can be found in: NRPA. Radioactivity in the Marine Environment 2005. Results from the Norwegian National Monitoring Programme (RAME). Strålevern Rapport 2007:10. Østerås: Norwegian Radiation Protection Authority, 2007.

- **Quality objectives:** Measurement of ^{210}Po in Brünnich's guillemots was part of the marine monitoring programme RAME (Radioactivity in the Marine Environment).
- **Reference level:**
- **Gaps in data coverage:** The study took place in only one year (2005).

Contact person/responsible person: Geir Wing Gabrielsen, NPI

Title: Contaminant levels in biota (E,I)

Parameter: Contaminants in Greenland halibut (E)

About the parameter

- ***Type of parameter: E***
- ***Priority of parameter: e***
- ***Rationale :*** Parameter needs to be developed

Overview of the subparameters

Subparameters (name)	*Institution responsible for monitoring*	*Time series period*	*Gaps in monitoring*	*Priority (“e”, “r” or “s”)*
Hg in fillet				
Other heavy metals in fillet and liver				
Organic contaminants in liver				
Cesium-137				
Strontium -90 in the skeleton				

Subparameter 1 – Mercury in fillet

- **Short facts about the parameter:**
- **Monitoring:**
- **Current status of the parameter:**
- **Reference level:**
- **Quality objectives:**

Subparameter 2 - Other heavy metals in fillet and liver

- **Short facts about the parameter:**

- **Monitoring:**
- **Current status of the parameter:**
- **Reference level:**
- **Quality objectives:**

Subparameter 3 - Organic contaminants in liver

Subparameter 4 – Cesium -137

Subparameter 5 - Strontium -90 in the skeleton

Contact person/responsible person:

Title: Contaminant in biota (E) levels

Parameter: Contaminants in polar bears (E)

About the parameter

- ***Type of parameter: E***
- ***Priority of parameter: e***
- ***Rationale :*** Polar bear is an apex predator of the arctic marine food web. It has a circumpolar distribution. Due to its position in the food web, it accumulates high levels of environmental contaminants. The species is stressed by several anthropogenic factors like changing climate and pollutants.

Overview of the subparameters

Subparameters (name)	*Institution responsible for monitoring*	*Time series period*	*Gaps in monitoring*	*Priority ("e", "r" or "s")*
Organic contaminants and metabolites in blood (DDT, HCB, HCH, Chlordanes, mirex, PCB, PBDE,HBCDD,Toxafene, PFAS)	*Norwegian Polar Institute*	*1989-*		e
Hg in hair	*Norwegian Polar Institute*	*1995-*		e
Other heavy metals in hair	*Not monitored*			s

Subparameter 1 - Organic contaminants and metabolites in blood

- **Short facts about the subparameter:** Organic contaminants are chemicals used in industry as well as pesticides. They are persistent, transported to the Arctic by air and ocean currents. They accumulate in the food web, and highest concentrations are found in top predators.
- **Why this is a key subparameter:** Organic contaminants accumulate at high levels in the top predators of the arctic marine food web. The levels detected in the polar bears may lead to toxic effects towards hormone and immune system.
- **Monitoring:** Samples for organic contaminants in polar bears are taken in spring in Svalbard by the Norwegian Polar Institute as a part of the yearly monitoring programme. Levels of organic contaminants are measured in plasma samples (adult females).
- **Current status of the subparameter:** Generally the levels of organic contaminants are declining. For further info please, see figures at http://mosj.npolar.no/no/influence/pollution/indicators/pcb_polarbear.html

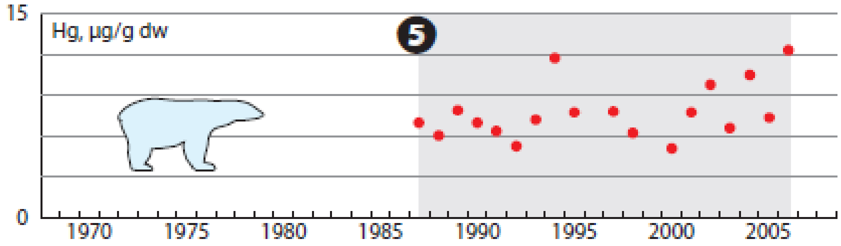
- **Quality objectives:** Organic contaminants in polar bear plasma from Svalbard are part of MOSJ.
- **Reference level:** There is no reference level.
- **Gaps in data coverage**: There are gaps in the time series. We are working on providing more data.
- **Other issues about the subparameter:** -

Subparameter 2 – Mercury in hair

Subparameter 3 – Other heavy metals

Not monitored, suggested for monitoring

- **Short facts about the subparameter:** The main source of mercury is coal production. It is transported to the Arctic by air and ocean currents. Mercury accumulates in the food web in the form of methyl-mercury, and highest concentrations are found in top predators.
- **Why this is a key subparameter:** Mercury accumulates at high levels in the top predators of the arctic marine food web. The levels detected in the polar bears may lead to toxic effects. Levels of mercury in Svalbard are generally low compared to the rest of the Arctic.
- **Monitoring:** Samples for mercury in polar bears are taken in spring in Svalbard by the Norwegian Polar Institute as a part of the yearly monitoring programme. Levels of mercury are measured in hair samples in collaboration with Aarhus University.
- **Current status of the subparameter:** There is no trend (figure from Braune, B., J. Carrie, et al. (2011). Are mercury levels in Arctic biota increasing or decreasing, and why? AMAP Assesment 2011: Mercury in the Arctic. P. Outridge and R. Dietz, AMAP: 85-111)



- **Quality objectives:** Organic contaminants in polar bear plasma from Svalbard are part of MOSJ.
- **Reference level:** There is no reference level.
- **Gaps in data coverage**: -
- **Other issues about the subparameter**: -

Contact person/responsible person: Heli Routti, NPI

Title: Demersal fauna biodiversity

About the indicator

- ***Type of indicator: E***
- ***Priority of indicator: e***
- ***Rationale:*** This indicator is based on the vector of biomasses of the demersal species caught during the ecosystem survey in the demersal trawl. It describes the main properties and state of the whole demersal fauna community, at the scale of 45 sub-areas (fig 1). Based on the ecosystem survey data, it shows how this community is structured in space and time in the Barents Sea. Following the widely accepted paradigm that diverse communities are more stable through time, and therefore more able to sustain either human or climate driven change, our approach can classify these sub-areas along a "resilience-to-change" gradient.

Overview of Parameters

Parameters (name)	***Type (“E”, “A”, or “I”)***	***Priority (“e”, “r” or “s”)***
Biomass per species of the demersal fauna.	*E*	*e*

Contact person/responsible person: Gregoire Certain, University of Uppsala

Title: Demersal fauna biodiversity indicator

Parameter: Biomass per species of the demersal fauna.

About the parameter

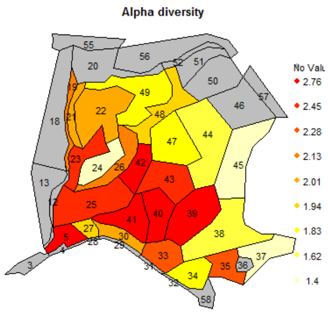
- ***Type of parameter: E***
- ***Priority of parameter: e***
- ***Rationale:*** This indicator is based on the vector of biomasses of the demersal species caught during the ecosystem survey in the demersal trawl. It describes the main properties and state of the whole demersal fauna community, at the scale of 45 sub-areas (fig 1). Based on the ecosystem survey data, it shows how this community is structured in space and time in the Barents Sea. Following the widely accepted paradigm that diverse communities are more stable through time, and therefore more able to sustain either human or climate driven change, our approach can classify these sub-areas along a "resilience-to-change" gradient.

Overview of the subparameters

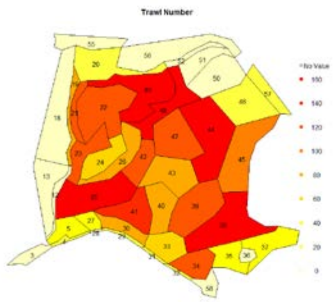
Subparameters (name)	***Institution responsible for monitoring***	***Time series period***	***Gaps in monitoring***	***Priority ("e", "r" or "s")***
α-diversity per subarea	*IMR/PINRO*	*2004 -present*		e
β-diversity per subarea	*IMR/PINRO*	*2004 -present*		e
+++ any other relevant community metric	*IMR/PINRO*	*2004 -present*		e

Subparameter 1 – α-diversity of the demersal fauna

- **Short facts about the subparameter:** The α-diversity can be viewed as a measure of species diversity at a local (trawl) scale.
- **Why this is a key subparameter:** it's one of the independent components of the species diversity that can be viewed as a proxy to measure ecosystem resilience.
- **Monitoring:** The data required are collected during the ecosystem survey: species identification and biomasses of the biological material contained in the bottom trawl.
- **Current status of the subparameter:**
  As it can be seen on the map below, α-diversity is higher in areas corresponding to the Atlantic waters and the polar front.



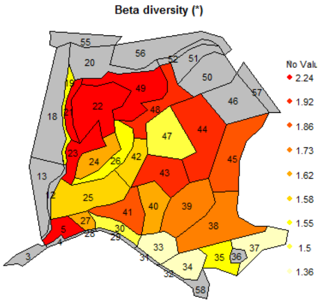
- **Quality objectives:** There is no particular quality objective for alpha diversity.
- **Reference level:** The observed pattern for the time period 2004-2008 can be used as a reference level.
- **Gaps in data coverage:** There is no real gap in data coverage. However, some polygons are better sampled than others, in term of number of trawl:



- **Other issues about the subparameter:** See the small appendix on α and β diversity for a more detailed explanation and some proposal concerning aggregation and joint interpretation of the subparameters.

Subparameter 2 – β-diversity of the demersal fauna

- **Short facts about the subparameter:** The β-diversity can be viewed as a measure of trawl heterogeneity at the regional (polygon) scale.
- **Why this is a key subparameter:** it's one of the independent componentы of the species diversity that can be viewed as a proxy to measure ecosystem resilience.
- **Monitoring:** The data required are collected during the ecosystem survey: species identification and biomasses of the biological material contained in the bottom trawl
- **Current status of the subparameter:**



As it can be seen on the map below, β-diversity is higher around Svalbard and in the North-East of the Barents sea.

- **Quality objectives:** There is no particular quality objective for beta diversity.
- **Reference level:** The observed pattern for the time period 2004-2008 can be used as a reference level.
- **Gaps in data coverage:** There is no real gap in data coverage. However, some polygons are better sampled than others, in term of number of trawl:

- **Other issues about the subparameter:** See the small appendix on α and β diversity for a more detailed explanation and some proposal concerning aggregation and joint interpretation of the subparameters.

Subparameter 3+

The subparameter presented here constitute the ”core” of biodiversity assessment. But it should be noted that much more diversity metrics are available if a more detailed biodiversity assessment is required. Furthermore, the same approach can be easily extended to the pelagic community, using data collected during standardized pelagic trawls.

Contact person/responsible person: Grégoire Certain, IMR, in collaboration with BarEcoRe colleagues

Appendix #1: Quantifying biodiversity for the demersal fauna in the Barents Sea

Description of the essential sub-parameters: α- and β-diversity

Methods to measure of diversity are numerous, often redundant, and not always well articulated with each other. Tuomisto (2010) provided a consistent synthesis and a detailed framework to produce "true" diversity measurement. Consider a community of *S* species in a given area where *N* diversity samples have been taken. Let us denotes m_{ij} the abundance of species *i* (*i = 1,….,S*) in sample *j* (*j=1,…,N*). From there, diversity can be measured in three complementary ways. Firstly, diversity of species frequency within samples can be estimated, that is termed α-diversity. Secondly, diversity of species frequency between samples can be estimated, that is termed β-diversity. Thirdly, the overall diversity for the sub-area can be computed by summing all the samples together, that is termed γ-diversity. Depending on authors, relationships between α-, β-, and γ-diversity can be specified in several ways, but perhaps the most convenient is the following simple multiplicative relationship:

$$\alpha \times \beta = \gamma \quad (eq.1)$$

There are numerous formulas to compute α-diversity. Simpson index, Shannon index, species richness, all can be viewed as α-diversity measures. Tuomisto (2010) provides a consistent formulation for α-diversity that links most of these metrics together. This is Hill's (1973) diversity number, also termed diversity of order *q*:

$$\alpha_q = \left(\sqrt[q-1]{\sum_{j=1}^{N} \sum_{i=1}^{S} p_{ij} \, p_{i|j}^{\;q-1}} \right)^{-1} \quad (eq.2)$$

Where the frequencies p_{ij} and $p_{i|j}$ are calculated as follows:

$p_{ij} = m_{ij} / m$, with $m = \sum_{j=1}^{N} \sum_{i=1}^{S} m_{ij}$ and

$p_{i|j} = m_{ij} / m_j$, with $m_j = \sum_{i=1}^{S} m_{ij}$

Estimating γ-diversity is achieved through a simplified version of *eq. (2)* corresponding to a single sample case (N=1):

$$\gamma_q = \left(\sum_{i=1}^{S} p_i^{\,q} \right)^{1/(1-q)} \quad (eq.\ 3)$$

Where $p_i = m_i / m$, with $m_i = \sum_{j=1}^{N} m_{ij}$

These diversity indices take different values, according to the value chosen for the parameter *q*. When $q = 0$, *α* and *γ* correspond to species richness estimates. In the limiting form when $q \to 1$, *α* and *γ* tends toward the exponent of the Shannon index. When $q = 2$, *α* and *γ* corresponds to the inverse Simpson index, and when $q \to \infty$ then *α* and *γ* tends toward the frequency of the most abundant species. Usual choices for diversity measures are either $q \to 1$ or $q = 2$, but for an exhaustive description one might be interested in the *α and β diversity profile,* that is plotting α_q and $\beta_q = \gamma_q / \alpha_q$ over the whole range of *q* values. In the following development, we use *q*=2

In essence, α-diversity can be understood as a measure of the local diversity in a given area, while β-diversity can be seen as a measure of the spatio-temporal heterogeneity of the local diversity in a given area. In a nutshell, α and β diversity are two independent components of the global (γ) diversity in a region. They should therefore constitute the "core" of any diversity assessment.

In addition from the true diversity indexes, one might be interested in adding other diversity metrics. Here, the debate is clearly open and no choice should be made before a careful examination of all indices available. However, some suggestions can be made and as an example, we might propose the use of Chao's compositional similarity and of the "regional variance excess" (see Chao 2008 and Tuomisto 2010 for details).

Defining an appropriate spatial scale for diversity assessment in the Barents Sea: the "Atlantis" polygons

Spatial scale issues are central points when designing an indicator set. The choice of the spatial scale drives both the degree to which data or information should be averaged, with the associated loss of variability, and the resolution at which information will be communicated to stakeholders, in other word the minimum scale at which it will be possible to identify any "problems" and subsequently the minimum scale at which operational management actions should be taken. In these conditions, achieving a perfect trade-off between (1) the scientific issues related to precision and objectivity of the information, and (2) the management needs of simplicity, effectiveness and tractability, is impossible. However, informed pragmatic choices may approach such a trade-off, and that's what the fig. 1 is attempting for the Barents Sea.

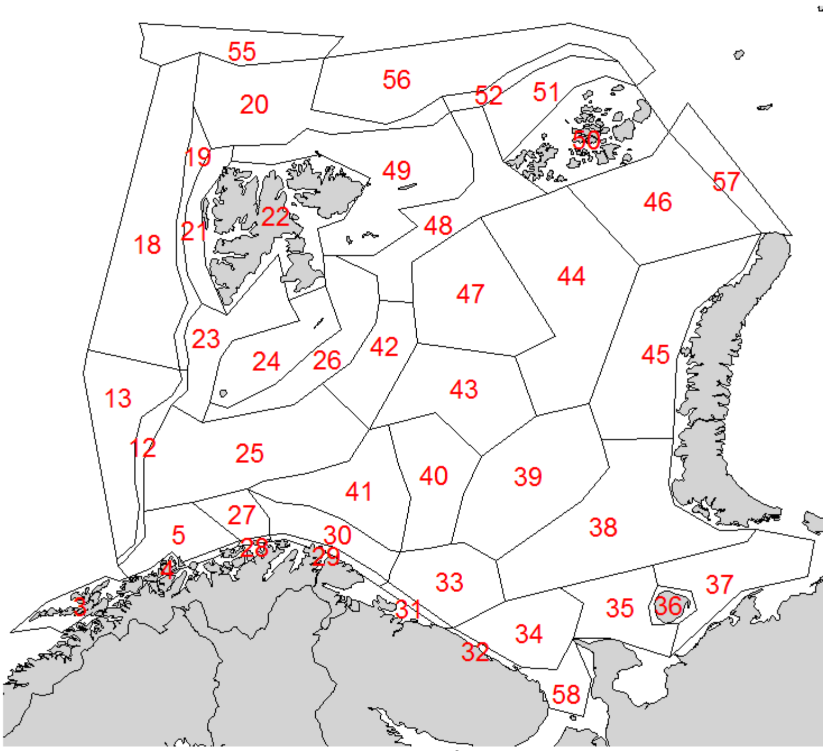


Fig 1. "Atlantis" polygons for the Barents Sea

Fig 1. Shows a decomposition of the Barents Sea achieved through expert-group discussions involving scientists from the IMR. This decomposition in 45 polygons integrates oceanographic information, biological specificities and sampling history and identifies 45 “homogeneous” areas that can be considered as management units.

Integrating diversity measures at the “Atlantis” scale for a single assessment.

Using the ecosystem survey data (biological material collected in the demersal trawl), it is therefore possible to compute diversity indices into each area, and then to classify them according to their biodiversity score (Fig 2).

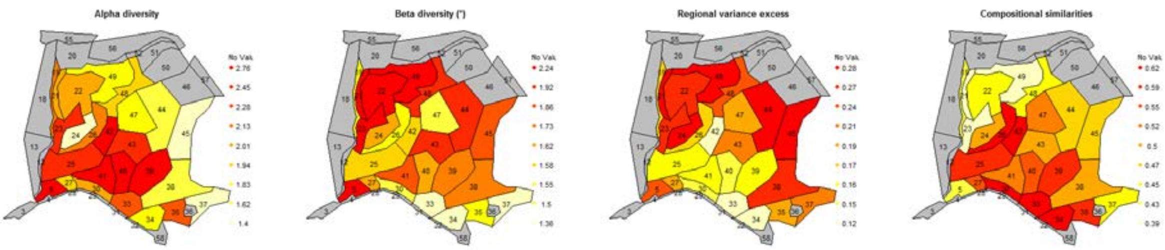


Fig 2. Diversity metrics computed from the frequencies (in biomass) of 81 demersal species found in the campellen trawl during the ecosystem survey. Data from the time period 2004-2008 have been grouped.

For a general synthesis, a PCA can be carried out on the polygon*metric table. See fig 3 for an example where axis 1 (horizontal) explains 60% of data variability and axis 2 explains 30% of data variability. Then, polygons can be ranked according to their PCA score on each axes. In this example, negative values on axis 1, and positive values on axis 2, are associated to high diversity. Let us denote Sc1 the vector of score of each polygons on PC1 and Sc2 the vector of score of each polygons on PC2, we can rank polygons according to the following formula: -0.6*Sc1 + 0.3*Sc2. We then get a ranking of polygons in term of biodiversity (Fig 3).

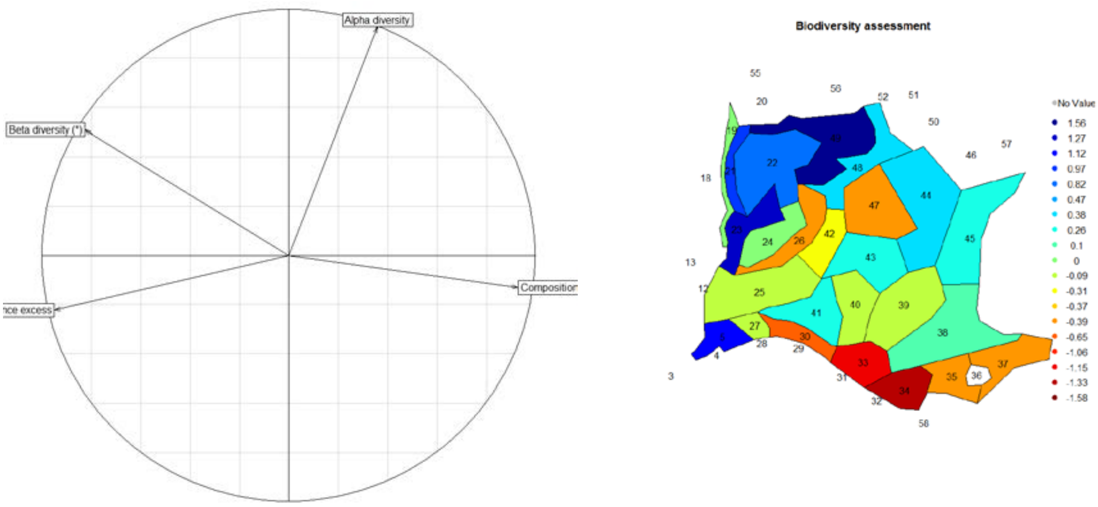


Fig 3. Multivariate biodiversity assessment for the Barents Sea. Left panel: correlation circle for the 4 biodiversity metric used. A negative score on axis 1 corresponds to high beta diversity, high regional variance, and low compositional similarities within samples, in other word to high regional heterogeneity. A positive score on the Axis 2 corresponds to high alpha diversity, i.e. high local diversity. Right panel: Averaged biodiversity score for each polygon, based on the PCA analysis. Highest values (blue polygons) correspond to highest diversity.

LITERATURE CITED

Hill, M. O. (1973). Diversity and Evenness : A Unifying Notation and Its Consequences. *Ecology*, *54*(2), 427-432.

Tuomisto, H. (2010). A diversity of beta diversities: straightening up a concept gone awry. Part 1. Defining beta diversity as a function of alpha and gamma diversity. *Ecography*, *33*(1), 2-22.

Title: Dynamics of ice associated marine mammals (E,I)

About the indicator

- ***Type of indicator: E,I***
- ***Priority of indicator: e***
- ***Rationale:*** Ice associated marine mammals are expected to be severely affected by declining sea ice extent. It is thus of great importance to monitor their population dynamics.

Overview of Parameters

Parameters (name)	***Type (“E”, “A”, or “I”)***	***Priority (“e”, “r” or “s”)***
Polar bear population	*E,I*	e
The Barents Sea/White Sea harp seal population	*E,I*	e
Walrus population in the Barents Sea	*E,I*	e
Ringed seal population in the Barents Sea	*E,I*	e

Contact person/responsible person: Kit M. Kovacs, NPI

Title: Dynamics of ice associated marine mammals (E,I)

Parameter: Polar bear population

About the parameter

- ***Type of parameter: E,I***
- ***Priority of parameter: e***
- ***Rationale :*** Polar bears are a redlisted species that are expected to be severely negatively impacted by climate change. They are also a charismatic species, and results from monitoring of polar bears can therefore be useful for communicating about effects of climate change on Arctic ecosystems.

Overview of the subparameters

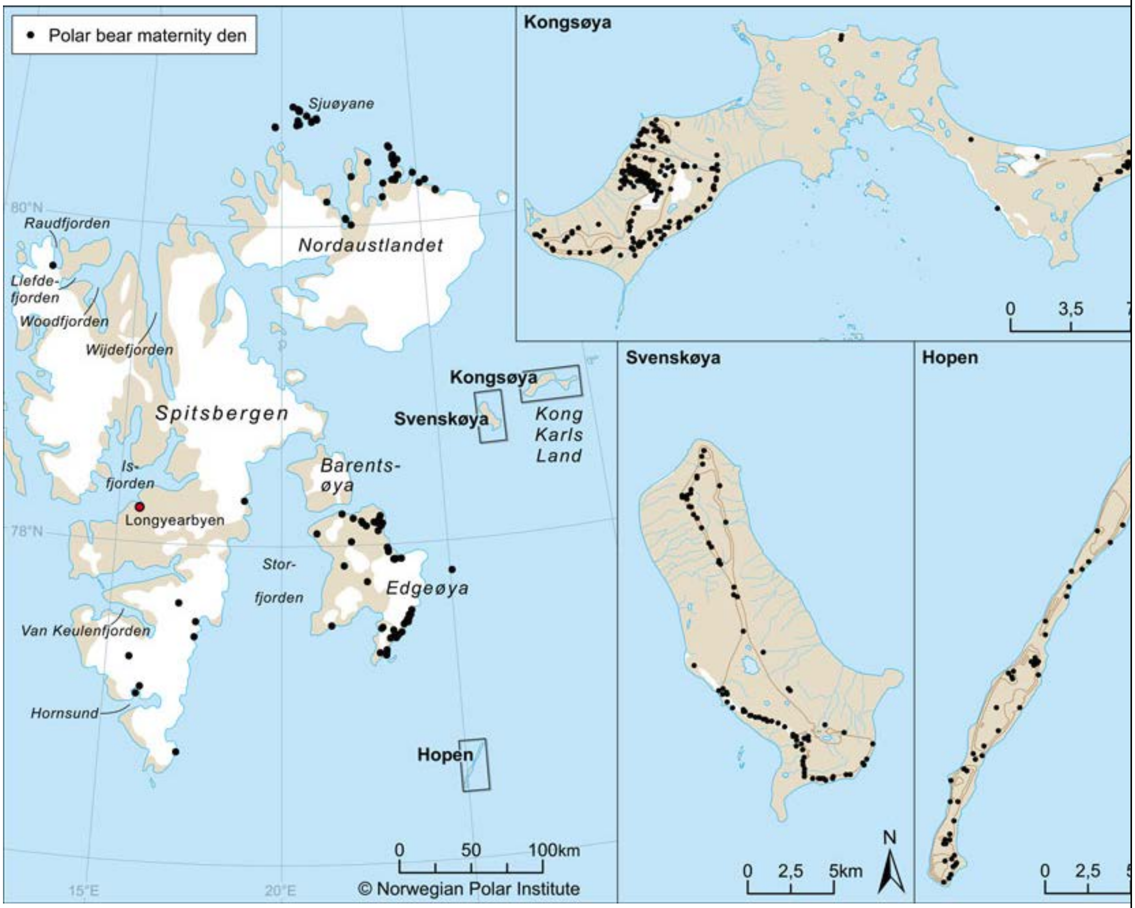
Subparameters (name)	***Institution responsible for monitoring***	***Time series period***	***Gaps in monitoring***	***Priority ("e", "r" or "s")***
Number of dens in important denning areas in Svalbard and Russia	*NPI*	*1978 - present*	*No*	e
Average number of cubs per female in reproductive age	*NPI*	*1992 - present*	*No*	e
Average body condition for males	*NPI*	*1987 - present*	*No*	r

Subparameter 1 – Number of dens in prime denning areas

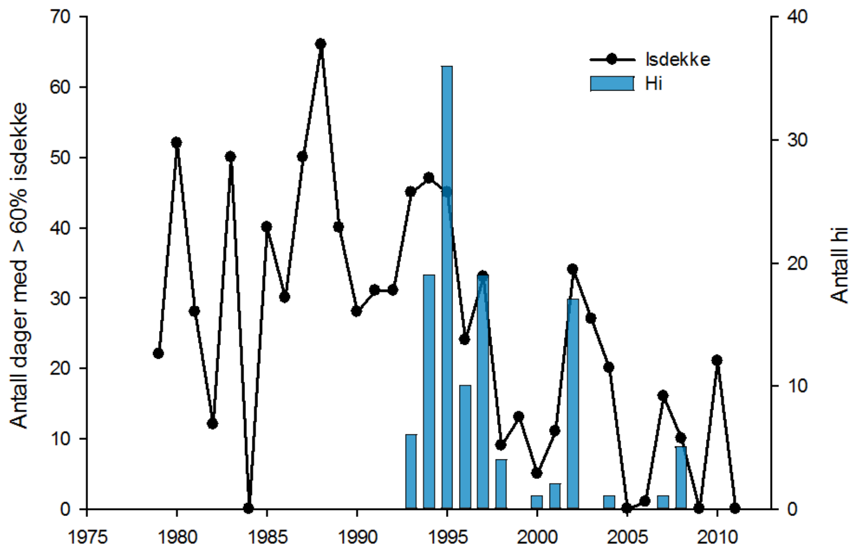
- **Short facts about the subparameter:** Polar bears (*Ursus maritimus*) have a circumpolar distribution. They are found in the northern part of the Barents Sea, on land and sea ice. In Svalbard important denning areas are generally found in the eastern part of the archipelago. Important prey species are ringed seals and bearded seals.

- **Why this is a key subparameter:** Monitoring of reproduction and body condition is considered to be the fastest way to detect effects of climate change on the polar bear population.

- **Monitoring:** Number of dens in Svalbard is estimated as females and cubs emerge from dens in late winter. This is done either from helicopter or on foot. Three areas are surveyed: parts of the eastern Edgeøya, Hopen and an area on Kongsøya (see map). The intention is to survey all three localities every year. However, weather and funding shortages may mean that this is not always possible.



- **Current status of the subparameter:** Monitoring is under development at NPI, operational in the first half of 2012. The figure below shows data from Hopen. Both number of dens (blue bars) and ice cover in the fall (black line) are shown. As sea ice cover has declined, number of dens has declined.

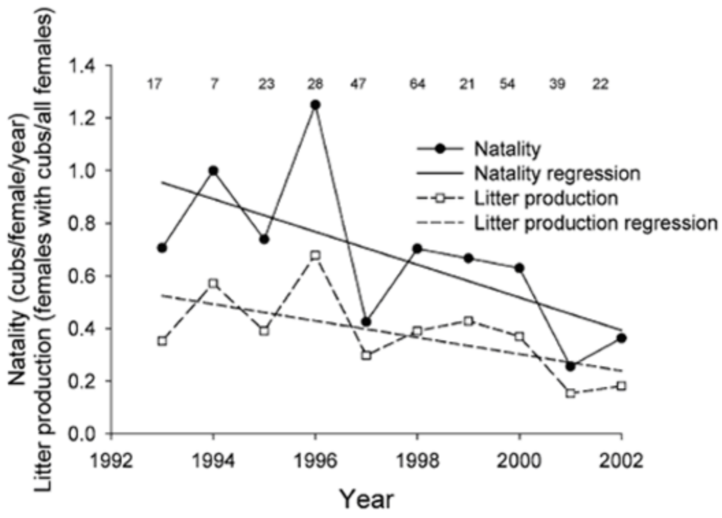


-

- **Quality objectives:** Not set.
- **Reference level:** To determine the reference level, the regression line for the relationship between time (year) and number of dens should be identified first. The reference level should then be set as predicted number of dens from this relationship for the year the monitoring started.
- **Gaps in data coverage:** There are years when data has not been collected, but no major gaps.
- **Other issues about the subparameter:** No other issues.

Subparameter 2 – Number of cubs per female

- **Short facts about the subparameter:** See above
- **Why this is a key subparameter:** Monitoring of reproduction and body condition is considered to be the fastest way to detect effects of climate change on the polar bear population.
- **Monitoring:** Average number of cubs will be monitored in connection with the tagging of adult bears at Svalbard. Surveys will be done every year. Areas surveyed will vary from year to year, but will mainly be located in the eastern part of Svalbard.
- **Current status of the subparameter:** The subparameter is under development at NPI, and will be operational in the first half of 2012. Preliminary results are shown below.



-
- **Quality objectives:** Not set.
- **Reference level:** To determine the reference level, the regression line for the relationship between time (year) and number of cubs should be identified first. The reference level should then be set as predicted number of cubs from this relationship for the year the monitoring started.
- **Gaps in data coverage:** No gaps.
- **Other issues about the subparameter:** No other issues.

Subparameter 3 – Body condition in males

- **Short facts about the subparameter:** See above
- **Why this is a key subparameter:** Monitoring of reproduction and body condition is considered to be the fastest way to detect effects of climate change on the polar bear population.
- **Monitoring:** Body condition will be monitored in connection with the tagging of adult bears at Svalbard. Surveys will be done every year. Areas surveyed will vary from year to year, but will mainly be located in the eastern part of Svalbard.
- **Current status of the subparameter:** The subparameter is under development at NPI, and will be operational in the first half of 2012.
- **Quality objectives:** Not set.
- **Reference level:** To determine the reference level, the regression line for the relationship between time (year) and body condition should be identified first. The reference level should then be set as predicted body condition from this relationship for the year the monitoring started.
- **Gaps in data coverage:** No gaps
- **Other issues about the subparameter:** No other issues.

Contact person/responsible person: Jon Aars, Magnus Andersen, NPI, Stanislav Belikov, VNIIPrirody

Title: Dynamics of ice associated marine mammals (E,I)

Parameter: Ringed seal population in the Barents Sea

About the parameter

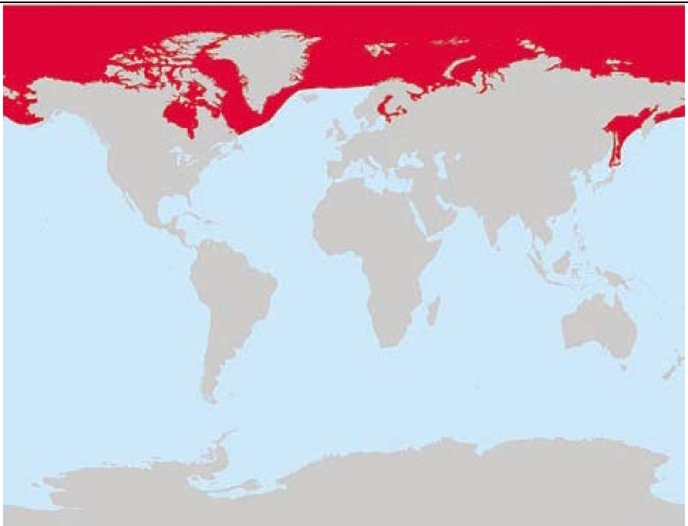
- ***Type of parameter: E,I***
- ***Priority of parameter: e***
- ***Rationale :*** Ringed seals (*Pusa hispida*) have been identified as key monitoring species in CAFF's Circumpolar Biodiversity Monitoring plan because the species is distributed throughout most of the circumpolar Arctic and is heavily reliant on sea ice. Ringed seals are important human food in some regions in the Arctic and the predominant prey species for polar bears. They rely on sea ice throughout their life cycle, being born on it, moulting and resting on it, and this species eats a diet that contains a lot of ice-associated fish and invertebrate species, particularly within young age classes. Declines in sea ice are a major threat to the continued existence of this species. Given the fact that ringed seals were the most numerous Arctic seal species, and the only species to be able to occupy extensive ice areas, declines in their numbers are likely to have consequences throughout much of the Arctic marine ecosystem.

Overview of the subparameters

Subparameters (name)	***Institution responsible for monitoring***	***Time series period***	***Gaps in monitoring***	***Priority ("e", "r" or "s")***
Population size	*NPI*	*Surveys done in 2001 and 2002, not repeated after this because of ice condition deterioration.*	*No surveys after 2002*	e
Reproductive rates of ringed seals	*NPI*	*Collections 2002 and 2012*	*10 year interval since last sampling occurred – but an annual programme is now envisaged for the next 5 years (at least)*	e

Subparameter 1 – Population size

- **Short facts about the subparameter:** Ringed seals (*Pusa hispida*) have a circumpolar Arctic distribution (see figure below). They feed on ice associated fish and invertebrates and are an important prey species for polar bears. They are also hunted for food for both humans and dog teams.



Ringed seal geographic distribution. IUCN Red List.

- **Why this is a key subparameter:** Abundance is the most essential "metric" for mammalian populations.
- **Monitoring:** Methods for estimation of ringed seal abundance in the changing sea ice environment in the Arctic, is currently under development. As a step in this process, it is vital to assess the site fidelity of individuals, because high site fidelity means that local surveys can give meaningful measures of changes in local abundance. If ringed seals, on the other hand, are shown to roam over large areas and not return to set breeding areas, then surveys will need to cover larger areas in order to provide estimates of abundance that can be meaningfully compared between years.
- **Current status of the subparameter:** Surveys from the west and north coasts of Svalbard were conducted in 2001 and 2002. Studies of site fidelity in Svalbard have been planned and can be conducted when funding is secured.
- **Quality objectives:** Not set.
- **Reference level:** The reference level would ideally be the abundance before the massive ice loss seen since the 2005 spring season. If site fidelity is high, this may be estimated from the 2001 and 2002 surveys in western Svalbard.
- **Gaps in data coverage:** As described above, work is under way to develop monitoring.
- **Other issues about the subparameter:** No issues.

Subparameter 2 – Reproductive rates

- **Short facts about the subparameter:** See above.
- **Why this is a key subparameter:** Reproductive rates are important to monitor, because this can provide an early detection of effects from sea ice loss on ringed seals population. While changes in abundance may take time to develop to levels where they are detectable from monitoring, effects may be detected more quickly for reproductive rates.
- **Monitoring:** Reproductive rates can be estimated from examination of reproductive organs of hunted animals.
- **Current status of the subparameter:** A hunter collection programme was established in 2012.
- **Quality objectives:** Not set.
- **Reference level:** The reference levels should be reproductive rates before the massive ice loss seen the last years. Time series are available from Svalbard since 1981. The most recent data are from Krafft et al. (2006) – in which ovulation rates are 0.86, MAM is 4.2 yr for males

and 3.5 years for females. All animals 6 yrs of age and older were sexually mature.

- **Gaps in data coverage:** A hunter collection programme was established in 2012 to update reproductive parameter monitoring.
- **Other issues about the subparameter:** No issues.

Contact person/responsible person: Kit M. Kovacs, NPI

Title: Dynamics of ice associated marine mammals (E,I)

Parameter: The Barents Sea/White Sea harp seal population

About the parameter

- ***Type of parameter: E,I***
- ***Priority of parameter: e***
- ***Rationale***: Based on available abundance estimates, harp seals are the most abundant marine mammal species in the Barents Sea area (~2 mill animals). As major consumers of fish and crustaceans they play an important role in the Barents Sea food web. Harp seals depend on ice as a substrate for pupping, nursing, moulting and resting and ongoing changes in ice conditions in the Barents Sea therefore add to the importance of including this species in an integrated ecosystem monitoring framework.

Overview of the subparameters

Subparameters (name)	***Institution responsible for monitoring***	***Time series period***	***Gaps in monitoring***	***Priority ("e", "r" or "s")***
Population size	*PINRO, IMR*	*Pup production estimates: 1998-2010* *Catch based model: 1945-present*		e
Distribution of harp seals in connection with reproduction	*PINRO*	*2009; 2010*	*(restricted coverage)*	s
Reproductive rates of female harp seals	*IMR* *PINRO*	*1963-72; 1976-85; 1990-93; 2006; 2011* *1962-64; 1988*		e
Diet shifts in harp seals	*IMR, NP and others*	*Stomachs and intestines: 1987-2011 (intermittently)* *Blubber: 1995, 2006, 2011*		s
Length at age and body condition parameters of harp seals	*IMR*	*1963-72 (only length), 1990 (only length), 1991, 1992, 1995, 1996, 1997,1998, 2000, 2004, 2005, 2006, 2011*		r

Subparameter 1 – Population size

- **Short facts about the subparameter:** Harp seals are distributed in Arctic and Subarctic areas of the north Atlantic with a global population size of around 11 million animals. In the northeast Atlantic, harp seals traditionally breed inside the White Sea (Barents Sea-White Sea stock) and off Northeast Greenland (Greenland Sea stock) (see Fig.1). Seals from these two breeding areas are genetically distinct from northwest Atlantic harp seals. Based on differences in timing of breeding and moulting, they are furthermore considered distinct demographic units and are managed separately. Both stocks feed in the Barents Sea, but the Barents Sea-White Sea (BSWS) stock is 2-3 times more numerous than the Greenland Sea stock and historically appears to have been more sensitive to changes in the Barents Sea ecosystem. BSWS harp seals are therefore the focus of this indicator.

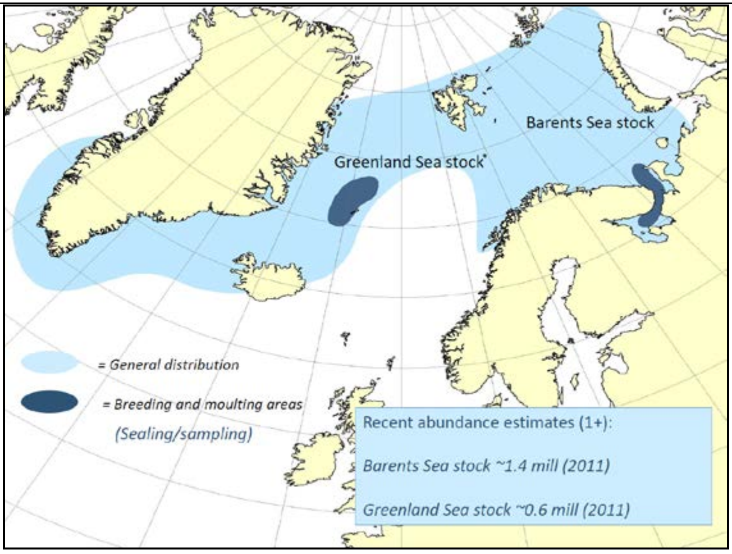
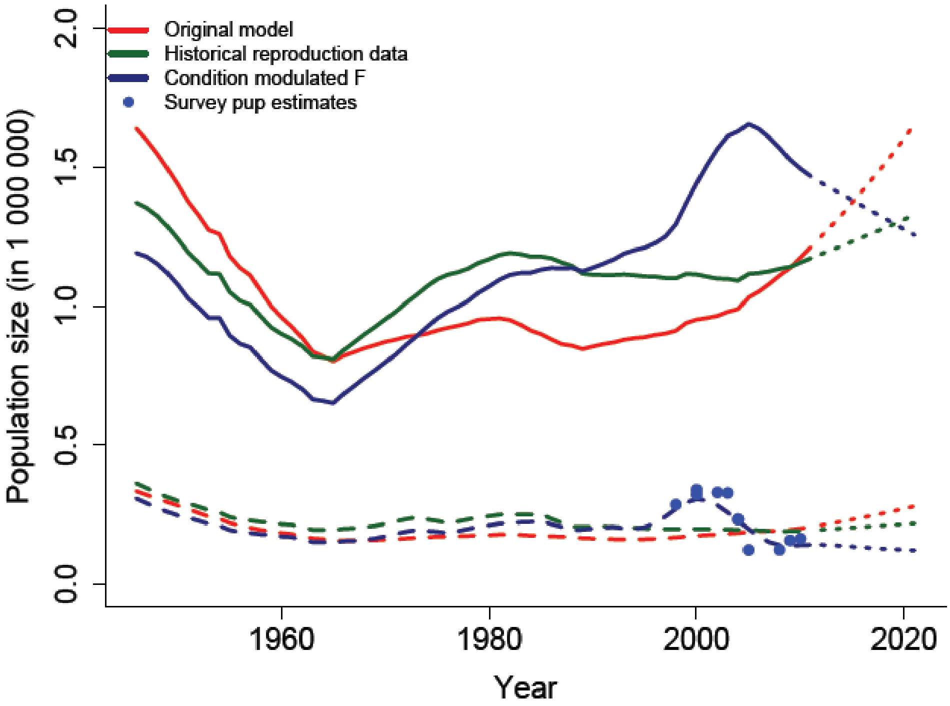


Fig. 1 Distribution of northeast Atlantic harp seals (based on Frie and Svetochev, 2007; abundance estimates updated based on ICES, 2011). Peak breeding time in the Barents Sea-White Sea stock is in late February-early March, while peak breeding time in the Greenland Sea stock is in late March-early April. Peak moulting is about a month after breeding.

- **Why this is a key subparameter:** Harp seal stocks across the North Atlantic have historically shown significant fluctuations in abundance. Most notably, the northwest Atlantic harp seal population increased from ~2 million in the early 1980s to ~9 million in 2010. In contrast, the BSWS harp seal stock has shown a dramatic reduction in pup production since 2003, in spite of very low hunting pressures in the preceding decades. The estimated effect of reduced pup production on the overall abundance of BSWS harp seals depends on the underlying mechanism for the decline (e.g. low pregnancy rates versus use of alternative breeding areas), which is currently uncertain. The observed declines in pup production within the traditional White Sea breeding patches, however, clearly suggest that the stock is experiencing major ecological changes. Variations in ocean temperatures and ice conditions are among the ultimate factors, which may have affected pup production capacity through effects on the distribution and availability of prey as well as suitable breeding and moulting habitat.
- **Monitoring:** Estimates of harp seal abundance are based on estimation of pup production by aerial surveys These estimates are then converted to total stock sizes using a population dynamic model also incorporating information on catches and female reproductive rates. Systematic pup production surveys for the Barents Sea-White Sea population have been conducted by PINRO in the White Sea breeding patches since 1998 and estimates have varied between 340.000 pups and 120.000 pups (Fig.2). Data on female reproductive rates have been collected intermittently by Norwegian and Russian scientists since the early 1960s (see subparameter text on female reproductive rates).
- **Current status of the subparameter:** Pup production estimates for BSWS harp seals from 2005 and onwards are about 50% lower than estimates from the period 1998-2003 (Fig 2). The best fit to the observed trend in pup production is obtained by scaling pregnancy rates to post breeding body condition of BSWS harp seals (blue dashed line in Fig.2). This model is, however, considered experimental and the current management model is based on available historical reproductive data (green lines, Fig.2).



-

Fig. 2 Modelled population trajectories for pups (dashed lines) and 1+ population (full lines) for various choices of reproduction data. ("Original model": Model based on reproductive data from 2006; "Historical reproductive data": Model based on time-varying maturity curves over the periods 1946-1973, 1976-1985, 1988-1993, 2006-2009 and pregnancy rates observed during the periods 1990-93 and 2006; "Condition modulated pregnancy rate": Model based on time-varying maturity curves and fitted annual pregnancy rates in the range of 30-95% (ICES 2011)

- **Quality objectives:** Barents Sea-White Sea harp seals are jointly managed by Norway and Russia based on advice from the Joint ICES-NAFO working group on harp and hooded seals (WGHARP). Both countries have adopted a management regime aiming at keeping the stock above 70% of the maximum level observed since the start of the pup production surveys in 1998. Based on the current model choice (green lines, Fig. 2) this maximum level is identical to the present abundance estimate of 1.4 million animals.
- **Reference level:** Due to the uncertainty regarding the most appropriate abundance model for BSWS harp seals, it is presently advisable to focus on pup production estimates alone for definition of a reference level for this subparameter. The most intuitive choice of reference level is the average pup production during the period 1998-2003.
- **Gaps in data coverage:** The data series on female reproductive rates over the last 10 years is too scarce to give firm guidance on the likely role of reduced pregnancy rates on the observed change in pup production.
- To improve the basis for choosing the most appropriate abundance model, future Norwegian-Russian monitoring of BSWS harp seals should prioritize synoptic collection of data on pup production, female reproductive rates and body condition. In addition, the area of reconnaissance flights should be extended to identify possible alternative breeding areas. A planned Norwegian-Russian satellite tagging project will provide additional information on possible changes in harp seal distribution patterns compared to data from the mid 1990s and in relation to changes in ice conditions and other oceanographic features.
- **Other issues about the subparameter:** No other issues.

References

Frie, A.K., Svetochev, V.: Building time series of female reproductive parameters for northeast Atlantic harp (*Pagohilus groenlandicus*) and hooded seals (*Cystophora cristata*) *In* Long term bilateral Russian-Norwegian scientific co-operation as a basis for sustainable management of living marine resources in the Barents Sea Proceedings of the 12th Russian-Norwegian Symposium Tromsø 21-22 september 2011. IMR-PINRO Joint report series Vol.5.

ICES, 2011. Report of the Joint ICES/NAFO Working Group on Harp and Hooded Seals: Technical report, St. Andrew's, Scotland, UK. ICES CM 2011, ACOM: 20: 73pp.

Subparameter 2 - Distribution of harp seals in connection with reproduction

- **Short facts about the subparameter:** Harp seals are generally distributed along the ice edge in the northern Barents Sea during summer and move southward during late autumn and winter, where they feed on pelagic fish prior to entering the White Sea for breeding in early spring. No major breeding patches have been discovered outside the White Sea, but small groups of breeding harp seals have historically been observed along the ice edge in the Barents Sea and in the Cheshkaya Bay to the east of Cape Kanin .

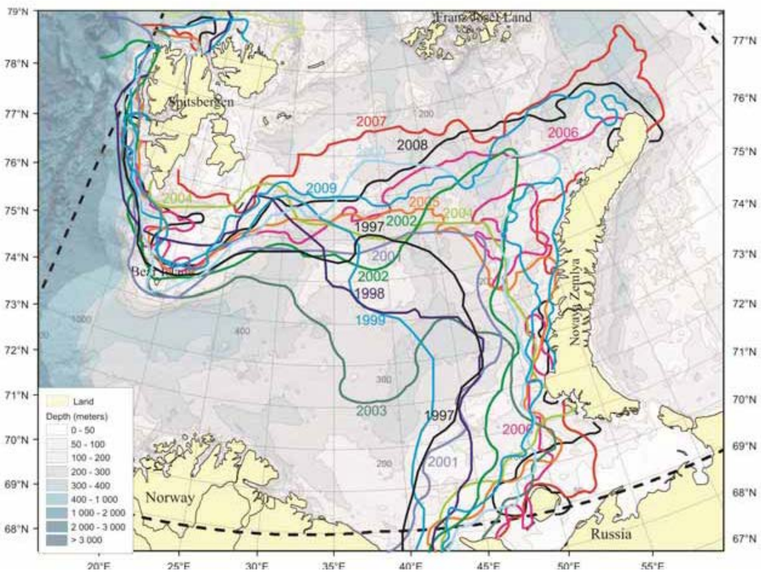
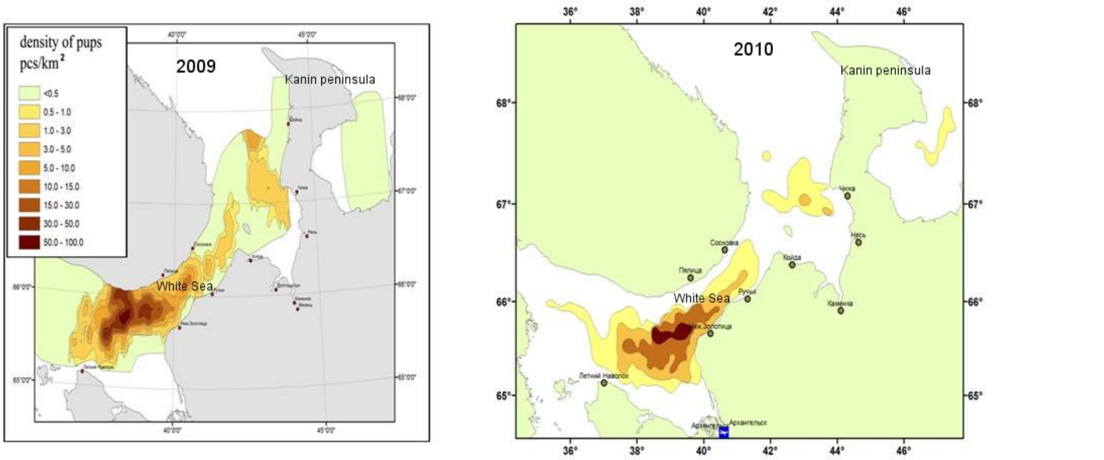


Fig. 3. Observed changes in winter ice cover in the Barents Sea. The colored lines show ice edge (40 % concentration) in late winter, 1997-2009 (from Ingvaldsen et al., 2011).

- **Why this is a key subparameter:** Within the past decade, the ice extension in the Barents Sea has changed substantially (Fig.3). This has likely affected the distribution pattern of several harp seal prey species and may also have affected the energetic costs of the traditional harp seal migration pattern. The sudden and persistent drop in pup production within the traditional breeding patches in the White Sea is consistent with a hypothetical change in breeding location for a part of the stock. The ecological implications of this hypothesis are radically different from alternative hypotheses based on a decline in pregnancy rate.
- **Monitoring:** There is currently no regular monitoring of possible alternative breeding patches of BSWS harp seals outside the White Sea. Potential search areas include the northern Barents Sea and areas to the south of Novaya Zemlya.
- **Current status of the subparameter:** For the 2009 pup production survey in the White Sea, PINRO conducted extended reconnaissance flights in the Cheshskaya Bay to the east of Cape Kanin (See Fig.4), but only very low numbers of pups were observed here.



-

- **Fig. 4.** Density of pups in areas surveyed by PINRO in 2009 and 2010 (Zabavnikov, V., unpublished presentation)

- **Quality objectives:** Not set
- **Reference level:** The reference level for this subparameter should be the case of no significant pupping of BSWS harp seals outside the White Sea.
- **Gaps in data coverage:**
- **Other issues about the subparameter:** No other issues
- **References:**

Ingvaldsen, R., Loeng, H. and Lind, S.2011. Barents Sea climate variability during the last decade. *In* Climate change and effects on the Barents Sea marine living resources Proceedings of the 15th Russian-Norwegian Symposium Longyearbyen 7-8 September 2011. IMR-PINRO Joint report series Vol.2.

Subparameter 3 - Reproductive rates of female harp seals

- **Short facts about the subparameter:** See subparameter on harp seal abundance
- **Why this is a key subparameter:** Long-term studies have shown considerable variability in reproductive rates of female harp seals. This is generally thought to reflect variability in per capita resource levels, but may also in some cases reflect variability in energy expenditure caused by changes in the physical environment (e.g. changes in sea temperature and availability of ice as a resting platform). Seals have a one-year reproductive cycle and female reproductive status therefore integrates the animal energy balance over several critical stages of the annual cycle.
- **Monitoring:** Since the early 1960s, female reproductive tracts (ovaries and lately also uteri) and teeth for age determination have been collected intermittently by Norwegian and Russian scientists. Most of the material is collected in the postbreeding period, when ovulations of the new cycle are generally visible as a *Corpus luteum.* Corpora resulting from pregnancy are generally visible for several years and in the first few weeks after birth, a corpus from pregnancy in the most recent breeding cycle can generally be distinguished from older corpora. This allows estimation of an approximate pregnancy rate, which has been done for recent samples. Retrospective analyses of archived ovaries dating back to the early 1960s are ongoing.
- **Current status of the subparameter:** Mean age at sexual maturity (MAM) for female BSWS harp seals has ranged from 5.5 years in the 1960s to 8.1 years in the period 1988-93 (See Fig. 5), which is the highest MAM recorded for harp seals. The peak in MAM is believed to reflect winter food shortage due to simultaneous low levels of capelin, herring and polar cod

in the southern Barents Sea. In 2006, MAM was estimated at 7.5 years, suggesting that living conditions for BSWS harp seals are still suboptimal compared to the 1960s and 70s.

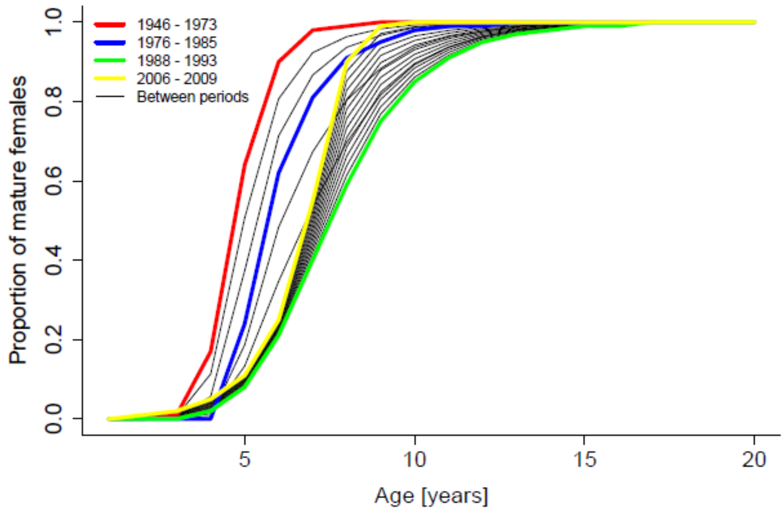


Fig.5 Maturity curves for Barents Sea harp seals. Coloured curves are based on empirical data, although time intervals indicated for the red and the yellow line are erroneous. The true intervals are 1963-1972 for the first interval (red line) and 2006 for the last interval (yellow line). Black curves show gradual extrapolations between curves used in the present population model (from Øigård et al. 2011a).

- **Quality objectives:** Not set
- **Reference level:** Across the North Atlantic, the lowest well documented values of MAM for harp seals are around 5-5.5 years. This likely reflects populations that are not experiencing resource limitations to growth and could serve as a reference level for this subparameter.
- **Gaps in data coverage:** The Joint ICES-NAFO working group on harp and hooded seals requires that data on reproductive rates be updated at least every five years for a stock to be considered data rich and suitable for determination of regular catch quotas. The sudden drop in pup production for the BSWS harp seal stock, however, highlights the need for better data on short term variability in reproductive rates. It is particularly desirable to obtain synoptic data on female reproductive rates and pup production.
- **Other issues about the subparameter:** Traditionally, analyses of reproductive data for northeast Atlantic harp seals have focused on maturity curves and MAM, but parameters like mean age at first birth, pregnancy rates and ovulation rates can be derived from the same material and have recently received more attention. Ovulation and pregnancy based reproductive parameters reflect different stages of the reproductive cycle and show different sensitivities to changes in energy reserves. It is recommended that a broader suite of reproductive parameters are included in the present subparameter as analyses become available.

References

Oigard, T.A., Haug, T., Frie, A.K., and Nilssen, K.T.2011a. The 2011 abundance of harp seals (*Pagophilus groenlandicus*) in the Barents Sea/White Sea. Unpublished working paper presented at the meeting of the ICES/NAFO Joint Working group on harp and hooded seals 15-19 August 20111, St. Andrews, Scotland, UK.

Subparameter 4 - Diet shifts in harp seals

- **Short facts about the subparameter:** During the most intensive feeding period from July to September, BSWS harp seals feed mainly on krill and amphipods in the Northern Barents Sea. In late autumn and winter they move southwards and shift to a diet mainly comprised by small pelagic fish like capelin (*Mallotus villosus*), herring (*Clupea harengus*) and polar cod (*Boreogadus saida*). Harp seals feed little during breeding (late February –Early March) and moulting (early April-May), but parturient females undertake a short feeding migration between breeding and moulting. Comparisons of late spring diet data between years of low and high capelin abundance support a shift in diet as a response to changes in capelin availability.
- **Why this is a key subparameter:** Harp seals feed opportunistically to optimize energy acquisition rates. Due to their high abundance and wide distribution in the Barents Sea, non-seasonal diet shifts may both reflect and cause changes in the trophic structure of the ecosystem. Functional responses of predators are affected by numerous factors and the outcome is not necessarily predictable based on available stock assessments of commercial species. Analyses of diet variability between years with different ice extensions and water mass characteristics are particularly useful for understanding population responses to climate perturbations.

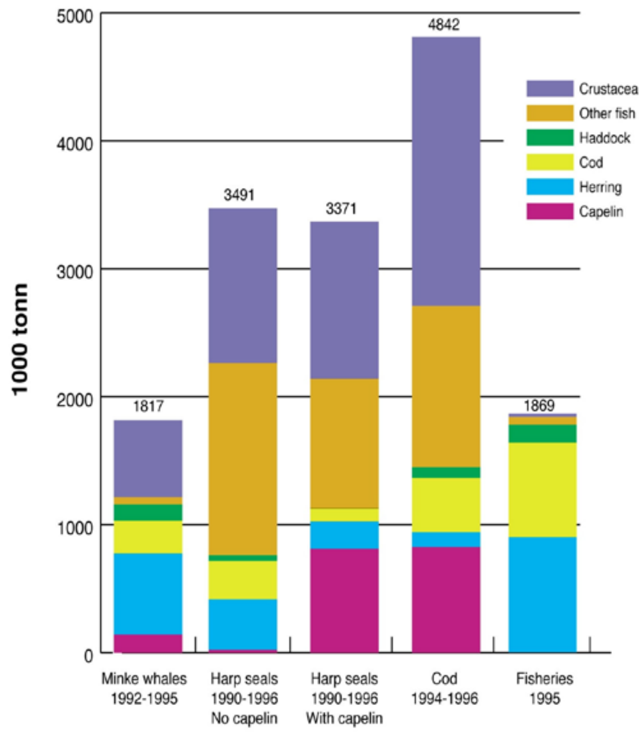


Fig.6 Annual "removals" of various prey species by major consumers in the Barents Sea including harp seals and minke whales (Tore Haug, unpublished presentation).

- **Monitoring:** Stomachs and intestines from BSWS harp seals have been sampled intermittently from 1987 to 2011, mainly by the IMR. The commercial hunt unfortunately occurs during a period of low feeding intensity and dedicated cruises are therefore required to obtain stomach and intestines from the active feeding periods. In contrast, analyses of fatty acid profiles and stable isotopes integrate diet information over weeks to months and are therefore applicable to samples from the commercial hunt. Fatty acid profiles of Barents Sea harp seals are available from blubber samples collected in the Northern Barents Sea October 1995. More samples were, however, collected in 2006 and 2011 and have been analysed using both fatty acid and stable isotope techniques.

- **Current status of the subparameter:** Available diet studies have established that harp seals are among the major consumers of crustaceans and fish in the Barents Sea food web (Fig.6). They also show that harp seals are generalist and opportunistic predators, which may change diet in response to ecosystem changes.
- **Quality objectives:** Not set
- **Reference level:** Reference levels for this parameter could be data for periods, when capelin are abundant in the Barents Sea ecosystem.
- **Gaps in data coverage:** Traditional diet data (stomach and intestinal contents) are scarce and more regular monitoring is probably only realistic based on samples from the commercial hunt.
- **Other issues about the subparameter:** Diet data based on analyses of faty acids and stable isotopes are less quantitative and species specific than stomach based data. They are nevertheless useful for evaluation of diet change.

Subparameter 5 - Length at age and body condition parameters of harp seals

- **Short facts about the subparameter:** Body size and energy reserves are important determinants of population dynamics in capital breeders like harp seals. Body length is the most commonly used measure of body size in seals, because it is less a subject to seasonal variation in blubber thickness than for example total body weight. For animals above a certain critical size, however, reproductive effort is determined by their overall body reserves. Variability in body condition indices during standardized sampling periods are therefore also a useful parameter of harp seal fitness.
- **Why this is a key subparameter:** Historically, length at age has been correlated with age at maturity in the BSWS stock supporting the hypothesis of reduced energy stores as an explanation for population level changes in reproductive rates. Body condition shows marked seasonal dynamics in harp seals, but recent analyses suggest a significant year effect on postbreding body condition indices which may be linked to changes in reproductive rates. Scaling pregnancy rates to postbreeding body condition significantly improves the population model fit to observed pup production estimates.
- **Monitoring:** Data on standard length and body condition for both male and female harp seals have been sampled intermittently by Norwegian scientists during commercial sealing operations in the southeastern Barents Sea (postbreeding-early moulting). The earliest data on standard body length were collected in the period 1963-72 and the latest in 2011. Body condition data (dorsal blubber thickness and axillary girth) have been collected from 1991-2011 and used for calculation of Ryg's body condition index (Ryg et al.1990; also requires information on standard body length).
- **Current status of the subparameter:** Both males and females have shown significant declines in length-at-age from 1963-72 to 1990-93 (Fig.7). More recent data have not yet been published. Analyses of Ryg's body condition index suggest at decline in post breeding body condition in samples from 1992, 2006 and 2011 compared to previous samples (Fig.8). Statistical modeling shows that although part of this difference is due to delayed sampling, a significant year effect is retained for both of the two most recent samples.

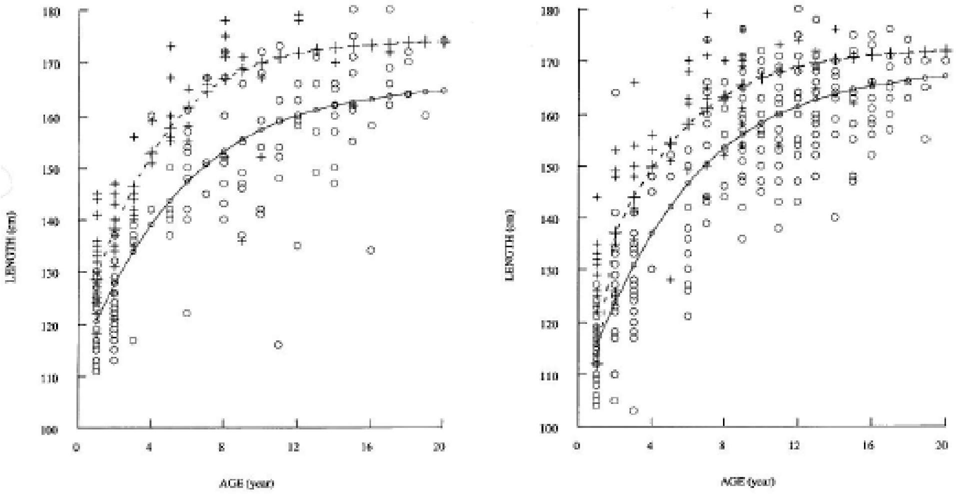


Fig. 7 Length at age for Barents Sea harp seals during the period 1963-72 (left panel) and 1990-93 (right side). Data points for for males are shown as plusses, while data points for females are shown as open circles. (From Kjellqwist et al. 1995)

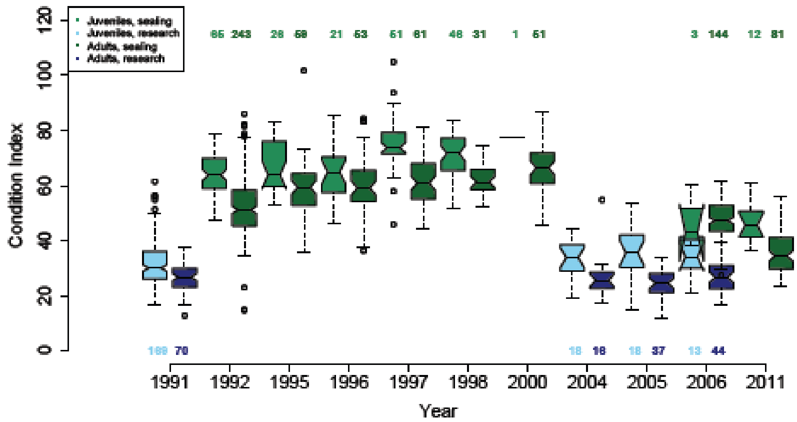


Fig.8. Box plots of the condition index of juvenile and adult harp seals in the years 1991-2011. Green boxes represent data sampled during commercial sealing operations in the Southeastern Barents Sea during the postbreeding period. Blue boxes represent data from Norwegian scientific sealing operations in the Northern Barents Sea in May-July. It should be noted that the 1992, 2006 and 2011 samples were collected rather late in and that this likely has contributed to the low values (From Øigård et al., 2011b).

- **Quality objectives:** Not set
- **Reference level:** The earliest length-at-age sample (1963-72) should be used as a reference level for length-at-age, because these data reflect growth at a time, when the population does not appear to have been resource limited (see subparameter on female reproductive rates).The period of high condition indices from 1998-2001 are recommended as reference level for body condition, because these samples reflect a period of high pup production estimates (see subparameter on pup production).
- **Gaps in data coverage:**
- **Other issues about the subparameter:** No other issues

References:

Kjellqwist, S. A., Haug, T., and Øritsland, T. 1995. Trends in age composition,growth and reproductive parameters of Barents Sea harp seals, *Phoca groenlandica*. ICES Journal of

Marine Science,52: 197–208.

Oigard, T.A., Lindstrøm, U., Haug, T. and Nilssen K.T. 2011b. Variations in body condition of Barents Sea harp seals during April-May 1992-2011.Unpublished working paper presented at the meeting of the ICES/NAFO Joint Working group on harp and hooded seals 15-19 august 2011, St. Andrews, Scotland, UK.

Ryg, M., Lydersen, C., Markussen, N. H., Smith, T. G., and Øritsland, N. A. 1990. Estimating the blubber content of phocid seals. Can. J. Fish. Aquat. Sci. 47: 1223-1227.

Contact person/responsible person: Anne Kristine Frie, Institute of Marine Research, Vlad Svetochev, PINRO

Title: Dynamics of ice-associated marine mammals (E,I)

Parameter: Walrus population in the Barents Sea

About the parameter

- ***Type of parameter: E,I***
- ***Priority of parameter: e***
- ***Rationale :*** Walruses (*Odobenus rosmarus*) have been identified as key monitoring species in CAFF's Circumpolar Biodiversity Monitoring plan because the species is distributed throughout most of the circumpolar Arctic and is heavily reliant on sea ice. Their sea ice habitat has experienced precipitous declines in recent decades and is expected to continue to decline in the future. Walruses are dependent on sea ice during many months of the year, including the times during which breeding and birthing take place. Their use of summer land-based sites, combined with ice platforms for resting at other times of year, undoubtedly extends their range and permits a higher environmental carrying capacity ("K"). Walruses are benthic feeders, so declining ice conditions may threaten the productivity of their principal food resources and make them sensitive to industrial disruption of benthic environments (e.g. oil development sites, mining etc.) Walruses were driven to near extinction in Svalbard, but have been protected from harvest for many decades. Recovery is expected within the frames of the carry capacity of the environment. Walruses in Svalbard are a principle "target" for the tourist industry and hence remote monitoring of site use and response to tourist visitation have been undertaken to assess potential impacts using remote cameras.

Overview of the subparameters

Subparameters (name)	*Institution responsible for monitoring*	*Time series period*	*Gaps in monitoring*	*Priority ("e", "r" or "s")*
Population size	*NPI*	*2006 -*	*Planned 5 year intervals (some variance expected due to weather and ice conditions in individual seasons.*	e
Remote camera monitoring of tourist visitation	*NPI*	*2007*		s

Subparameter 1 – Population size

- **Short facts about the subparameter:** Walruses (*Odobenus rosmarus*) have a circumpolar distribution. They are mainly benthic feeders, but some individuals also prey on seals. Polar bears and killer whales can prey on walruses, often targeting calves. Walruses in the Barents Sea are protected, but some hunting is known to occur along the Russian coast in some areas.

- **Why this is a key subparameter:** Abundance is the most essential "metric" for mammalian populations and should thus be included.
- **Monitoring:** Walrus abundance is estimated from aerial surveys of haul-out sites. A correction factor is used to adjust for animals that are in the water when the survey is flown.
- **Current status of the subparameter:** The first survey was done in Svalbard in 2006 and is planned to be repeated with a 5 year cycle. For practical reasons, a survey could not be done as planned in 2011 and will instead be conducted in 2012. The Pechora Sea was surveyed for the first time in 2012.
- **Quality objectives:** Not set.
- **Reference level:** An ideal reference level (which is obviously not available) would be population size before intensive hunting started in the 17th century. But, the reference point from the 2006 survey is suitable to track modern trends in the Svalbard part of the Barents Sea population.
- **Gaps in data coverage:** Data are lacking from Russian parts of the Barents Sea.
- **Other issues about the subparameter:** No other issues.

Subparameter 2 - Remote camera monitoring of tourist visitation

- **Short facts about the subparameter:** See above.
- **Why this is a key subparameter:** Marine-based tourism has increased rapidly in recent decades in Svalbard (and other Polar locations) and there is a potential for disturbance at walrus resting sites.
- **Monitoring:** Cameras have been deployed at three sites for several years, and recently two additional sites have been added to monitor sensitive sites where mothers and calves reside.
- **Current status of the subparameter:** Cameras are deployed annually during the summer season. Some data gaps have occurred due to technical problems with this system, and more data is required before conclusions can be drawn. But, the system looks very promising for monitoring impacts of visitation. Additionally, this system has provided good site use data and given insight into predation pressure from bears and other potential walrus population stressors.
- **Quality objectives:** Not set.
- **Reference level:** Reference level should be no significant disturbance levels from visitors.
- **Gaps in data coverage:** As said above, some gaps exist.
- **Other issues about the subparameter:** No other issues.

Contact person/responsible person: Christian Lydersen, NPI

Title: Dynamics of non ice associated marine mammals (E,I)

About the indicator

- ***Type of indicator: E,I***
- ***Priority of indicator: e***
- ***Rationale :*** Non ice associated marine mammals in the Barents Sea inhabit highly productive areas subject to intensive human activity (fishing, aquaculture, oil and gas exploration). In addition, some species are actively hunted or subjected to bycatching. Non ice associated marine mammals are also likely to be affected by global warming through effects on prey availability and community structure. At high abundances marine mammals may in turn affect ecosystem processes and human commercial interests on local and regional scales. Monitoring the dynamics of non ice associated marine mammals in the Barents Sea area is essential for understanding overall ecosystem dynamics and as a basis for assessing and mitigating impacts of human activities on the marine fauna.

Overview of Parameters

Title	***Type (“E”, “A”, or “I”)***	***Priority (“e”, “r” or “s”)***
Abundance and spatial distribution	*E,I*	e

Contact/responsible person: Anne Kirstine Frie, IMR

Title: Dynamics of non ice associated marine mammals (E,I)

Parameter: Abundance and spatial distribution of marine mammals

About the parameter

- ***Type of parameter: E,I***
- ***Priority of parameter: e***
- ***Rationale :*** Change in abundance is the ultimate metric for population level responses. In long-lived animals, changes in abundance are, however, typically slow and changes in spatial distribution may serve as an early warning of significant ecological changes.

Overview of the subparameters

Subparameters (name)	*Institution responsible for monitoring*	*Time series period*	*Gaps in monitoring*	*Priority ("e", "r" or "s")*
Distribution of balaenopterids (minke, fin and humpback whales) and white beaked dolphin	*IMR/PINRO*	*2003-present*		e
Abundance of minke whales	*IMR*	*CPUE:1938-83 Sighting surveys: 1988/89-present*		e
By-catches of common porpoises	*IMR*			s

Subparameter 1 - Distribution of balaenopterids (minke, fin and humpback whales) and white-beaked dolphins

- **Short facts about the parameter:** Minke whales (*Balaenoptera acutorostrata)* are among the most important consumers in the Barents Sea and prey predominantly on larger zooplankton and small pelagic fish. Together with the larger balaenopterids, humpback whales (*Megaptera novaeangliae)* and fin whales (*B. physalus),* they are widely distributed in the Barents Sea. White-beaked dolphins (*Lagenorrhyncus albirostris*) are the most numerous toothed whales in the Barents Sea and are predominantly distributed in the central and southern Barents Sea.
- **Why this is a key sub parameter:** Balaenopterid whales and particularly minke whales are key predators in the Barents Sea system, and historic shifts in distributions have coincided with significant changes in prey base and prey distributions. White-beaked dolphins are piscivorous top-predators and a recent shift away from the southwestern part of the system

likely reflects the reduced abundance of blue whiting. The spatial distributions of these species thus appear useful as indicators of top predator responses to fluctuations in prey stocks and fisheries management. In addition, information on the spatial dynamics of pelagic cetaceans is important for evaluating potential interactions with human activities such as shipping, fishing and petroleum activity (e.g. seismic investigations).

- **Monitoring:** Annually, by marine mammal observers on board the vessels during the joint Russian Norwegian Ecosystem Survey - since 2003 by IMR and PINRO, but no joint analyses.
- **Current status of the parameter:** The same parameter is developed for the western Barents Sea in the Norwegian monitoring programme. The figure below (Fig. 1) demonstrates the mean, pooled distribution of minke, fin and humpback whales in the years 2003-2007 and the observations from the 2010 survey.

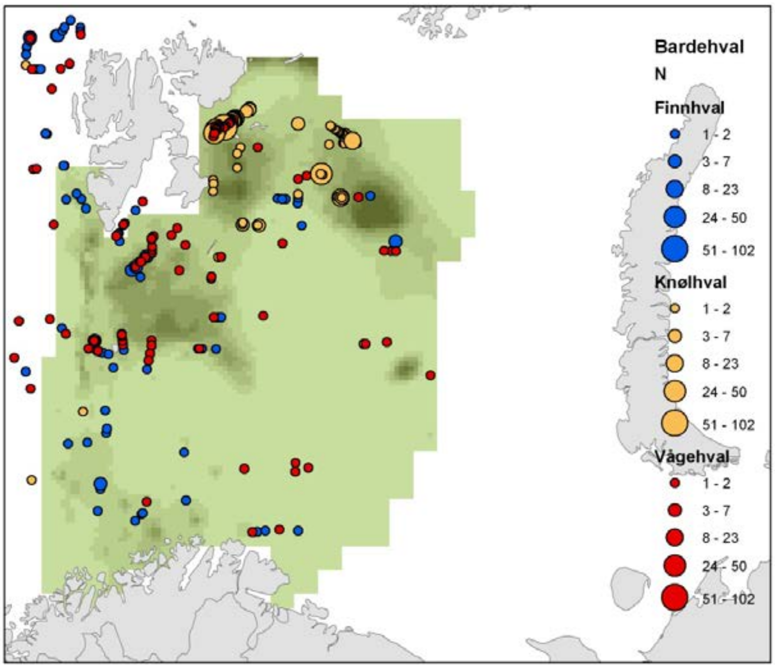


Figure 1. Balaenopterid distributions as observed in the western Barents Sea during the ecosystem survey. Green shades: Averaged densities of baleen whales (fin, minke and humpback whales) in the years 2003-2007. Dots: observations of fin (blue), humpback (yellow) and minke (red) whales during the 2010 ecosystem survey. Russian observations are not included in the figure.

- **Quality objectives***:* No quality objectives are given for this indicator
- **Reference level:** For the national Norwegian Barents Sea monitoring programme it has been agreed to use the first 10 years of monitoring to identify a base level against which the following years data sets may be compared.
- **Gaps in data coverage***:* Differences in observation effort on Russian and Norwegian vessels are an obstacle to the development of an integrated Norwegian-Russian indicator on marine mammal distributions for the entire Barents Sea area. Methods can be developed to take this into account, and development of common monitoring approach will be discussed at a joint meeting in March 2012.

Contact persons/responsible person: Mette Mauritzen, IMR, Vladimir Zabavnikov, PINRO, Anne Kirstine Frie, IMR

Subparameter 2 – Abundance of minke whales (Balaenoptera acutorostrata acutorostrata)

- **Short facts about the parameter:** Like most other baleen whales, North Atlantic minke whales (*Balaenoptera acutorostrata acutorostrata*) undertake seasonal migrations between assumed calving and wintering areas at lower latitudes and feeding areas at high latitudes, of which the Barents Sea constitutes an important summering area in the northeast Atlantic. The minke whale is the most abundant cetacean species in the Barents Sea area and is currently the only cetacean species commercially harvested in the area. The harvest is regulated according to the so-called *Revised Management Procedure* (RMP) developed by the Scientific committee of the International Whaling Commission.
- **Why this is a key parameter:** Minke whales are significant consumers in the Barents Sea and fluctuations in their abundance/presence in the Barents Sea may affect ecosystem processes and human commercial interests.
- **Monitoring:** The Norwegian procedure for monitoring of minke whale abundance is approved by the International Whaling Commission and all results go through a strict international review process. Catch statistics over the period 1938-1983 have been analyzed to give a catch per unit effort (CPUE) index of abundance. The index shows large shifts from year-to year but also long-term trends. A whale survey programme was started in 1988/89, based on visual observation on line transects. Synoptic surveys of the northeast Atlantic were conducted in 1988/89 and 1995. From 1996 onwards a six-year mosaic survey cycle was established to give a full coverage of the northeast Atlantic during the period and estimate the abundance of minke whales for the total survey area every six years. Russia does not conduct quantitative abundance monitoring of minke whales.
- **Current status of the parameter:** Abundance estimates are available for the following years/survey periods: 1988-89, 1995, 1996-2001 and 2002-2007. At new survey period will be completed by 2013. The point estimates with 95% confidence bounds for the northeastern Medium Area minke whale population show relatively stable abundances although with a peak in 1995 (Fig. 1).Surveys of minke whale abundance are a prerequisite for hunting under the RMP and will therefore likely continue.

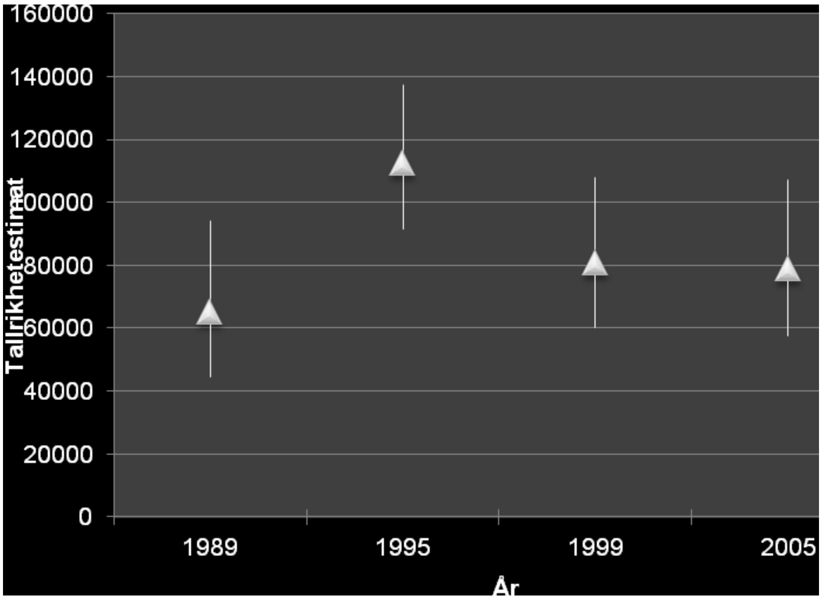


Fig. 2. Survey based abundance estimates of minke whales in the Barents Sea area (Nils Øien, unpublished).

- **Quality objectives and reference level:**
  The RMP aims at a long-term population target level defined for a simulation after 100 years. The target level in the Norwegian application is 60% of the original stock level as defined by the RMP internal population model.
- **Gaps in data coverage:**

Contact persons: Nils Øien and Anne Kirstine Frie, IMR

Subparameter 3 – Bycatch of harbour porpoises (Phocoena phocoena)

- **Short facts about the parameter:** The harbour porpoise (*Phocoena phocoena*) is a small toothed whale, which is mainly distributed in coastal waters. Studies from the North Sea show a diet comprising mackerel (*Scomber scombrus*), herring (*Clupea harengus*) and sand lance (*Ammodytes tobianus*) as well as codfish. Harbour porpoises often feed in areas exposed to human fishing activity and high bycatch rates have been documented in several areas of the North Sea. Preliminary results from a Norwegian bycatch monitoring programme initiated by the IMR in 2006 also suggest high bycatch rates in some areas outside the North Sea such as the Vestfjord area in Northern Norway.
- **Why this is a key parameter:** Bycatch mortality is a direct human impact factor, which may have large population level effects on harbour porpoises and possibly also on the surrounding ecosystem due to changes in predation pressure and patterns.
- **Monitoring:** The IMR has established a coastal reference fleet in order to monitor byactch rates of various species of fish, birds and mammals in gill net fisheries. A pilot study showed particularly high byctch rates of marine mammals in gillnet fisheries for lumpsucker (*Lumpus cyclopterus*) , angler fish (*Lophius piscatorius*) and bottom set gillnets for gadoids. Later monitoring has focused on fisheries with bottom set gill nets for angler fish and gadoids. Fig. 3 shows annual catches of harbour porpoises by the Norwegian coastal reference fleet for 2006-2009.

Harbour porpoises

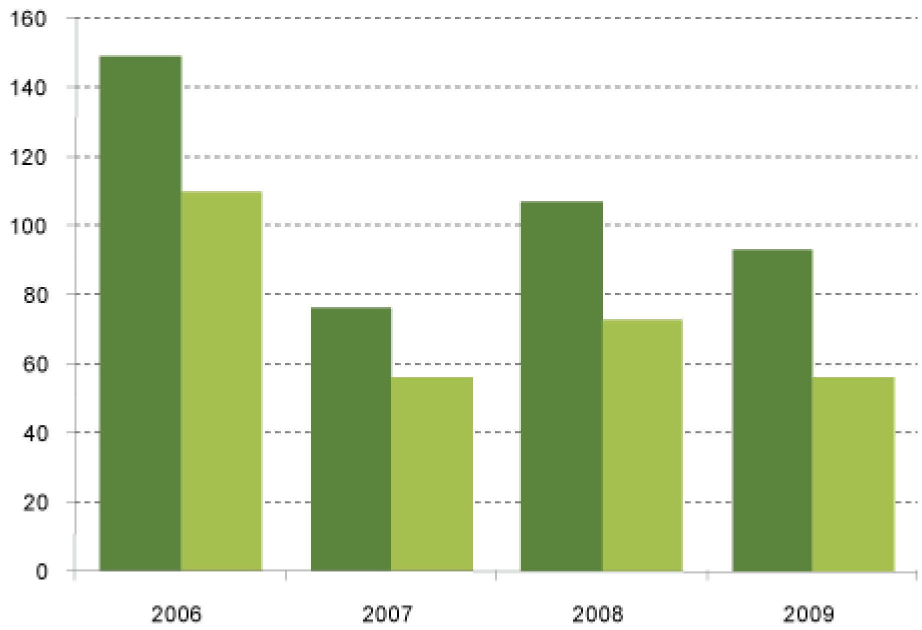


Fig. 3 Bycatches of harbour porpoises by the Norwegian coastal reference fleet 2006-2009. Dark green columns indicate total byctach rates and light green columns indicate byctaches in the Barents Sea area. (Source: www.miljøstatus.no 2011).

Bycatch data from the Norwegian coastal reference fleet are collected on an annual basis, but numbers for 2010 and 2011 are not yet available for reporting.

- **Current status of the parameter:** Available reports from the coastal reference fleet on bycatches of harbour porpoises in Northern Norway suggest a decrease after 2006. No conclusions can, however, be drawn on trends in overall bycatch levels before the numbers from the reference fleet are extrapolated to the entire coastal fleet. This work is in progress at the IMR and preliminary results suggest considerable harbour porpoise bycatch rates in Northern Norway. Unfortunately there are no reliable estimates of the abundance of harbour porpoises in Norwegian waters. This complicates the interpretation of changes in bycatch rates and evaluation of the likely population effects .
- **Quality objectives:** Maintaining bycatch levels below the average level for the period 2006-2008 has been selected as a preliminary quality objective in the Norwegian monitoring programme for the Barents Sea.
- **Reference level:** The mean bycatch rate of the first three years of monitoring has been selected as a reference level.
- **Gaps in data coverage:** Current monitoring does not include gillnet fisheries for lumpsucker, which, according to the pilot study, also has significant bycatch rates for harbour porpoises. Bycatches of harbour porpoises are currently not reported in Russian coastal waters of the Barents Sea.

Contact persons: Arne Bjørge and Anne Kirstine Frie, IMR

Title: Fish and shrimp biomass (E)

About the indicator

- ***Type of indicator: E***
- ***Priority of indicator: e***
- ***Rationale:*** The rationale behind the use of fish and shrimp biomass is to include parameters that are important parts of the Barents Sea ecosystem. The stocks development of key species such as capelin, cod and young herring is tightly connected and important for the dynamics between these stocks as well as for zooplankton, other fish species, sea mammals and sea birds. Most of these stocks are impacted by fisheries directly or indirectly, while state of others (0-group fish and young herring) reflects natural variations.

Overview of Parameters

Parameters (name)	*Type (“E”, “A”, or “I”)*	*Priority (“e”, “r” or “s”)*
Blue whiting	*E*	s
Beaked red fish	*E*	s
BS capelin	*E*	e
NEA cod	*E*	e
NEA haddock	*E*	e
Long rough dab	*E*	r
Polar cod	*E*	r
Greenland halibut	*E*	r
NSS herring	*E*	r
Deep sea shrimp	*E*	r
Biomass of 0-group fish	*E*	e

Contact person/responsible person: Gro I. van der Meeren, IMR, Edda Johannesen, IMR, Andrei Dolgov, PINRO

Title: Fish and shrimp biomass (E)

Parameter: Biomass of 0-group fish

About the parameter

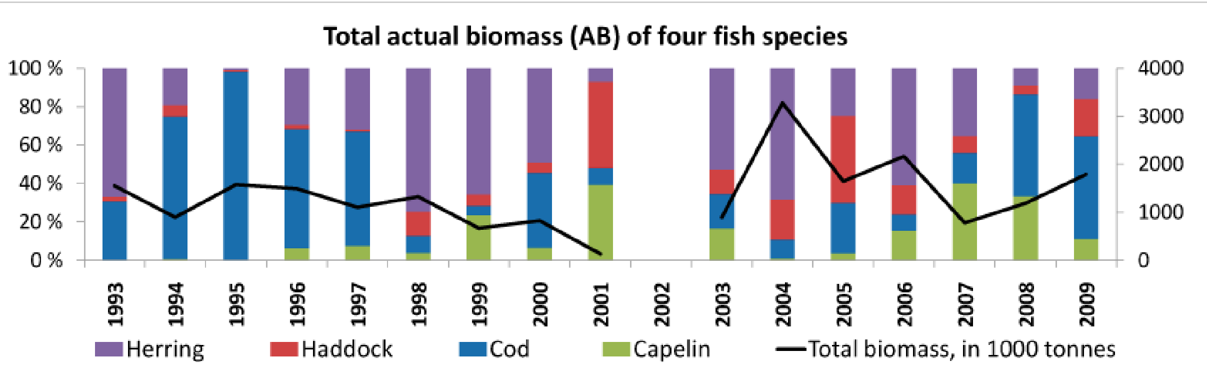
- ***Type of parameter: E***
- ***Priority of parameter: e***
- ***Rationale :*** 0-group fish may play a significant role in the ecosystem, both as predators and as prey. In years with high abundance, the biomass of the most abundant species may add up to more than 1 million tonnes. Given the high consumption per body weight, the prey consumption by 0-group fish can be significant compared to the consumption by pelagic fish.

Overview of the parameter

Parameters (name)	*Institution responsible for monitoring*	*Time series period*	*Gaps in monitoring*	*Priority ("e", "r" or "s")*
Biomass of 0-group fish	*IMR and PINRO*	*1980-*	*None*	e

Parameter 1 - Biomass of 0-group fish

- **Short facts about the parameter:** In years with high recruitment, the biomass of 0-group fish in summer may be as high as ca 3.3 million tonnes, which is comparable to that of pelagic fishes. In the Barents Sea (Figure 2.4.17, Eriksen et al. 2011). Although 0-group fish are widely distributed in the Barents Sea, the central area seems to be the most important, accounting for approximately 70% of the annual biomass, responding to 300-600 thousand tonnes. Thus, 0-group fish can be important to the ecosystem both as predator and prey.



- Recruitment of Barents Sea fish species has significant inter-annual variability (Figure 2.4.17). Factors contributing to this variability include: spawning stock biomass; climate conditions; food availability; and abundance and distribution of predators.

- It should be noted that 0-group fish may play a significant role in the ecosystem, both as predators and as prey. In years with high abundance, the biomass of the most abundant species may add up to more than 3 million tonnes. Given the high consumption per body weight, the prey consumption by 0-group fish can be significant compared to the consumption by pelagic fish and pelagically distributed demersal fish, particularly in the central areas where little adult capelin is found. This suggests that keeping high spawning stocks may have a positive effect on the ecosystem even though the gain in fish recruitment may be limited compared to at intermediate spawning stock sizes.
- **Why this is a key parameter:** 0-group fish may play a significant role in the ecosystem, both as predators and as prey. In years with high abundance, the biomass of the most abundant species may add up to more than 3 million tonnes. Given the high consumption per body weight, the prey consumption by 0-group fish can be significant compared to the consumption by pelagic fish, particularly in the central areas where little capelin is found.
- **Monitoring:** 0-group fish is sampled annually in late summer, by IMR during ecosystem surveys.
- **Current status of the parameter:** Status of 0-group fish is shown in the figures below.

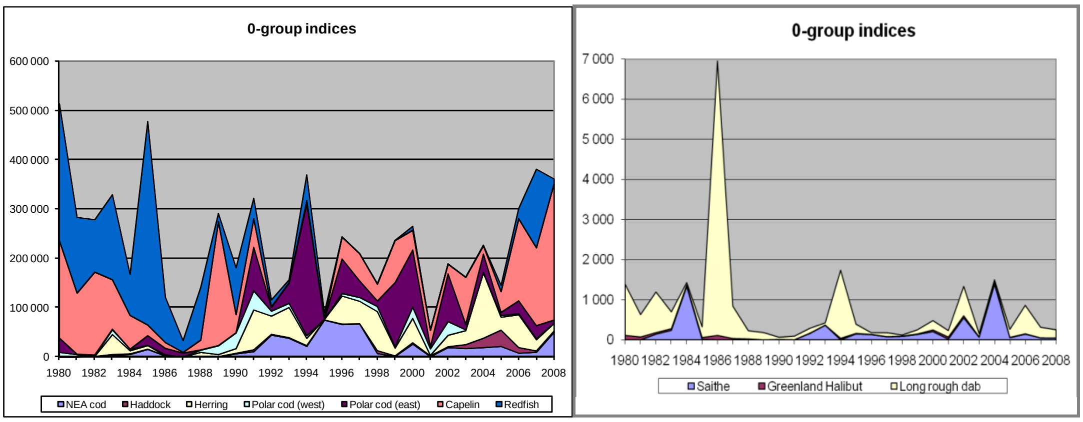


Figure 2.4.17. 0 age-group abundance indices (in millions of individuals) not corrected for catching efficiency. Note that the vertical axes differ between the two panels.

- **Environmental objectives:** Quality objectives have not been set for this parameter. Abundance index show the quantity of year-class, expected recruitments, reflection of environmental conditions and SSB situation.
- **Reference level:** Reference level has not been set. Poor, medium or strong year-class can be compared to long-term mean.
- **Gaps in data coverage:** None.

Contact person/responsible person: Gro I. van der Meeren, IMR

Title: Fish and shrimp biomass (E)

Parameter: NSS herring

About the parameter

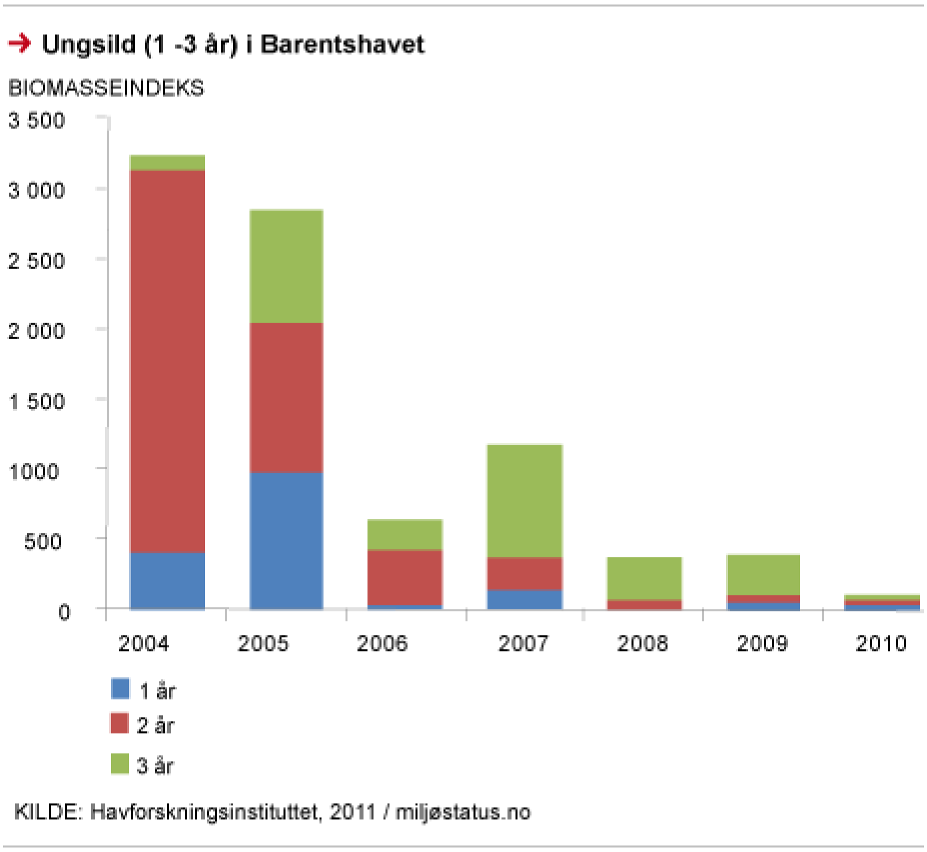
- ***Type of parameter: E***
- ***Priority of parameter: e***
- ***Rationale :*** Juvenile herring in the Barents Sea is an important predator on capelin and may cause the capelin stock to collapse when herring numbers are large. Because capelin is a key species in the Barents Sea ecosystem, herring can have a key role in the overall dynamics.

Overview of the parameter

Parameters (name)	*Institution responsible for monitoring*	*Time series period*	*Gaps in monitoring*	*Priority („e", "r" or "s")*
Biomass of juvenile herring	*IMR/PINRO*	*1973 -*	*None*	e

Parameter 1 – Biomass of juvenile herring

- **Short facts about the parameter:** Norwegian spring spawning herring (*Clupea harengus*) spawns along the Norwegian coast. The larvae drift into the Barents Sea where the first 3-4 years are spent.
- **Why this is a key parameter:** As described above, juvenile herring is important for the overall dynamics of the Barents Sea ecosystem because predation on capelin may cause the capelin stock to collapse.
- **Monitoring:** Biomass of 1-3 year old herring is done in the autumn during the Russian-Norwegian ecosystem cruise. The biomass estimate is based acoustic data. Age determination is done on samples taken by trawl and used to in combination with the acoustic data to estimate biomass of the different age groups.
- **Current status of the parameter:** The last year the Norwegian spring spawning herring produced a strong year class was in 2004. Since then the biomass of juvenile herring in the Barents Sea has declined and is now at a low level. The figure below shows data from 2004 and onwards.



-

- **Environmental objectives:** Managed through SSB, strongly influenced by environmental conditions and recruitments, agreed MP.
- **Reference level:** Bpa, Fpa.
- **Gaps in data coverage:** None.

Contact person/responsible person: Per Arneberg, IMR

Title: Fish and shrimp biomass (E)

Parameter: Shrimp

About the parameter

- ***Type of parameter: E***
- ***Priority of parameter: e***
- ***Rationale:*** Shrimp is an important fishery resource in the Barents Sea and may also be ecologically important as prey for predatory fish. It is important to monitor the size and composition of the stock in order to assess stock dynamics and determine the productive potential for human consumption, as well as predator-prey interactions.

Overview of the parameters

Parameters (name)	***Institution responsible for monitoring***	***Time series period***	***Gaps in monitoring***	***Priority ("e", "r" or "s")***
Total biomass, spawning stock biomass and recruitment	*IMR and PINRO*	*Norwegian trawl survey 1982-2005 Russian trawl survey 1984-2005 Joint Ecosystem survey 2004-*		e

Parameter 1 - Total biomass, spawning stock biomass and recruitment

- **Short facts about the parameter**: Northern shrimp (*Pandalus borealis*) is distributed in most deep waters of the Barents Sea and Spitsbergen. The densest concentrations are found in the central region of the Barents Sea, Hopen Deep, Thor Iversen Bank and near the western Murman coast at depths from 200 to 400 meters. A targeted shrimp fishery in inshore areas began in the mid 1930s. Following some exploratory fishery in 1970-71, the offshore fishery began and soon established itself as one of the most economically important fisheries in the Barents Sea area. Since the beginning of the offshore fishery in 1970, catches increased rapidly to reach some 128 000 tonnes in 1984. Since then the yield has fluctuated, largely due to varying fishing effort. The yield peaked again at 80 000 tonnes in 1990 and in 2000 but has since decreased to about 22 000 tonnes in 2012. These shrimp feed mainly on detritus, but may also scavenge. They are found in the diet of many fish species, including cod, Greenland halibut, and redfish and have also occasionally been found in stomachs of seals.
- **Why this is a key parameter:** It is important to monitor biomass, spawning stock biomass and recruitment of shrimp to understand the productive potential for human consumption, as well as predator-prey interactions.

- **Monitoring:** The available data consists of landings by country, a Norwegian standardized commercial CPUE series, and three surveys: (1) a Norwegian shrimp survey (1982–2004) (2) a Russian survey 1984-2006 and (3) a joint Norwegian-Russian ecosystem survey (2004–onwards). None of the surveys have been inter-calibrated and are treated as a separate survey series.
- **Current status of the parameter:** A targeted shrimp fishery in the Barents Sea area began in the mid 1930s, and then only in fjords and inshore areas. The inshore fishery gradually became more widespread, and following some exploratory fishery in 1970-71, the offshore fishery began and soon established itself as one of the most economically important fisheries in the Barents Sea area. In the Svalbard zone a multinational fishery with participants from Norway, Russia, the EU, the Faroes, Iceland, Greenland and Canada evolved, while only Norway and Russia were operating in the central Barents Sea within their respective EEZs. Since the beginning of the offshore fishery in 1970, catches increased rapidly to reach some 128 000 tonnes in 1984. Since then the yield has fluctuated, largely due to varying fishing effort. The yield peaked again at 80 000 tonnes in 1990 and in 2000 but has since decreased to about 22 000 tonnes in 2012. Since the late 1990s the stock has varied with an overall increasing trend and reached a level in 2010 estimated to be close to the carrying capacity of the Barents Sea. The stock is considered in a good condition and harvested sustainably.
- **Environmental objectives:** Quality objectives not set for this parameter.
- **Reference level:** stock status is measured relative to precautionary reference points Blim (lower limit reference for stock biomass) and Fmsy (the fishing mortality that maximises yield)
- **Gaps in data coverage:** None.

Contact person/responsible person: Carsten Hvingel, IMR

Title: Fish and shrimp biomass (E)

Parameter: Beaked redfish

About the parameter

- ***Type of parameter: E***
- ***Priority of parameter: e***
- ***Rationale :*** Biomass, spawning stock biomass and recruitment of Beaked redfish is important to understand the productive potential for human consumption, as well as predator—prey interactions.

.

Overview of the parameters

Subparameters (name)	*Institution responsible for monitoring*	*Time series period*	*Gaps in monitoring*	*Priority ("e", "r" or "s")*
Biomass index	*IMR and PINRO*	*2004-*	*None*	E

Parameter 1 – Biomass index

- **Short facts about the parameter:** The Barents Sea and Svalbard area is the main area for juvenile beaked redfish (*Sebastes mentella*). The redfish is found close to the bottom in the Barents Sea. The spawning area is along the shelf break from Shetland to Tromsøflaket. Adult redfish is mainly found between 400-600 m depth. Zooplankton is important in the first years of life. As it grows it includes more fish in its diet. When juvenile redfish was more abundant it was an important component of cod diet. Beaked redfish is a slow growing, late maturity, low fecundity fish that bear live young. The life history traits make the beaked redfish vulnerable to overfishing. There was a recruitment failure of redfish between 1996 and 2003.
- **Monitoring:** Annual data on beaked redfish in the Barents Sea are available from three bottom trawl surveys the Joint IMR-PINRO winter survey (index available from 1986), the Russian demersal winter survey (index starting) and the ecosystem survey. Data from the ecosystem survey is available from 2004, bottom trawl index needs to be developed. The data are included in an assessment model used to estimate the population size and demography. The results of this model, including the size of the spawning stock is made available for the International Council (ICES) for stock assessments.
- **Current status of the parameter:** stock assessments are presented in AFWG, index from ecosystem survey need to be developed, the work is underway.
- **Environmental objectives:** No quality objective has been set for the Barents Sea, Fpa and Bpa applicable to stock. ICES recommendation – no bottom fishery, Norway and Russia suggests MP.
- **Reference level:** No reference level is set for the Barents Sea. Fpa and Bpa applicable to stock.
- **Gaps in data coverage:** None.

Contact person/responsible person: Gro I. van der Meeren, IMR

Title: Fish and shrimp biomass (E)

Parameter: Blue whiting

About the parameter

- ***Type of parameter: E***
- ***Priority of parameter: e***
- ***Rationale :*** Biomass of blue whiting in the BS is determined mainly by the size of the juvenile stock in the Norwegian Sea. When abundant, the stock penetrates into to deeper parts of the south-western BS in high numbers. This typically coincides with warm periods. Blue whiting feeds mainly on krill, a key species in the BS food web and is therefore important for predator-prey interactions in the BS when abundant.

Overview of the parameters

Subparameters (name)	*Institution responsible for monitoring*	*Time series period*	*Gaps in monitoring*	*Priority ("e", "r" or "s")*
Total biomass	*IMR and PINRO*	*2004-*	*None*	e

Parameter 1 - Total biomass

- **Short facts about the parameter:** Blue whiting (*Micromesistius poutassou*) is an Atlantic mesopelagic fish, mostly found between 100-600m depths. It is one of the most abundant fish species in mid water layers in the northeast Atlantic. It spawns mainly west of the British Isles. The stock is managed as one, but consists of two main components, the northern having its main feeding area is the Norwegian Sea. When the stock level in the Norwegian Sea is high it enters the western part of the Barents Sea dominated by Atlantic water masses. High recruitment and high stock levels of Blue whiting often coincides with warm periods. Blue is mainly a plankton feeder, with krill as the main prey, but it also feed on small fish. There is fishing on the species but not in the Barents sea.
- **Monitoring:** The stock size in the Barents Sea has annually been measured acoustically at the ecosystem survey in the Barents Sea since 2004.
- **Current status of the parameter:** The abundance of blue whiting in the BS is currently low.

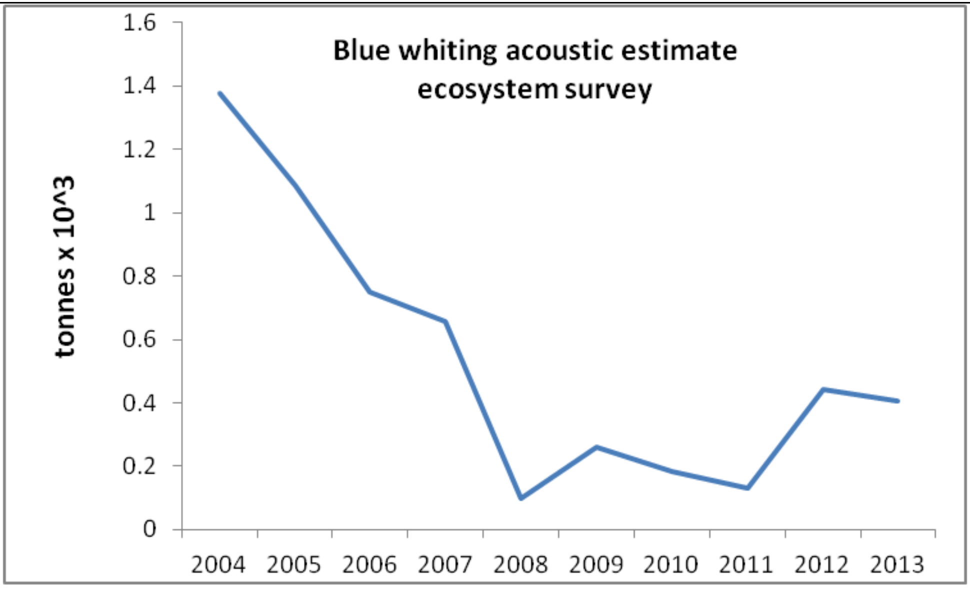


Figure 1. Blue whiting Barents Sea stock size estimates obtained by acoustics, 2004–2012.

- **Environmental objectives:** No quality objective has been set for the Barents Sea, international management plan for the stock agreed by coastal states.
- **Reference level:** No reference level is set for the Barents Sea. Bpa, Fpa
  In 2008 EU, Norway, Iceland and Faeroe Island agreed on a long term management strategy. The target fishing mortality should be 0.18, and reduced if the spawning stock biomass falls below 2.25 million tonnes. ICES has evaluated the management plan and found it to be in line with the precautionary approach.
- **Gaps in data coverage:** None.

Contact person/responsible person: Gro I. van der Meeren, IMR

Title: Fish and shrimp biomass (E)

Parameter: BS capelin

About the parameter

- ***Type of parameter: E***
- ***Priority of parameter: e***
- ***Rationale:*** Capelin often feeds in the northern and eastern parts of the Barents Sea, in the productive area near the marginal ice zone. Spawning takes part near the mainland shore in the southern part of the area. Capelin is therefore important for transporting energy from the marginal ice zone to the southern parts of the Barents Sea.

Overview of the parameters

Parameters (name)	***Institution responsible for monitoring***	***Time series period***	***Gaps in monitoring***	***Priority ("e", "r" or "s")***
Total biomass, maturing biomass and recruitment of BS capelin	*IMR and PINRO*	*1972-*	*none*	e

Parameter 1 - Total biomass, maturing biomass and recruitment of BS capelin

- **Short facts about the parameter:** Capelin (*Mallotus villosus*) eats mainly krill and copepods, and the effect of capelin on zooplankton is so strong that a significant negative relationship can be seen between the amount of zooplankton in the Barents Sea and capelin abundance. Capelin also has profound effects on its predators (Gjøsæter et al., 2009). If alternative prey is not present, a severely reduced capelin stock will have a strong negative impact on top predators in the Barents Sea, as observed in the late 1980s (Gjøsæter et al. 2009). A low capelin stock might for example have negative impacts on a range of seabird and sea mammal species in the area (Hamre 1994, Sakshaug et al. 1994).
- **Why this is a key parameter:** Information on total biomass is relevant for understanding the impact capelin may have on other species in the ecosystem and capelin as basis for the fisheries. Information of maturing biomass and recruitment is relevant for understanding development of the stock.
- **Monitoring:** The spawning stock of capelin is predicted annually from the acoustic survey in September the year before and a model, which estimates maturity, growth and mortality (including predation by cod). The model takes account of uncertainties both in the survey estimate and in other input data.
- **Current status of the parameter:** The stock size is slowly decreasing. An updated figure of total stock biomass, recruitment and landings is presented in the report with the 2012 ICES advice on the stock, which can be found at: http://www.ices.dk/committe/acom/comwork/report/2012/2012/cap-bars.pdf

- **Quality objectives:** No objectives have been set.
- **Reference level:** No reference level has been set for this stock. The joint Russian-Norwegian fisheries commission has adopted a management rule stating that there should be less than 5% probability that the spawning stock biomass should fall below 200 000 t at the time of spawning. ICES gives advice according to this rule.
- **Gaps in data coverage:** No gaps.

Contact person/responsible person: Gro I. van der Meeren, IMR

Title: Fish and shrimp biomass (E)

Parameter: Greenland halibut

About the parameter

- ***Type of parameter: E***
- ***Priority of parameter: e***
- ***Rationale :*** Biomass, spawning stock biomass and recruitment of Greenland halibut is important to understand the productive potential for human consumption, as well as predator—prey interactions.

Overview of the parameters

Parameters (name)	*Institution responsible for monitoring*	*Time series period*	*Gaps in monitoring*	*Priority ("e", "r" or "s")*
Total biomass, spawning stock biomass and recruitment	*IMR and PINRO*	*1964-2011*	*There is at present no accepted analytical assessment for Greenland halibut, mainly due to age-reading problems. ICES benchmark is planned in 2013.*	e

Parameter 1 - Total biomass, spawning stock biomass and recruitment

- **Short facts about the parameter:** Greenland halibut (*Reinhardtius hippoglossoides*), is a large piscivorous flatfish that has the continental slope — between the Barents Sea and the Norwegian Sea — as its most important adult area; it is also found in the deeper parts of the Barents Sea. Investigations during the period 1968-1990 indicated that cephalopods (squids, octopuses) and fish (mainly capelin and herring) predominated in Greenland halibut stomachs. With increasing predator length, ontogenetic shifts in prey preference were clear: decreasing proportion of small prey (shrimps and small capelin); and increasing proportion of larger fish. Greenland halibut is a long-lived species showing considerable sexual dimorphism in growth and maturation. Age-reading methodology for this stock has been reviewed in recent years and there is evidence to show that growth is slower than previously thought.

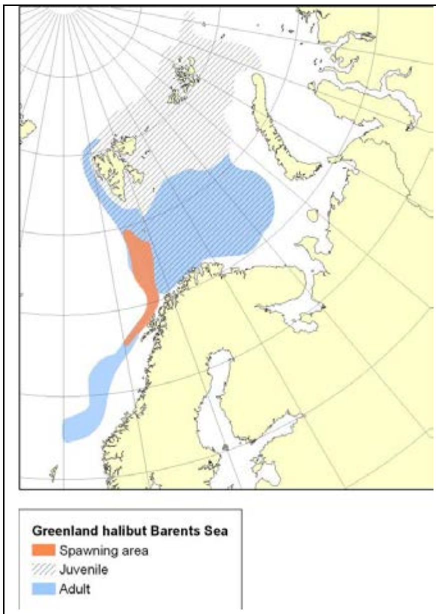


Figure 1. Distribution area for Northeast Arctic Greenland halibut.

- **Why this is a key parameter:** Biomass, spawning stock biomass and recruitment of Greenland halibut is important to understand the productive potential for human consumption, as well as predator-prey interactions.
- **Monitoring:** Includes the Norwegian Greenland halibut survey in autumn and the Russian bottom trawl surveys in October-December (ICES acronym: RU-BTr-Q4). The Norwegian autumn survey covers the continental slope from Norway to west of Spitsbergen (68–80°N, 400–1500 m depth) including the main spawning areas, and thus covers the adult part of the population. This survey was not conducted in 2010, but is continued biennially from 2011 onwards. The Russian October–December survey (100–900 m depth) does not go as far south on the slope (ca 71°N), but covers adult areas on the northern slope and additionally extends east into central parts of the Barents Sea where catches contain a higher proportion of immature Greenland halibut. Additionally annually bottom trawl information from the Norwegian bottom trawl survey in August in the Barents Sea and Svalbard (1995-2003) and the August-September Barents Sea ecosystem survey (ICES acronym: Eco-NoRu-Q3) have been important.
- **Current status of the parameter:** There is at present no accepted analytical assessment for Greenland halibut, mainly due to age-reading problems. In the absence of defined reference points and an accepted assessment the status of the stock cannot be fully evaluated. The stock has been at a low level for several years and it is a long-lived species, which can only sustain low exploitation. Indications from fishery independent surveys are not consistent but give evidence of a relatively stable or increasing stock (Figure 2). During the last 15 years, average catches have been around 13 000 t. TAC for 2013 was set to 19 000 t by Russia and Norway.

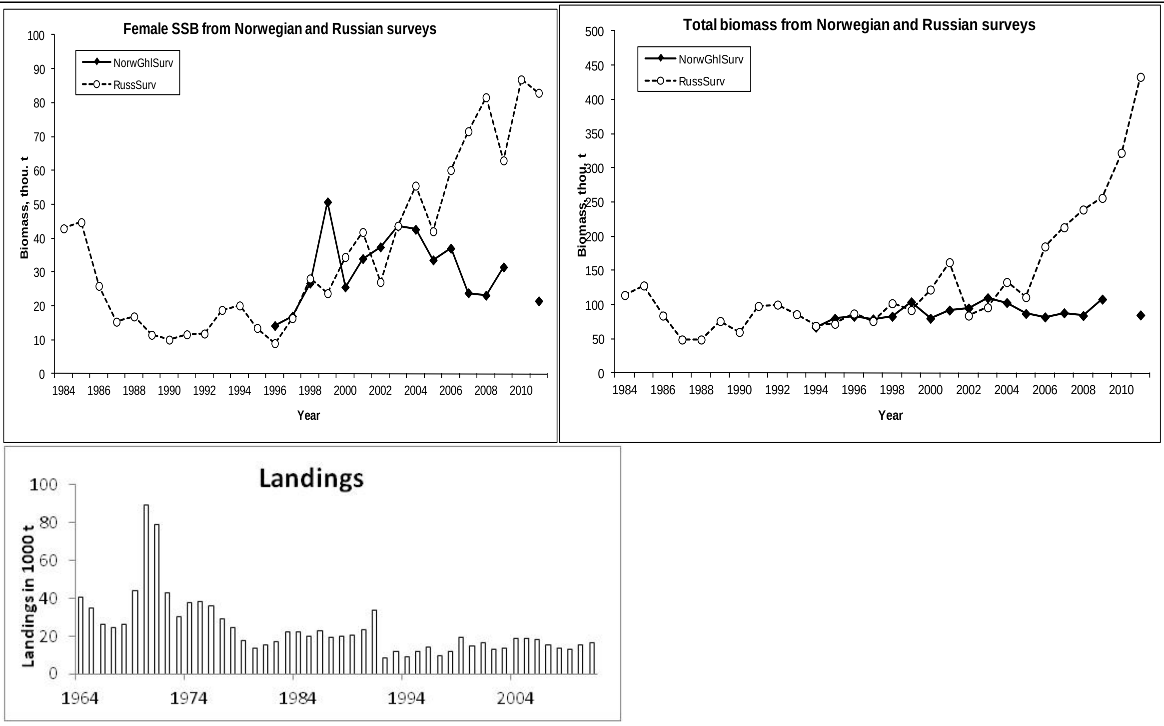


Figure 2. Above: Northeast Arctic Greenland halibut; Female spawning stock biomass and totalbiomass estimates from two surveys targeting Greenland halibut, the Norwegian Greenland halibut survey (NorwGhlSurv) along the continental slope in autumn and the Russian autumn trawl survey in October-Desember (RussSurv). No Norwegian survey in 2010.
Below: Northeast Arctic Greenland halibut; landings 1964-2011.

- **Environmental objectives:** No objectives have been set. Need to develop age reading, analytical assessment, reference points.
- **Reference level:** No reference level is set for this stock at the moment. For 2013 ICES advises on the basis of precautionary considerations that catches should not be allowed to increase and should not exceed 15 000 t (ICES advice 2012).
- **Gaps in data coverage:** There is at present no accepted analytical assessment for Greenland halibut, mainly due to age-reading problems.

Contact person/responsible person: Gro I. van der Meeren, IMR

Title: Fish and shrimp biomass (E)

Parameter: Long rough dab

About the parameter

- ***Type of parameter: E***
- ***Priority of parameter: e***
- ***Rationale :*** Long rough dab is a key fish species in the benthic community in the Barents Sea. It is important to understand the productive potential for human consumption as well as predator—prey interactions.

Overview of the parameters

Parameters (name)	*Institution responsible for monitoring*	*Time series period*	*Gaps in monitoring*	*Priority ("e", "r" or "s")*
Total biomass, spawning stock biomass and recruitment	*Monitoring not started*	*Monitoring not started*	*Monitoring not started*	e

Parameter 1 - Total biomass, spawning stock biomass and recruitment

- **Short facts about the parameter:** Long rough dab (*Hippoglossoides platessoides*) are abundant and very widely distributed in the Barents Sea, as one of the most common groundfish species it plays an important role in the benthic community. Because it is hardly a commercial species, detailed information on the life history and ecology is lacking, and physical processes that influence the dynamics of this species are not well understood. For 2004-2005 and 2010-2011, the swept area abundance of long rough dab was estimated at about 300,000 tons based on the ecosystem survey. This is probably a minimum estimate of stock abundance.
- **Why this is a key parameter:** Information on total biomass is relevant for understanding the impact long rough dab may have on other species in the ecosystem. Information of maturing biomass and recruitment is relevant for understanding development of the stock.
- **Monitoring:** Analytical assessments have not been conducted on long rough dab, but observations (abundance by length group) are taken annually during the ecosystem survey.
- **Current status of the parameter:** For 2004-2005 and 2011, the swept area abundance of long rough dab was estimated at 300,000 tons based on the ecosystem survey. This is probably a minimum estimate of stock abundance.
- **Quality objectives:** No objective has been set.
- **Reference level:** No reference level has been set.
- **Gaps in data coverage:** Monitoring is not started.

Contact person/responsible person: Gro I. van der Meeren, IMR

Title: Fish and shrimp biomass (E)

Parameter: NEA cod

About the parameter

- ***Type of parameter: E***
- ***Priority of parameter: e***
- ***Rationale :*** Cod is a keystone species and the most important predatory fish in the Barents Sea. It feeds on a wide range of prey, including: larger zooplankton species; most available fish species, in particular capelin; and shrimp.

Overview of the parameters

parameters (name)	*Institution responsible for monitoring*	*Time series period*	*Gaps in monitoring*	*Priority ("e", "r" or "s")*
Total biomass, spawning stock biomass and recruitment	*IMR and PINRO*	*1946-*	*None*	e

Parameter 1 - Total biomass, spawning stock biomass and recruitment

- **Short facts about the parameter:** NEA cod (*Gadus morhua*) is important for the dynamics in the ecosystem because it is the most abundant top predator in the ecosystem. In marine ecosystem with many similarities to the Barents Sea, large changes have occurred in the system after the collapse of cod stocks. The role of cod in different ecosystems is described by Link et al. (2009). Medium-sized cod prey mainly on capelin, while large cod in addition also prey on medium to large sized fish (e.g. young cod, haddock, flatfish). It should also be noted that small cod as prey for larger cod (i.e. cannibalism) is one important factor in the cod stock dynamics, which may contribute to self-regulation of the stock.
- **Why this is a key parameter:** Information on total biomass is relevant for understanding the impact cod may have on other species in the ecosystem and cod as basis for the fisheries. Information of maturing biomass and recruitment is relevant for understanding development of the stock.
- **Monitoring:** Annually Joint Barents Sea winter survey (bottom trawl and acoustics) *Acronyms: BS-NoRu-Q1 (BTr) and BS-NoRu-Q1 (Aco)* Before 2000 this survey was made without participation from Russian vessels, while in 2001-2005 and 2008-2012 Russian vessels have covered important parts of the Russian zone. In 2006-2007 the survey was carried out only by Norwegian vessels.
  Lofoten annually acoustic survey on spawners Acronym: Lof-Aco-Q1. The estimated abundance indices from the Norwegian acoustic survey off Lofoten and Vesterålen (the main spawning area for this stock) in March/April.
  Russian autumn survey Acronym: RU-BTr-Q4. Annually. Abundance estimates from the Russian autumn survey (November-December).
  Joint Ecosystem survey Acronym: Eco-NoRu-Q3 (Btr). Annually swept area bottom trawl

estimates from the joint Norwegian-Russian ecosystem survey in August-September for the period 2004-2012.

- **Current status of the parameter:** The geographical distribution of NEA cod (*Gadus morhua*) has in recent years expanded to the north and east. This is related to the increase in temperature observed in the Barents Sea in recent years. It is important that the spatial coverage of the surveys is increased to take this into account. Based on the most recent estimates of spawning stock biomass (SSB, Figure 1), ICES classifies the stock as having full reproductive capacity and being harvested sustainably.

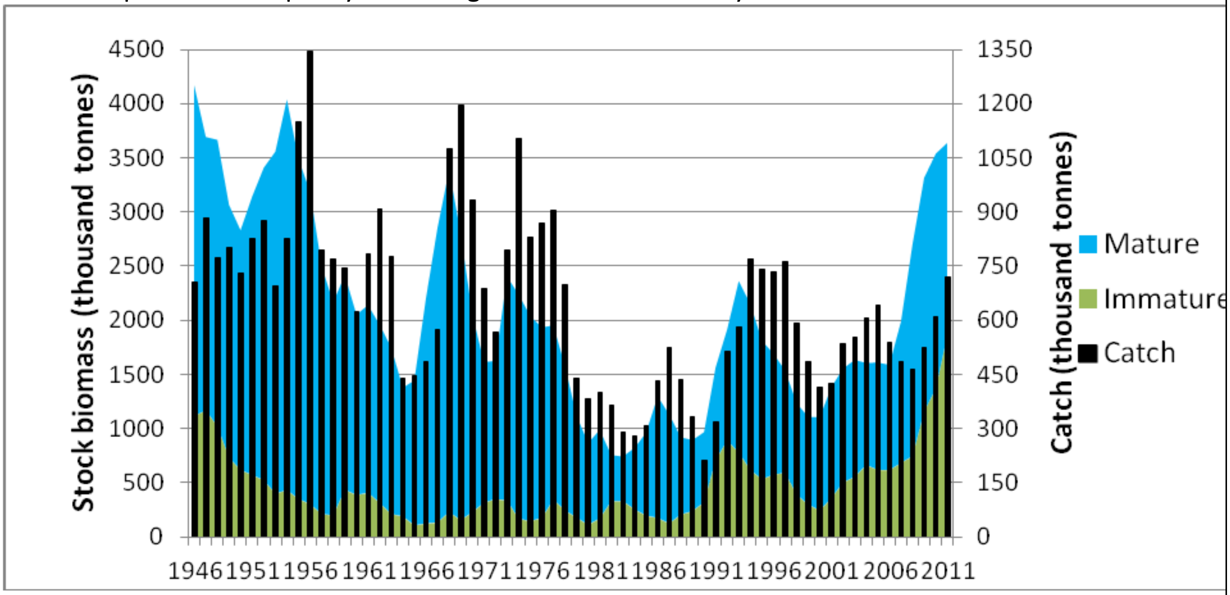


Figure 1. Northeast Arctic cod, development of spawning stock biomass (green area), total stock biomass (age 3 and older, blue area) and landings (columns).

- **Environmental objectives:** The Joint Norwegian-Russian Fisheries Commission has set this objective: “The stock must be fished in accordance with harvesting rules approved by ICES”.
- **Reference level:** The spawning stock biomass should not fall below 460 000 t.
- **Gaps in data coverage**: None.

Contact person/responsible person: Gro I. van der Meeren, IMR

Title: Fish and shrimp biomass (E)

Parameter: NEA haddock

About the parameter

- ***Type of parameter: E***
- ***Priority of parameter: e***
- ***Rationale :*** Haddock is an important predator on benthos, and thus an important species in the ecosystem.

Overview of the parameters

Parameters (name)	*Institution responsible for monitoring*	*Time series period*	*Gaps in monitoring*	*Priority (“e”, “r” or “s”)*
Total biomass, spawning stock biomass and recruitment	*IMR and PINRO*	*1951-*	*None*	e

Parameter 1 - Total biomass, spawning stock biomass and recruitment

- **Short facts about the parameter:** NEA haddock *(Melanogrammus aeglefinus)* is an important demersal gadoid species that undertakes extensive migrations to and from its spawning grounds in the Barents Sea (ICES c2007-2008). Variation in recruitment of haddock has been associated with changes in the influx of Atlantic waters to the Barents Sea. Water temperature at the first and second years of the haddock life cycle is an indicator of year class strength. Strong year classes occur in warm years only, but water temperature is not a consistent determinant of year-class strength; however, a steep rise or fall in water temperature can have a marked effect. Haddock feed primarily on relatively small benthic organisms including crustaceans, mollusks, echinoderms, worms, and fish. They are omnivorous, however, and also feed on plankton. During capelin spawning, haddock prey on capelin and their eggs. When capelin abundance is low, or when their areas of distribution do not overlap, haddock may switch to other fish species, i.e. young herring, or consume euphausiids and other benthic organisms (Zatsepin 1939; Tseeb 1964). Haddock stock size large natural variation, and is believed to be density-dependent. Similar to cod, annual consumption of haddock by marine mammals (primarily seals and whales) depends on the availability of capelin. During years when the capelin stock is large, the importance of haddock in the diet of marine mammals is minimal; when the capelin stock is reduced, the proportion of haddock in the diet of marine mammals increases.

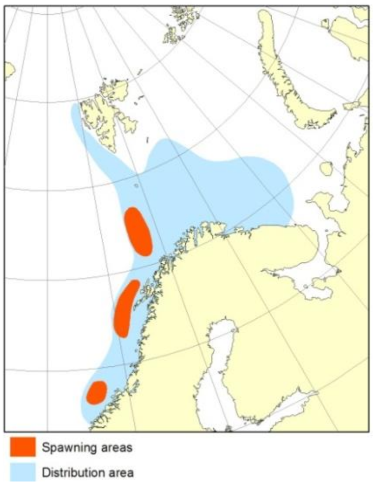


Fig.1. Distribution area for Northeast Arctic Haddock

- **Why this is a key parameter:** Information on total biomass is relevant for understanding the impact NEA haddock may have on other species in the ecosystem. Information of maturing biomass and recruitment is relevant for understanding development of the stock.
- **Monitoring:** NEA haddock is monitored annually with acoustic surveys during the IMR winter/autumn (ecosystem) surveys through four tuning fleets: Russian bottom trawl survey (RU-BTr-Q4); Joint Barents Sea survey – acoustic (BS-NoRU-Q1(Aco)); Joint Barents Sea survey – bottom trawl (BS-NoRu-Q1 (BTr)); Joint Russian–Norwegian ecosystem autumn survey in the Barents Sea – bottom trawl (Eco-NoRu-Q3 (Btr)).
- **Current status of the parameter:** Historic high stock biomass.
  Based on the most recent estimates of SSB (Figure 1), ICES classifies the stock as having full reproductive capacity and being harvested sustainably.

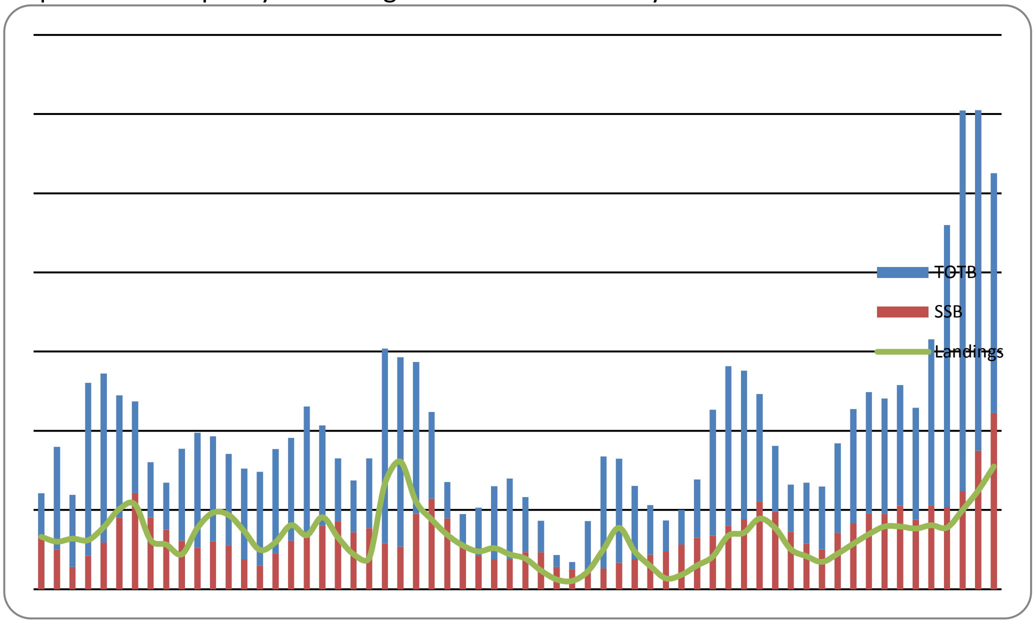


Figure 1. Northeast Arctic haddock, development of spawning stock biomass (red bars), total stock biomass (age 3 and older, blue bars) and landings (green curve).

- **Environmental objectives:** Quality objectives are not set.
- **Reference level:** Reference levels, as precautionary reference point is recognized by ICES as SSB_{MP*}, which is in accordance with SSB_{pa} at 80 000 mt.
- **Gaps in data coverage:** None.

* MP= The Joint Norwegian-Russian Fisheries Commission 2004.

Contact person/responsible person: Gro I. van der Meeren, IMR

Title: Fish and shrimp biomass (E)

Parameter: Polar cod

About the parameter

- ***Type of parameter: E***
- ***Priority of parameter: e***
- ***Rationale :*** Biomass of polar cod is important to understand the productive potential for human consumption, as well as predator-prey interactions.

Overview of the parameters

Subparameters (name)	*Institution responsible for monitoring*	*Time series period*	*Gaps in monitoring*	*Priority (“e”, “r” or “s”)*
Total biomass	*IMR and PINRO*	*1986-*	*None*	e

Parameter 1 - Total biomass, spawning stock biomass and recruitment

- **Short facts about the parameter:** Polar cod (*Boreogadus saida*) is a cold-water species largely inhabiting eastern and northern regions of the Barents Sea. It spawns in both the south-eastern corner; and to the east of Spitsbergen. It is important prey for several marine mammals, but also for Arctic cod (Orlova et al., 2001). Polar cod is semi-pelagic and inhabits the lower water column. It is a plankton feeder, with a rather short life cycle; fish older than 5 years are rarely found. There is at present little fishing on this stock.
- **Monitoring:** The stock size has annually been measured acoustically since 1986.
- **Current status of the parameter:** The polar cod (*Boreogadus saida*) stock is presently derceasing.

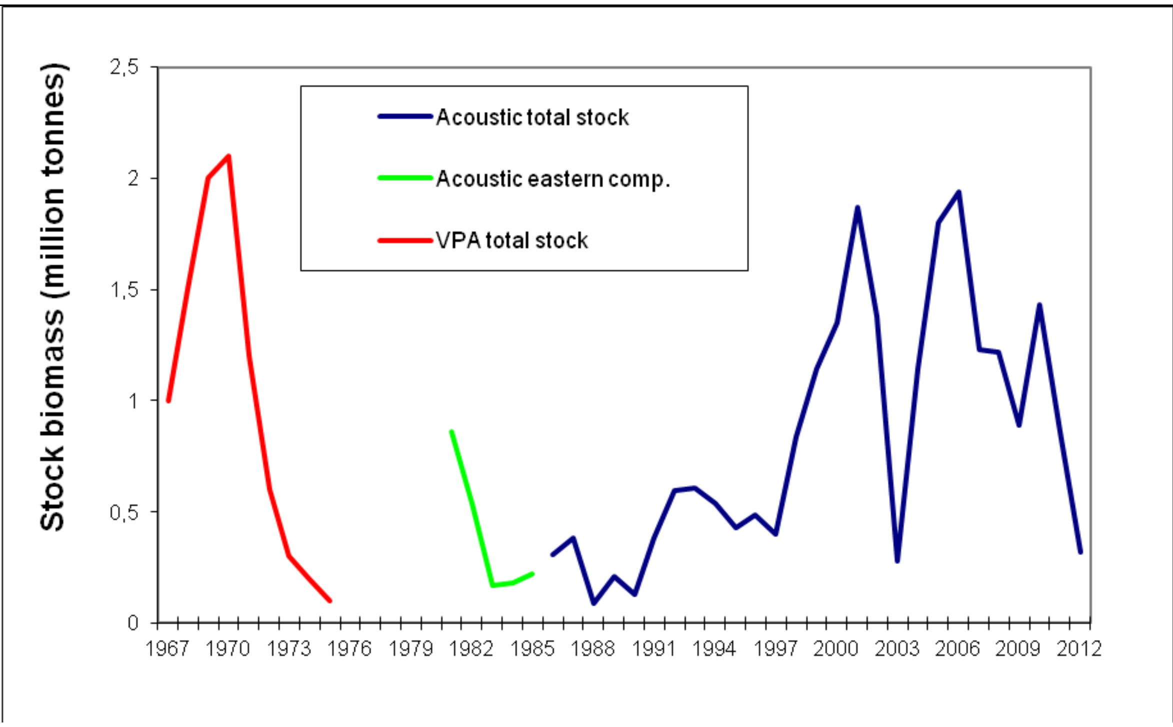


Figure 1. Polar cod. Stock size estimates obtained by acoustics, 1986–2008.

- **Quality objectives:** No quality objective has been set. Should be developed if fishery becomes important.
- **Reference level:** No reference level has been set. Should be developed if fishery becomes important, F0.1-Russia.
- **Gaps in data coverage:** None.

Contact person/responsible person: Gro I. van der Meeren, IMR

Title: Fishing pressure

About the indicator

- ***Type of indicator: A***
- ***Priority of indicator: e***
- ***Rationale:*** Fishing can remove large part of key commercial stock from the ecosystem, thereby influencing directly and indirectly the other ecosystem components. Normalized fishing mortalities shows if a stock is harvested sustainable (according to given international reference levels). Landings show how much biomass that is removed and IUU fishing, ghost fishing and dumping show unwanted human harvest of key ecosystem components.

Overview of Parameters

Parameters (name)	***Type (“E”, “A”, or “I”)***	***Priority (“e”, “r” or “s”)***
Normalized fishing mortalities	*A*	e
Fishing landings/catches by commercial fleets	*A*	e
IUU fishing	*A*	s
Ghost fishing	*A*	s
Dumping	*A*	s

Contact person/responsible person: Jan Erik Stiansen, IMR

Title: Fishing pressure (A)

Parameter: Dumping

About the parameter

- ***Type of parameter: A***
- ***Priority of parameter: s***
- ***Rationale :*** Dumping is an unwanted human impact on fisheries.

Overview of the parameters

Parameters (name)	*Institution responsible for monitoring*	*Time series period*	*Gaps in monitoring*	*Priority ("e", "r" or "s")*
Dumping	*Russia and Norway: Coast guards*	*none*		s

Parameter 1 - Dumping

- **Short facts about the parameter:** Needs to be developed.
- **Why this is a key parameter:** Dumping of fish from commercial fisheries is an unwanted human impact on the ecosystem.
- **Monitoring:** Little knowledge on this parameter.
- **Current status of the parameter:** Needs to be developed.
- **Quality objectives**: Should be as low as possible.
- **Reference level:** Monitoring and introduction of new legal measures to decrease.
- **Gaps in data coverage:** Unknown.
- **Other issues about the subparameter:**

Contact person/responsible person: Jan Erik Stiansen, IMR

Title: Fishing pressure (A)

Parameter: Fishing landings/catches by commercial fleets

About the parameter

- ***Type of parameter: A***
- ***Priority of parameter: e***
- ***Rationale :*** Landings show how much biomass that is removed of key commercial fish stock. These commercial stocks are among the largest fish stocks in the Barents Sea, and therefore will have a direct or indirect impact on all other ecosystem components.

Overview of the subparameters

Subparameters (name)	*Institution responsible for monitoring*	*Time series period*	*Gaps in monitoring*	*Priority ("e", "r" or "s")*
Landings NEA cod	*ICES*	*1949-present*	*no*	e
Landings NEA haddock	*ICES*	*1960-present*	*no*	e
Landings NEA saithe	*ICES*	*1950-present*	*no*	s
Landings NEA capelin	*ICES*	*1965-present*	*no*	e

Subparameter 1 - Landings NEA cod

Cod (Gadus morhua)
Adult cod have an annual spawning migration from the Barents Sea to the western coast of Norway. Spawning largely occurs in the Lofoten area during March-April. Cod larvae are advected with the Norwegian coastal current and Norwegian Atlantic current back to the Barents Sea where they settle at the bottom around October. Cod is a keystone species and the most important predatory fish in the Barents Sea. It feeds on a wide range of prey, including: larger zooplankton species; most available fish species; and shrimp. Cod prefer capelin as prey, and feed on them heavily as they migrate into southern and central regions to spawn. Capelin stock fluctuations strongly effect cod growth, maturation, and fecundity; they also indirectly affect cod recruitment, as cod cannibalism is reduced in years with high capelin biomass. Euphausiids are also important prey for cod during the first year of life Ponomarenko (1973, 1984); in years when the capelin stock is low, cod predation on euphausiids increases (Ponomarenko and Yaragina 1990).
Along the Norwegian coast, coastal cod is fished together with Northeast Arctic cod. However, there is no separate TAC for coastal cod; the Norwegian cod TAC includes both coastal cod and Northeast Arctic cod. The coastal cod is at a low level. The catches are separated to type of cod by the structure of the otoliths taken from samples of the commercial fishery.

- **Why this is a key subparameter:** Cod is a key species in the ecosystem. It is one of the economically most important species for human fisheries. It is also a large predator in the system, and is an important prey for seals.

- **Monitoring:** The landings data are taken from reports of the commercial fleets landings. ICES AFWG then aggregates the data given by the national fishing authorities.
- **Current status of the subparameter:** Presently the landings of cod are at a medium high level (2010 as latest year. The landings have continued to rise in 2011 and 2012).
- **Quality objectives:**
- **Reference level:** Landings are subject to international agreed quotas for the stock, which relates to the fishing mortality F.
- **Gaps in data coverage:**
- **Other issues about the subparameter:**

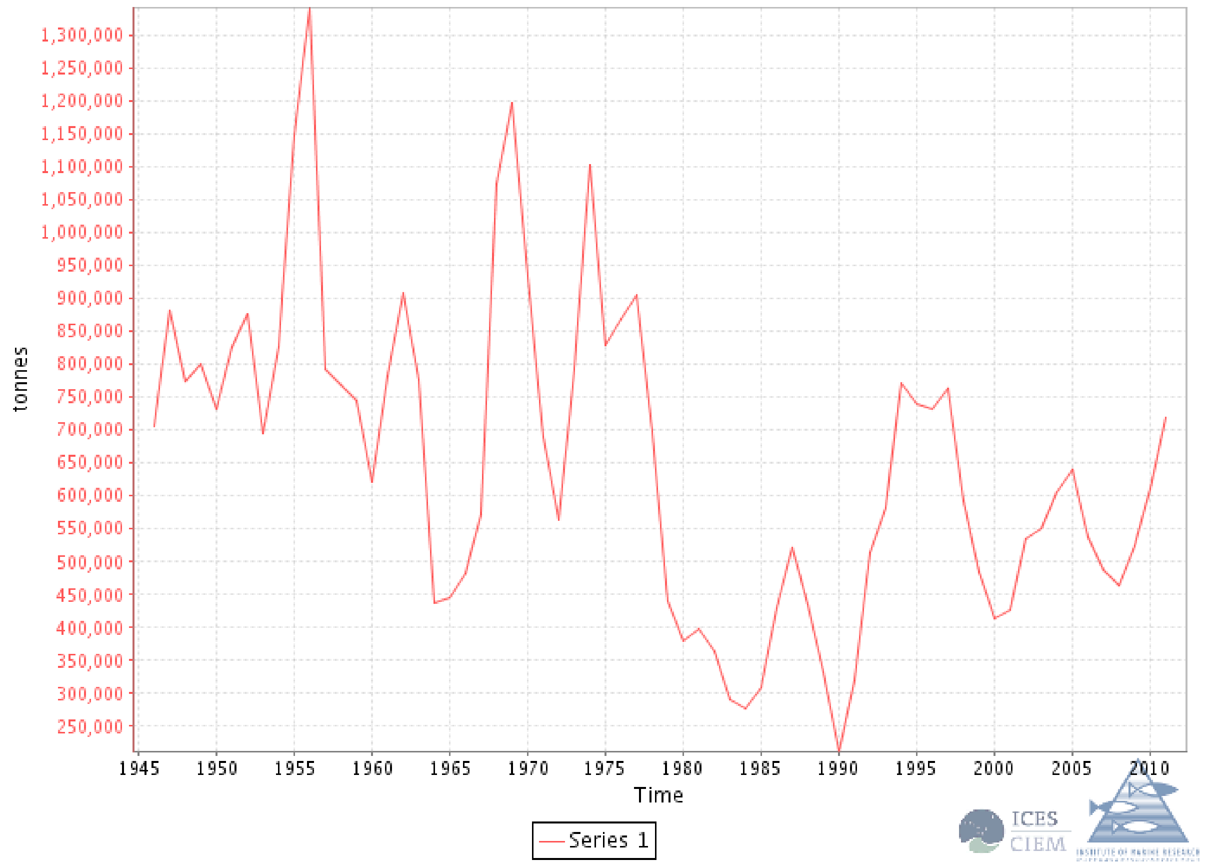


Figure 1. Landings of North East Arctic cod in ICES fisheries area I, IIa og IIb. (AFWG report 2011 Table 3.25

Subparameter 2 - Landings NEA haddock

Haddock (Melanogrammus aeglefinus)

Haddock is an important demersal gadoid species that undertakes extensive migrations to and from its spawning grounds in the Barents Sea (ICES c2007-2008) (Figure 2.4.19).

Variation in recruitment of haddock has been associated with changes in the influx of Atlantic waters to the Barents Sea.

Water temperature at the first and second years of the haddock life cycle is an indicator of year class strength; during this period of its life cycle if mean annual water temperature in the bottom layer does not exceed 3.8°C the probability of having a strong year class is low, even if other remaining factors are favourable. Water temperature is not a consistent determinant of year-class strength; however, a steep rise or fall in water temperature can have a marked effect. Haddock feed primarily on relatively small benthic organisms including crustaceans, molluscs, echinoderms, worms, and fish. They are omnivorous, however, and also feed on plankton. During capelin spawning, haddock prey on capelin and their eggs. When capelin abundance is low, or when their areas of distribution do not overlap, haddock may switch to other fish species, i.e. young herring, or consume euphausiids and other benthic organisms (Zatsepin 1939; Tseeb 1964). Haddock stock size has large natural variation, and is believed to be density-dependent. Similar to cod, annual consumption of haddock by marine mammals (primarily seals and whales) depends on the availability of capelin. During years when the capelin stock is large, the importance of haddock in the diet of marine mammals is minimal; when the capelin stock is reduced, the proportion of haddock in the diet of marine mammals increases.

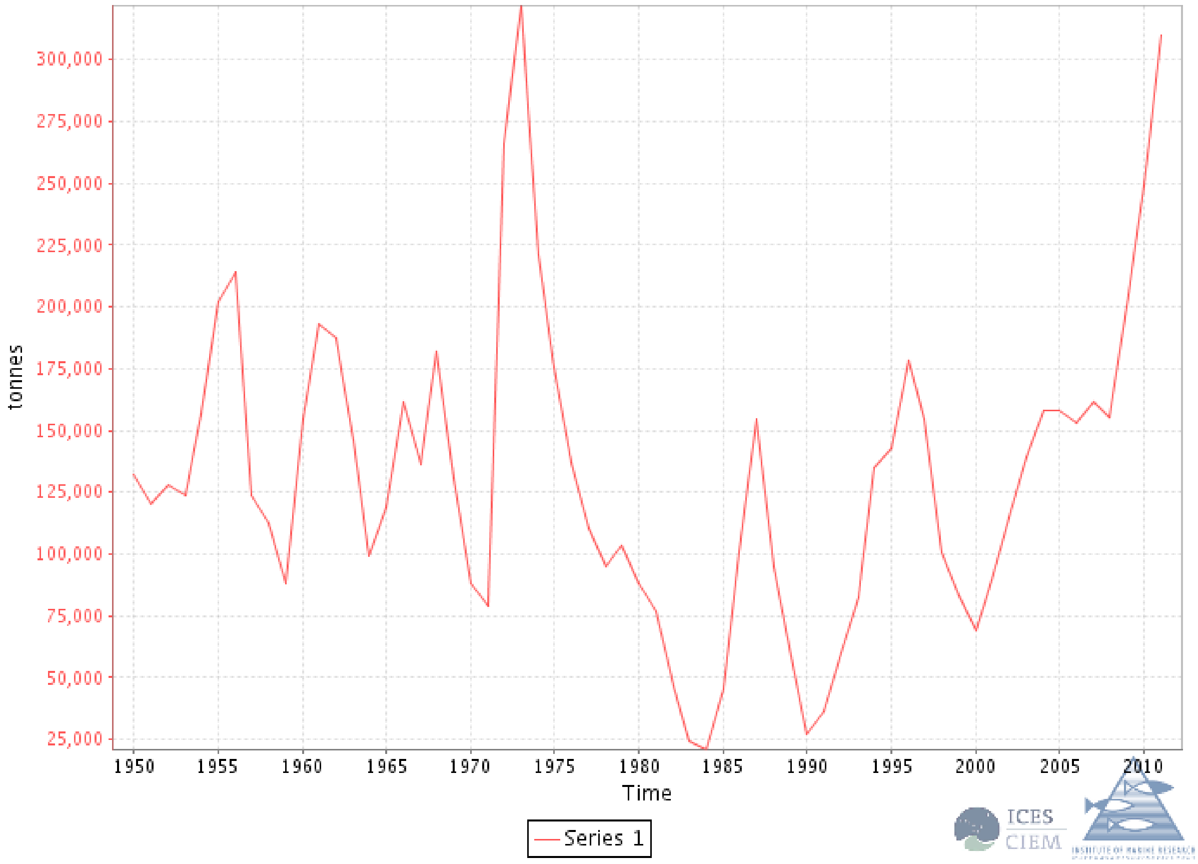


Figure 2. Landings of North East Arctic haddock. (AFWG report 2012 Table 4.18)

- **Why this is a key subparameter:** Haddock is a key species in the ecosystem, especially in the southeastern parts of the Barents Sea. It is one of the economically most important species for human fisheries. It is also a large benthic predator in the system.
- **Monitoring:** The landings data are taken from reports of the commercial fleets landings. ICES AFWG then aggregates the data given by the national fishing authorities.
- **Current status of the subparameter:** Presently the landings of haddock are at a very high level (2010 as latest year).
- **Quality objectives:**
- **Reference level:** Landings are subject to international agreed quotas for the stock, which relates to the fishing mortality F.
- **Gaps in data coverage:**
- **Other issues about the subparameter:**

Subparameter 3 - Landings NEA saithe

Saithe (Pollachius virens)

Saithe is a boreal species found in north Atlantic waters (Figure 2.4.26). In the north-eastern Atlantic saithe is separated into six stocks: 1) west of Ireland; 2) west of Scotland; 3) at Iceland; 4) at the Faeroe Islands; 5) in the North Sea; and 6) northeast Arctic saithe — along the coast of Norway (62° N at Møre to Kola Peninsula) and the south-eastern Barents Sea. It also occurs at Svalbard in low abundance. Tagging experiments indicate that saithe make both feeding and spawning migrations; there are also migrations between stocks. Young saithe may migrate extensively from the western Norwegian coast to the North Sea. Adults follow Norwegian spring-spawning herring far out into the Norwegian Sea, sometimes all the way to Iceland and Faeroe Islands. Saithe are both pelagic and demersal, found at depths from 0-300 m. They often occur in dense concentrations, e.g. in the pelagic zone where currents concentrate prey items. Predominant prey items for young saithe are *Calanus*, krill, and other crustaceans; with age they become increasingly piscivorous and prey on: herring; sprat; young haddock; Norway pout; and blue whiting. In the northeast Arctic saithe spawn during winter; the peak is during February at depths from 150-200 m and temperatures from 6–10 ˚C. They take regular annual spawning migrations from the northern coast of Norway to spawning areas off the western coast of Norway; they sometimes migrate to northern regions of the North Sea, but to a lesser extent. Principal spawning areas are: Lofoten, Haltenbanken, and banks outside Møre and Romsdal region in the Sunnmøre archipelago. Eggs and larvae drift northward with the currents, 0 age-group saithe use as nursery grounds shore areas extending on the western coast of Norway to south-eastern regions of the Barents Sea; they migrate to coastal banks as 2–4 year olds.

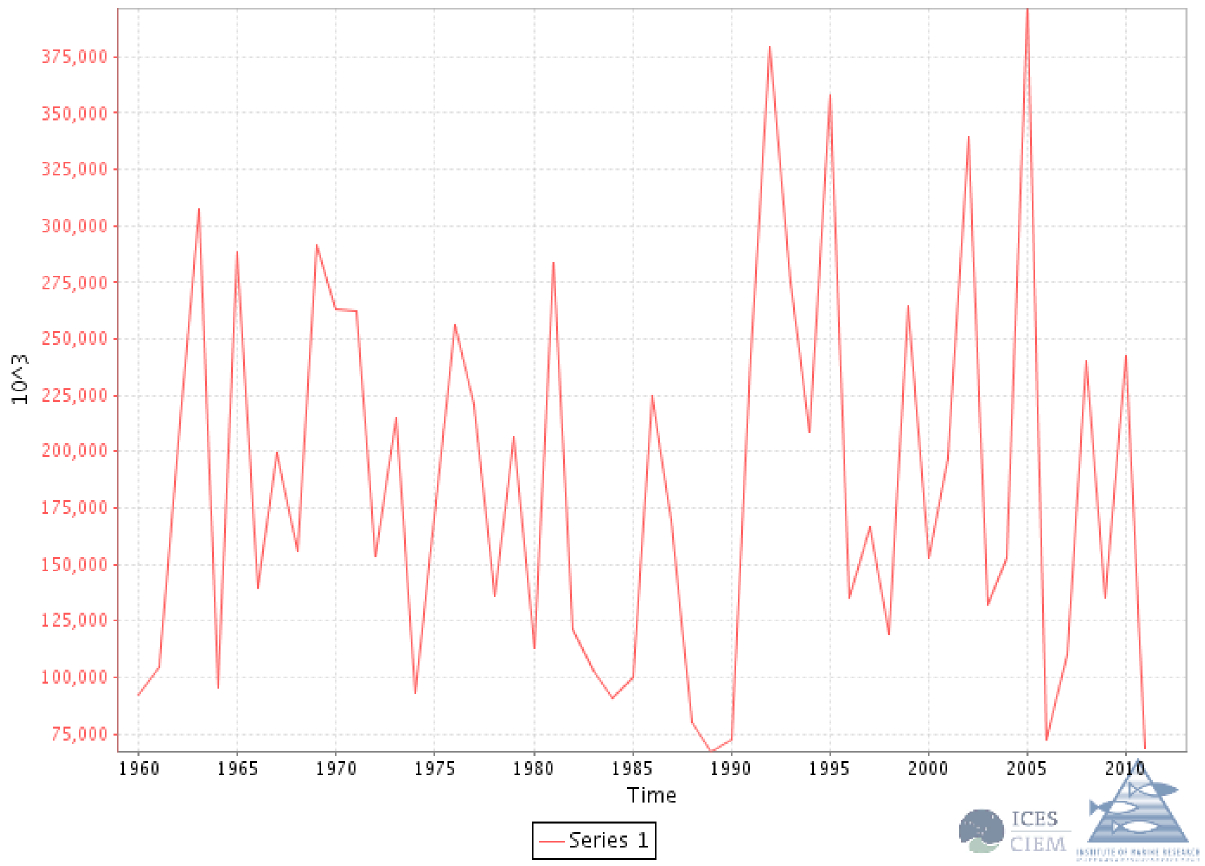


Figure 3. Landings of North East Arctic saithe in ICES fisheries area I, IIa and IIb. (AFWG table 5.5.7)

- **Why this is a key subparameter:** Saithe is a key species in the ecosystem, especially in the south-western part of the Barents Sea and along the Norwegian coast.

- **Monitoring:** The landings data are taken from reports of the commercial fleets landings. ICES AFWG then aggregates the data given by the national fishing authorities.
- **Current status of the subparameter:** Presently the landings of saithe are at a medium low level (2010 as latest year).
- **Reference level:** Landings are subject to international agreed quotas for the stock, which relates to the fishing mortality F.
- **Gaps in data coverage:**
- **Other issues about the subparameter:**

Subparameter 4 - Landings NEA capelin

Capelin (Mallotus villosuss)

Capelin eats mainly krill and copepods, and the effect of capelin on zooplankton is so strong that a significant negative relationship can be seen between the amount of zooplankton in the Barents Sea and capelin abundance. Capelin also has profound effects on its predators (Gjøsæter et al., 2009). If alternative prey is not present, a severely reduced capelin stock will have a strong negative impact on top predators in the Barents Sea, as observed in the late 1980s (Gjøsæter et al. 2009). A low capelin stock might for example have negative impacts on a range of seabird and sea mammal species in the area (Hamre 1994, Sakshaug et al. 1994).

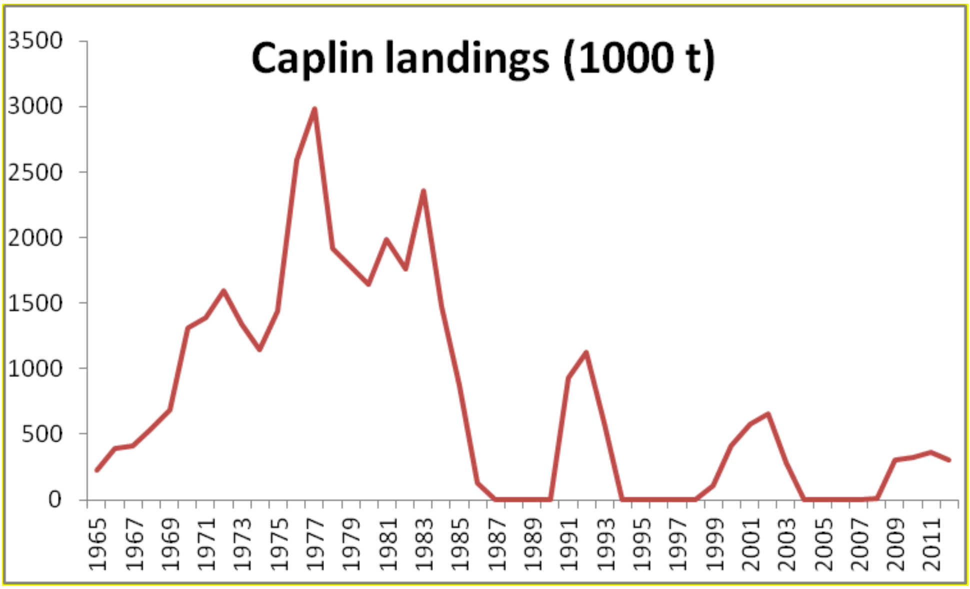


Figure 4. Landings of North East Arctic saithe in ICES fisheries area I, IIa and IIb. (AFWG table 5.5.7)

- **Why this is a key subparameter:** Capelin is a key species in the ecosystem
- **Monitoring:** The landings data are taken from reports of the commercial fleets landings. ICES AFWG then aggregates the data given by the national fishing authorities.
- **Current status of the subparameter:** Presently the landings of capelin are at a low level (2013 as latest year).
- **Quality objectives:**
- **Reference level:** Landings are subject to international agreed quotas for the stock, which relates to the fishing mortality *F.*

- **Gaps in data coverage:**
- **Other issues about the subparameter:**

Contact person/responsible person: Jan Erik Stiansen (text is taken from Stiansen et al 2009)

Title: Fishing pressure (A)

Parameter: Ghost fishing

About the parameter

- ***Type of parameter: A***
- ***Priority of parameter: s***
- ***Rationale :*** Lost gears such as gillnets may continue to fish for a long time (ghost fishing). The catch efficiency of lost gillnets has been examined for some species and areas, but at present no estimate of the total effect is available.

Overview of the parameters

parameters (name)	***Institution responsible for monitoring***	***Time series period***	***Gaps in monitoring***	***Priority („e", "r" or "s")***
Ghost fishing	*Norwegian: fishery directorate, Russian: PINRO time-to-time*	*none*		s

Parameter 1 - Ghost fishing

- **Short facts about the parameter:**
- **Why this is a key parameter:** It is an indicator for unwanted human impact.
- **Monitoring**: No estimate is presently available. Needs to be developed.
- **Current status of the parameter**: Needs to be developed.
- **Quality objectives:** Should be as low as possible.
- **Reference level:** Monitoring and introducing new legal measures to reduce the occurrence.
- **Gaps in data coverage:** Unknown.
- **Other issues about the subparameter:**

Contact person/responsible person: Jan Erik Stiansen, IMR

Title: Fishing pressure (A)

Parameter: IUU fishing

About the parameter

- ***Type of parameter: A***
- ***Priority of parameter: s***
- ***Rationale :*** IUU fishing is illegal unreported and unregulated fishing. Such fishing is conducted outside the quotas system and therefore infers wrong estimates of the stock.

Overview of the parameters

Parameters (name)	*Institution responsible for monitoring*	*Time series period*	*Gaps in monitoring*	*Priority ("e", "r" or "s")*
IUU fishing	*Norwegian: fishery directorate, Russia and Norway: Coast guards*			s

Parameter 1 - IUU fishing

- **Short facts about the parameter:** There has been focus on the work to solve the problems of IUU fishing and trans-shipment in the Barents Sea area. An important field is to find measures to reduce discards of catches. IUU fishing on the cod stock was a serious problem some years ago, but is now considered to be less serious.
- **Why this is a key parameter:** See above.
- **Monitoring:** Some data exists in the Barents Sea for the cod fisheries, based on vessel satellite tracking of the activity of fishing vessels. The Norwegian Fisheries directorate has done some calculations on this. In the mid 2000's IUU fishing was considered a problem with an estimated IUU catch of up to 25% of allowed quotas catch. However, regulation steps have been taken and IUU fishing in the Barents Sea is not any longer considered a large problem.
- **Current status of the parameter:**
- **Quality objectives:** Should be as low as possible.
- **Reference level:** Monitoring and introducing new legal measures to decrease the occurrence.
- **Gaps in data coverage:**
- **Other issues about the subparameter:**

Contact person/responsible person: Jan Erik Stiansen, IMR

Title: Fishing pressure (A)

Parameter: Normalized fishing mortalities

About the parameter

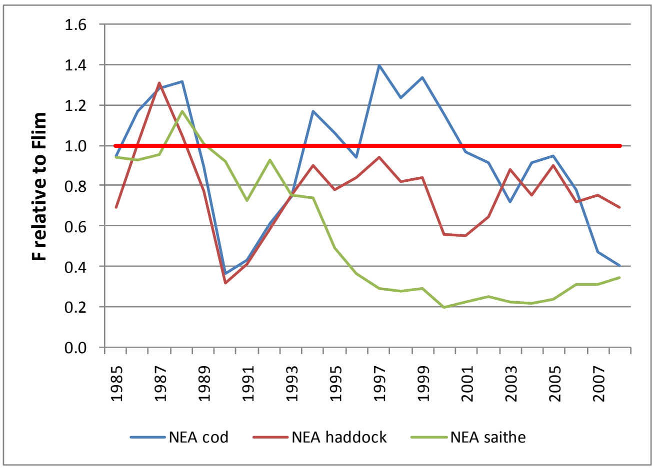
- ***Type of parameter: A***
- ***Priority of parameter: e***
- ***Rationale :*** Normalized fishing mortalities relate to sustainable levels of commercial catch of key fish stocks in the Barents Sea. These stocks are major components in the ecosystem and their sustainability has both direct and indirect effects on other ecosystem components. The parameter also measures human impact.

Overview of the parameters

Parameters (name)	*Institution responsible for monitoring*	*Time series period*	*Gaps in monitoring*	*Priority ("e", "r" or "s")*
Normalized fishing mortalities	*ICES*	*1985-present*		e

Parameter 1 - Normalized fishing mortalities

- **Short facts about the parameter:** Fishing mortalities relative to management reference level F_{lim} for different commercial fish species.
- **Why this is a key parameter:** The parameter measures how well a stock is managed. It is an indication on human impact through fishing.
- **Monitoring:** Data are taken from ICES working groups.



-

Figure 1. 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 (ICES 2009).

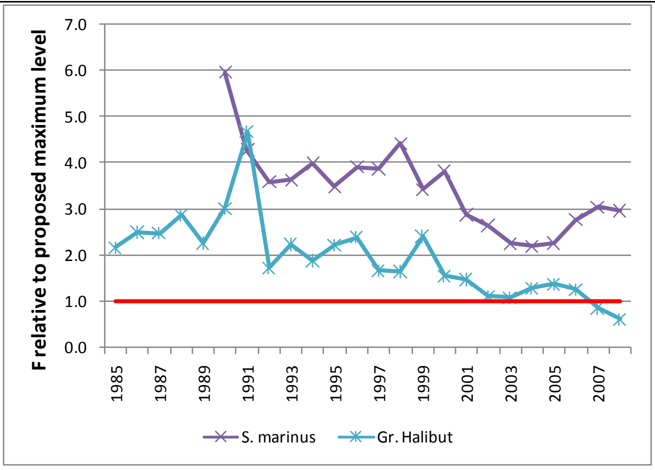


Figure 2. Annual fishing mortalities of Golden redfish (*Sebastes marinus*) and Greenland halibut (*Reinhardtius hippoglossoides*) relative to the proposed maximum levels above which the fishing mortality over time most probably will impair the recruitment (ICES 2009).

- **Current status of the parameter:**
- **Quality objectives:**
- **Reference level:** Target levels (Fpa). The figures shows clearly how a stock is fished relative to a sustainable level (F_{lim})
- **Gaps in data coverage:**
- ***Other issues about the subparameter:***

Contact person/responsible person: Jan Erik Stiansen, IMR

Title: Introduced species (E,I)

About the indicator

- ***Type of indicator: E, I***
- ***Priority of indicator: e***
- ***Rationale:*** Next to climate changes, introduced species represent the largest threat to biodiversity and habitat destruction in the world. Alien species may expel native fauna and cause serious changes in the ecosystem functionality. Exotic species are commonly dispersed by human activities, and ballast water and biofouling are thought to be the most important vectors in the marine environment.

Overview of Parameters

Parameters (name)	***Type (“E”, “A”, or “I”)***	***Priority (“e”, “r” or “s”)***
Distribution and biomass of king and snow crabs	*E,I*	e
Species composition in ballast waters and hull fouling	*E,I*	e
Impact of the king crab	*E,I*	e
Impact of the snow crab	*E,I*	e
Door step species	*E,I*	**s**

Contact person/responsible person: Jan H. Sundet, IMR, Maria Tsiganova, VNIIPrirody

Title: Introduced species (E,I)

Parameter: Distribution and biomass of king and snow crabs

About the parameter

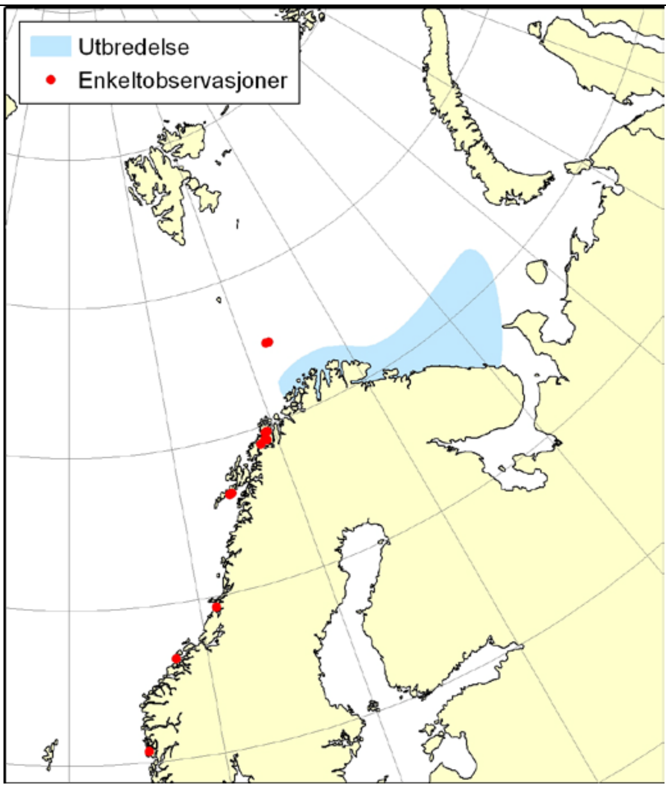
- ***Type of parameter: E, I***
- ***Priority of parameter: e***
- ***Rationale :*** Distribution of the red king and the snow crabs in the Barents Sea are surveyed annually by Russian (PINRO) and Norwegian (IMR) scientists. Today the red king crab seems to inhabit the southern part of the Barents Sea, whilst the snow crab is more northeasterly (Arctic) distributed. So far, most snow crabs are in the Russian part of the Barents Sea, but it is continuously spreading west – and northwestwards in this area.

Overview of the subparameters

Subparameters (name)	*Institution responsible for monitoring*	*Time series period*	*Gaps in monitoring*	*Priority (“e”, “r” or “s”)*
Red king crab distribution in NEZ	*IMR*	*1993 - 2011*		e
Snow crab distribution in NEZ	*IMR*	*2004 -*		e
Red king crab in REZ	*PINRO*	*?*		e
Snow crab distribution in REZ	*PINRO*	*?*		e

Subparameter 1 - Red king crab distribution in NEZ

- **Short facts about the parameter:** The red king crab (*Paralithodes camtschaticus*) is an introduced species to the Barents Sea and is continuously spreading. It is shown to have significant impact on the benthic ecosystem in areas with high densities of crabs.
- **Monitoring:** The distribution of the red king crab is monitored annually both in Norwegian and Russian waters (see figure).
  There are two major management objectives for the red king crab in Norway: to maintain a long term fishery within a quota regulated area (east of 26^{o} E), and to limit the spread of this crab outside the quota regulated area.



Distribution (blue shading) and single observations (red dots) of the red king crab in northeast Atlantic.

Subparameter 2 - Snow crab distribution in NEZ

- **Monitoring:** Joint Norwegian Russian ecosystem survey**.**
- **Current state:** The snow crab (*Chionoecetes opilio*) was recorded for the first time in the Barents Sea in 1996. Its origin is not known and the most prominent hypothesis is that it has migrated north of Siberian coast from the Bering Sea. The crab has increased in abundance, particularly in the eastern Barents Sea (Goose Bank), and seem to adopt a more northerly distribution in the Barents Sea than the red king crab (see figure 1).

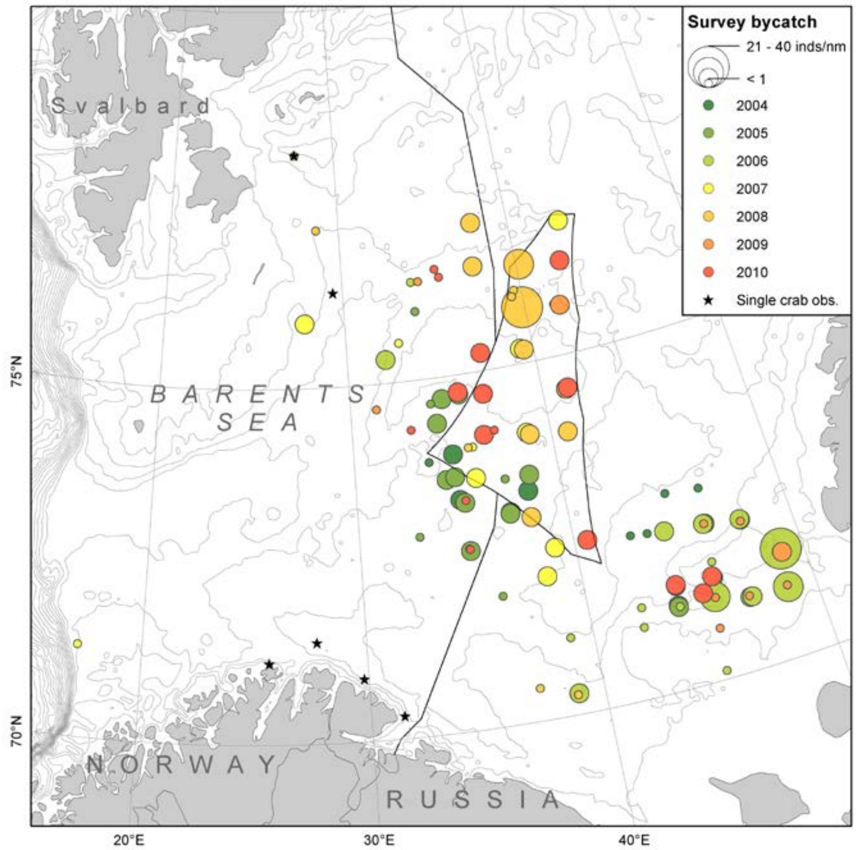


Figure 1. Catch rates of snow crabs in the Barents Sea at Norwegian scientific surveys during 2004 – 2010.

- **Environmental objectives.** Not explicitly developed: In Russia: likely aiming for a sustainable fishery, In Norway: Currently regarded as an NIS, at least for Spitzbergen and close to the Norwegian coast. Decisions on management at the Central bank is pending.

Contact person/responsible person: Jan H. Sundet, IMR, Anders Jelmert, IMR, Maria Tsiganova, VNIIPrirody

Title: Introduced species (E,I)

Parameter: Door step species

About the parameter

- ***Type of parameter: E,I***
- ***Priority of parameter: e***
- ***Rationale :*** Door step species are non-native species with a high potential to be introduced to a region from neighboring areas. Probability for introduction is dependent on possible vectors as well as ecological distance. In the Barents Sea, door step species need to be identified as soon as possible particularly due to the increased ship traffic and petroleum activity in the area. This work should be an obligatory part of the obligatory environmental evaluations done before the start of any petroleum activity.

Overview of the subparameters

Subparameters (name)	*Institution responsible for monitoring*	*Time series period*	*Gaps in monitoring*	*Priority ("e", "r" or "s")*

Subparameter 1 - name

- **Short facts about the subparameter:**
- **Why this is a key subparameter:**
- **Monitoring:**
- **Current status of the subparameter:**
- **Quality objectives**:
- **Reference level:**
- **Gaps in data coverage:**
- **Other issues about the subparameter:**

Contact person/responsible person: Jan H. Sundet, IMR

Title: Introduced species (E,I)

Parameter: Impact of king crab

About the parameter

- ***Type of parameter: I***
- ***Priority of parameter: e***
- ***Rationale :*** Introduced species that becomes invasive may have serious impact on the receiving ecosystem. Therefore, it is important that any anticipated effects of the king crab should be monitored. Since the crab is benthic living it is believed that the most conspicuous impact would be on the benthic ecosystem. Size of area susceptible to be impacted is also an important parameter regarding introduced species. Therefore, monitoring the spread of the king crab is crucial.

Overview of the subparameters

Subparameters (name)	***Institution responsible for monitoring***	***Time series period***	***Gaps in monitoring***	***Priority (“e”, “r” or “s”)***
Monitoring impact on the Barents Sea benthos	*IMR and PINRO*	*2008 -*		e
Monitoring spread of the red king crab	*IMR and PINRO*	*1994 -*		e

Subparameter 1 – Monitoring impact on the Barents Sea benthos

- **Monitoring:** The red king crab is shown to affect the biomass and species diversity of benthos both on the Russian and the Norwegian areas in the southern Barents Sea. Changes in benthos diversity are monitored annually in three fjords in Finnmark by sampling with beam trawl. Study of consequences of king crab introduction in the Barents Sea took place in the Motovsky bay during 2002-2004 and 2005-2007 in the frame of the joint Russian-Norwegian research programs. Based on the results of the study, it was suggested that observed changes in benthic communities in Motovsky bay were likely connected to fishing rather than due to the effects of the king crab population growth. Studies of king crab‘s consumption of fish eggs were conducted in 2001 and showed that crabs consumed 0,03% of total weight of capelin eggs in the Russian economic zone, and that could not have any significant impact on spawning stocks of the capelin. Long term studies of possible trophic competition between king crab and haddock in the Russian part of the Barents Sea during 1971-1977 and 1995-2002 has not shown any impact on haddock. However, during the research of the state of benthic communities of the Murman coast, including Motovsky bay, results indicating changes in the benthic communities’ structure were obtained (Frolova, etc 2003). In the Dal’nezelenetzkiy bay (Eastern Murman), a number of sea urchins have declined when compared to their population numbers before the crab introduction. (Rzhavskiy etc 2004) Decline in numbers and biomass of some species of invertebrates that are crabs’ prey was noted in the same area (Pavlova, 2004) All those changes, however, may be reflective of simple fluctuations in benthic biota. Thus, multiple studies, including some long-term research, show a broad range of results, including contradictory ones. It is obvious that there is a need for further long-term studies. To reach correct conclusions, research should be planned on standardized polygons, with regular monitoring and unified techniques to obtain comparable results.

- **Environmental objectives:** Environmental objectives are defined for Norwegian and Russian EEZ.

Subparameter 2 - Monitoring spread of the red king crab

- **Monitoring:** Westward spread of the red king crab is monitored annually during a trap survey in June.

Contact person/responsible person: Jan H. Sundet, IMR, Anders Jelmert IMR and Maria Tsiganova, VNIIPrirody

Title: Introduced species (E,I)

Parameter: Impact of snow crab

About the parameter

- ***Type of parameter: I***
- ***Priority of parameter: e***
- ***Rationale :*** Introduced species that becomes invasive may have serious impact on the receiving ecosystem. Therefore, it is important that any anticipated effects of the two crab species should be monitored. Since the crab is a benthic living species, it is believed that the most conspicuous impact would be on the benthic ecosystem. Size of area susceptible to the impact is also an important parameter regarding introduced species. Therefore, monitoring the spread of the snow crab species is crucial.

Overview of the subparameters

Subparameters (name)	*Institution responsible for monitoring*	*Time series period*	*Gaps in monitoring*	*Priority (“e”, “r” or “s”)*
Monitoring impact on the Barents Sea benthos	*IMR and PINRO*	*2008 -*		e
Monitoring spread of the snow crab	*PINRO and IMR*	*1996/2004 -*		e

Subparameter 1 – Monitoring impact on the Barents Sea benthos

- Parameter is not fully developed.
- **Monitoring:** The snow crab is believed to affect the biomass and species diversity of benthos both on the Russian and the Norwegian areas in the southern Barents Sea. Changes in benthos diversity should be regularly monitored in these areas.
- **Environmental objectives:** In Russia: Sustainable fishery (?) In Norway: NIS (but depending on NIS status) Environmental objectives would probably be dependent of the NIS-status of the snow crab. (Review indicator when status is clarified).

Subparameter 2 - Monitoring spread of the snow crab

The snow crab appears to reveal a more northerly distribution than the red king crab, and may enter the marine environment around the Svalbard archipelago. Further spread to this area should therefore be monitored regularly. Data from the IMR/PINRO ecosystem surveys are reported annually.

Contact person/responsible person: Jan H. Sundet, IMR, Anders Jelmert IMR, Maria Tsiganova, VNIIPrirody

Title: Introduced species (E,I)

Parameter: Species composition in ballast waters and hull fouling

About the parameter

- ***Type of parameter: I***
- ***Priority of parameter: r***
- ***Rationale :*** Ballast water is by far the most important vector in spreading alien marine species worldwide. Increasing maritime transport in the Arctic region due to climate change, therefore, enhance the potential for introducing new species to these waters. In the Barents Sea there are two potential pathways for introduction via ballast water: from south (Europe) to north (Svalbard), and from east to west through the North-east passage.

Overview of the subparameters

Subparameters (name)	***Institution responsible for monitoring***	***Time series period***	***Gaps in monitoring***	***Priority ("e", "r" or "s")***
Monitoring ballastwater and hull fouling to Svalbard	*IMR*			r
Monitoring ballast water and hull fouling from the Far East	*IMR*			r

Subparameter 1 - Monitoring ballastwater to Svalbard

There is an ongoing project, lead by Inger Alsos, University of Tromsø, which main objectives are to monitor and describe all detectable species from ballast water brought to Svalbard. IMR is a partner in this project, and results are expected to be available in 2014.

Subparameter 2 - Monitoring ballastwater from the Far East

To be developed

Contact person/responsible person: Jan H. Sundet, IMR, Anders Jelmert, IMR, Maria Tsiganova, VNIIPrirody

Title: Meteorological conditions

About the indicator

- ***Type of indicator: E***
- ***Priority of indicator: e***
- ***Rationale:*** The air temperature influences ice conditions and shows the warming and the cooling in the region. The summer Barents Sea air temperature correlates to the ice conditions in the region. The winter temperature correlates to the sea surface temperature (SST). The atmospheric pressure difference between coastlines of Norway and Svalbard is a representative characteristic for estimation of the atmospheric circulation. It can be used as a characteristic of influence of the atmospheric circulation on the regional climate.

Overview of Parameters

Parameters (name)	***Type (“E”, “A”, or “I”)***	***Priority (“e”, “r” or “s”)***
Air temperature	*E*	e
Meteorological pressure indices	*E*	e
Precipitation	*E*	s

Contact person/responsible person: Alexander Smirnov, AARI

Title: Meteorological conditions
Parameter: Air temperature

About the parameter

- ***Type of parameter: E***
- ***Priority of parameter: e***
- ***Rationale:*** The air temperature influences ice conditions and shows the warming and the cooling in the region. The summer BS air temperature correlates to the ice conditions in region. The winter temperature correlates to the sea surface temperature (SST) in the region.

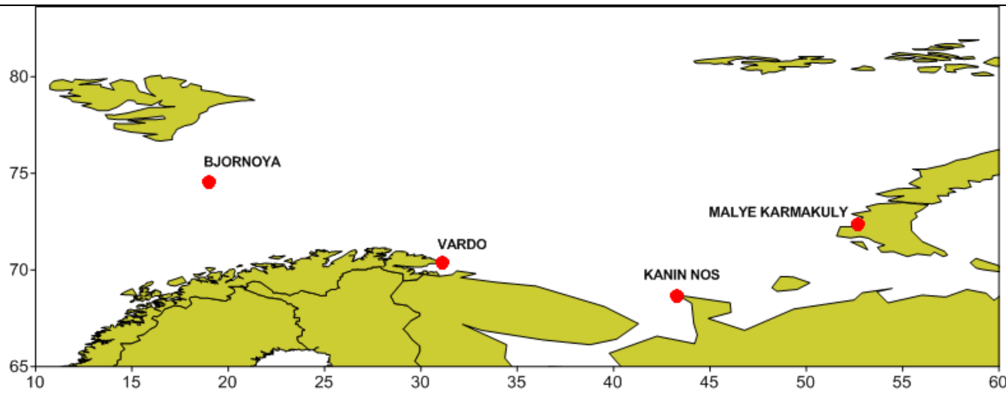
Overview of the subparameters

Subparameters (name)	***Institution responsible for monitoring***	***Time series period***	***Gaps in monitoring***	***Priority ("e", "r" or "s")***
Individual times series	*AARI*	*1926-2011*	*no*	s
Aggregated air temp product from met stations surrounding the Barents Sea	*AARI*	*1926-2011*	*no*	e

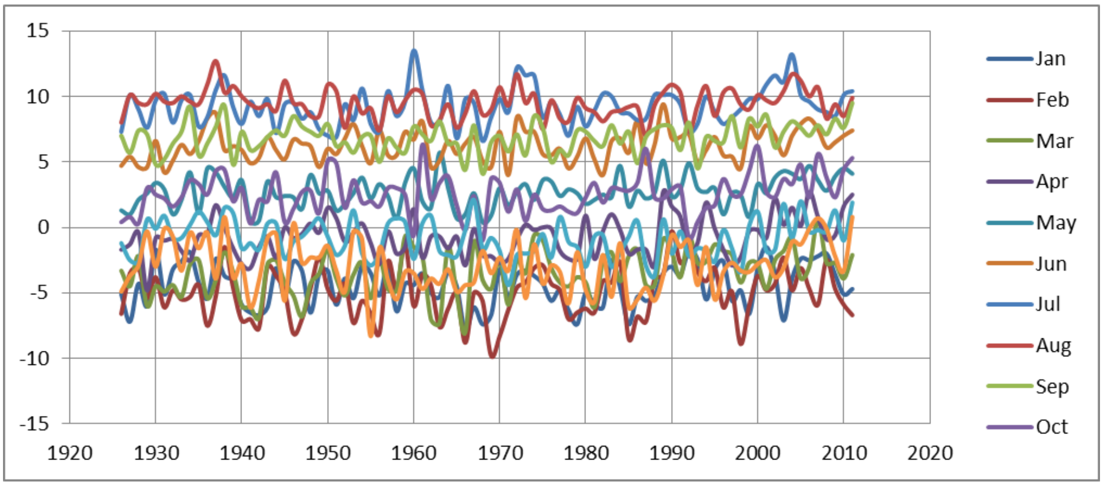
Subparameter 1 - Individual times series

- **Short facts about the subparameter:** Individual time series for four stations around the Barents Sea.

WMO	**Station name**	**Coordinates**
01028	BJORNOYA	74.517N 19.017E
01098	VARDO	70.367N 31.100E
22165	KANIN NOS	68.650N 43.300E
20744	MALYE KARMAKULY	72.367N 52.700E



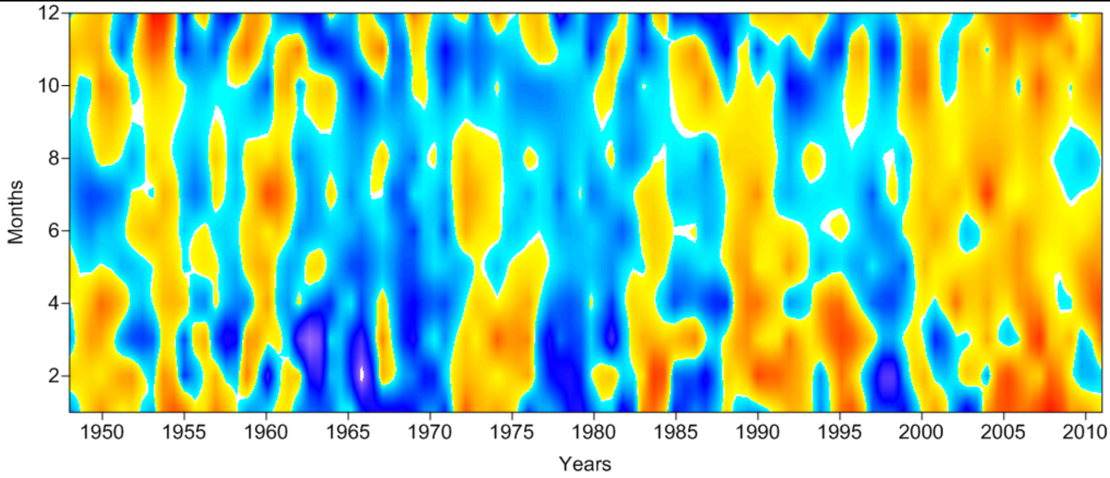
- **Why this is a key subparameter:** The air temperature influences on ice conditions and shows the warming and the cooling in the region.
- **Monitoring:** Monthly mean values of the air temperature.
- **Current status of the subparameter:** example of data for all month for st. VARDO.



- **Quality objectives:**
- **Reference level:**
- **Gaps in data coverage:** No gaps.
- **Other issues about the subparameter:**

Subparameter 2 - Aggregated air temp product from met stations surrounding the Barents Sea

- **Short facts about the subparameter:** Aggregated air temperature product from met stations surrounding the Barents Sea. 1926-2011. Existing stations are Vardø, Bjørnøya (Bear Island)/Hopen, Murmansk, M.Karmakuly, Krenkel, Kanin Nos.
- **Why this is a key subparameter:** The air temperature influences on ice conditions and shows the warming and the cooling in the region.
- **Monitoring:** Averaged air temperature from four meteorological stations (see tbl. 1) converted into anomalies.
- **Current status of the subparameter:** Time diagram shows temperature anomalies in the region.



- **Quality objectives:**
- **Reference level:**
- **Gaps in data coverage:** No gaps.
- **Other issues about the subparameter:**

Contact person/responsible person: Alexander Smirnov, AARI

Title: Meteorological conditions
Parameter: Meteorological pressure indices

About the parameter

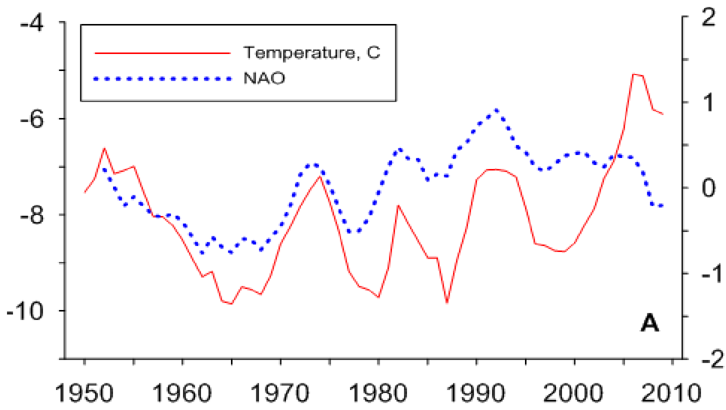
- ***Type of parameter: E***
- ***Priority of parameter: e***
- ***Rationale :*** Meteorological pressure indexes show the transport of warm air into the Barents Sea region from the North Atlantic.

Overview of the subparameters

Subparameters (name)	*Institution responsible for monitoring*	*Time series period*	*Gaps in monitoring*	*Priority ("e", "r" or "s")*
NAO	*AARI*	*1950-2011*	*no*	s
AO	*AARI*	*1899-2011*	*no*	s
Barents Sea Atm. Circ index	*AARI*	*1976-2011*	*no*	e

Subparameter 1 - NAO

- **Short facts about the subparameter:** North Atlantic Oscillation (NAO) is an index of the atmospheric circulation in the Northern Atlantic, which is responsible for the transport of warm air and warm sea water into the Barents Sea region.
- **Why this is a key subparameter:** The North Atlantic oscillation (NAO) is a climatic phenomenon in the North Atlantic Ocean of fluctuations in the difference of atmospheric pressure at sea level between the Icelandic low and the Azores high. Through east-west oscillation motions of the Icelandic low and the Azores high, it controls the strength and direction of westerly winds and storm tracks across the North Atlantic
- **Monitoring:** calculated monthly values.
- **Current status of the subparameter:**

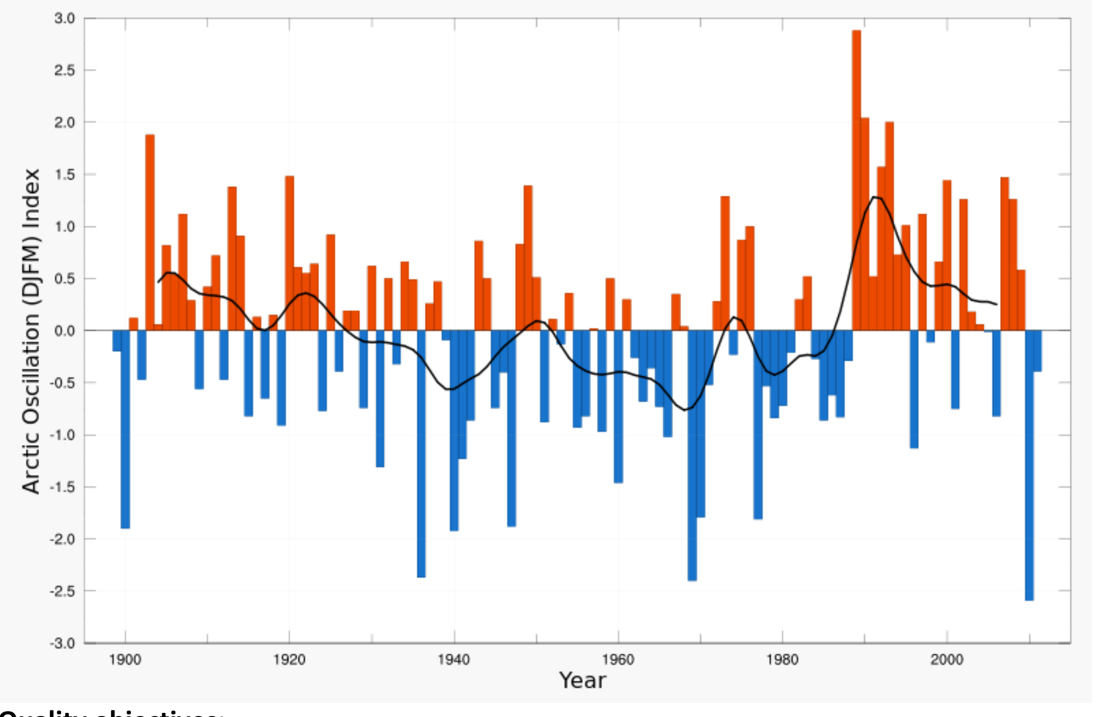


- The figure above shows significant disagreement between the NAO index and the air temperature occurred after 1995. This fact indicates insufficient representativeness of the NAO for the region.

- **Quality objectives:**
- **Reference level:**
- **Gaps in data coverage:** No gaps.
- **Other issues about the subparameter:**

Subparameter 2 - AO

- **Short facts about the subparameter:** The Arctic oscillation (AO) is an index of the dominant pattern of non-seasonal sea-level pressure variations north of 20N latitude, and it is characterized by pressure anomalies of one sign in the Arctic with the opposite anomalies centered about 37–45N.
- **Why this is a key subparameter:** The AO is believed to be causally related to, and thus partially predictive of, weather patterns in locations many thousands of miles away, including many of the major population centres of Europe and North America.
- **Monitoring:** calculated monthly values.
- **Current status of the subparameter:**



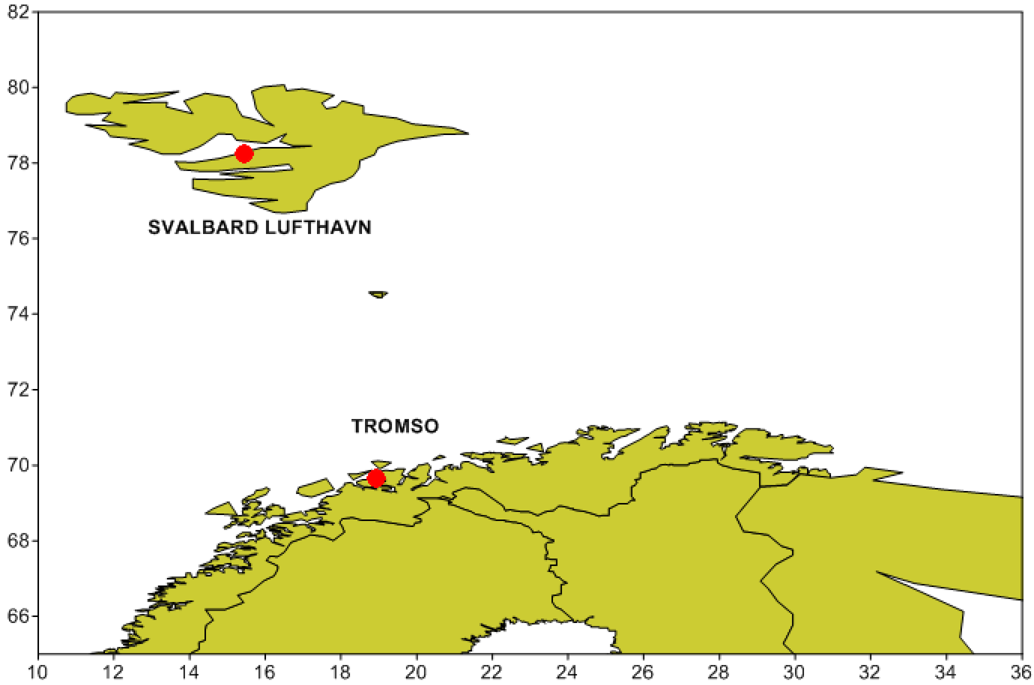
- **Quality objectives:**
- **Reference level:**
- **Gaps in data coverage:** No gaps
- **Other issues about the subparameter:**

Subparameter 3 – Barents Sea atmospheric circulation

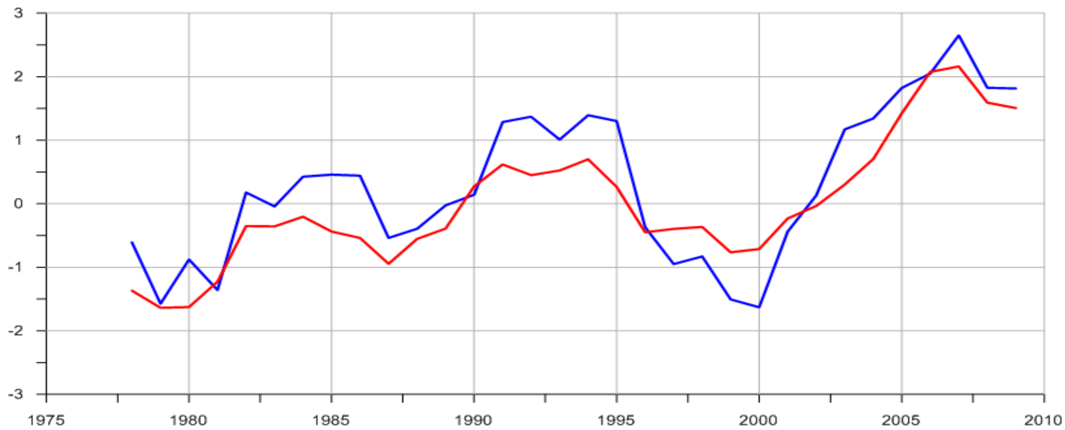
- **Short facts about the subparameter:** Barents Sea atmospheric circulation is the atmospheric pressure difference between northern Norway and Svalbard.

WMO	Station name	Coordinates

10080	SVALBARD LUFTHAVN	78.250N 15.467E
90450	TROMSO	69.649N 18.955E



- **Why this is a key subparameter:** The Barents Sea Index is a characteristic of influence of the atmospheric circulation on the regional climate.
- **Monitoring:** calculated monthly values.
- **Current status of the subparameter:**



- There is a significant correlation between atmospheric pressure difference (Tromso – Svalbard, blue curve) and the air temperature (red curve). The atmospheric pressure difference between coastlines of Norway and Svalbardas is suggested as a characteristic of influence of the atmospheric circulation on the regional climate.
- **Quality objectives:**
- **Reference level:**
- **Gaps in data coverage:** No gaps.
- **Other issues about the subparameter:**

Contact person/responsible person: Alexander Smirnov, AARI

Title: Meteorological conditions
Parameter: Precipitation

About the parameter

- ***Type of parameter: E***
- ***Priority of parameter: s***
- ***Rationale :*** Precipitation is the general term for rainfall, snowfall and other forms of frozen or liquid water falling from clouds. Precipitation is intermittent, and the character of the precipitation when it occurs depends greatly on temperature and the weather situation. Precipitation is a major component of the water cycle, and is responsible for depositing the fresh water onto the region. Also, as climate changes, several direct influences alter precipitation amount, intensity and frequency.

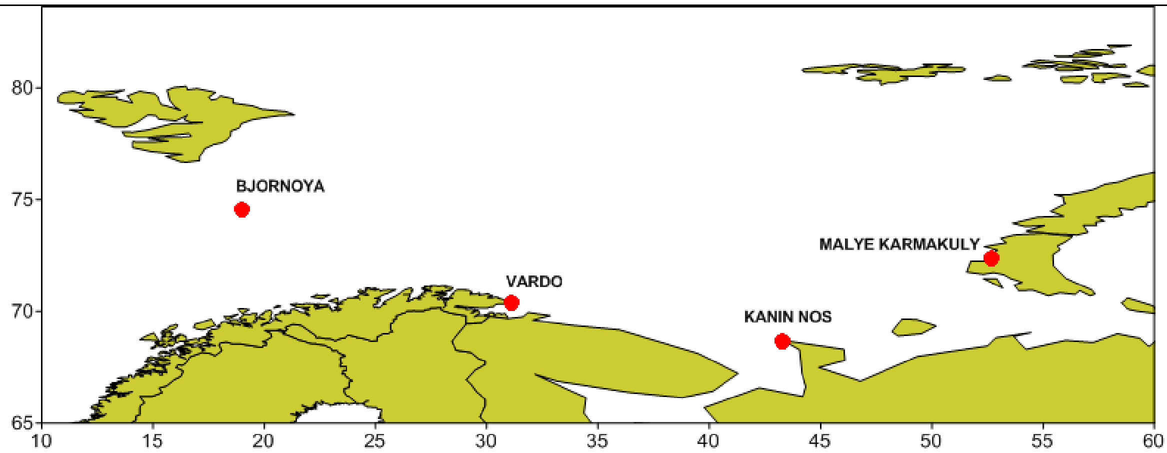
Overview of the subparameters

Subparameters (name)	*Institution responsible for monitoring*	*Time series period*	*Gaps in monitoring*	*Priority ("e", "r" or "s")*
Rain+Snow	*AARI*	*1926-2011*	*no*	e

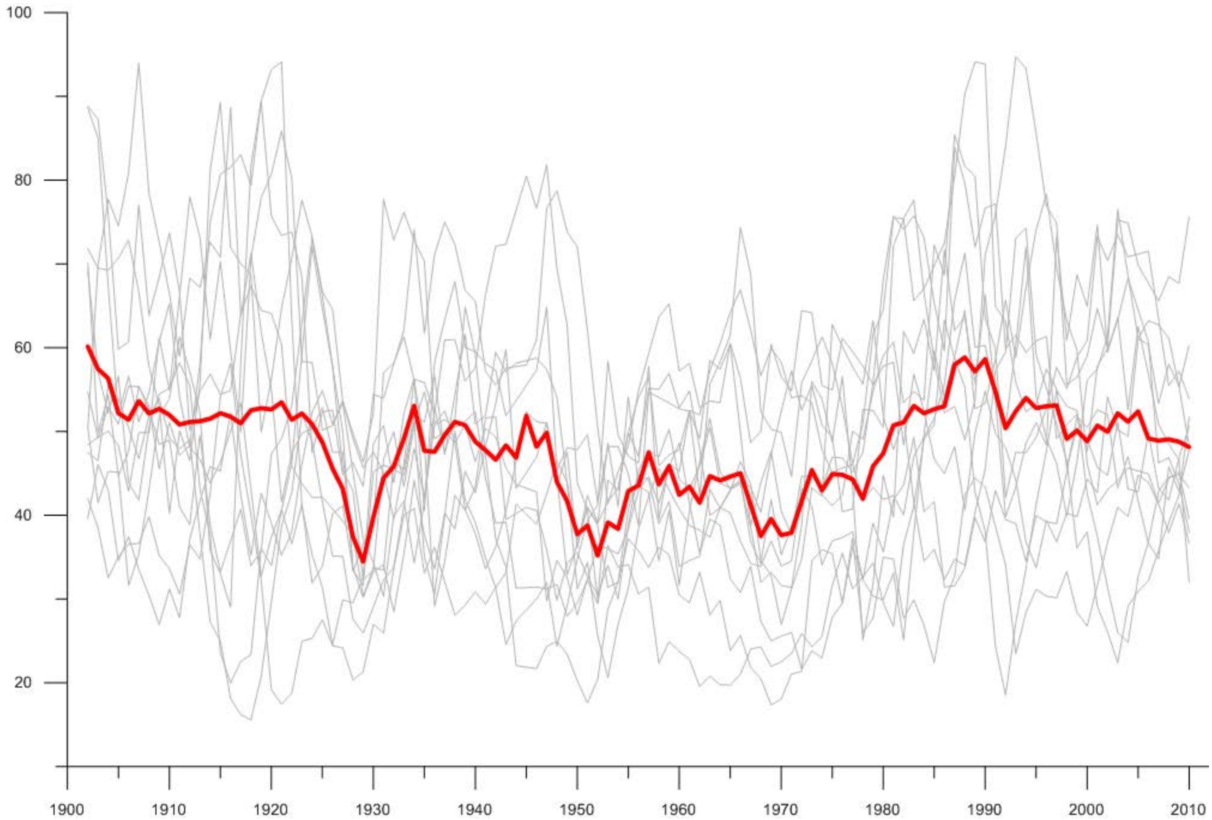
Subparameter 1 - Precipitation

- **Short facts about the subparameter:** Individual time series for four stations around the Barents Sea.

WMO	Station name	Coordinates
01028	BJORNOYA	74.517N 19.017E
01098	VARDO	70.367N 31.100E
22165	KANIN NOS	68.650N 43.300E
20744	MALYE KARMAKULY	72.367N 52.700E



- **Why this is a key subparameter:** Precipitation is a major component of the water cycle, and is responsible for depositing the fresh water onto the region
- **Monitoring:** Monthly mean values of the precipitation
- **Current status of the subparameter:** example of data for all month for st. VARDO



- **Quality objectives:**
- **Reference level:**
- **Gaps in data coverage:** no gaps
- ***Other issues about the subparameter:***

Contact person/responsible person: Alexander Smirnov (AARI)

Title: Microbes (archaea and bacteria) biomass and diversity (E)

About the indicator

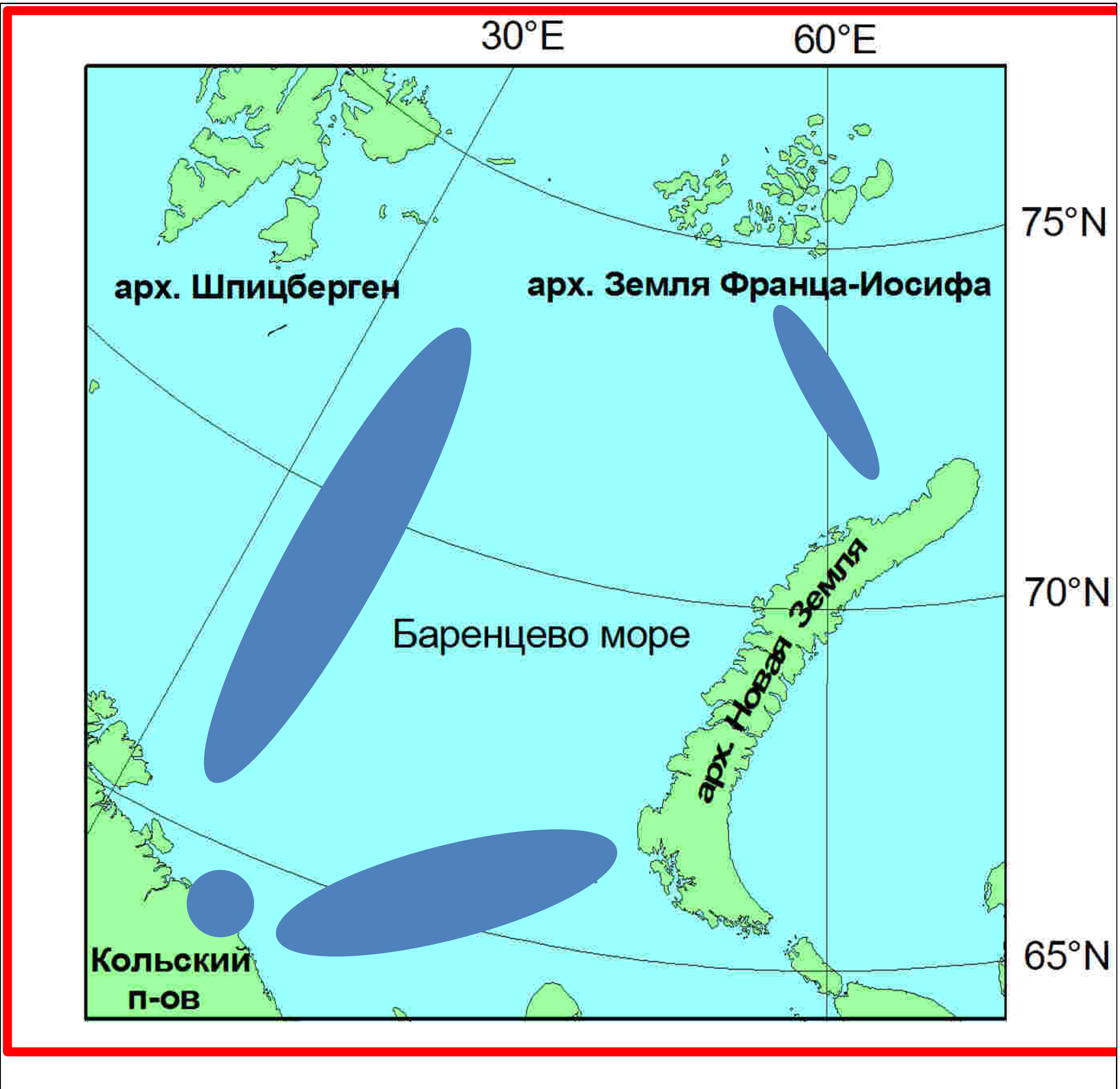
- ***Type of indicator: E***

- ***Priority of indicator: e***

- ***Rationale:*** The procaryotic bacteria and archaea, as a result of their diversity and unique types of metabolism, are involved in the cycles of virtually all essential elements. Bacteria play an important role in the microbial loop, which constitutes a set of trophic pathways in the marine microbial food web where dissolved organic carbon (DOC) is returned to higher trophic levels via the incorporation into bacterial biomass, and coupled with the classic food chain formed by phytoplankton-zooplankton-nekton.
  We may assume that bacterial communities have sensitive reactions to environmental changes. However, approach to the microbial studies and drawn conclusions differ significantly between Norway and Russia.
  Norwegian scientists claim that the bacterial number is not a sensitive indicator of environmental changes based on a decade of consistent research on the distribution of bacterial number in the marine environment, which shows that total microbial abundance vary only between 10^5 and 10^6 cells ml^{-1}.
  However, long-term observations by the Russian scientists demonstrate that the number of bacteria in the sea water may vary by two orders of magnitude and thus support the use of bacterial counts as an indicator of pollution level in the environment.
  Genetic markers show promising potential as monitoring tools, because genetic response is both fast and specific genes can be detected by very sensitive methods. However, probes suitable for monitoring need to be tailored for specific purposes, and no such probes are available to monitor general environmental changes. Moreover, the development in the field of genetics and genetic methodology is very fast, and therefore methods looking very promising today may well be very old fashioned in near future.
  The indicator must be further developed, given the present differences in approach.

- ***Monitoring:***
  Areas suggested for monitoring:
- The Kola Section – the highest priority, because of its long research history
- Franz-Josef Land – interesting water flows out of the Arctic Ocean
- Novaya Zemlya – opening of the White Sea to the Barents Sea
- Spitsbergen archipelago – the northern part, highly touristic

- ***Frequency:***
- Once a year – October-November
- Or all seasons: 1 winter, 2 spring, 1 summer, 1 autumn (5 times a year)



Overview of parameters

Parameters (name)	*Type (“E”, “A”, or “I”)*	*Priority (“e”, “r” or “s”)*
Total bacterial cell number	*E*	s
Average cell volume	*E*	s
Bacterial biomass	*E*	s
Morphological structure	*E*	*s*
Live-dead count	*E*	*s*
Production rate	*E*	*s*
Genetic structure	*E*	*s*

Parameter 1: Total bacterial cell number

Bacterial cell number is a basic variable in the analysis of microbial communities, and has been quantified in a variety of environments since the 1970s. It is essential because combined with cell volume and production rate it allows to calculate growth rates. The growth rates show much higher sensitivity than cell count. Bacterial cell number is traditionally measured by epiflourescence microscopy, but the counting is currently frequently replaced with flow cytometry.

Parameter 2: Average cell volume

Average cell volume is slightly related to trophic status, and is necessary to estimate biomass, which is calculated from cell number and average cell volume. Average cell volume is traditionally measured by epiflourescene microscopy, but this is currently frequently replaced with flow cytometry.

Parameter 3: Bacterial biomass

Bacterial biomass is calculated from the total cell count and their average cell volume.

Parameter 4: Morphological structure

Additional information can be obtained by recording the morphologies observed in the bacterial communities from microscopic analysis.

Parameter 5: Live—dead count

Live and dead counts can be obtained by a variety of staining methods, combined with epifluorecence microscopy. This approach is necessary to obtain additional information to the total cell count. By recording the fraction of the total number of live cells (with intact cell membranes or showing the presence of active metabolism), added value is obtained for the total counts.

Parameter 6: Production rate

The total heterotrophic bacterial activity in a sample is reflected in the bacterial production rate, which can be measured using radioactive tracers. The most common tracers are tritated thymidine and carbon 14 labeled leucine, or a combination of the two. The use is currently somewhat decreasing because of restrictions in the use of radioisotopes. The method is fairly time consuming, but still essential to get a full description of the basic status of a microbial community.

Parameter 7: Genetic structure

All environmental factors act as selection pressure on the gene level, and genetic analysis may provide the ultimate method to identify specific environmental factors, for example the influence of specific toxic substances. Also on a broader perspective genetic analysis provide a massive amount of information, and such methods are fast developing. In the context of monitoring, the choice of method will have to rely on the specific aim of the monitoring programme.

Contact person/responsible person:
Tatiana Shirokolobova (MMBI)
Knut Yngve Børsheim (IMR)

Title: Ocean Acidification and ocean CO2 uptake

About the indicator

- ***Type of indicator: E,I***

- ***Priority of indicator: e***

- ***Rationale :*** The ocean has taken up between 30 to 50% of the human induced CO_2. This has led to a pH decrease and a decrease in carbonate ion concentration ($[CO_3^{2-}]$). Together with Calcium, $[CO_3^{2-}]$ are part of the formation of calcium carbonate ($CaCO_3$) that is used to form shells and skeleton for marine organisms. This may have large consequences for calcifying marine organisms. Since calcium is in excess in the ocean, the $CaCO_3$ dissolution is controlled by the CO_3^{2-} concentration. The most labile form of $CaCO_3$ is aragonite, hence aragonite-forming organisms are particularly at risk. In that sense we can understand the "ocean acidification" state by investigating the $[CO_3^{2-}]$ and the $CaCO_3$ saturation (Ω). This can bet determined by measuring two out of four measurable parameters in the oceans carbonate system (also referred as the marine CO_2 system). Ω is a measure of the dissolution of $CaCO_3$. If Ω is < 1 it means that $CaCO_3$ will dissolve. An Ω> 1 means that the formed $CaCO_3$ will stay in solid state.

  Ω and $[CO_3^{2-}]$ is calculated using A_T, C_T, nutrients, salinity, temperature and pressure together with a chemical speciation model. The ocean CO_2 system is affected by biological processes such as primary production bacteria respiration and calcification, air-sea CO_2 exchange, temperature and physical processes such as upwelling of deep-water, vertical and horizontal advection, sea-ice formation/melt, river runoff, anthropogenic CO_2 in the atmosphere. That means that there is a large natural seasonal and interannual variability. Long-term monitoring is required to discern the change due to increased CO_2 and its impact on OA state.

Overview of Parameters

Parameters (name)	***Type (“E”, “A”, or “I”)***	***Priority (“e”, “r” or “s”)***
Total Alkalinity (AT)	*E*	*e*
Total Inorganic Carbon (CT)	*E*	*e*
Calcium carbonate saturation (Ω)	*E*	*e*
pH in situ	*E*	*r*
Partial pressure of CO2 (pCO2)	*E*	*s*

Contact person/responsible person: Melissa Chierici, Ph.D, Institute of Marine Research

Title: Ocean Acidification and ocean CO_2 uptake

Parameter: Calcium carbonate saturation (Ω)

About the parameter

- ***Type of parameter: E***
- ***Priority of parameter: e***
- ***Rationale :*** Calcium carbonate saturation (Ω) is a measure of the dissolution of solid calcium carbonate ($CaCO_3$) forms of calcite or aragonite $CaCO_3$. The dissolution is controlled by the concentration of carbonate ions, which has decreased as a result of ocean acidification. If Ω is < 1 it means that $CaCO_3$ will dissolve, and Ω> 1 means that the formed $CaCO_3$ will stay in solid state. Thus Ω has relevance for the calcification process and changes in Ω may effect the formation of shells and skeleton by organisms. Aragonite is the least stable form of $CaCO_3$, thus aragonite forming organisms (e.g. pteropods, cold water corals) are likely the most vulnerable.

Ω cannot be measured directly and is calculated from two other CO_2 system parameters, preferably A_T and C_T.
Ω is affected by changes in freshwater content, temperature, salinity, primary production, respiration, upwelling, physical mixing, air-sea CO_2 exchange. Long-term monitoring of Ω (through measurements of other CO_2 system parameters) are necessary to estimate the impact of anthropogenic and natural processes.

Overview of the subparameters

Subparameters (name)	***Institution responsible for monitoring***	***Time series period***	***Gaps in monitoring***	***Priority (“e”, “r” or “s”)***
Calculated from AT and CT FB, VN, Kola, Kanin)	*IMR (FB, VN) and PINRO*	*IMR started repeated transect FB in 2010.*	*No data in eastern and northern Barents Sea, long term monitoring required.*	e
Calculated from AT and CT northern Barents Sea (defined Arctic water box, scientific surveys)	*IMR and PINRO*		*No data in Arctic water and need information in marginal ice zone*	e
Calculated from pH and pCO_2 on mooring	*IMR investigate possibilities*			s

Subparameter 1 - calculated from AT and CT FB, VN, Kola, Kanin)

Ω calculated from AT and CT along fixed transects FB, VN, Kola, Kanin)

- **Short facts about the subparameter:** Long-term monitoring of AT and CT along repeated transects in the Barents Sea. Fugløya-Bjørnøya, Vardø-North, Kola and Kanin (Figure 1). Long-term monitoring required.
- **Why this is a key subparameter:** F-B transect covers the Barents Sea opening which is used to investigate the inflow of Atlantic water to the Barents Sea and the Arctic. Vardø-north and Kola, Kanin transects covers the marginal ice zone, the Arctic water and the Atlantic water outflow to the Kara Sea. Important to understand the effect of climate change on the CO_2 system dynamics, oceanic CO_2 uptake and ocean acidification.

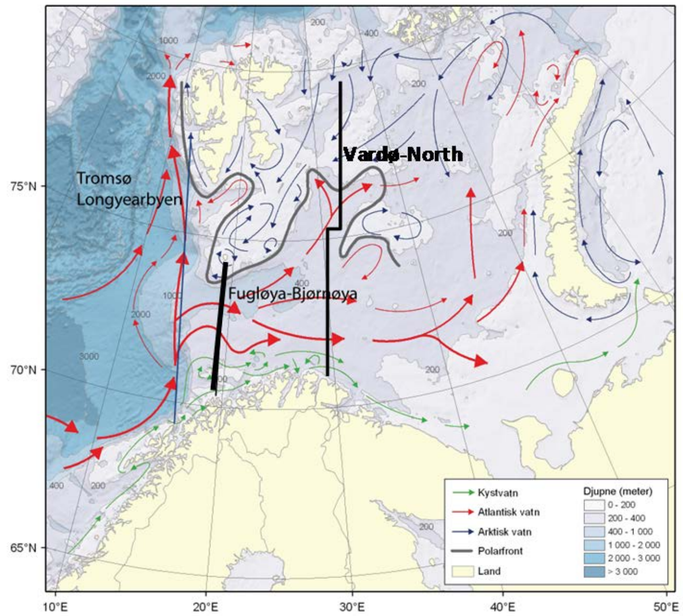


Figure 1. Schematic overview of the circulation pattern and different water masses in the Barents sea. The black lines show the repeated transects that IMR have initiated sampling and measurements for OA studies and oceanic CO_2 uptake.

- **Monitoring:** Sampling of the water column for AT and CT at standard depths from CTD-Niskin bottle system onboard research vessels. Either measured directly onboard or preserved for post-cruise analysis at laboratory. IMR F-B transect started sampling and measurements in 2010. IMR will be responsible for Vardø-N (VN). PINRO responsible for Kola, Kanin. Important to capture the conditions before and after the bloom. Typically winter and late summer, resulting in sampling at least twice annually. The sampling month can show regional differences. Depending on sea-ice cover and bloom situation.
- **Current status of the subparameter:** FB sampled AT and CT twice annually by IMR,Vardø-N initiated by IMR 2012. The parameter shows large variability in relation to physical and biological processes in the BSO. Need more and longer time series to estimate the development and seasonal patterns.
- **Quality objectives:** The aimed precision and accuracy for AT and CT is ±1 µmol/kg. Accuracy is controlled by the use of international recognized certified reference material (CRM). This follows the standards of the international CO_2 system (UNESCO-IOCCP) and ocean acidification community described in Dickson et al., 2007.
- **Reference level:** $CaCO_3$ saturation (Ω) < 1 means calcium carbonate shell dissolution, which

is taken as a threshold level. Most organisms require higher Ω to be able to form $CaCO_3$ shell and skeleton.

- **Gaps in data coverage:** few or no data in the northern and eastern part of the Barents Sea. Need more data to cover the influence of changes in the marginal ice-zone and at the outflow to the Arctic.
- **Other issues about the subparameter:** Calculated from two CO_2 system parameters, salinity, temperature, depth and nutrients.

Subparameter 2 - calculated from AT and CT northern Barents Sea (defined Arctic water box, scientific surveys)

calculate Ω from AT and CT northern Barents Sea (defined Arctic water box, scientific surveys)

Sampling for Arctic water is necessary to cover changes in the distribution of Atlantic and Arctic water. Same type of monitoring, sampling and motivation as for subparameter 1. Arctic water is colder and fresher and has already a relatively low Ω. Increased uptake or change in freshwater addition, and physical upwelling may induce further decrease in Ω. This means that the Arctic region is particularly vulnerable for increased ocean CO_2.

Subparameter 3 - calculated from pH and pCO_2 on mooring

Ω calculated from pH and pCO_2 on mooring
Automated measurements of pH and pCO_2 sensors deployed on moorings at strategic locations in the BS, such as the BSO, exit towards the Kara Sea, northern part.
Need to calibrate the sensors with conventional water column sampling and measurements of CT and AT, pH, using existing state-of-the-art methods and certified reference material.
Precision and accuracy is estimated to ±15 µatm for pCO_2.
Valuable to cover interannual and seasonal variability which cannot be covered using research vessels.

Contact person/responsible person: Melissa Chierici, IMR

Title: Ocean Acidification and ocean CO_2 uptake

Parameter: Partial pressure of CO_2 (pCO_2)

About the parameter

- ***Type of parameter: E***
- ***Priority of parameter: s***
- ***Rationale :*** The partial pressure of CO_2 (pCO_2) is a measure of the dissolved carbon dioxide gas content . Increased ocean CO_2 has lead to increased pCO2. Since pCO_2 is highly dependent on temperature, high-quality temperature measurements have to be performed in conjunction with pCO_2 measurements. pCO_2 is affected by changes in air-sea CO_2 exchange, temperature, salinity, primary production, respiration, physical upwelling and mixing, and freshwater content. pCO_2 instrumentation is used onboard volunteer observing ships to estimate the ocean's CO_2 uptake. Measuring pCO_2 using continuous system is fast and when used onboard VOS ships can cover large temporal variability. Large effort into developing pCO_2 sensors for autonomous measurements on buoys and moorings. Long-term monitoring of pCO_2 can be used to deduce the anthropogenic or natural processes behind oceans carbon dioxide uptake. International pCO_2 network has resulted in climatology for ocean CO_2 uptake and the role of the oceans in the global CO_2 cycle. Necessary to calibrate the instrument using traceable to internationally agreed gas standards. Note, one more CO_2 system parameter needs to be measured for pCO_2 to be useful in direct ocean acidification studies. pCO_2 and pH gives the largest error in calculated Ω and pH.

Overview of the subparameters

Subparameters (name)	*Institution responsible for monitoring*	*Time series period*	*Gaps in monitoring*	*Priority ("e", "r" or "s")*
pCO_2 sensor on mooring				s

Subparameter 1 - pCO_2 sensor on mooring

- Partial pressure of carbon dioxide is generally used onboard research vessels and ship of opportunity to measure the pCO_2 in the surface water. Together with knowledge of the atmospheric pCO_2 level and wind speed, the air-sea CO_2 flux and ocean CO_2 uptake can be estimated.

- **Why this is a key subparameter:** Together with knowledge of the atmospheric pCO_2 level and wind speed, the air-sea CO_2 flux and ocean CO_2 uptake can be estimated. Follow long-term trend in both water and air to understand the anthropogenic CO_2 uptake.
- **Monitoring:** Either as a sensor on board a research vessel for surface ocean CO_2

measurements or deployed on a mooring for good temporal coverage. Together with another parameter or data on total alkalinity it is possible to use AT and salinity relationships to deduce the AT, which is used together with pCO_2 to estimate the pH in situ or $CacO_3$ saturation level) Ω).
Sensors are under development and needs to be tested with conventional pCO_2 instrumentation or AT, CT, pH measurements.

- **Current status of the subparameter:** pCO_2 on board ship-of-opportunity between Tromsø and Longyear yen exists, but needs improved quality checks. Large variability due to changes in biological and physical processes and temperature.
- **Quality objectives:** aimed precision is ±1µatm, current level is ±15µatm. Challenges for proper calibration of sensors.
- **Reference level:** No obvious reference level. Follow long-term trend in both water and air to understand the anthropogenic CO_2 uptake.
- **Gaps in data coverage:** Few pCO_2 data points in the Barents Sea. A sensor on mooring at specific locations is powerful to achieve improved temporal coverage.
- **Other issues about the subparameter:** Need one more parameter to be able to estimate pH in situ and Ω.

Contact person/responsible person: Melissa Chierici, IMR

Title: Ocean acidification and ocean CO_2 uptake

Parameter: pH *in situ*

About the parameter

- ***Type of parameter: E***

- ***Priority of parameter: r***

- ***Rationale :*** pH is a measure of the oceans hydrogen ion concentration, "acidity" (i.e. activity). Increased ocean CO_2 has lead to decrease in pH and carbonate ion concentration. pH is affected by changes in air-sea CO_2 exchange, temperature, primary production, respiration, physical upwelling and mixing, and freshwater content. Hydrogen ions are used by organisms in a number of cell regulatory processes such as the proton-pump and protein synthesis. A change in pH could thus affect the organism on a cellular level. pH is also used to investigate the oceans CO_2 uptake. Measuring pH is fast and relatively easy (spectrophotometry is preferable) and it is likely that pH sensors will be the first to become available as autonomous sensors for long-term monitoring on buoys and moorings. Recently new standards have been developed to quality assure pH measurements, which has not been available previously.

Overview of the subparameters

Subparameters (name)	***Institution responsible for monitoring***	***Time series period***	***Gaps in monitoring***	***Priority ("e", "r" or "s")***
In fixed transects (FB, VN, Kola, Kanin)	*IMR (FB, VN) and PINRO*	*Not started*	*No data in eastern and northern Barents Sea, long term monitoring required.*	e
From northern Barents Sea (defined Arctic water box, scientific surveys)	*IMR and PINRO*		*No data in Arctic water and need information in marginal ice zone*	E
pH sensor on moorings	*IMR investigate possibilities in 2012*			s

Subparameter 1 – in fixed transects (FB, VN, Kola, Kanin)

pH in situ is calculated from measured pH and either AT and CT along fixed transects FB, VN, Kola, Kanin). pH should be measured spectrophotometrically.

- **Short facts about the subparameter:** Long-term monitoring of AT and CT, along repeated transects in the Barents Sea. Fugløya-Bjørnøya, Vardø-North, Kola and Kanin (Figure 1). Long-term monitoring required.

- **Why this is a key subparameter:** F-B transect covers the Barents Sea opening which is used to investigate the inflow of Atlantic water to the Barents Sea and the Arctic. Vardø-north and Kola, Kanin transects covers the marginal ice zone, the Arctic water and the Atlantic water outflow to the Kara Sea. Important to understand the effect of climate change on the CO_2 system dynamics, oceanic CO_2 uptake and ocean acidification.

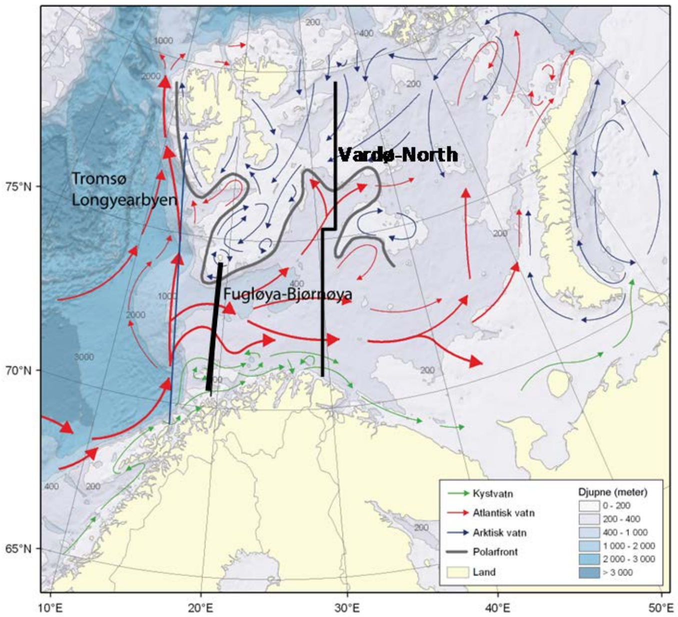


Figure 1. Schematic overview of the circulation pattern and different water masses in the Barents sea. The black lines show the repeated transects that IMR have initiated sampling and measurements for OA studies and oceanic CO_2 uptake.

- **Monitoring:** Sampling of the water column for pH spectrophotometric measurements together with AT and CT at standard depths from CTD-Niskin bottle system onboard research vessels. Either measured directly onboard or preserved for post-cruise analysis at laboratory. IMR F-B transect started sampling and measurements in 2010. IMR will be responsible for Vardø-N (VN). PINRO responsible for Kola, Kanin. Important to capture the conditions before and after the bloom. Typically winter and late summer, resulting in sampling at least twice annually. The sampling month can show regional differences depending on sea-ice cover and bloom situation.
- **Current status of the subparameter:** FB sampled AT and CT, calculated pH in situ twice annually by IMR,Vardø-N initiated by IMR 2012. The parameter shows large variability in relation to physical and biological processes in the BSO. Need more and longer time series to estimate the development and seasonal patterns.
- **Quality objectives:** The aimed precision is ±0.001 and accuracy for pH is ±0.003. Accuracy is controlled by the use of international recognized certified reference material (CRM). This follows the standards of the international CO_2 system (UNESCO-IOCCP) and ocean acidification community described in Dickson et al., 2007.
- **Reference level:** no reference level possible, depend on the full CO_2 system.
- **Gaps in data coverage:** few or no data in the northern and eastern part of the Barents Sea. Needs more data to cover the influence of changes in the marginal ice-zone and at the outflow to the Arctic.
- **Other issues about the subparameter:** Need one more CO_2 system parameter (preferably AT), salinity, temperature , pressure to calculate pH In situ. Should also use the certified

reference material for pH which has been available recently. pH should be measured spectrophotometrically which is the most recognized method at the time.

Valuable to measure three parameters in the CO_2 system for internal consistency and quality checks. The system is over determined which is an extra quality control on the measured parameters in addition to CRM. Spectrophotometric pH is a fast and reliable measurements method which can be used to measure surface water underway to achieve good spatial coverage.

Subparameter 2 - from northern Barents Sea (defined Arctic water box, scientific surveys)

Measurements of pH in the northern Barents Sea (defined Arctic water box, scientific surveys)

Sampling for Arctic water is necessary to cover changes in the distribution of Atlantic and Arctic water. Same type of monitoring, sampling and motivation as for subparameter 1. Arctic water is colder and fresher and has already a relatively low pH. Increased uptake or change in freshwater addition, and physical upwelling may induce further decrease in pH. This means that the Arctic region is particularly vulnerable for increased ocean CO_2.

Subparameter 3 – pH sensor on moorings

pH in situ on mooring

Enables high temporal coverage at specific strategically chosen locations such as the BSO, exit towards the Kara Sea, northern part.
Powerful together with pCO_2 sensors and other biogeochemical parameters on the same mooring and depth to follow the biological and physical processes affecting pH.

Need to calibrate the sensors with conventional water column sampling an measurements of CT and AT, pH. Using existing state-of-the-art methods and certified reference material.
Valuable to cover interannual and seasonal variability which cannot be covered using research vessels.

Contact person/responsible person: Melissa Chierici, IMR

Title: Ocean Acidification and ocean CO_2 uptake

Parameter: Total Alkalinity (AT)

About the parameter

- ***Type of parameter: E***
- ***Priority of parameter: e***
- ***Rationale :*** Total Alkalinity (A_T) is a measure of the charge balance and gives information on the buffering capacity against acid input. OA has resulted in decreased concentration of carbonate ions ($[CO_3^{2-}]$). A_T is not affected directly by CO_2 (since that is an uncharged molecule). A_T is one of four parameters that can be measured directly to study the oceans carbonate system. A_T is more conservative with salinity and less affected than C_T by direct CO_2 exchange primary production/respiration than C_T. A_T is affected by calcification, and physical processes such as upwelling of deep-water, vertical and horizontal advection, sea-ice formation/melt, river runoff. The ratio between A_T and C_T gives relevant information on changes in carbonate system which is due to changes in either $[CO_3^{2-}]$ or CO_2 used to estimate the influence of anthropogenic or natural processes on OA state. Long-term monitoring is required to discern the change due to increased CO_2 and its impact on OA state. Uptake of anthropogenic CO_2 in the atmosphere will change the carbonate chemistry (lower pH and carbonate ion concentration and lead to increased ocean acidification. A_T is together with total inorganic carbon the most preferable parameter to be used in calculation of carbonate concentration and calcium carbonate saturation (Ω) of aragonite and calcite, which is a key indicator for calcifying organisms and to investigate the ocean acidification state. Methods for the measurements on C_T and A_T can be quality assured and are state-of-art .

Overview of the subparameters

Subparameters (name)	***Institution responsible for monitoring***	***Time series period***	***Gaps in monitoring***	***Priority ("e", "r" or "s")***
In fixed transects (FB, VN, Kola, Kanin)	*IMR (FB, VN) and PINRO*	*IMR started repeated transect FB in 2010.*	*No AT data in eastern and northern Barents Sea, long term monitoring required.*	e
From northern Barents Sea (defined Arctic water box, scientific surveys)	*IMR and PINRO*		*No data in Arctic water and need information in marginal ice zone*	e

Subparameter 1 - in fixed transects (FB, VN, Kola, Kanin)

AT in fixed transects (FB, VN, Kola, Kanin)

- **Short facts about the subparameter:** Long-term monitoring along repeated transects in the Barents Sea. Fugløya-Bjørnøya, Vardø-North, Kola and Kanin (Figure 1). Long-term monitoring required.
- **Why this is a key subparameter***:* F-B transect covers the Barents Sea opening which is used to investigate the inflow of Atlantic water to the Barents Sea and the Arctic. Vardø-North and Kola, Kanin transects covers the marginal ice zone, the Arctic water and the Atlantic water outflow to the Kara Sea. Important to understand the effect of climate change on the CO_2 system dynamics, oceanic CO_2 uptake and ocean acidification.

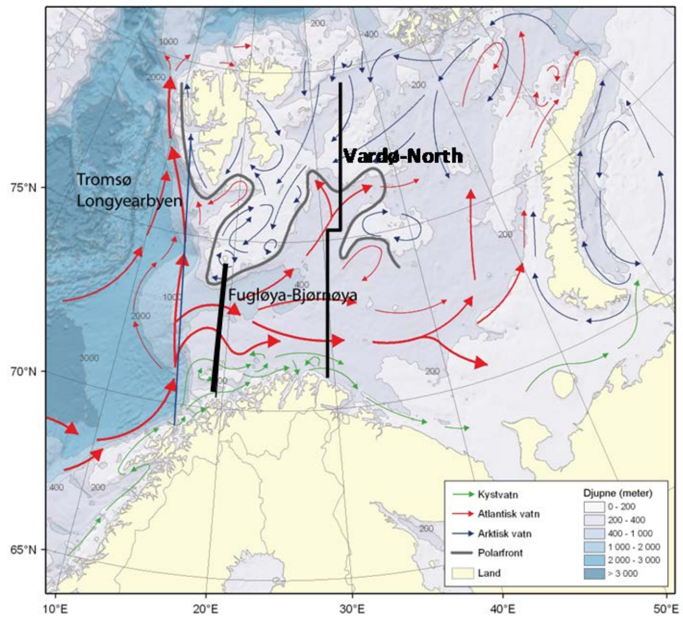


Figure 1. Schematic overview of the circulation pattern and different water masses in the Barents sea. The black lines show the repeated transects that IMR has initiated sampling and measurements for OA studies and oceanic CO_2 uptake.

- **Monitoring:** Sampling of the water column and standard depths from CTD-Niskin bottle system onboard research vessels. Either measured directly onboard or preserved for post-cruise analysis at laboratory. IMR F-B transect started sampling and measurements in 2010. IMR will be responsible for Vardø-N (VN). PINRO responsible for Kola, Kanin. Important to capture the conditions before and after the bloom. Typically winter and late summer, resulting in sampling at least twice annually. The sampling month can show regional differences. Depending on sea-ice cover and bloom situation.
- **Current status of the subparameter:** FB sampled twice annually by IMR, Vardø-N initiated by IMR 2012. The parameter shows large variability in relation to physical and biological processes in the BSO. Need more and longer time series to estimate the development and seasonal patterns.
- **Quality objectives:** The aimed precision and accuracy for AT is ±1 µmol/kg. Accuracy is controlled by the use of international recognized certified reference material (CRM). This follows the standards of the international CO_2 system (UNESCO-IOCCP) and ocean acidification community described in Dickson et al., 2007.

- **Reference level:** No reference level possible for this parameter. Depends on the full system.
- **Gaps in data coverage***:* few or no data in the northern and eastern part of the Barents Sea. Needs more data to cover the influence of changes in the marginal ice-zone and at the outflow to the Arctic.
- **Other issues about the subparameter:** Need to measure one more CO_2 system parameter to follow ocean acidification and oceanic CO_2 uptake. Preferably total inorganic carbon (CT). Should also be sampled in alignment with nutrients.

Subparameter 2 - from northern Barents Sea (defined Arctic water box, scientific surveys)

AT from northern Barents Sea (defined Arctic water box, scientific surveys)
Sampling for Arctic water is necessary to cover changes in the distribution of Atlantic and Arctic water. Same type of monitoring, sampling and motivation as for subparameter 1.

Contact person/responsible person: Melissa Chierici, IMR

Title: Ocean Acidification and ocean CO2 uptake

Parameter: Total Inorganic Carbon (CT)

About the parameter

- ***Type of parameter: E***
- ***Priority of parameter: e***
- ***Rationale :*** Total inorganic carbon (CT) is a measure of the total content of inorganic carbon in the oceans and is one of four parameters that can be measured directly to study the oceans carbonate system. CT is affected by biological processes such as primary production, respiration and calcification, air-sea CO_2 exchange, temperature and physical processes such as upwelling of deep-water, vertical and horizontal advection, sea-ice formation/melt, river runoff, and uptake of anthropogenic CO_2 in the atmosphere. That means that there is a large natural seasonal and interannual variability. Long-term monitoring is required to discern the change due to increased CO_2 and its impact on OA state. Uptake of anthropogenic CO_2 in the atmosphere will change the carbonate chemistry (lower pH and carbonate ion concentration and lead to increased ocean acidification. CT is together with total alkalinity the most preferable parameters to be used in calculation calcium carbonate saturation which is a key indicator for calcifying organisms and to investigate the ocean acidification state. Methods for measuring CT and AT can be quality assured and are state-of-art.

Overview of the subparameters

Subparameters (name)	*Institution responsible for monitoring*	*Time series period*	*Gaps in monitoring*	*Priority ("e", "r" or "s")*
In fixed transects (FB, VN, Kola, Kanin)	*IMR (FB, VN) and PINRO*	*IMR started repeated transect FB in 2010.*	*No CT data in eastern and northern Barents Sea, long term monitoring required.*	e
From northern Barents Sea (defined Arctic water box, scientific surveys)	*IMR and PINRO*		*No data in Arctic water and need information in marginal ice zone*	e

Subparameter 1 - in fixed transects (FB, VN, Kola, Kanin)

CT in fixed transects (FB, VN, Kola, Kanin)

- **Short facts about the subparameter:** Long-term monitoring along repeated transects in the Barents Sea. Fugløya-Bjørnøya, Vardø-North, Kola and Kanin (Figure 1). Long-term monitoring required.

- **Why this is a key subparameter:** F-B transect covers the Barents Sea opening which is used to investigate the inflow of Atlantic water to the Barents Sea and the Arctic. Vardø-North and Kola, Kanin transects covers the marginal ice zone, the Arctic water and the Atlantic water outflow to the Kara Sea. Important to understand the effect of climate change on the CO_2 system dynamics, oceanic CO_2 uptake and ocean acidification.

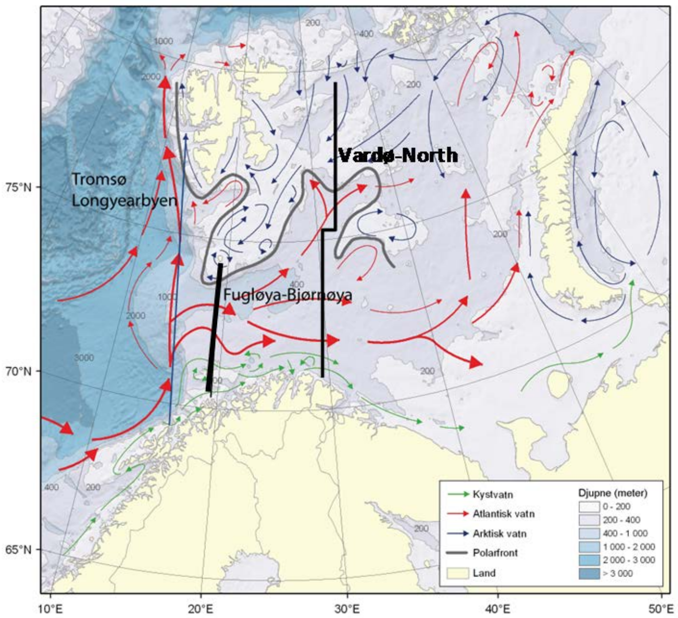


Figure 1. Schematic overview of the circulation pattern and different water masses in the Barents sea. The black lines show the repeated transects that IMR have initiated sampling and measurements for OA studies and oceanic CO_2 uptake.

- **Monitoring:** Sampling of the water column and standard depths from CTD-Niskin bottle system onboard research vessels. Either measured directly onboard or preserved for post-cruise analysis at laboratory. IMR F-B transect started sampling and measurements in 2010. IMR will be responsible for Vardø-N (VN). PINRO responsible for Kola, Kanin. Important to capture the conditions before and after the bloom. Typically winter and late summer, resulting in sampling at least twice annually. The sampling month can show regional differences. Depending on sea-ice cover and bloom situation.
- **Current status of the subparameter:** FB sampled twice annually by IMR,Vardø-N initiated by IMR 2012. The parameter shows large variability in relation to physical and biological processes in the BSO. Need more and longer time series to estimate the development and seasonal patterns.
- **Quality objectives:** The aimed precision and accuracy for CT is ±1 µmol/kg. Accuracy is controlled by the use of international recognized certified reference material (CRM). This follows the standards of the international CO_2 system (UNESCO-IOCCP) and ocean acidification community described in Dickson et al., 2007.
- **Reference level:** No reference level possible for this parameter. Depends on the full system
- **Gaps in data coverage:** few or no data in the northern and eastern part of the Barents Sea. Needs more data to cover the influence of changes in the marginal ice-zone and at the outflow to the Arctic.
- **Other issues about the subparameter:** Need to measure one more CO_2 system parameter to follow ocean acidification and oceanic CO_2 uptake. Preferably total alkalinity (AT). Should also be sampled in alignment with nutrients.

Subparameter 2 - from northern Barents Sea (defined Arctic water box, scientific surveys)

CT from northern Barents Sea (defined Arctic water box, scientific surveys)

Sampling for Arctic water is necessary to cover changes in the distribution of Atlantic and Arctic water. Same type of monitoring, sampling and motivation as for subparameter 1.

Contact person/responsible person: Melissa Chierici, IMR

Title: Oceanographic conditions in the Barents Sea

About the indicator

- ***Type of indicator: E***
- ***Priority of indicator: e***
- ***Rationale:*** Hydrological conditions play a key role in the functioning of the Barents Sea ecosystem. The temperature in the Barents Sea is dependent on the advection of heat through the southwestern opening and defines the distribution of various important species as well as the extent of the seasonal sea-ice cover. Hence, monitoring hydrological properties is important for the management of the ecosystem of the Sea.

Overview of Parameters

Parameters (name)	***Type (“E”, “A”, or “I”)***	***Priority (“e”, “r” or “s”)***
Water temperatures	*E*	*e*
Salinity	*E*	*e*
Nutrients	*E*	*e*
Oxygen	*E*	*e*

Contact person/responsible person: Jan Erik Stiansen, IMR

Title: Oceanographic conditions in the Barents Sea

Parameter: Nutrients

About the parameter

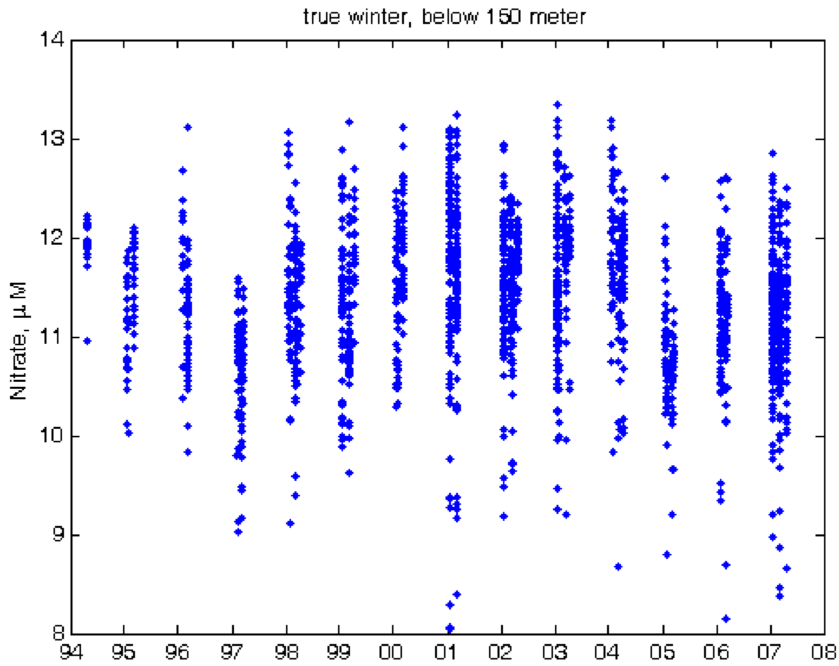
- ***Type of parameter: E***
- ***Priority of parameter: e***
- ***Rationale :*** The distribution of nutrients in time and space determines the carrying capacity for phytoplankton standing stock. During spring bloom phytoplankton typically assimilates all major nutrients present at the end of the winter in the euphotic zone. After the spring bloom production is dependent on recycled nutrients and diffusion from the nutrient rich deeper waters. Natural variation of nutrient concentration is mainly controlled by the combined effect of the annual cycle of assimilation versus remineralization. Human influence of nutrients in the Barents Sea is probably restricted to Norwegian coastal water. Phosphate and nitrogenous nutrients partially have antropogenic sources such as agricultural fertilization and sewage, whereas silicate also is highly influenced by variation in freshwater runoff and erosion. However, the major controlling factor of nutrients is the composition of the Atlantic water entering the Barents Sea from the South, and the Polar water entering from the North.

Overview of the subparameters

Subparameters (name)	***Institution responsible for monitoring***	***Time series period***	***Gaps in monitoring***	***Priority ("e", "r" or "s")***
In fixed transects (FB, VN, Kola, Kanin)	*FB & VN: IMR Kola & Kanin: PINRO*	*1980->*		e
From northern Barents Sea (defined Arctic water box, scientific surveys)	*IMR, Økosystemtoktet*	*1980->*		e
In whole area (maps). Depth: 50 m and bottom	*IMR*	*1980->*		r

Subparameter 1 – Nutrients, Sections

- **Why this is a key subparameter:** The distribution of nutrients in time and space determines the carrying capacity for phytoplankton standing stock.
- **Monitoring:** Water samples are collected from profiles during scientific cruises and chemically analysed either on board or on preserved samples.
- **Current status of the subparameter:**

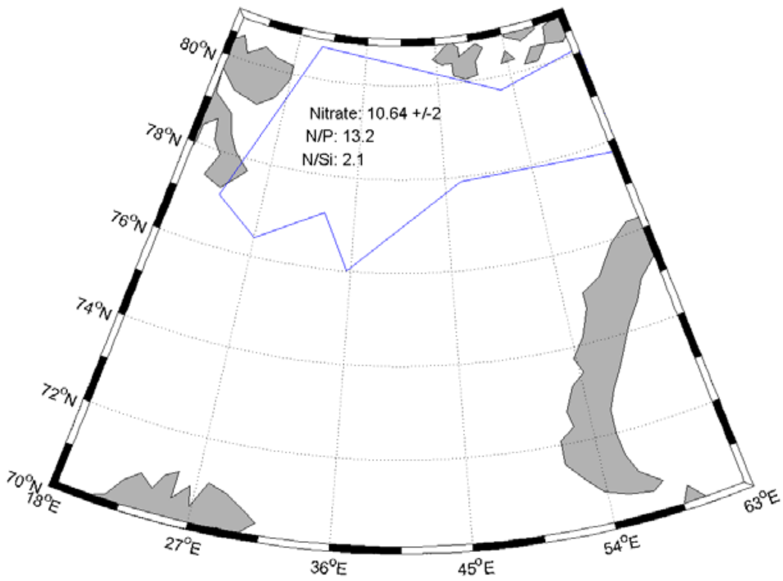


Time course of average winter concentration of nitrate in the Fugløy-Bjørnøya section 1994-2008.

- **Quality objectives:** Quality objectives are not set.
- **Reference level:**
- **Gaps in data coverage:**
- **Other issues about the subparameter:**

Subparameter 2 – Nutrients, Northern Barents Sea

- **Why this is a key subparameter:** The distribution of nutrients in time and space determines the carrying capacity for phytoplankton standing stock.
- **Monitoring:** Water samples are collected from profiles during scientific cruises and chemically analysed either on board or on preserved samples.
- **Current status of the subparameter:**



Average concentration of nitrate in Arctic water below 50 m, and the ratio of nitrate to phosphate and silicate.

Subparameter 3 – Nutrients, whole area

- **Why this is a key subparameter:** The distribution of nutrients in time and space determines the carrying capacity for phytoplankton standing stock.
- **Monitoring:** Water samples are collected from profiles during scientific cruises and chemically analysed either on board or on preserved samples.
- **Current status of the subparameter:** Average nitrate concentration below 50 meter depth in 1993-2007.
- **Quality objectives:** Quality objectives are not set.
- **Reference level:**
- **Gaps in data coverage:** Continuous since 1980.
- **Other issues about the subparameter:**

Contact person/responsible person: Knut Yngve Børsheim, IMR

Title: Oceanographic conditions in the Barents Sea

Parameter: Oxygen

About the parameter

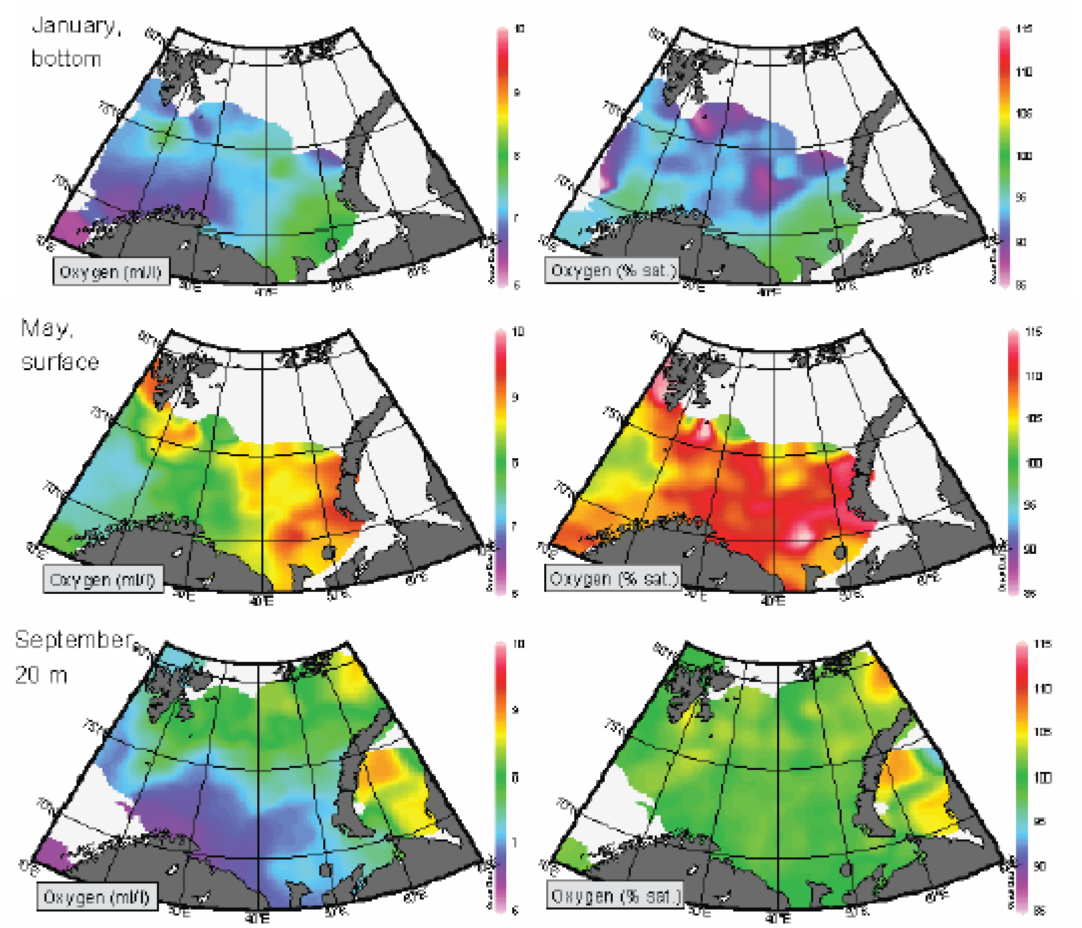
- ***Type of parameter: E***
- ***Priority of parameter: e***
- ***Rationale :*** Oxygen saturation of the near-bottom layer in the Kola region is used for monitoring of long-term variations of oxygen content, because variation of oxygen content is closely related to variation of water temperature, and oxygen content in the surface layers is subjected to significant seasonal variations. The oxygen saturation in the bottom layer of the Kola section is one of key parameters in regression models developed by Titov (Titov, AFWG 2010, WD 22) and Titov et al. (AFWG 2005, WD 16) and having 1 to 4 year prediction possibility for abundance of age3 recruits for NEA cod.

Overview of the subparameters

Subparameters (name)	*Institution responsible for monitoring*	*Time series period*	*Gaps in monitoring*	*Priority ("e", "r" or "s")*
in fixed transects (Kola)	*PINRO*			e
new sections (Kanin, FB, VN)				e
from northern Barents Sea (defined Arctic water box, scientific surveys)				e
New: whole area (maps). Depth: 50 m and bottom				r
New: oxygen (surface; e.g. Ferry box)				s

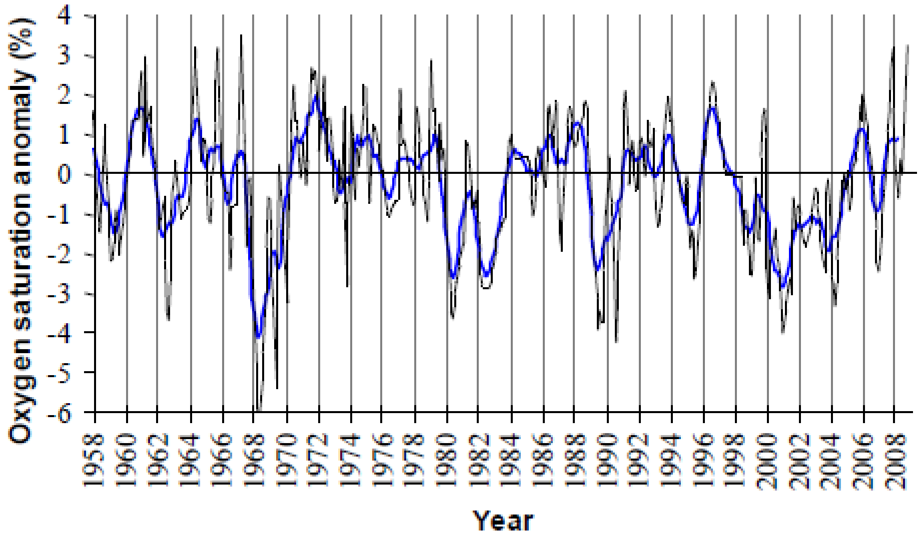
Subparameter 1 – Oxygen in fixed transects (Kola)

- **Short facts about the subparameter:** During winter, the maximum oxygen content is observed where water temperature is lowest and oxygen saturation of the whole water column is below 100 %. During spring, surface water masses are oversaturated with oxygen in most of the Barents Sea, and in May, oxygen saturation can reach 105-115 % and the oxygen content is 8.0-9.5 ml/l. During September, oxygen saturation of sea water in the photic layer (up to 20-50 m) is 100-105 % (Titov and Nesvetova, 2003).



Long-term mean distribution of oxygen in the bottom layer in January (upper row), in the surface layer in May (middle row), and in the surface layer in September (lower row).

- **Why this is a key subparameter:** The oxygen saturation in the bottom layer of the Kola section is one of key parameters in regression models developed by Titov (Titov, AFWG 2010, WD 22) and Titov *et al*. (AFWG 2005, WD 16) and having 1 to 4 year prediction possibility for abundance of age3 recruits for NEA cod.
- **Monitoring:** Oxygen saturation of the near-bottom layer in the Kola region is used for monitoring of long-term variations of oxygen content, because variation of oxygen content is closely related to variation of water temperature, and oxygen content in the surface layers is subjected to significant seasonal variations. Oxygen content in the near-bottom layer in the Kola section is sampled 5-8 times per year.
- **Current status of the subparameter:** Monthly oxygen anomalies in the bottom layer of the Kola Section ranges between 3% and -6%. A time-series shows a considerable interannual variability.



Monthly and annual oxygen anomalies in the bottom layer of the Kola Section in 1958-2008 **(Anon., 2009).**

- **Quality objectives:**
- **Reference level:**
- **Gaps in data coverage**
- **Other issues about the subparameter:**

Subparameters to be developed

new sections (Kanin, FB, VN)
from northern Barents Sea (defined Arctic water box, scientific surveys)
New: whole area (maps). Depth: 50 m and bottom
New: Oxygen (surface; e.g. Ferry box)

No measurements are performed now

Contact person/responsible person: Oleg Titov, PINRO

Title: Oceanographic conditions in the Barents Sea (E)
Parameter: Salinity

About the parameter

- ***Type of parameter: E***
- ***Priority of parameter: e***
- ***Rationale :*** Salinity defines the position of frontal zones and thereby contribute in restricting the extent of the different ecosystems. Salinity is affected by freshwater input through runoff from land, net precipitation and sea-ice melt. In northern parts of the Barents Sea salinity controls the stratification and hence the starting time of the phytoplankton bloom. Salinity is affected both by natural and human caused changes through temperature-driven changes in sea-ice extent.

Overview of the subparameters

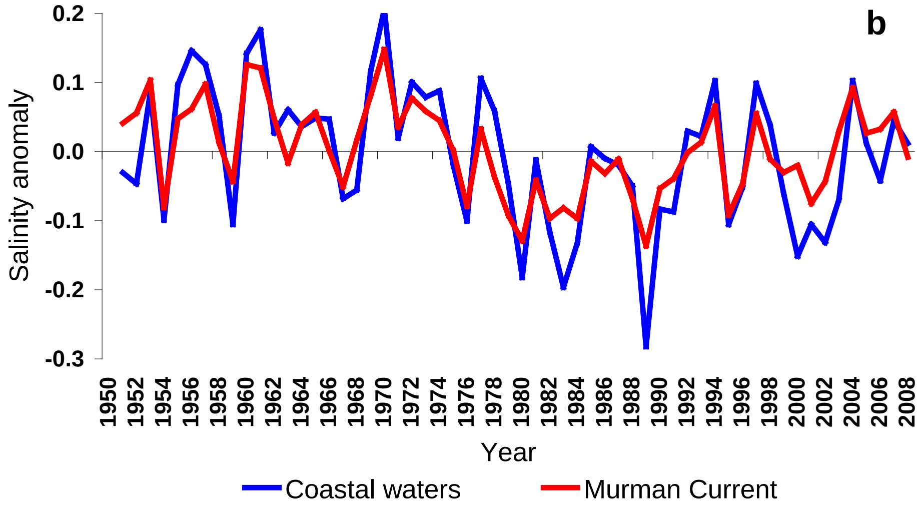
Subparameters (name)	*Institution responsible for monitoring*	*Time series period*	*Gaps in monitoring*	*Priority ("e", "r" or "s")*
in fixed transects (FB, VN, Kola, Kanin)	*IMR and PINRO*	*1900 - present; 1977 - present*		e
from northern Barents Sea (defined Arctic water box, scientific surveys)	*IMR and PINRO*			e
in whole area (maps). Depth: 50 m and bottom	*IMR*	*1970 – 2008*		r
Fixed stations in coastal waters (Ingøy, 50, 200 etc.)	*IMR*	*1936 - present*	*1945-1968, 1977 - 1978*	e
SSS (sea surface salinity from reanalysed data	*ECMWF*	*1958 - present*		s

Subparameter 1 – Fixed transects

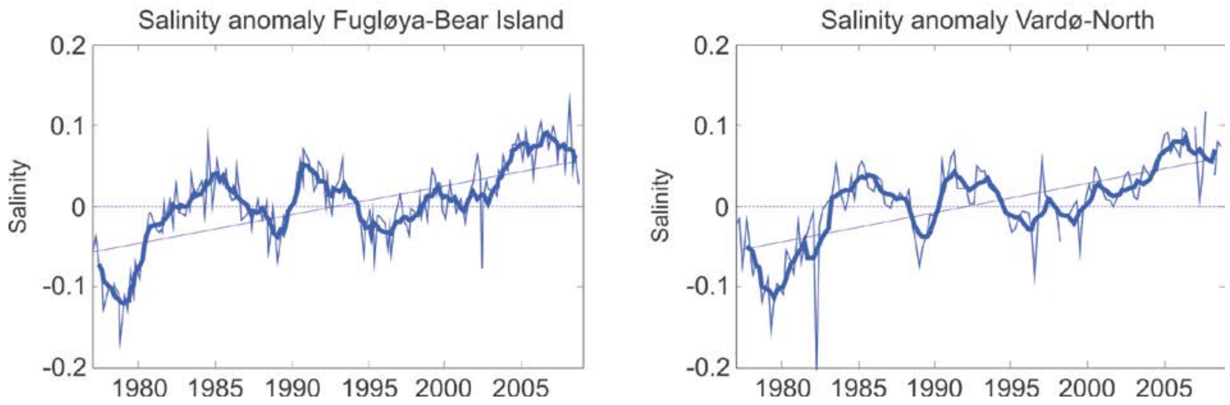
- **Short facts about the subparameter:** Sections consisting of fixed stations in various key areas in the southern Barents Sea and covering the main flow path of Atlantic and Coastal Water. Value is integrated over certain area restricted by horizontal and vertical limits: FB: 50-200 m depth, 71˚ 30'N to 73˚ 30'N; VN: 0-200 m depth; Kola: 0-200 m depth, sta. 3-7.
- **Why this is a key subparameter:** Monitors the salinity of the inflowing Atlantic and Coastal water to the Barents Sea, which is important for e.g. the sea-ice distribution and phytoplankton dynamics. Kola section is the world's longest continuous oceanic time series.
- **Monitoring:** Monitored by Conductivity-Temperature-Depth (CTD) measurements at fixed stations in the southern Barents Sea through cruise activity. Intervals vary between monthly (Kola) to seasonally (VN). Kola covers the period 1900-present, while FB and VN covers 1977

present.

- **Current status of the subparameter:**



Annual mean salinity anomalies between 0-200 meter depth in the Kola Section, 1951-2008. Coastal waters are defined as stations 1-3 and the Murman Current as stations 3-7 (Anon., 2009). The time series show that the Coastal and Atlantic water salinity vary in phase and the variability is dominated by inter-annual variations. Also, the low-frequency multidecadal variability is clearly seen with a minimum in the 1980s.



Salinity anomalies between 50 – 200 meter depth in FB (left) and VN (right), showing interannual variability superimposed onto a trend from multidecadal variations. Most notably is the great negative salinity anomaly in the late 1970s (GSA70s).

- **Quality objectives:**
  Current and potential human impact on the parameters listed here are virtually zero, except for the regional impacts from human induced climate change. Therefore, no environmental objectives, targets and subsequent actions are suggested. However, the physical conditions impact the ecosystem, both directly and indirectly, at all trophic levels. Therefore, monitoring the listed parameters and reporting their potential impacts on the ecosystem remains an important task. Examples include the retreating sea-ice cover owing to regional climate change, that impact the ecosystem both directly by, e.g., changing the habitat of many species (e.g., polar bears and seals) and indirectly by, e.g., affecting the stratification of the ocean and subsequently the timing and strength of the spring bloom. The Barents Sea sea-ice cover is currently at a historically low and is, according to climate models, now

entering a stage that is outside the range of natural variability. Hence, this indicator suggests that action should be taken, if any such action was possible.

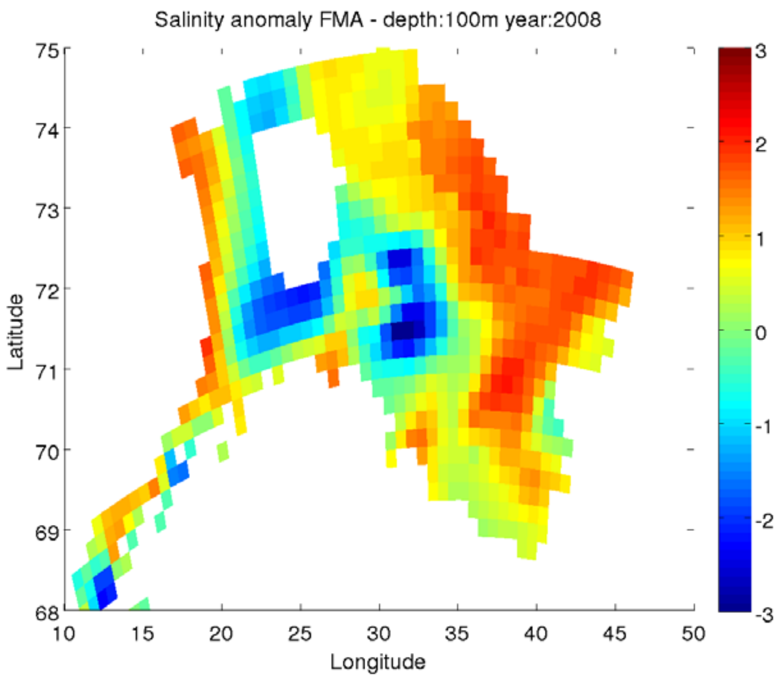
- **Reference level:** Long-term average within each time series/section. One should, however, define a climatic period (e.g. 1980-2009) to avoid that the reference level is adjusted with each update of the time series .
- **Gaps in data coverage:**
- **Other issues about the subparameter:**

Subparameter 2 – Northern Barents Sea

- **Short facts about the subparameter:** Salinity in the northern Barents Sea.
- **Why this is a key subparameter:** Salinity determines the stratification in the northern Barents Sea and hence affects the phytoplankton dynamics, as well as defining frontal zones which affect species distribution.
- **Monitoring:** CTD-measurements during regular cruise activity. Dependent on sea-ice coverage/conditions, hence usually monitored during summer/autumn.
- **Current status of the subparameter:**
- **Quality objectives:** Not set.
- **Reference level:** Not set.
- **Gaps in data coverage:**
- **Other issues about the subparameter:**

Subparameter 3 – Map of whole area

- **Short facts about the subparameter:** Salinity in the Barents Sea from maps based on objective analysis of point measurements.
- **Why this is a key subparameter:** Provides information on the distribution of variation in salinity, haline fronts, etc.
- **Monitoring:** CTD-measurements during regular cruise activity.
- **Current status of the subparameter:**

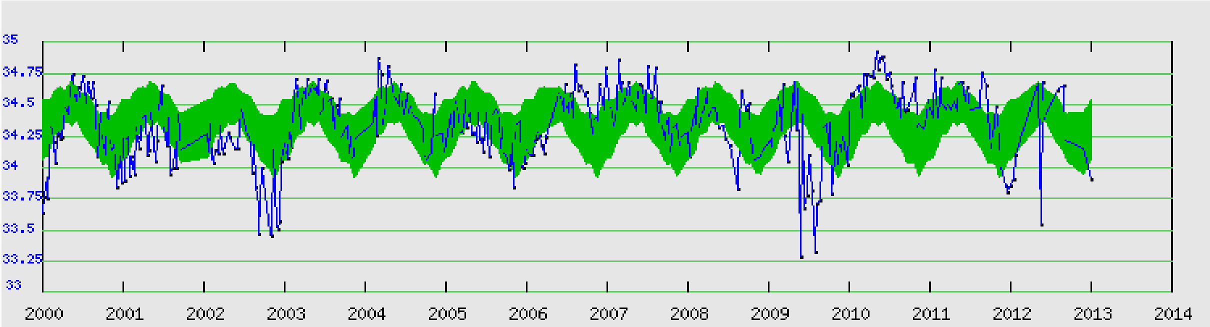


Salinity anomaly divided by standard deviation in winter (Feb-Mar-Apr) 2008 relative to 1970-2008.

- **Quality objectives:**
- **Reference level:** Whole timeseries (1970-2008). However, a climatic reference period should be defined (e.g. 1980-2009).
- **Gaps in data coverage:** Regular spatial coverage is desirable with respect to the quality of the objective analysis.
- **Other issues about the subparameter:**

Subparameter 4 – Fixed stations

- **Short facts about the subparameter:** Salinity at fixed coastal station Ingøy
- **Why this is a key subparameter:** Subparameter provides vertical profile of salinity at a fixed point at a temporal resolution that resolve the seasonal cycle. Very long time series that provides vital information on climate variability.
- **Monitoring:** CTD-measurements twice a month.
- **Current status of the subparameter:**



Salinity at 50 m depth (blue curve) and mean +/- one standard deviation (shaded green) at Fixed station Ingøy for the period 2000-2013. The figure shows the seasonal cycle with interannual variations, with large anomalies in some years (e.g. 2002 and 2009).

- **Quality objectives:**

- **Reference level:** None, but should correspond to the climatic period defined for other subparameters.
- **Gaps in data coverage**: Data missing for periods 1945-1968 and 1977-1978
- **Other issues about the subparameter:**

Subparameter 5 – SSS (reanalysis data)

- **Short facts about the subparameter:** Sea surface salinity from modeled reanalysis
- **Why this is a key subparameter:** SSS is used to determine the extent of different water masses that determine the area available for various species.
- **Monitoring:** Reanalysis depends on various observations, such as CTD, SSH from AVISO, sea ice, etc.
- **Current status of the subparameter**: Reanalysis is updated continuously and is available on web.
- **Quality objectives:**
- **Reference level:** No reference level.
- **Gaps in data coverage:**
- **Other issues about the subparameter:**

Contact person/responsible person: Jan Erik Stiansen, Vidar S. Lien, IMR

Title: Hydrological conditions in the Barents Sea (E)

Parameter: Water temperatures

About the parameter

- ***Type of parameter: E***
- ***Priority of parameter: e***
- ***Rationale :*** Temperature affects the ecosystem by defining the temperature-dependent species distribution, affecting metabolism and temperature-dependent growth, affecting the sea-ice distribution, and in the southern parts controlling the stratification and thereby determining the starting time of the phytoplankton bloom. Temperature is affected by natural variations through large-scale atmospheric circulation and upstream advection of heat, and by humans through anthropogenic-driven climate change.

Overview of the subparameters

Subparameters (name)	***Institution responsible for monitoring***	***Time series period***	***Gaps in monitoring***	***Priority (“e”, “r” or “s”)***
in fixed transects (FB, VN, Kola, Kanin)	*IMR and PINRO*	*1900 – present 1977 - present*		e
from northern Barents Sea (defined Arctic water box, scientific surveys)	*IMR and PINRO*			e
in whole area (maps). Depth: 50 m and bottom	*IMR*	*1970 – 2008*		r
Fixed stations in coastal waters (Ingøy, 50, 200 m, others?)	*IMR*	*1936 - present*	*1945 – 1968, 1977 - 1978*	e
SST in situ, e.g. ferry box	*NIVA and IMR*	*1998 - present*		s
SST (sea surface temperature from satellite	*NERSC*	*1981 - present*		s
SST (reanalyzed data)	*ECMWF*	*1958 - present*		e

Subparameter 1 - in fixed transects (FB, VN, Kola, Kanin)

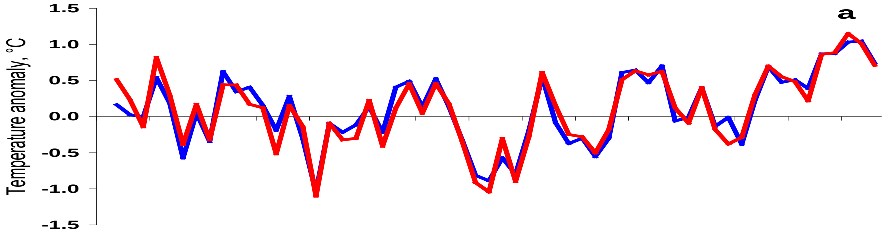
- **Short facts about the subparameter:** Sections consisting of fixed stations in various key areas in the southern Barents Sea and covering the main flow path of Atlantic and Coastal Water. Value is integrated over certain area restricted by horizontal and vertical limits: FB: 50-200 m depth, 71˚ 30’N to 73˚ 30’N; VN: 0-200 m depth; Kola: 0-200 m depth, sta. 3-7.

(Insert map)

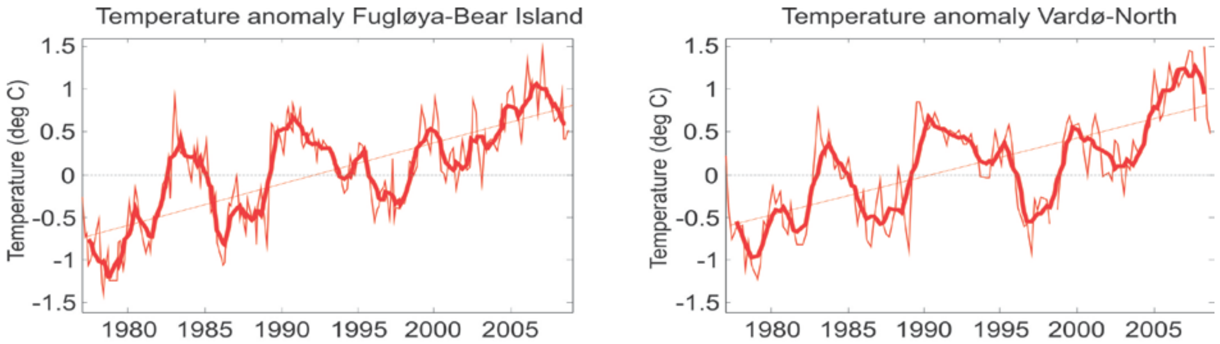
- **Why this is a key subparameter:** Monitors the temperature of the inflowing Atlantic and Coastal water to the Barents Sea, which is important for e.g. the sea-ice distribution and phytoplankton dynamics. Kola section is the world's longest continuous oceanic time series.

- **Monitoring:** Monitored by Conductivity-Temperature-Depth (CTD) measurements at fixed stations in the southern Barents Sea through cruise activity. Intervals vary between monthly (Kola) to seasonally (VN). Kola covers the period 1900-present, while FB and VN covers 1977-present.

- **Current status of the subparameter:**



Annual mean temperature anomalies between 0-200 meter depth in the Kola section, 1951-2008. Coastal Water (blue) is defined as stations 1-3 and the Murman Current (red) is defined as stations 3-7 (Anon., 2009). The time series show that the coastal and Atlantic waters vary in phase and the variability is dominated by interannual time scales. However, multidecadal variability is clearly visible, with a minimum in the 1970s and maxima in the 1950s and present.



Temperature anomalies between 50-200 meter depth in FB (left) and VN (right), showing interannual variations superimposed onto a trend from multidecadal variations.

- **Quality objectives.** It is not possible to set environmental objectives for this parameter Studies have suggested that the net heat transport from the north-eastern Barents Sea to the Arctic Ocean is small (at least an order of magnitude less than heat inflow to the Barents Sea in the south-west) and almost negligible in the long term (inter-annual and longer timescales), due to severe atmospheric cooling and subsequent ice formation. As the temperature in the Barents Sea region keeps increasing, the Atlantic Water flow through the Barents Sea could enter a new stage, in which the atmosphere is unable to absorb all the excess heat. As a consequence, the Barents Sea could become a net source of heat for the downstream Arctic Ocean. Thus, as for the sea ice, also the temperature indicator suggests that we are approaching the range of natural variability and that action should be taken, if any such was possible. However, increased monitoring efforts in the north-eastern Barents Sea, as suggested in Ocean-3, is needed in order to increase our knowledge of both the current state and the possible future changes of the Barents Sea climate, as well as its impacts on the ecosystem.

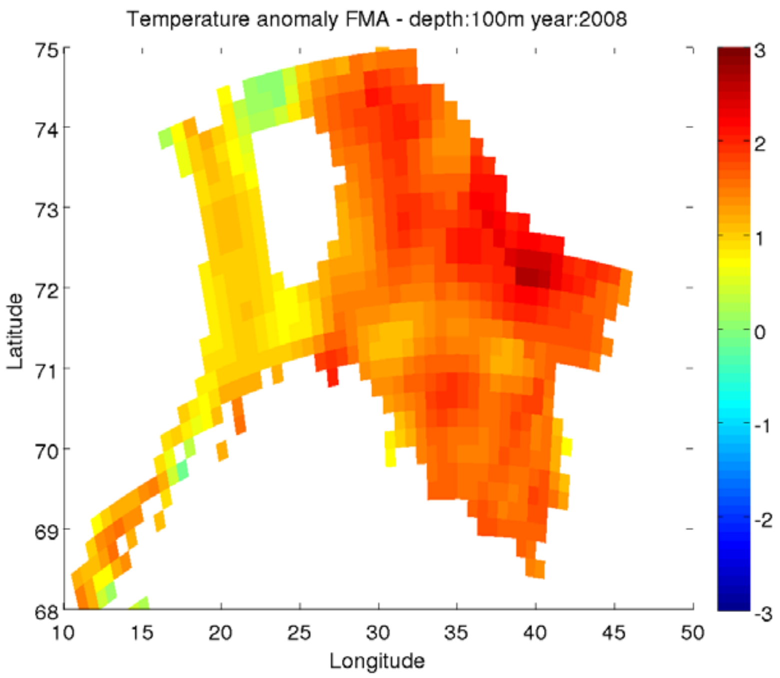
- **Reference level:** Long-term average within each time series/section. One should, however, define a climatic period (e.g. 1980-2009) to avoid that the reference level is adjusted with each update of the time series.
- **Gaps in data coverage:**
- **Other issues about the subparameter:**

Subparameter 2 – Northern Barents Sea

- **Short facts about the subparameter:** Temperature in the northern Barents Sea.
- **Why this is a key subparameter:** Temperature affects the stratification in the northern Barents Sea and hence affects the phytoplankton dynamics, as well as defining frontal zones which restrict species distribution.
- **Monitoring:** CTD-measurements during regular cruise activity. Dependent on sea-ice coverage/conditions, hence usually monitored during summer/autumn.
- **Current status of the subparameter:**
- **Quality objectives:**
- **Reference level:**
- **Gaps in data coverage:**
- **Other issues about the subparameter:**

Subparameter 3 – Map of whole area

- **Short facts about the subparameter:** Salinity in the Barents Sea from maps based on objective analysis of point measurements.
- **Why this is a key subparameter:** Provides information on the distribution of variation in salinity, haline fronts, etc.
- **Monitoring:** CTD-measurements during regular cruise activity.
- **Current status of the subparameter:**



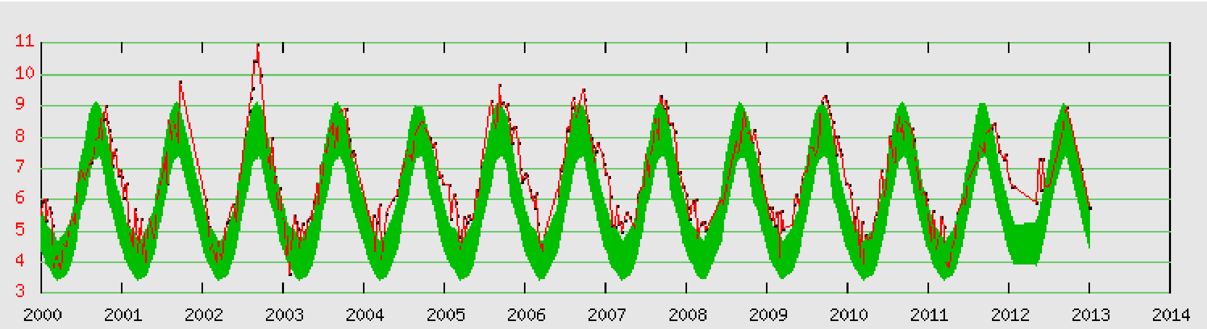
Temperature anomaly divided by standard deviation in winter (Feb-Mar-Apr) 2008 relative to 1970-2008.

- **Quality objectives:**

- **Reference level:** Whole timeseries (1970-2008). However, a climatic reference period should be defined (e.g. 1980-2009).
- **Gaps in data coverage**: Regular spatial coverage is desirable with respect to the quality of the objective analysis.
- **Other issues about the subparameter:**

Subparameter 4 – Fixed stations

- **Short facts about the subparameter:** Temperature at fixed coastal station Ingøy
- **Why this is a key subparameter:** Subparameter provides vertical profile of temperature at a fixed point at a temporal resolution that resolve the seasonal cycle. Very long time series that provides vital information on climate variability.
- **Monitoring:** CTD-measurements twice a month.
- **Current status of the subparameter:**



Temperature at 50 m depth (red curve) and mean +/- one standard deviation (shaded green) at Fixed station Ingøy for the period 2000-2013. The figure shows the seasonal cycle superimposed onto interannual variations, with large anomalies in some years (e.g. 2002).

- **Quality objectives:**
- **Reference level:** Long term mean (should consider the climatic period defined for other subparameters).
- **Gaps in data coverage**: Data missing for periods 1945-1968 and 1977-1978.
- **Other issues about the subparameter:**

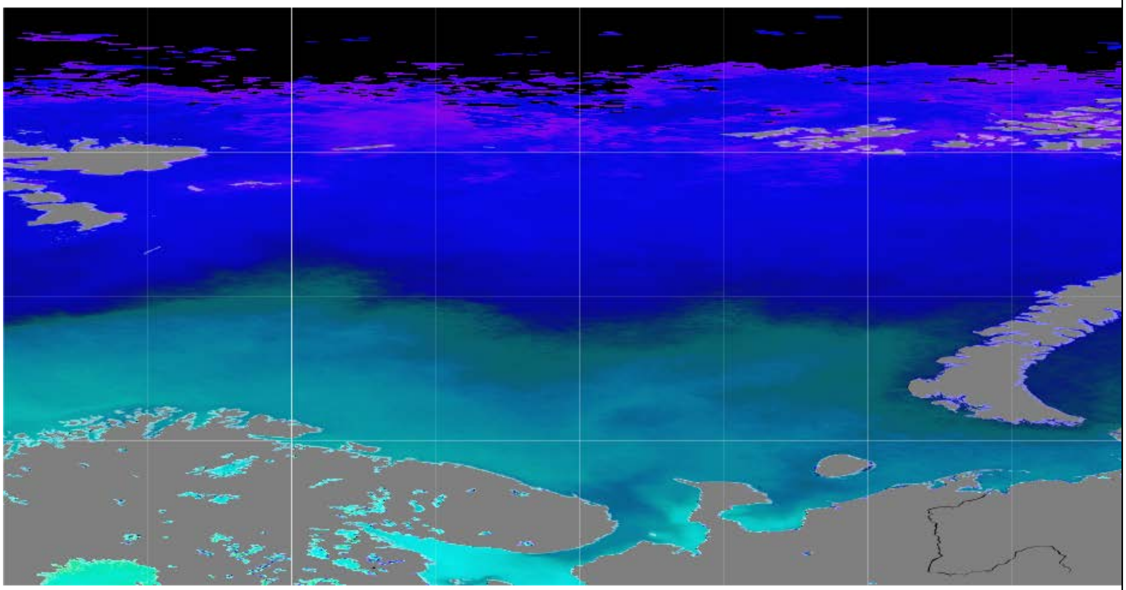
Subparameter 5 – SST in situ (e.g. ferry box)

- **Short facts about the subparameter**: Along track sea surface temperature along commercial ship tracks (Tromsø – kirkenes; Tromsø – Longyearbyen).
- **Why this is a key subparameter:** Provides temperature information on a high-frequency temporal scale.
- **Monitoring:** Two routes are operated by NIVA (Tromsø – Kirkenes (2004 – present) and Tromsø – Longyearbyen (2008 - present)), while IMR operate one (Tromsø – Kirkenes (1998 – present)). The Tromsø – Kirkenes route follows the coast at two-week intervals.
- **Current status of the subparameter:**
- **Quality objectives:**
- **Reference level:** No reference level
- **Gaps in data coverage:**
- **Other issues about the subparameter:**

Subparameter 6 – Sea surface temperature from satellite

- **Short facts about the subparameter:** Weekly maps of sea surface temperature derived from satellite data at 1 km or ¼ degree resolution.

- **Why this is a key subparameter:** Provides temperature information for the entire surface of the Barents Sea with rather high high temporal resolution. Cheap and easy to estimate from remote sensing data.
- **Monitoring:** SST is calculated from IR or microwave satellite data. IR data has higher spatial resolution (1 km) but is limited by clouds. Microwave data has resolution about ¼ degree but is not limited by clouds. Images are available daily but due to clouds IR data has to be averaged over week.
- **Current status of the subparameter:** SST is being effectively estimated from satellite data since 1981. Several satellite missions provide IR and microwave data and 30 years of observations are already collected. More satellites to carry IR and microwave sensors onboard to be launched by space agencies are planned and expected. The figure below shows spatial distribution of SST in the surface waters of the Barents sea in summer as averaged over ten years 2002 – 2012.



- **Quality objectives:**
- **Reference level:** 30 years climatology.
- **Gaps in data coverage**: only due to clouds.
- **Other issues about the subparameter:**

Subparameter 7 – SST (reanalysis data)

- **Short facts about the subparameter:** Sea surface temperature from modeled reanalysis
- **Why this is a key subparameter:** SST shows location of fronts and the extent of different water masses, that determines the area available for species with temperature-dependent preferences.
- **Monitoring:** Reanalysis depends on various observations, such as CTD, SSH from AVISO, sea ice, etc.
- **Current status of the subparameter:** Reanalysis is updated continuously and is available on web.
- **Quality objectives:**
- **Reference level:** No reference level.
- **Gaps in data coverage:**
- **Other issues about the subparameter:**

Contact person/responsible person: Jan Erik Stiansen, Vidar S. Lien, IMR

Title: Phy*toplankton diversity, abundance and biomass*

About the indicator

- ***Type of indicator: E***
- ***Priority of indicator: e***
- ***Rationale:*** Phytoplankton is the first link of all trophic chains in marine ecosystems and only the primary producer in the open water. Its diversity, abundance, biomass and production will be important for how much energy is available. When the importance of the indicator is better clarified, it may perhaps be included in a basis for accommodating harvesting at a higher trophic level to the primary production. Species composition may also be used to assess climate change.

Overview of Parameters

Parameters (name)	***Type (“E”, “A”, or “I”)***	***Priority (“e”, “r” or “s”)***
Species composition	*E*	e
Diversity indices	*E*	e
Species abundance	*E*	s
Group abundance	*E*	e
Total biomass	*E*	e
Chlorophyll	*E*	e
Net primary productivity	*E*	e
CDOM, satellite	*E*	e
PIC, satellites'	*E*	e
Start, duration and intensity of the spring bloom	*E*	e
Start, duration and intensity of the late summer bloom	*E*	e

Contact person/responsible person: Viktor Larionov, Pavel Makarevich, MMBI, Stuart Larsen, IMR

Phytoplankton diversity, abundance and biomass

Parameter: CDOM, satellite

About the parameter

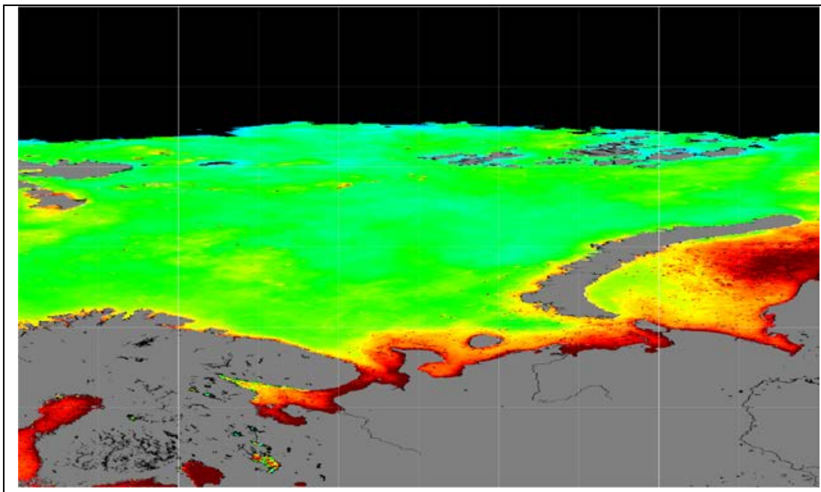
- ***Type of parameter: E***
- ***Priority of parameter: e***
- ***Rationale :*** Colored dissolved organic matter (CDOM) intensively attenuates light, it is brought into the ocean with riverine waters (in coastal areas) or produced by phytoplankton (especially during and after spring phytoplankton bloom) therefore absorption of CDOM indicates impact of river discharge and phytoplankton abundance on nutrient and light availability in the ocean.

Overview of the subparameters

Subparameters (name)	*Institution responsible for monitoring*	*Time series period*	*Gaps in monitoring*	*Priority (“e”, “r” or “s”)*
Barents Sea, surface	***NERSC***	***1998 - present***	***Winter time***	e

Subparameter 1 - Barents Sea, surface

- **Short facts about the subparameter:**
  Absorption of surface colored dissolved organic matter (CDOM)
- Absorption of surface colored dissolved organic matter gives essential information about nutrient and light availability in the ocean
- It is related to phytoplankton production of detritus and river discharge of organic matter of terrestrial origin
- It is easy and cheap to estimate from satellite remote sensing data
- **Monitoring:** Surface concentration of CDOM is calculated from optical remote sensing satellite data using either standard global or locally tuned algorithms. Satellite measurements are performed in the Barents Sea every day however low elevation of sun limits observations to the period from April to August and cloudiness significantly reduces the amount of high quality data. Therefore only the spring-summer period (from April to August) and only monthly averaged values of satellite derived of CDOM concentration is a feasible indicator.
- **Current status of the subparameter:** CDOM absorption is being effectively estimated from satellite data since 1998. Several satellite missions provide optical data and 15 years of observations are already collected. More satellites to carry optical sensors on board to be launched by space agencies are planned and expected. The figure below shows spatial distribution of CDOM in the surface waters of the Barents Sea as averaged over ten years 2002 – 2012 in August - month of enhanced river discharge.



- **Quality objectives**: The accuracy of surface CDOM estimate is 5e-3 m-1
- **Reference level:** 15 years climatology collected by SeaWIFS/MODIS/MERIS satellite sensors during 1998 – 2012

Contact person/responsible person: Anton Korosov (NERSC)

Phytoplankton diversity, abundance and biomass

Parameter: Chlorophyll

About the parameter

- ***Type of parameter: E***
- ***Priority of parameter: e***
- ***Rationale :*** Chlorophyll a concentration in the water column indicates the amount of phytoplankton and especially its physiological state. Therefore this parameter gives a possibility to estimate how much energy is available in the pelagic ecosystem and would be transferred to higher trophic levels.

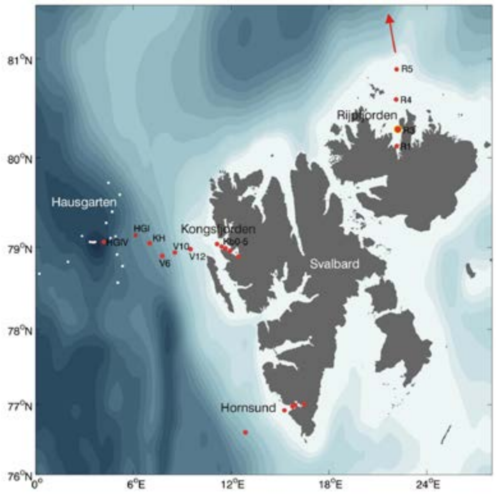
Overview of the subparameters

Subparameters (name)	*Institution responsible for monitoring*	*Time series period*	*Gaps in monitoring*	*Priority ("e", "r" or "s")*
Kongsfjorden-section	*NPI (AEM/MOSJ)*	*Today summer/winter, but should include spring*	*spring*	e
Fugløya-Bjørnøya (Bear Island)	*CBMP, Arctos-network/NPI, IMR*	*Today summer/winter, but should include spring*	*spring*	e
Vardø-N	*CBMP, Arctos-network/NPI, IMR*	*Today summer/winter, but should include spring*	*spring*	e
Kola	*CBMP, Arctos-network/NPI, IMR and PINRO*	*Today summer/winter, but should include spring*	*spring*	e
Lidar, at fixed poligon (to some depth)				s
Satellite, Barents Sea, surface	*IMR/Monitoring group (Norwegian Management Plan) NERSC*	*Spring/early summer as a minimum, preferable longer. This method, however, only gives good results when chlorophyll maximum is located high in the water (usually in spring)*	*winter*	e

		1998 - present		

Subparameter 1 - Kongsfjorden-section

- **Short facts about the subparameter:**
  Chlorophyll a concentration along the Kongsfjorden transect. The parameter complements measurements of zooplankton abundance, taxonomy and distribution taken at the same time.



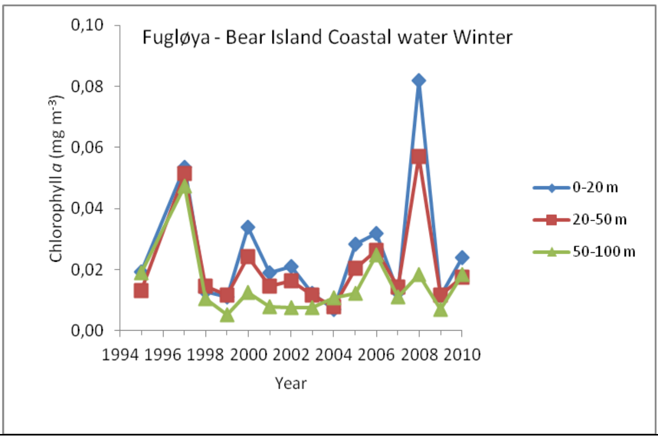
- **Why this is a key subparameter:** The Kongsfjorden marine ecosystem functions under the balance of influx of Atlantic waters from the West Spitsbergen Current and Arctic waters from the coastal current and inter-annual variations in the inflow of Atlantic water are common. Pelagic sampling along the Kongsfjorden transect was established to provide a baseline for phytoplankton and zooplankton abundance, taxonomy and distribution and to monitor how interannual changes in hydrography (local and regional scale) affect these parameters. Phytoplankton is at the base of the marine food web and determines amount of energy that is available for higher trophic levels. Changes in Chl a abundance help to explain changes in zooplankton abundance, species composition and distribution and the consequences for higher trophic levels. The transect extends towards the outer shelf and the Fram Strait and allows comparisons between responses in the pelagic community in the open ocean compared to the and inner fjord system.
- **Monitoring:** The Kongsfjorden transect consists of 11 stations: 5 in the inner part of Kongsfjorden, 3 over the shelf break, and three stations in the Fram Strait (part of the AWI Hausgarten network). Chlorophyll a has been measured at these stations since 2009. Sampling takes place every year in the second half of July by the Norwegian Polar Institute (Arctic Ecosystem Monitoring as part of MOSJ-Miljøovervåkning for Svalbard and Jan Mayen).
  Water sample for Chl a are taken with Niskin bottles attached to the CTD rosette from 0, 10, 25 and 50 m depth and the depth Chl *a* max (if that differs from the standard depth). 50-1000 mL of water from each depth (depending on biomass – a light colour on the filter is enough) are filtered through 25 mm GF/F filters. The filter is extracted in 5 ml methanol over night (12 h) and chlorophyll concentration is measure fluorometrically the next day. If fluoremeter is not available on board the filters are frozen (-20 C) and extraction takes place shortly after the cruise.
- **Current status of the subparameter:** Not available yet.
- **Quality objectives:** No quality objectives have been set for this parameter in the other monitoring programs .

- **Reference level:** Monitoring of this parameter is started relatively recently, no reference level has been identified.
- **Gaps in data coverage:** Not all stations in the outer part of the transect are sampled every year due to weather conditions.
- **Other issues about the subparameter:**

Contact /responsible person: Malin Daase, NPI, Stuart Larsen, IMR

Subparameter 2 - Fugløya-Bjørnøya

- **Short facts about the subparameter:** The Fugløya-Bjørnøya (Bear Island) section covers the entrance to the Barents Sea from the Norwegian Sea, also known as the Barents Sea Opening (BSO).
- **Why this is a key subparameter:** The observations carried out at this section capture the physical, chemical and biological characteristics of the inflowing waters, both Coastal and Atlantic waters, from the Norwegian Sea to the Barents Sea. It also covers Arctic waters flowing out from the Barents Sea at Bjørnøya (Bear Island). It is part of the monitoring programme from IMR carried out for over 30 years and serves as a basis for assessing ecosystem changes over long-term periods.
- **Monitoring:** The section is usually covered by IMR research vessels 5-6 times a year (January, March, April, July, August and September) and comprises 20 oceanographic stations between the Norwegian Coast and Bear Island. The sampling programme comprises, among others, observations of hydrography, nutrients at standard depths down to the bottom and phytoplankton biomass expressed as chlorophyll *a* concentration in the upper 100 meters.
- **Current status of the subparameter:** Phytoplankton biomass can be expressed as the concentration of chlorophyll *a*, their main light absorbing pigment. During winter chlorophyll *a* concentrations are very low, usually below 0,05 mg m^{-3}. During summer the concentrations increase dramatically but show large variability mainly due to the grazing of zooplankton on phytoplankton. The figure below shows the year to year variability of chlorophyll *a* concentrations at three depth strata during winter and summer at the two main water masses, Coastal water and Atlantic water (see attached figure).



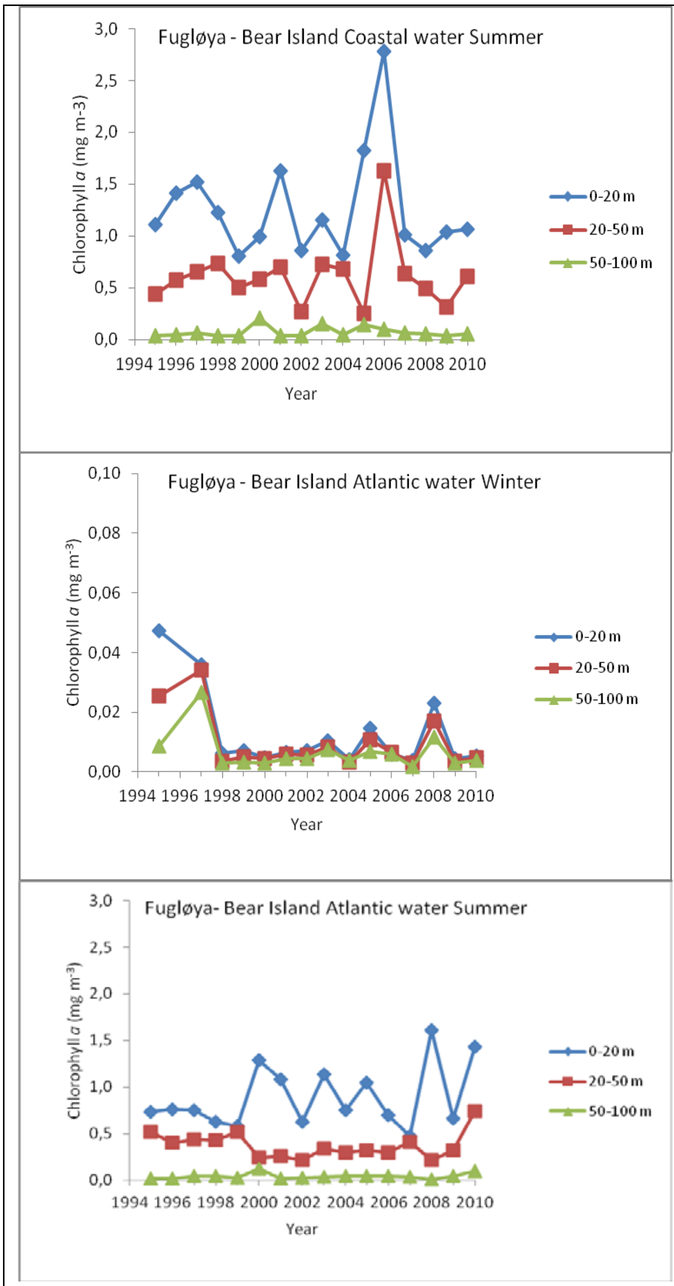


Figure 1. Winter and summer average chlorophyll a concentrations at three depth strata at the Fugløya - Bear Island section from 1995 to 2010.

- **Quality objectives:**
- **Reference level:**
- **Gaps in data coverage:** There is need of complementing the monitoring with coverage during spring (May) in order to capture the phytoplankton spring bloom.
- **Other issues about the subparameter:**

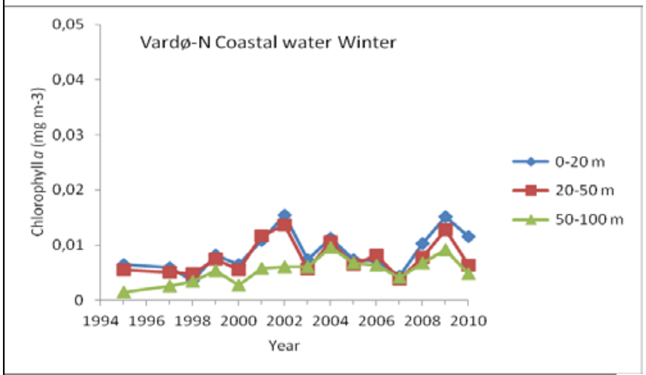
Coordinator/responsible person: Francisco Rey, IMR

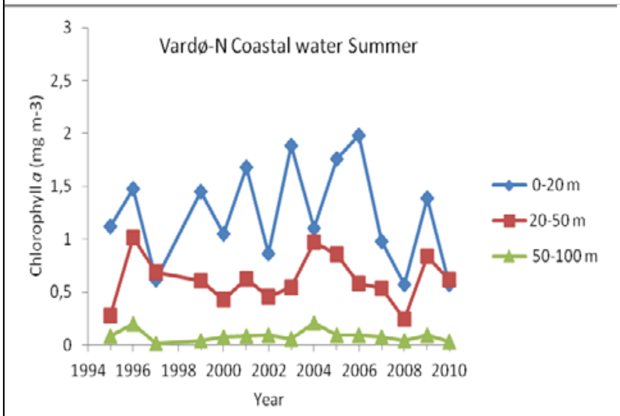
Subparameter 3 - Vardø-N

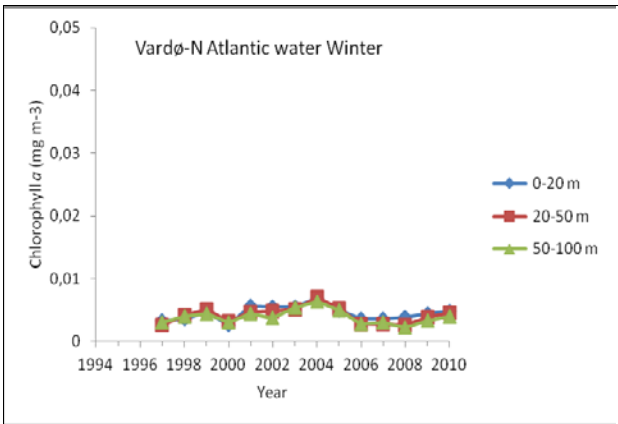
- **Short facts about the subparameter:** The Vardø-North section start off Vardø at the

Norwegian coast and extends northwards along the 31°13`E until 76°30`N or until the ice edge during winter.

- **Why this is a key subparameter:** The observations carried out at this section captures the physical, chemical and biological characteristics of both Coastal and Atlantic waters, from the Norwegian Coast and northwards into the Central Barents Sea. It also occasionally covers the Arctic waters north of the Polar Front during the summer cruises. It is part of the monitoring programme from IMR carried out for over 30 years and serves as a basis for assessing ecosystem changes over long-term periods.
- **Monitoring:** The section is usually covered by IMR research vessels 4-5 times a year (January, March, July, August and September)and comprises 22 oceanographic stations between the Norwegian Coast and the Central Barents Sea. The sampling programme comprises, among others, observations of hydrography, nutrients at standard depths down to the bottom and phytoplankton biomass expressed as chlorophyll *a* concentration in the upper 100 meters.
- **Current status of the subparameter:** Phytoplankton biomass can be expressed as the concentration of chlorophyll *a*, their main light absorbing pigment. During winter chlorophyll *a* concentrations are very low, usually below 0,05 mg m^{-3}. During summer the concentrations increase dramatically but show large variability mainly due to the grazing of zooplankton on phytoplankton. The figure below shows the year to year variability of chlorophyll *a* concentrations at three depth strata during winter and summer at the two main water masses, Coastal water and Atlantic water (*see attached figure*).







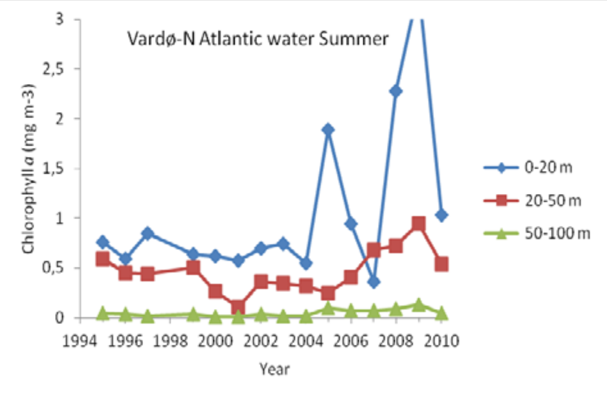


Figure 2 Winter and summer average chlorophyll a concentrations at three depth strata at the Vardø-North section from 1995 to 2010.

- **Quality objectives:**
- **Reference level:**
- **Gaps in data coverage:** As for the Fugløya-Bjørnøya (Bear Island) section there is a need for spring coverage during May.
- **Other issues about the subparameter:**

Coordinator/responsible person: Francisco Rey, IMR

Subparameter 4 – Kola section

- **Short facts about the subparameter:** Kola section – area of the Barents Sea near Kola bay.
- **Why this is a key subparameter:** Kola section – It is the most accessible and frequently studied area (expeditions PINRO and MMBI are annual). Qualitative and quantitative characteristics of phytoplankton (including taxonomical diversity, abundance and biomass of organisms, chlorophyll concentration and their seasonal dynamics) in this part of the Barents Sea plays an important role in assessing climate change.
- The section is usually covered by MMBO and PINRO research vessels 2-3 times a year (May, June, August and September) and comprises 16 oceanographic stations between Kola Bay and the Central Barents Sea.
- **Current status of the subparameter:**
- **Quality objectives:**
- **Reference level:** MMBI regularly conducts research on the Kola section. These works include oceanological and biological studies. Thus, there is archival database, which will allow for a

correlation between changes in the composition and the structure of the phytoplankton community and changes in hydrological parameters.

- **Gaps in data coverage:**
- **Other issues about the subparameter:**

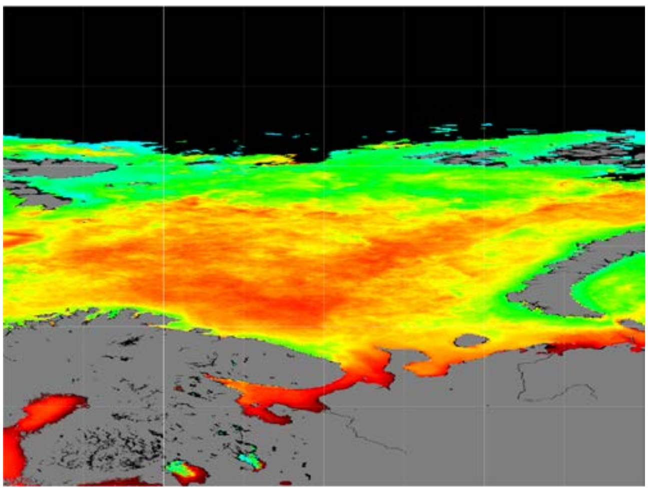
Contact/responsible level: Viktor Larionov, MMBI

Subparameter 5 - Lidar, at fixed poligon (to some depth)

To be developed

Subparameter 6 – Surface concentration of phytoplankton chlorophyll-a (Satellite, Barents Sea, surface)

- **Short facts about the subparameter:** Surface concentration of phytoplankton chlorophyll-a gives essential information about the first trophic level of the Barents Sea ecosystem related to production and biomass of phytoplankton. It is easy and cheap to estimate from satellite remote sensing data.
- **Monitoring:** Surface concentration of chlorophyll-a is calculated from optical remote sensing satellite data using either standard global or locally tuned algorithms. Satellite measurements are performed in the Barents Sea every day however low elevation of sun limits observations to the period from April to August and cloudiness significantly reduces amount of high quality data. Therefore only the spring-summer period (from April to August) and only monthly averaged values of satellite derived of chlorophyll-a concentration is a feasible indicator.
- **Current status of the subparameter:** Surface concentration of chlorophyll-a is being estimated from satellite data since 1980s. Several satellite missions provide optical data and 15 years of observations are already collected. More satellites to carry optical sensors onboard to be launched by space agencies are planned and expected. The figure below shows spatial distribution of chlorophyll-a in the surface waters of the Barents sea as averaged over ten years 2002 – 2012 of spring months.



- **Quality objectives**: The accuracy of surface chlorophyll-a estimate is 0.5 mg m-3.

- **Reference level:** 15 years climatology collected by SeaWiFS/MODIS/MERIS satellite sensors during 1998 – 2012.
- **Gaps in data coverage:** Only summer data is available.

Coordinator/ responsible person: Anton Korosov, NERSC

Contact person/responsible person: Viktor Larionov, Pavel Makarevich, MMBI, Stuart Larsen, IMR

Title: Phytoplankton diversity, abundance and biomass

Parameter: Diversity indices

About the parameter

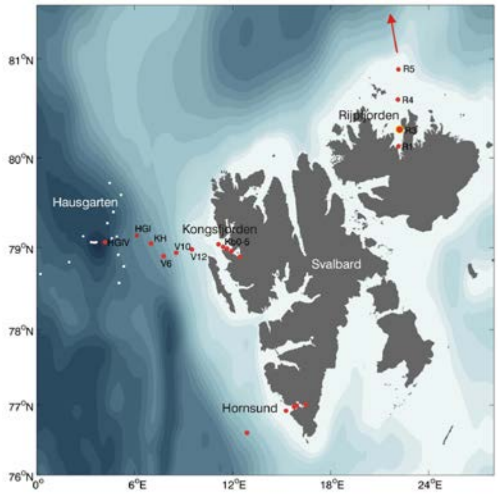
- ***Type of parameter: E***
- ***Priority of parameter: s***
- ***Rationale :*** Which species and large taxonomical groups are dominant and subdominant in pelagic algocenosis will be important for how much energy is available. Species composition and diversity may also be used to assess climate change and human impact.

Overview of the subparameters

Subparameters (name)	***Institution responsible for monitoring***	***Time series period***	***Gaps in monitoring***	***Priority ("e", "r" or "s")***
Kongsfjorden-section	*NPI*	*Today summer/winter, but should include spring*		e
Fugløya-Bjørnøya/(Bear Island)	*IMR*	*Today summer/winter, but should include spring*		e
Vardø-N	*IMR*	*Today summer/winter, but should include spring*		e
Kola section	*MMBI and PINRO*	*Today summer/winter, but should include spring*		e

Subparameter 1 - Kongsfjorden-section

- **Short facts about the subparameter**: Qualitative and quantitative characteristics of phytoplankton (including taxonomical diversity, abundance) along the Kongsfjorden transect provides the basis to calculate diversity indices that can be used to track changes in phytoplankton community composition over time and in relation to hydrographic changes.



- **Why this is a key subparameter:** The Kongsfjorden marine ecosystem functions under the balance of influx of Atlantic waters from the West Spitsbergen Current and Arctic waters from the coastal current and inter-annual variations in the inflow of Atlantic water are common. Pelagic sampling along the Kongsfjorden transect was established to provide a baseline for phytoplankton and zooplankton abundance, taxonomy and distribution and to monitor how interannual changes in hydrography (local and regional scale) affect these parameters. Phytoplankton is at the base of the marine food web and determines the amount of energy that is available for higher trophic levels. Qualitative and quantitative characteristics of phytoplankton (including taxonomical diversity, abundance) gives information regarding the species composition in different hydrographic regimes along the transect. Changes in the species composition could affect the food availability to higher trophic levels (zooplankton). A change in the phytoplankton from preferable food to less optimal prey will have large effect on the energy transport in marine food webs.
- **Monitoring:** The Kongsfjorden transect consists of 11 stations: 5 in the inner part of Kongsfjorden, 3 over the shelf break, and three stations in the Fram Strait (part of the AWI Hausgarten network). Phytoplankton has been sampled at these stations since 2009. Sampling takes place every year in the second half of July by the Norwegian Polar Institute (Arctic Ecosystem Monitoring as part of MOSJ – Environmental monitoring for Svalbard and Jan Mayen). Water sample for phytoplankton composition, abundance and distribution are taken with Niskin bottles attached to the CTD rosette from 0, 10, 25 and 50 m depth and the depth Chl *a* max (if that differs from the standard depth). Samples are fixed in 1 % hexamine-buffered Formaldehyde and 0.1% Glutaraldehyde. Furthermore, to assess microplankton abundance water samples are taken from four Niskin bottles (32 L) at the surface, Chl *a* max and the next standard depth below the Chl *a* max. The water is filtered through a 20 µm net. To assess the abundance of rare taxa a 20 µm phytoplankton net is hauled vertical from 20-0 m. These samples are fixed in 1% hexamine-buffered Formaldehyde and Strontiumchloride stock solution (3ml to 100 ml) is added in order to preserve Acantharians. Samples are analysed by IOPAS in Gdansk, Poland (contact: Josef Wiktor).
- **Current status of the subparameter:** No data is available so far. The parameter was only recently added to the monitoring programme (2009) and it takes 1-2 years after samples were taken before results become available.

- **Quality objectives:** No quality objectives have been set for this parameter in the other monitoring programs.
- **Reference level:**
- **Gaps in data coverage:**
- **Other issues about the subparameter:**

Contact person/responsible person: Malin Daase, NPI

Subparameter 2 - Fugløya-Bear Island

- **Short facts about the subparameter:** The Fugløya-Bear Island section covers the entrance to the Barents Sea from the Norwegian Sea, also known as the Barents Sea Opening (BSO)
- Qualitative and quantitative characteristics of phytoplankton (including taxonomical diversity, abundance). The data is basis for diversity index and to describe the species composition and changes over time (between years).
- **Why this is a key subparameter:** Qualitative and quantitative characteristics of phytoplankton (including taxonomical diversity, abundance) gives information regarding the species composition along the section and in different water masses. Phytoplankton composition influenced by different processes and environmental condition e.g. temperature/climate, stratification, nutrient conditions and water transport as well as biological processes. Changes in the species composition could influence on higher trophic levels (zooplankton). A change in the phytoplankton from preferable food to less optimal prey will have large effect on the energy transport in marine food webs.
- **Monitoring:** The section is usually covered by IMR research vessels 5-6 times a year (January, March, April, July, August and September) and comprises 20 oceanographic stations between the Norwegian Coast and Bear Island. The sampling programme comprises hydrography, nutrients at standard depths down to the bottom and phytoplankton biomass expressed as chlorophyll *a* concentration in the upper 100 metres. Samples for species composition and abundance (cells/l).
- **Current status of the subparameter:** Qualitative and quantitative characteristics of phytoplankton has been analyzed since 2005 and are a relatively time series. Due to the large inter annual variability there is a need for longer period to determined “normal” condition along the section. Data used to give the seasonal description of the species composition and changes.
- **Quality objectives:**
- **Reference level:** It is challenging to set reference condition for diversity, since it could change due to different factors, including monitoring routine and predictability. However, the ongoing activity will increase the “biological knowledge” for the area and will as a database be a “reference” line. Variation in the diversity can be detected if new species occur.
- **Gaps in data coverage:** Time resolution is always a problem when dealing with parameters that vary considerably on short time scales. As a minimum there should also be included samples covering the spring (May).
- **Other issues about the subparameter:**

Contact person/responsible person: Stuart Larsen, IMR

Subparameter 3 - Vardø-N

- **Short facts about the subparameter:** The Vardø-North section start off Vardø at the Norwegian coast and extends northwards along the 31°13`E until 76°30`N or until the ice edge during winter.
  Qualitative and quantitative characteristics of phytoplankton (including taxonomical diversity, abundance). The data is basis for diversity index and to describe the species composition and changes over time (between years).
- **Why this is a key subparameter:** Qualitative and quantitative characteristics of phytoplankton (including taxonomical diversity, abundance) gives information regarding the species composition along the section and in different water masses. Phytoplankton composition influenced by different processes and environmental condition e.g. temperature/climate, stratification, nutrient conditions and water transport as well as biological processes. Changes in the species composition could influence on higher trophic levels (zooplankton). A change in the phytoplankton from preferable food to less optimal prey will have large effect on the energy transport in marine food webs.
- **Monitoring:** The section is usually covered by IMR research vessels 4-5 times a year (January, March, July, August and September) and comprises 22 oceanographic stations between the Norwegian Coast and the Central Barents Sea. The sampling programme comprises hydrography, nutrients at standard depths down to the bottom and phytoplankton biomass expressed as chlorophyll *a* concentration in the upper 100 metres. Samples for species composition and abundance (cells/l).
- **Current status of the subparameter:** Qualitative and quantitative characteristics of phytoplankton has been analyzed since 2005 and are a relatively time series. Due to the large inter annual variability there is a need for longer period to determined “normal” condition along the section. Data used to give the seasonal description of the species composition and changes.
- **Quality objectives:**
- **Reference level:** It is challenging to set reference condition for diversity, since it could be change due to different factors also monitoring routine and predictability. However, the ongoing activity will increase the “biological knowledge” for the area and will as a database be a “reference” line. Divagation in the diversity will can be detected if new species occur.
- **Gaps in data coverage:** Time dissolution is always a problem when dealing with parameters that vary considerable on short time scale. As a minimum there should be included a covering during the spring (May).
- **Other issues about the subparameter:**

Contact person/responsible person: Stuart Larsen, IMR

*Subparameter 4 – **Kola section***

- **Short facts about the subparameter:** Kola section – area of the Barents Sea near Kola bay.
- **Why this is a key subparameter:** Kola section is the most accessible and frequently studied area (expeditions PINRO and MMBI an annual). Qualitative and quantitative characteristics of phytoplankton (including taxonomical diversity, abundance and biomass of organisms, chlorophyll concentration and their seasonal dynamics) in this part of the Barents Sea play an important role in assessing climate change.
- **Monitoring:** Conduct a yearly (4 time per year) sampling of phytoplankton. The following

parameters are assessed: the species composition, diversity indices, the number (abundance) of species groups and the total number (abundance) (cells/l), the total biomass and chlorophyll concentration (mcg/l).

- **Current status of the subparameter:**
- **Quality objectives:**
- **Reference level:** MMBI regularly conducts research on the Kola section. These works include oceanological and biological studies. Thus, there is archival database, which will allow for a correlation between changes in the composition and the structure of the phytoplankton community and changes in hydrological parameters.
- **Gaps in data coverage:**
- **Other issues about the subparameter:**

Contact person/responsible person: Viktor Larionov, MMBI

Contact person/responsible person: Viktor Larionov and Pavel Makarevich, MMBI, Stuart Larsen, IMR

Title: Phytoplankton diversity, abundance and biomass

Parameter: Group abundance

About the parameter

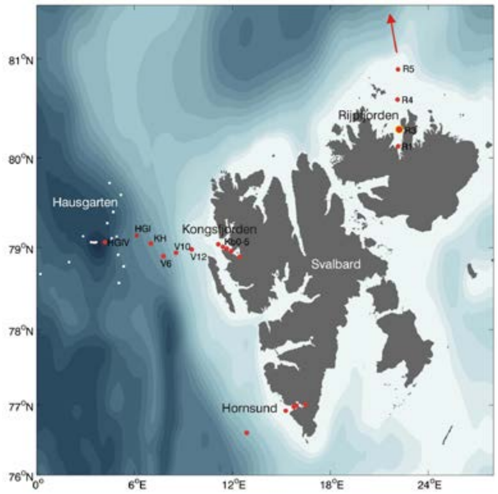
- ***Type of parameter: E***
- ***Priority of parameter: e***
- ***Rationale :*** Which species and large taxonomical groups are dominant in pelagic algocenosis will be important for how much energy is available. Species composition may also be used to assess climate change.

Overview of the subparameters

Subparameters (name)	***Institution responsible for monitoring***	***Time series period***	***Gaps in monitoring***	***Priority (“e”, “r” or “s”)***
Kongsfjorden-section	*CBMP, Arctos-network/NPI, IMR and PINRO?*	*Today summer/winter, but should include spring*		e
Fugløya-Bjørnøya (Bear Island)	*CBMP, Arctos-network/NPI, IMR and PINRO?*	*Today summer/winter, but should include spring*	*Spring*	e
Vardø-N	*CBMP, Arctos-network/NPI, IMR and PINRO?*	*Today summer/winter, but should include spring*	*Spring*	e
Kola	*MMBI and PINRO?*	*Today summer/winter, but should include spring*		e

Subparameter 1 - Kongsfjorden-section

- **Short facts about the subparameter.**
  Abundance of total phytoplankton along the Kongsfjorden transect. Phytoplankton abundance provides an indication how much energy is available for higher trophic levels.



- **Why this is a key subparameter:** The Kongsfjorden marine ecosystem functions under the balance of influx of Atlantic waters from the West Spitsbergen Current and Arctic waters from the coastal current and inter-annual variations in the inflow of Atlantic water are common. Pelagic sampling along the Kongsfjorden transect was established to provide a baseline for phytoplankton and zooplankton abundance, taxonomy and distribution and to monitor how interannual changes in hydrography (local and regional scale) affect these parameters. Phytoplankton is at the base of the marine food web and determines amount of energy that is available for higher trophic levels. Quantitative characteristics of phytoplankton (abundance) gives information regarding the amount of phytoplankton present in different hydrographic regimes along the transect. Changes in abundance affect the feeding conditions of higher trophic levels (zooplankton) which repercussions throughout the marine food web.
- **Monitoring:** The Kongsfjorden transect consists of 11 stations: 5 in the inner part of Kongsfjorden, 3 over the shelf break, and three stations in the Fram Strait (part of the AWI Hausgarten network). Phytoplankton has been sampled at these stations since 2009. Sampling takes place every year in the second half of July by the Norwegian Polar Institute (Arctic Ecosystem Monitoring as part of MOSJ (Miljøovervåkning for Svalbard and Jan Mayen). Water sample for phytoplankton composition, abundance and distribution are taken with Niskin bottles attached to the CTD rosette from 0, 10, 25 and 50 m depth and the depth Chl *a* max (if that differs from the standard depth). Samples are fixed in 1% hexamine-buffered Formaldehyde and 0.1% Glutaraldehyde Furthermore, to assess microplankton abundance water samples are taken from four Niskin bottles (32 L) at the surface, Chl *a* max and the next standard depth below the Chl *a* max. The water is filtered through a 20 µm net. To assess the abundance of rare taxa a 20 µm phytoplankton net is hauled vertical from 20-0 m. These samples are fixed in 1% hexamine-buffered Formaldehyde and Strontium chloride stock solution (3ml to 100 ml) is added in order to preserve Acantharians. Samples are analysed by IOPAS in Gdansk, Poland (phytoplankton species composition, abundance of single taxa and total abundance).
- **Current status of the subparameter:** No data is available so far. The parameter was only recently added to the monitoring program (2009) and it takes 1-2 years after samples were taken before results become available.
- **Quality objectives:** Not set.
- **Reference level:**
- **Gaps in data coverage:**
- **Other issues about the subparameter:**

Subparameter 2 - Fugløya-Bear Island

- **Short facts about the subparameter:** The Fugløya-Bear Island section covers the entrance to the Barents Sea from the Norwegian Sea, also known as the Barents Sea Opening (BSO)
- Qualitative and quantitative characteristics of phytoplankton (including taxonomical diversity, abundance). The data are basis for diversity index and to describe the species composition and changes over time (between years).
- **Why this is a key subparameter:** Qualitative and quantitative characteristics of phytoplankton (including taxonomical diversity, abundance) gives information regarding the species composition along the section and in different water masses. Phytoplankton composition influenced by different processes and environmental condition e.g. temperature/climate, stratification, nutrient conditions and water transport as well as biological processes. Changes in the species composition could influence on higher trophic levels (zooplankton). A change in the phytoplankton from preferable food to less optimal prey will have large effect on the energy transport in marine food webs.
- **Monitoring:** The section is usually covered by IMR research vessels 5-6 times a year (January, March, April, July, August and September) and comprises 20 oceanographic stations between the Norwegian Coast and Bjørnøya (Bear Island). The sampling programme comprises hydrography, nutrients at standard depths down to the bottom and phytoplankton biomass expressed as chlorophyll *a* concentration in the upper 100 meters. Samples for species composition and abundance (cells/l).
- **Current status of the subparameter:** Qualitative and quantitative characteristics of phytoplankton has been analyzed since 2005 and are a relatively time series. Due to the large inter annual variability there is a need for longer period to determined "normal" condition along the section. Data used to give the seasonal description of the species composition and changes.
- **Quality objectives:** Not set.
- **Reference level:** It is challenging to set reference condition for diversity, since it could be change due to different factors also monitoring routine and predictability. However, the ongoing activity will increase the "biological knowledge" for the area and will as a database be a "reference" line. Divagation in the diversity will can be detected if new species occur.
- **Gaps in data coverage:** Time dissolution is always a problem when dealing with parameters that vary considerable on short time scale. As a minimum there should be included a covering during the spring (May).
- **Other issues about the subparameter:**

Subparameter 3 - Vardø-N

- **Short facts about the subparameter:** The Vardø-North section start off Vardø at the Norwegian coast and extends northwards along the 31°13`E until 76°30`N or until the ice edge during winter.
- Qualitative and quantitative characteristics of phytoplankton (including taxonomical diversity, abundance). The data is basis for diversity index and to describe the species composition and changes over time (between years).
- **Why this is a key subparameter:** Qualitative and quantitative characteristics of phytoplankton (including taxonomical diversity, abundance) gives information regarding the species composition along the section and in different water masses. Phytoplankton composition influenced by different processes and environmental condition e.g. temperature/climate, stratification, nutrient conditions and water transport as well as biological processes. Changes in the species composition could influence on higher trophic

levels (zooplankton). A change in the phytoplankton from preferable food to less optimal prey will have large effect on the energy transport in marine food webs.

- **Monitoring:** The section is usually covered by IMR research vessels 4-5 times a year (January, March, July, August and September) and comprises 22 oceanographic stations between the Norwegian Coast and the Central Barents Sea. The sampling program comprise, hydrography, nutrients at standard depths down to the bottom and phytoplankton biomass expressed as chlorophyll *a* concentration in the upper 100 meters. Samples for species composition and abundance (cells/l).
- **Current status of the subparameter:** Qualitative and quantitative characteristics of phytoplankton has been analyzed since 2005 and are a relatively time series. Due to the large inter annual variability there is a need for longer period to determined "normal" condition along the section. Data used to give the seasonal description of the species composition and changes.
- **Quality objectives:** not set
- **Reference level:** It is challenging to set reference condition for diversity, since it could be change due to different factors also monitoring routine and predictability. However, the ongoing activity will increase the "biological knowledge" for the area and will as a database be a "reference" line. Variation in the diversity may be detected if new species occur.
- **Gaps in data coverage:** Time resolution is always a problem when dealing with parameters that vary considerably on a short time scale. As a minimum there should be included a covering during the spring (May).
- **Other issues about the subparameter:**

Subparameter 4 – Kola section

- **Short facts about the subparameter:** Kola section – area of the Barents sea near Kola bay.
- **Why this is a key subparameter:** Kola section – It is the most accessible and frequently studied area (expeditions PINRO and MMBI an annual). Qualitative and quantitative characteristics of phytoplankton (including taxonomical diversity, abundance and biomass of organisms, chlorophyll concentration and their seasonal dynamics) in this part of the Barents Sea play an important role in assessing climate change.
- **Monitoring:** Conduct a yearly (4 time per year) sampling of phytoplankton. The following parameters are assessed: the species composition, diversity indices, the number (abundance) of species groups and the total number (abundance) (cells/l), the total biomass and chlorophyll concentration (mcg/l).
- **Current status of the subparameter:**
- **Quality objectives:** Not set
- **Reference level:** MMBI regularly conducts research on the Kola section. These works include oceanological and biological studies. Thus, there is archival database, which will allow for a correlation between changes in the composition and the structure of the phytoplankton community and changes in hydrological parameters.
- **Gaps in data coverage:**
- **Other issues about the subparameter:**

Contact person/responsible person: Viktor Larionov, MMBI

Contact person/responsible person: Viktor Larionov and Pavel Makarevich, MMBI, Stuart Larsen, IMR

Phytoplankton diversity, abundance and biomass

Parameter: Net primary productivity

About the parameter

- ***Type of parameter: E***
- ***Priority of parameter: e***
- ***Rationale :*** *Net primary production (NPP)* is the production of organic compounds from aquatic carbon dioxide which occurs through the process of photosynthesis, using light as a source of energy. All life in the ocean is directly or indirectly reliant on primary production.

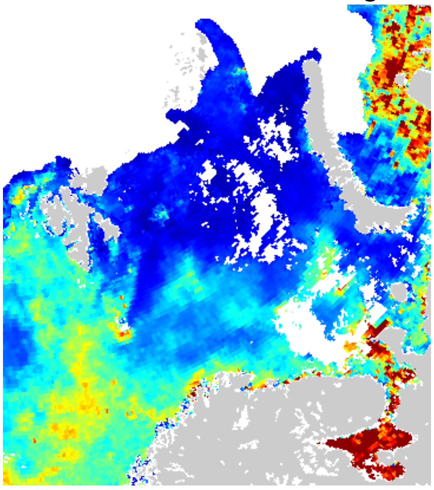
Overview of the subparameters

Subparameters (name)	*Institution responsible for monitoring*	*Time series period*	*Gaps in monitoring*	*Priority ("e", "r" or "s")*
Barents Sea, surface	*NERSC*	*1998 - present*	*Winter time*	e

Subparameter 1 – Barents Sea, surface

- **Why this is a key subparameter:** Net primary production (NPP)
- Net primary production is source of energy to all life in the ocean;
- It depends on weather, light and ocean conditions and therefore on climate / environment status as well as grazing from higher trophic levels;
- It is easy and cheap to estimate from satellite remote sensing data;

- **Monitoring:** NPP is calculated from values of chlorophyll (from satellite data), photosynthetically available radiation (PAR, from satellite data), water temperature (from satellite data), mixed layer depth (e.g. from models or from climatologies) using either global standard or locally tuned algorithms. Satellite measurements are performed in the Barents Sea every day however low elevation of sun limits observations to the period from April to August and cloudiness significantly reduces amount of high quality data. Therefore only spring-summer period (from April to August) and only monthly averaged fields of NPP values is a feasible indicator.
- **Current status of the subparameter:** The algorithms for estimating NPP in the Arctic are validated and enough accurate. Several satellite missions provide optical and thermal data for estimation of chlorophyll, PAR and SST. Several global hydro-dynamic models provide data on mixed layer depth. More satellites to carry optical and thermal sensors onboard to be launched by ESA or NASA are expected. The image below shows spatial distribution of NPP in the the Barents sea as estimated by the Behrenfeld algorithms from chlorophyll derived from MODIS data using standard OC4 algorithm in August 2002.



- **Quality objectives**: The accuracy of surface NPP estimate is 500 mgC m-2 day-1.
- **Reference level:** 10 years climatology calculated from MODIS/MERIS satellite sensors during 2002 – 2012.

Contact person/responsible person: Anton Korosov, NERSC

Phytoplankton diversity, abundance and biomass

Parameter: PIC, satellites

About the parameter

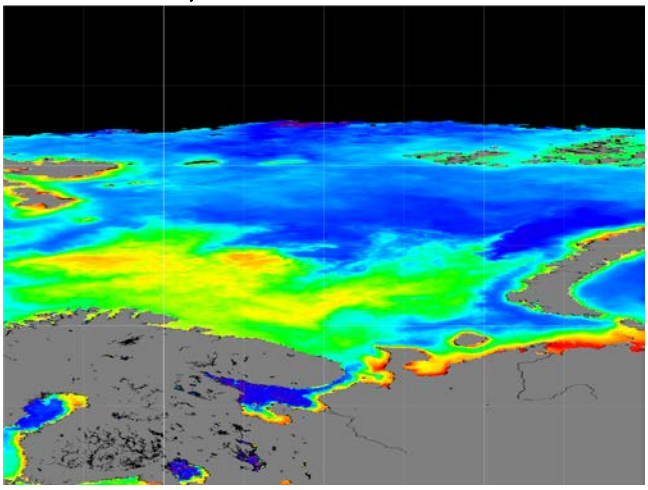
- ***Type of parameter: E***
- ***Priority of parameter: e***
- ***Rationale :*** Particulate inorganic carbon (PIC) concentration in surface waters indicate abundance of coccolithophorid algae (e.g. Emiliania h.) which depends on weather and light conditions, influences acidification processed in the ocean and changes light regime due to very high scattering.

Overview of the subparameters

Subparameters (name)	***Institution responsible for monitoring***	***Time series period***	***Gaps in monitoring***	***Priority ("e", "r" or "s")***
Barents Sea, surface	*NERSC*	*2002 - present*	*Winter time*	e

Subparameter 1 - Barents Sea, surface

- **Why this is a key subparameter:** Surface concentration of particulate inorganic carbon (PIC)
- Surface concentration of particulate inorganic carbon gives essential information on the occurrence of coccolithophorid algae.
- It is related to production and biomass of phytoplankton, acidification processes and light availability
- It is easy and cheap to estimate from satellite remote sensing data
- **Monitoring:** Surface concentration of PIC is calculated from optical remote sensing satellite data using either standard global or locally tuned algorithms. Satellite measurements are performed in the Barents Sea every day however low elevation of sun limits observations to the period from April to August and cloudiness significantly reduces amount of high quality data. Therefore only the spring-summer period (from April to August) and only monthly averaged values of satellite derived of PIC concentration is a feasible indicator.
- **Current status of the subparameter:** Surface concentration of PIC is being effectively estimated from satellite data since 2002. Several satellite missions provide optical data and 10 years of observations are already collected. More satellites to carry optical sensors onboard to be launched by space agencies are planned and expected. The figure below shows spatial distribution of PIC in the surface waters of the Barents Sea as averaged over ten years 2002 – 2012 of summer months during typical blooming period of coccolithophorid Emiliania Huxley.



- **Quality objectives**: The accuracy of surface PIC estimate is 2e-6 mol m-3.
- **Reference level:** 10 years climatology collected by MODIS/MERIS satellite sensors during 2002 - 2012

Contact person/responsible person: Anton Korosov, NERSC

Title: Phytoplankton diversity, abundance and biomass

Parameter: Species abundance

About the parameter

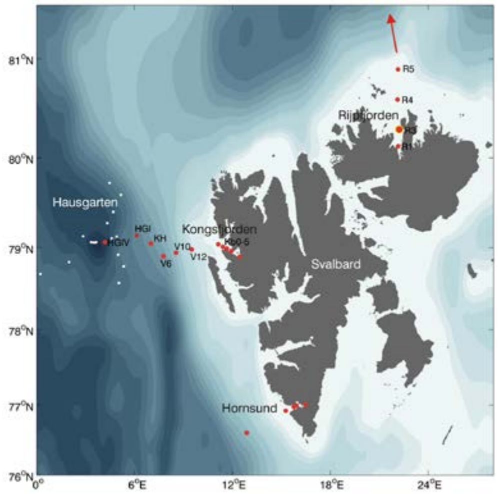
- ***Type of parameter: E***
- ***Priority of parameter: s***
- ***Rationale :*** Which species and large taxonomical groups are dominant in pelagic algocenosis will be important for how much energy is available. Species composition may also be used to assess climate change.

Overview of the subparameters

Subparameters (name)	***Institution responsible for monitoring***	***Time series period***	***Gaps in monitoring***	***Priority ("e", "r" or "s")***
Kongsfjorden-section	*NPI*	*Today summer/winter, but should include spring*		s
Fugløya- Bjørnøya (Bear Island)	*IMR*	*Today summer/winter, but should include spring*	*Spring*	s
Vardø-N	*IMR*	*Today summer/winter, but should include spring*	*Spring*	s
Kola	*MMBI and PINRO*	*Today summer/winter, but should include spring*		s

Subparameter 1 - Kongsfjorden-section

- **Short facts about the subparameter.**
  Abundance all species of phytoplankton along the Kongsfjorden transect. Phytoplankton species abundance provides an indication how much energy is available for higher trophic levels and which species dominated (in what form is the energy available)



- **Why this is a key subparameter:**
- The Kongsfjorden marine ecosystem functions under the balance of influx of Atlantic waters from the West Spitsbergen Current and Arctic waters from the coastal current and inter-annual variations in the inflow of Atlantic water are common. Pelagic sampling along the Kongsfjorden transect was established to provide a baseline for phytoplankton and zooplankton abundance, taxonomy and distribution and to monitor how interannual changes in hydrography (local and regional scale) affect these parameters. Phytoplankton is at the base of the marine food web and determines the amount of energy that is available for higher trophic levels. Quantitative and qualitative characteristics of phytoplankton (abundance and species composition) gives information regarding the amount of phytoplankton present in different hydrographic regimes along the transect and which species dominate at a given time and place. Changes in abundance and species composition affect the feeding conditions of higher trophic levels (zooplankton) which percussions throughout the marine food web.
- **Monitoring:**
  The Kongsfjorden transect consists of 11 stations: 5 in the inner part of Kongsfjorden, 3 over the shelf break, and three stations in the Fram Strait (part of the AWI Hausgarten network). Phytoplankton has been sampled at these stations since 2009. Sampling takes place every year in the second half of July by the Norwegian Polar Institute (Arctic Ecosystem Monitoring as part of MOSJ (Miljøovervåkning for Svalbard and Jan Mayen). Water sample for phytoplankton composition, abundance and distribution are taken with Niskin bottles attached to the CTD rosette from 0, 10, 25 and 50 m depth and the depth Chl *a* max (if that differs from the standard depth). Samples are fixed in 1% hexamine-buffered Formaldehyde and 0.1% Glutaraldehyde Furthermore, to assess microplankton abundance water samples are taken from four Niskin bottles (32 L) at the surface, Chl *a* max and the next standard depth below the Chl *a* max. The water is filtered through a 20 µm net. To assess the abundance of rare taxa a 20 µm phytoplankton net is hauled vertical from 20-0 m. These samples are fixed in 1% hexamine-buffered Formaldehyde and Strontiumchloride stock solution (3ml to 100 ml) is added in order to preserve Acantharians. Samples are analysed by IOPAS in Gdansk, Poland (phytoplankton species composition, abundance of single taxa and total abundance).

- **Current status of the subparameter:** No data is available so far. The parameter was only recently added to the monitoring program (2009) and it takes 1-2 years after samples were taken before results become available.
- **Quality objectives:** No quality objectives have been set for this parameter in the other monitoring programs (i.e. the Norwegian mom. Progr., OSPAR etc)
- **Reference level:**
- **Gaps in data coverage:**
- **Other issues about the subparameter:**

Subparameter 2 - Fugløya-Bear Island

- **Short facts about the subparameter:** The Fugløya-Bjørnøya (Bear Island) section covers the entrance to the Barents Sea from the Norwegian Sea, also known as the Barents Sea Opening (BSO)
- Qualitative and quantitative characteristics of phytoplankton (including taxonomical diversity, abundance). The data is basis for diversity index and to describe the species composition and changes over time (between years).
- **Why this is a key subparameter:** Qualitative and quantitative characteristics of phytoplankton (including taxonomical diversity, abundance) gives information regarding the species composition along the section and in different water masses. Phytoplankton composition influenced by different processes and environmental condition e.g. temperature/climate, stratification, nutrient conditions and water transport as well as biological processes. Changes in the species composition could influence on higher trophic levels (zooplankton). A change in the phytoplankton from preferable food to less optimal prey will have large effect on the energy transport in marine food webs.
- **Monitoring:** The section is usually covered by IMR research vessels 5-6 times a year (January, March, April, July, August and September) and comprises 20 oceanographic stations between the Norwegian Coast and Bear Island. The sampling programme comprises hydrography, nutrients at standard depths down to the bottom and phytoplankton biomass expressed as chlorophyll *a* concentration in the upper 100 meters. Samples for species composition and abundance (cells/l).
- **Current status of the subparameter:** Qualitative and quantitative characteristics of phytoplankton has been analyzed since 2005 and are a relatively time series. Due to the large inter annual variability there is a need for longer period to determined "normal" condition along the section. Data used to give the seasonal description of the species composition and changes.
- **Quality objectives:**
- **Reference level:** It is challenging to set reference condition for diversity, since it could be change due to different factors also monitoring routine and predictability. However, the ongoing activity will increase the "biological knowledge" for the area and will as a database be a "reference" line. Divagation in the diversity will can be detected if new species occur.
- **Gaps in data coverage:** Time dissolution is always a problem when dealing with parameters that vary considerable on short time scale. As a minimum there should be included a covering during the spring (May).
- **Other issues about the subparameter:**

Subparameter 3 - Vardø-N

- **Short facts about the subparameter:** The Vardø-North section start off Vardø at the

Norwegian coast and extends northwards along the 31°13`E until 76°30`N or until the ice edge during winter.
Qualitative and quantitative characteristics of phytoplankton (including taxonomical diversity, abundance). The data is basis for diversity index and to describe the species composition and changes over time (between years).

- **Why this is a key subparameter:** Qualitative and quantitative characteristics of phytoplankton (including taxonomical diversity, abundance) gives information regarding the species composition along the section and in different water masses. Phytoplankton composition influenced by different processes and environmental condition e.g. temperature/climate, stratification, nutrient conditions and water transport as well as biological processes. Changes in the species composition could influence on higher trophic levels (zooplankton). A change in the phytoplankton from preferable food to less optimal prey will have large effect on the energy transport in marine food webs.
- **Monitoring:** The section is usually covered by IMR research vessels 4-5 times a year (January, March, July, August and September) and comprises 22 oceanographic stations between the Norwegian Coast and the Central Barents Sea. The sampling programme comprises, hydrography, nutrients at standard depths down to the bottom and phytoplankton biomass expressed as chlorophyll *a* concentration in the upper 100 meters. Samples for species composition and abundance (cells/l).
- **Current status of the subparameter:** Qualitative and quantitative characteristics of phytoplankton has been analyzed since 2005 and are a relatively time series. Due to the large inter annual variability there is a need for longer period to determined "normal" condition along the section. Data used to give the seasonal description of the species composition and changes.
- **Quality objectives:**
- **Reference level:** It is challenging to set reference condition for diversity, since it could be change due to different factors also monitoring routine and predictability. However, the ongoing activity will increase the "biological knowledge" for the area and will as a database be a "reference" line. Divagation in the diversity will can be detected if new species occur.
- **Gaps in data coverage:** Time dissolution is always a problem when dealing with parameters that vary considerable on short time scale. As a minimum there should be included a covering during the spring (May).
- **Other issues about the subparameter:**

Subparameter 4 – Kola section

- **Short facts about the subparameter:** Kola section – area of the Barents Sea near Kola bay.
- **Why this is a key subparameter:** Kola section – It is the most accessible and frequently studied area (expeditions PINRO and MMBI an annual). Qualitative and quantitative characteristics of phytoplankton (including taxonomical diversity, abundance and biomass of organisms, chlorophyll concentration and their seasonal dynamics) in this part of the Barents Sea play an important role in assessing climate change.
- **Monitoring:** Conduct a yearly (4 time per year) sampling of phytoplankton. The following parameters are assessed: the species composition, diversity indices, the number (abundance) of species groups and the total number (abundance) (cells/l), the total biomass and chlorophyll concentration (mcg/l).
- **Current status of the subparameter:**
- **Quality objectives:**
- **Reference level:** MMBI regularly conducts research on the Kola section. These works

include oceanological and biological studies. Thus, there is archival database, which will allow for a correlation between changes in the composition and the structure of the phytoplankton community and changes in hydrological parameters.

- **Gaps in data coverage:**
- **Other issues about the subparameter:**

Contact person/responsible person: Viktor Larionov, MMBI

Contact person/responsible person: Viktor Larionov, Pavel Makarevich, MMBI

Title: Phytoplankton diversity, abundance and biomass

Parameter: Species composition

About the parameter

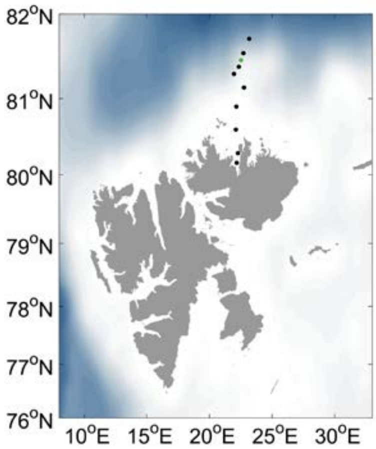
- ***Type of parameter: E***
- ***Priority of parameter: e***
- ***Rationale :*** Which species and large taxonomical groups are dominant in pelagic algocenosis will be important for how much energy is available. Species composition may also be used to assess climate change and human impact.

Overview of the subparameters

Subparameters (name)	*Institution responsible for monitoring*	*Time series period*	*Gaps in monitoring*	*Priority ("e", "r" or "s")*
Rijpfjorden transect	*NPI, UNIS*	*Today summer/winter, but should include spring*		e
Kongsfjorden-section	*NPI*	*Today summer/winter, but should include spring*		e
Fugløya-Bjørnøya (Bear Island)	*IMR*	*Today summer/winter, but should include spring*	*Spring*	e
Vardø-N	*IMR*	*Today summer/winter, but should include spring*	*Spring*	e
Kola	*MMBI and PINRO*	*Today summer/winter, but should include spring*		e
ES, Barents Sea	*To be developed*			e

Subparameter 1 - Rijpfjorden transect

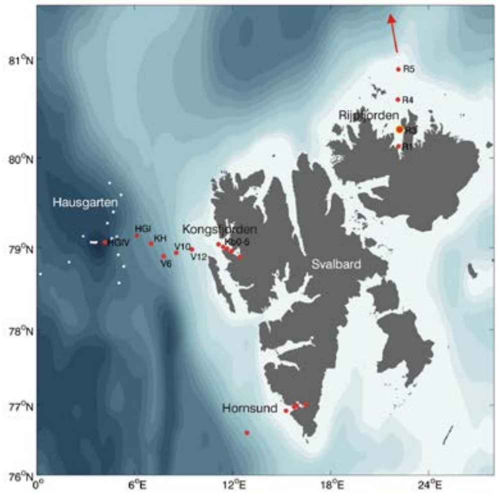
- **Phytoplankton species composition along the Rijpfjorden transect.** Species composition provides an indication how much and in which form energy is available for higher trophic levels, and can be used to calculate diversity indices.



- **Why this is a key subparameter:** The Rijpfjorden is a north-facing fjord with a wide opening towards the broad shallow shelf which extends to the shelf-break of the Polar Basin at approx. 81°N. Rijpfjorden is dominated by cold Arctic water masses and the inflow of Atlantic water is much less pronounced compared fjords located on the western coast of Svalbard. Pelagic sampling along the Rijpfjorden transect was established in 2004 to provide a baseline for phytoplankton and zooplankton abundance, taxonomy and distribution and to monitor how interannual changes in hydrography (local and regional scale) affect these parameters. These parameters complement similar monitoring activities along the Kongsfjorden transect. Phytoplankton is at the base of the marine food web and determines the amount of energy that is available for higher trophic levels. Quantitative and qualitative characteristics of phytoplankton (abundance and species composition) gives information regarding the amount of phytoplankton present in different hydrographic regimes along the transect and which species dominate at a given time and place. Changes species composition affect the feeding conditions of higher trophic levels (zooplankton) which percussions throughout the marine food web.
- **Monitoring:** The Rijpfjorden consists of 2 stations in the inner fjord, 2-3 stations on the shelf and a number of stations over the shelf break and into the Arctic Ocean. The total number of stations and the northwards extend of the transect varies between the years depending on on ice conditions and available ship time. Phytoplankton has been sampled at these stations since 2009. Sampling takes place every year sometime in between July and September either by the Norwegian Polar Institute (ICE Centre). Additional sampling may be provided by UNIS in connection with teaching cruises. Water sample for phytoplankton composition, abundance and distribution are taken with Niskin bottles attached to the CTD rosette from 0, 10, 25 and 50 m depth and the depth Chl *a* max (if that differs from the standard depth). Samples are fixed in 1% hexamine-buffered Formaldehyde and 0.1% Glutaraldehyde Furthermore, to assess microplankton abundance water samples are taken from four Niskin bottles (32 L) at the surface, Chl *a* max and the next standard depth below the Chl *a* max. The water is filtered through a 20 µm net. To assess the abundance of rare taxa a 20 µm phytoplankton net is hauled vertical from 20-0 m. These samples are fixed in 1% hexamine-buffered Formaldehyde and Strontiumchloride stock solution (3ml to 100 ml) is added in order to preserve Acantharians.
- **Current status of the subparameter:** No data is available so far. The parameter was only recently added to the monitoring programme (2009) and it takes 1-2 years after samples were taken before results become available.
- **Quality objectives:** No quality objectives have been set for this parameter in the other monitoring programmes (i.e. the Norwegian mom. Progr., OSPAR etc).
- **Reference level:**
- **Gaps in data coverage:**
- **Other issues about the subparameter:**

Subparameter 2 - Kongsfjorden-section

- **Short facts about the subparameter:** Phytoplankton species composition along the Kongsfjorden transect. Species composition provides an indication how much and in which form energy is available for higher trophic levels, and can be used to calculate diversity indices.



- **Why this is a key subparameter:** The Kongsfjorden marine ecosystem functions under the balance of influx of Atlantic waters from the West Spitsbergen Current and Arctic waters from the coastal current and inter-annual variations in the inflow of Atlantic water are common. Pelagic sampling along the Kongsfjorden transect was established to provide a baseline for phytoplankton and zooplankton abundance, taxonomy and distribution and to monitor how interannual changes in hydrography (local and regional scale) affect these parameters. Phytoplankton is at the base of the marine food web and determines the amount of energy that is available for higher trophic levels. Quantitative and qualitative characteristics of phytoplankton (abundance and species composition) gives information regarding the amount of phytoplankton present in different hydrographic regimes along the transect and which species dominate at a given time and place. Changes in species composition affect the feeding conditions of higher trophic levels (zooplankton) with repercussions throughout the marine food web.
- **Monitoring:** The Kongsfjorden transect consists of 11 stations: 5 in the inner part of Kongsfjorden, 3 over the shelf break, and three stations in the Fram Strait (part of the AWI Hausgarten network). Phytoplankton has been sampled at these stations since 2009. Sampling takes place every year in the second half of July by the Norwegian Polar Institute (Arctic Ecosystem Monitoring as part of MOSJ-Miljøovervåkning for Svalbard and Jan Mayen). Water sample for phytoplankton composition, abundance and distribution are taken with Niskin bottles attached to the CTD rosette from 0, 10, 25 and 50 m depth and the depth Chl *a* max (if that differs from the standard depth). Samples are fixed in 1% hexamine-buffered Formaldehyde and 0.1% Glutaraldehyde Furthermore, to assess microplankton abundance water samples are taken from four Niskin bottles (32 L) at the surface, Chl *a* max and the next standard depth below the Chl *a* max. The water is filtered through a 20 µm net. To assess the abundance of rare taxa a 20 µm phytoplankton net is hauled vertical from 20-0 m. These samples are fixed in 1% hexamine-buffered Formaldehyde and Strontiumchloride stock solution (3ml to 100 ml) is added in order to preserve Acantharians. Samples are analysed by IOPAS in Gdansk, Poland (phytoplankton species composition, abundance of single taxa and total abundance).
- **Current status of the subparameter:** No data is available so far. The parameter was only

recently added to the monitoring programme (2009) and it takes 1-2 years after samples were taken before results become available.

- **Quality objectives:** No quality objectives have been set for this parameter in the other monitoring programmes (i.e. the Norwegian mom. Progr., OSPAR etc).
- **Reference level:**
- **Gaps in data coverage:**
- **Other issues about the subparameter:**

Subparameter 3 - Fugløya-Bear Island

- **Short facts about the subparameter:** The Fugløya-Bjørnøya (Bear Island) section covers the entrance to the Barents Sea from the Norwegian Sea, also known as the Barents Sea Opening (BSO).
- Qualitative and quantitative characteristics of phytoplankton (including taxonomical diversity, abundance). The data is basis for diversity index and to describe the species composition and changes over time (between years).
- **Why this is a key subparameter:** Qualitative and quantitative characteristics of phytoplankton (including taxonomical diversity, abundance) gives information regarding the species composition along the section and in different water masses. Phytoplankton composition influenced by different processes and environmental condition e.g. temperature/climate, stratification, nutrient conditions and water transport as well as biological processes. Changes in the species composition could influence on higher trophic levels (zooplankton). A change in the phytoplankton from preferable food to less optimal prey will have large effect on the energy transport in marine food webs.
- **Monitoring:** The section is usually covered by IMR research vessels 5-6 times a year (January, March, April, July, August and September) and comprises 20 oceanographic stations between the Norwegian Coast and Bear Island. The sampling programme comprises hydrography, nutrients at standard depths down to the bottom and phytoplankton biomass expressed as chlorophyll *a* concentration in the upper 100 meters. Samples for species composition and abundance (cells/l).
- **Current status of the subparameter:** Qualitative and quantitative characteristics of phytoplankton has been analyzed since 2005 and are a relatively time series. Due to the large inter annual variability there is a need for longer period to determined “normal” condition along the section. Data used to give the seasonal description of the species composition and changes.
- **Quality objectives:**
- **Reference level:** It is challenging to set reference condition for diversity, since it could be change due to different factors also monitoring routine and predictability. However, the ongoing activity will increase the “biological knowledge” for the area and will as a database be a “reference” line. Variation in the diversity will can be detected if new species occur.
- **Gaps in data coverage:** Time resolution is always a problem when dealing with parameters that vary considerably on short time scale. As a minimum there should be included a covering during the spring (May).
- **Other issues about the subparameter:**

Subparameter 4 - Vardø-N

- **Short facts about the subparameter:** The Vardø-North section start off Vardø at the Norwegian coast and extends northwards along the 31°13`E until 76°30`N or until the ice edge during winter.
  Qualitative and quantitative characteristics of phytoplankton (including taxonomical diversity, abundance). The data is basis for diversity index and to describe the species composition and changes over time (between years).
- **Why this is a key subparameter:** Qualitative and quantitative characteristics of phytoplankton (including taxonomical diversity, abundance) gives information regarding the species composition along the section and in different water masses. Phytoplankton composition influenced by different processes and environmental condition e.g. temperature/climate, stratification, nutrient conditions and water transport as well as biological processes. Changes in the species composition could influence on higher trophic levels (zooplankton). A change in the phytoplankton from preferable food to less optimal prey will have large effect on the energy transport in marine food webs.
- **Monitoring:** The section is usually covered by IMR research vessels 4-5 times a year (January, March, July, August and September) and comprises 22 oceanographic stations between the Norwegian Coast and the Central Barents Sea. The sampling programme comprise, hydrography, nutrients at standard depths down to the bottom and phytoplankton biomass expressed as chlorophyll *a* concentration in the upper 100 metres. Samples for species composition and abundance (cells/l).
- **Current status of the subparameter:** Qualitative and quantitative characteristics of phytoplankton has been analyzed since 2005 and are a relatively time series. Due to the large inter annual variability there is a need for a longer period to determined "normal" condition along the section. Data are used to give the seasonal description of the species composition and changes.
- **Quality objectives:**
- **Reference level:** It is challenging to set a reference condition for diversity, since it could be change due to different factors and also monitoring routine and predictability. However, the ongoing activity will increase the "biological knowledge" for the area and will as a database be a "reference" line. Divagation in the diversity will can be detected if new species occur.
- **Gaps in data coverage:** Time resolution is always a problem when dealing with parameters that vary considerably on short time scale. As a minimum there should be included a covering during the spring (May).
- **Other issues about the subparameter:**

Subparameter 5 – Kola section

- **Short facts about the subparameter:** Kola section – area of the Barents sea near Kola bay.
- **Why this is a key subparameter:** Kola section – It is the most accessible and frequently studied area (expeditions PINRO and MMBI an annual). Qualitative and quantitative characteristics of phytoplankton (including taxonomical diversity, abundance and biomass of organisms, chlorophyll concentration and their seasonal dynamics) in this part of the Barents Sea play an important role in assessing climate change.
- **Monitoring:** Conduct a yearly (4 time per year) sampling of phytoplankton. The following parameters are assessed: the species composition, diversity indices, the number (abundance) of species groups and the total number (abundance) (cells/l), the total biomass and chlorophyll concentration (mcg/l).
- **Current status of the subparameter:**
- **Quality objectives:**

- **Reference level:** MMBI regularly conducts research on the Kola section. These works include oceanological and biological studies. Thus, there is archival database, which will allow for a correlation between changes in the composition and the structure of the phytoplankton community and changes in hydrological parameters.
- **Gaps in data coverage:**
- **Other issues about the subparamete**r:

Contact person/responsible person : Viktor Larionov

Subparameter 6 – ES, Barents Sea

To be developed

Contact person/responsible person: Viktor Larionov, Pavel Makarevich, MMBI, Stuart Larsen, IMR

Phytoplankton diversity, abundance and biomass

Parameter: Start, duration and intensity of the late summer bloom

About the parameter

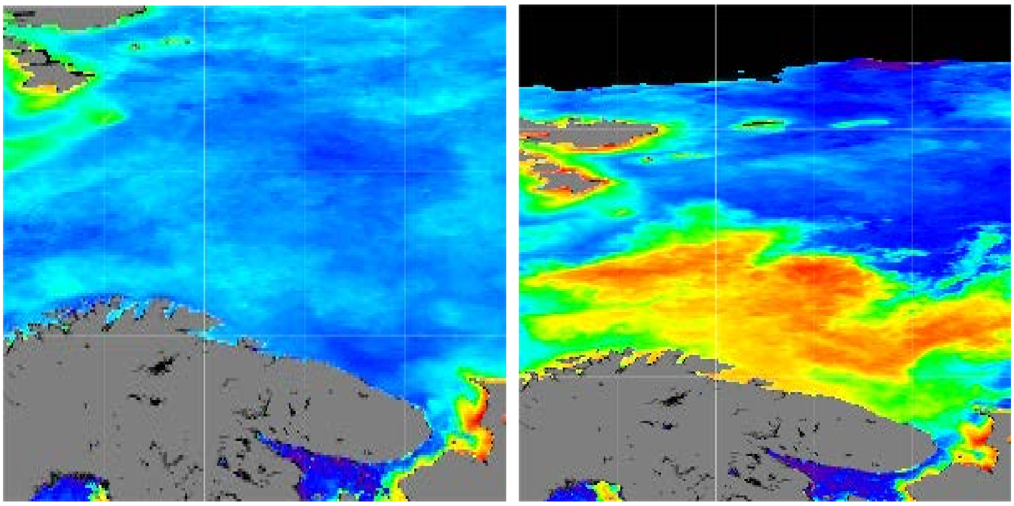
- ***Type of parameter: E***
- ***Priority of parameter: e***
- ***Rationale :*** This parameter provides compulsory and sufficient information about immediate response of the lowest level biotic processes to physical forcing factors. Higher trophic levels directly depend on phytoplankton. Therefore we should have information about the direct link between physical and biological processes.

Overview of the subparameters

Subparameters (name)	***Institution responsible for monitoring***	***Time series period***	***Gaps in monitoring***	***Priority ("e", "r" or "s")***
Barents Sea, surface	*NERSC*	*1998 - now*	*Winter time*	e

Subparameter 1 - Barents Sea, surface

- **Short facts about the subparameter:** Phenology of *la*te summer *phytoplankton* bloom
  The late summer phytoplankton bloom is mainly composed of coccolithophorid species (e.g. Emiliania h.) The timing of start, duration and decay of the bloom depends on weather, light and ocean conditions, nutrient availability, grazing and therefore on climate / environment variability; It is easy and cheap to estimate from satellite remote sensing data.
- **Monitoring:** Start, duration and end is estimated from time series of satellite images of concentration of particulate inorganic carbon (PIC) at weekly resolution. When a average concentration of PIC exceeds background value the bloom is considered to be started. When the average concentration is again back to background the bloom is over and duration can be estimated. Intensity of the bloom is either maximum concentration of PIC or integral of PIC over the bloom period.
- **Current status of the subparameter:** Surface concentration of PIC is being effectively estimated from satellite data since 2002. Several satellite missions provide optical data and 10 years of observations are already collected. More satellites to carry optical sensors onboard to be launched by space agencies are planned and expected. The figure below shows spatial distribution of PIC in the surface waters of the Barents sea as averaged over ten years 2002 – 2012 of June (before the bloom) and August (during the bloom) of coccolithophorid Emiliania Huxley.



- **Quality objectives**: The accuracy of dates estimate is 7 days.
- **Reference level:** 10 years climatology calculated from MODIS/MERIS satellite sensors during 2002 - 2012

Contact person/responsible person: Anton Korosov, NERSC, Viktor Larionov, MMBI

Phytoplankton diversity, abundance and biomass

Parameter: Start, duration and intensity of the spring bloom

About the parameter

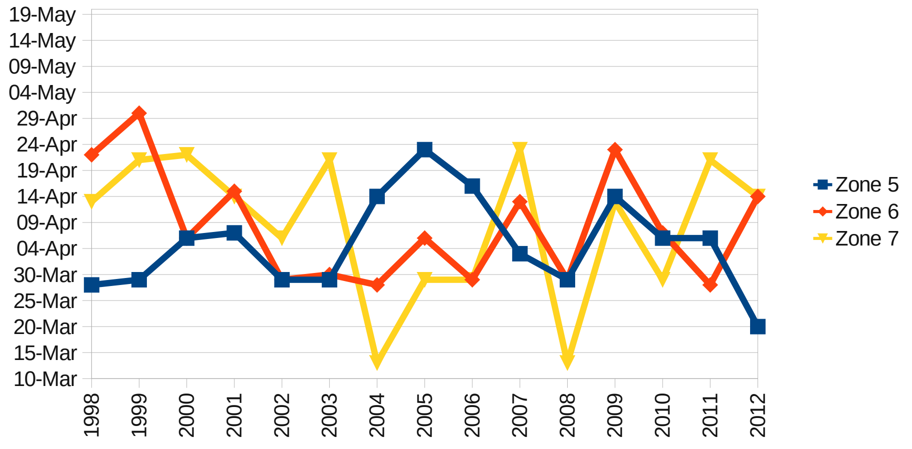
- ***Type of parameter: E***
- ***Priority of parameter: e***
- ***Rationale :*** This parameter provides compulsory and sufficient information about immediate response of the lowest level biotic processes to physical forcing factors. Higher trophic levels directly depend on phytoplankton. Therefore we should have information about the direct link between physical and biological processes.

Overview of the subparameters

Subparameters (name)	***Institution responsible for monitoring***	***Time series period***	***Gaps in monitoring***	***Priority (“e”, “r” or “s”)***
Barents Sea, surface	*NERSC*	*1998 - present*	*Winter time*	e

Subparameter 1 - Barents Sea, surface

- **Short facts about the subparameter:**
- Phenology of spring phytoplankton bloom
- The spring phytoplankton bloom is mainly composed of diatoms species
- The timing of spring phytoplankton bloom onset evolution and decay depends on weather, light and ocean conditions, available nutrients, grazing and therefore on climate / environment variability;
- It is easy and cheap to estimate from satellite remote sensing data;
- **Monitoring:** Start, duration and end is estimated from time series of satellite images measuring concentrations of chlorophyll-a at weekly time resolution. When an average concentration of chlorophyll-a exceed background value the bloom is considered to be started. When the average concentration is again back to background the bloom is over and duration can be estimated. Intensity of the bloom is either maximum concentration of chlorophyll or integral of chlorophyll concentration over the bloom period.
- **Current status of the subparameter:** Surface concentration of chlorophyll is being effectively estimated from satellite data since 1980s. Several satellite missions provide optical data and 15 years of observations are already collected. More satellites to carry optical sensors onboard to be launched by space agencies are planned and expected. The plot below shows time series of starting day of spring phytoplankton bloom in the Barents Sea estimated since 1998 until present.



- **Quality objectives**: The accuracy of dates estimate is 7 days.
- **Reference level:** 15 years climatology calculated from MODIS/MERIS satellite sensors during 2002 – 2012.

Contact person/responsible person: Anton Korosov, NERSC, Viktor Larionov, MMBI

Title: Phytoplankton diversity, abundance and biomass

Parameter: Total biomass

About the parameter

- ***Type of parameter: E***
- ***Priority of parameter: e***
- ***Rationale :*** Biomass and production in the water column indicate the amount of phytoplankton and therefore how much energy is available. Change in biomass of phytoplankton affects the amount of food available for higher trophic levels.

Overview of the subparameters

Subparameters (name)	***Institution responsible for monitoring***	***Time series period***	***Gaps in monitoring***	***Priority ("e", "r" or "s")***
Kongsfjorden-section	*CBMP, Arctos-network/NPI, IMR*	*Today summer/winter, but should include spring*		e
Fugløya-Bear Island	*CBMP, Arctos-network/NPI, IMR*	*Today summer/winter, but should include spring*		e
Vardø-N	*CBMP, Arctos-network/NPI, IMR*	*Today summer/winter, but should include spring*	*Spring*	e
Kola	*MMBI and PINRO*	*Today summer/winter, but should include spring*	*Spring*	e

Subparameter 1 - Kongsfjorden-section

Biomass is not estimated along the Kongsfjorden transect.

Subparameter 2 - Fugløya-Bjørnøya

For phytoplankton IMR use the Chl a as a ”total biomass” indicator. Biomass could be performed by estimating phytoplankton carbon based on the taxonomic and abundance data. This is not performed today and will require more time/money.

Subparameter 3 - Vardø-N

For phytoplankton IMR uses the Chl a as a ”total biomass” indicator. Biomass could be performed by estimating phytoplankton carbon based on the taxonomic and abundance data. This is not performed today and will require more time/money.

Subparameter 4 – Kola section (Viktor Larionov)

- **Short facts about the subparameter:** Kola section – area of the Barents sea near Kola bay.
- **Why this is a key subparameter:** Kola section – It is the most accessible and frequently studied area (expeditions PINRO and MMBI an annual). Qualitative and quantitative characteristics of phytoplankton (including taxonomical diversity, abundance and biomass of organisms, chlorophyll concentration and their seasonal dynamics) in this part of the Barents Sea play an important role in assessing climate change.
- **Monitoring:** Conduct a yearly (4 times per year) sampling of phytoplankton. The following parameters are assessed: the species composition, diversity indices, the number (abundance) of species groups and the total number (abundance) (cells/l), the total biomass and chlorophyll concentration (mcg/l).
- **Current status of the subparameter:**
- **Quality objectives:** Not set.
- **Reference level:** MMBI regularly conducts research on the Kola section. These works include oceanological and biological studies. Thus, there is archival database, which will allow for a correlation between changes in the composition and the structure of the phytoplankton community and changes in hydrological parameters.
- **Gaps in data coverage:**
- **Other issues about the subparameter:**

Contact person/responsible person: Viktor Larionov, Pavel Makarevich, MMBI

Title: Pollution levels in the physical environment (E, I)

About the indicator

- ***Type of indicator: E,I***
- ***Priority of indicator: e***
- ***Rationale:*** POPs, heavy metals (in particular Hg is of concern) and radionuclides are transported on a regional/ hemispheric/global scale. The Arctic is a sink region for these pollutants, where they may accumulate in biota and affect other parts of the ecosystems.

Overview of Parameters

Parameters (name)	***Type (“E”, “A”, or “I”)***	***Priority (“e”, “r” or “s”)***
Pollution levels in air	*E, I*	e
Pollution levels in sea water	*E, I*	e
Oil in water from regular discharges	*E, I*	r
Pollution levels in sediments	*E, I*	e

Contact person/responsible person: Camilla F. Pettersen, Norwegian Environment Agency

Title: Pollution levels in the physical environment

Parameter: Oil in water from regular discharges

- ***Type of parameter: E,I***
- ***Priority of the parameter, and why: r***

Overview of the subparameters

Parameters (name)	***Type ("E", "I", or "A")***	***Institution responsible for monitoring***	***Time series period***	***Have environmental quality objectives been set for this subparameters in the other monitoring programmes (i.e. the Norwegian mon.?***	***Priority ("e", "r" or "s")***
THC (total hydrocarbons) (> 30 mg/l)	*E, I*	*The operators on all installations which have discharges of produced water to the sea* The Climate and Pollution Agency, Norwegian Petroleum Directorate	*Monthly mean and reporting of derogation from OSPAR limit in the annual reports* 2005 - present	Yes	r

- **Short facts about the parameter:** Oil from the petroleum industry is one of the contributions to the influence of hydrocarbons (THC) in the marine environments in the Barents Sea. It may be appropriate to look at the contribution of the regular discharges on the Norwegian continental shelf up against other inputs which occur naturally such as leaks from the seabed (seeps), accidental spills from ships and from other sources, such as long-range transport by ocean currents (eg, from the British petroleum sector). The extent of regular discharges from the petroleum industry can be used to assess pollution in the sea. There are international obligations related to keeping track of Norwegian oil discharges to the seas (OSPAR).
- **Monitoring:** On all platforms with regular discharges of produced water to the sea, daily discharges are measured by sampling three times a day and the flow rate is measured. Today gas chromatographs are used all over the shelf. Oil concentrations are multiplied by the daily total water quantities which provide monthly figures in the reports. Monitoring of oil in water has been done for some years on the Norwegian continental shelf, but the methods have been changed along the way. Good time series exist for the past decade.

  The network of stations is shaped by the individual oil fields (Snøhvit) and the significance level is good for data which includes regular emissions. Accidental emissions are based on

rougher estimates.
Annual results are reported to the Agency and the Environmental Web (EW). The amounts of oil in water can be estimated from regular emissions.

- **Current status of the parameter:** Not yet in use for the Barents Sea since no fields with discharges of produced water are in production. In the future a principle of “zero discharge” will be implemented. This parameter has been used for many years in the North and Norwegian Seas.

Contact person/responsible person: Per Erik Iversen and Camilla Fossum Pettersen, The Norwegian Environment Agency, Tor Fadnes, Norwegian Petroleum Directorate.

Title: Pollution levels in the physical environment (E,I)

Parameter: Pollution levels in air

About the parameter

- ***Type of parameter: E,I***

- ***Priority of the parameter: e***

- ***Rationale :*** POPs, heavy metals (in particular Hg is of concern) and radionuclides are transported on a regional/ hemispheric/global scale. The Arctic is a sink region for these pollutants, where they may accumulate in biota and the other compartments of the ecosystems.

  Atmospheric transport and deposition is the most important transfer of these pollutants to the Arctic. It describes the pollutant load to the region.
  The parameter is already monitored regularly at the Zeppelin observatory as well as at 16 meteorological stations on the Murmansk coast of the Barents Sea. (http://kolgimet.ru/index.php?option=com_content&view=article&id=81&Itemid=27). For some of the subparameters a long time series of data can be provided, showing the development of the pollutant load from the atmosphere to the Arctic. Radioactivity samples are collected from three monitoring stations in the northern part of Norway. The samples are measured on a weekly basis for gamma emitters by HPGe detectors by the NRPA (Norwegian Radiation Protection Authority). Radionuclides need to be considered further (s), since the main task for the parameter is in the emergency preparedness.

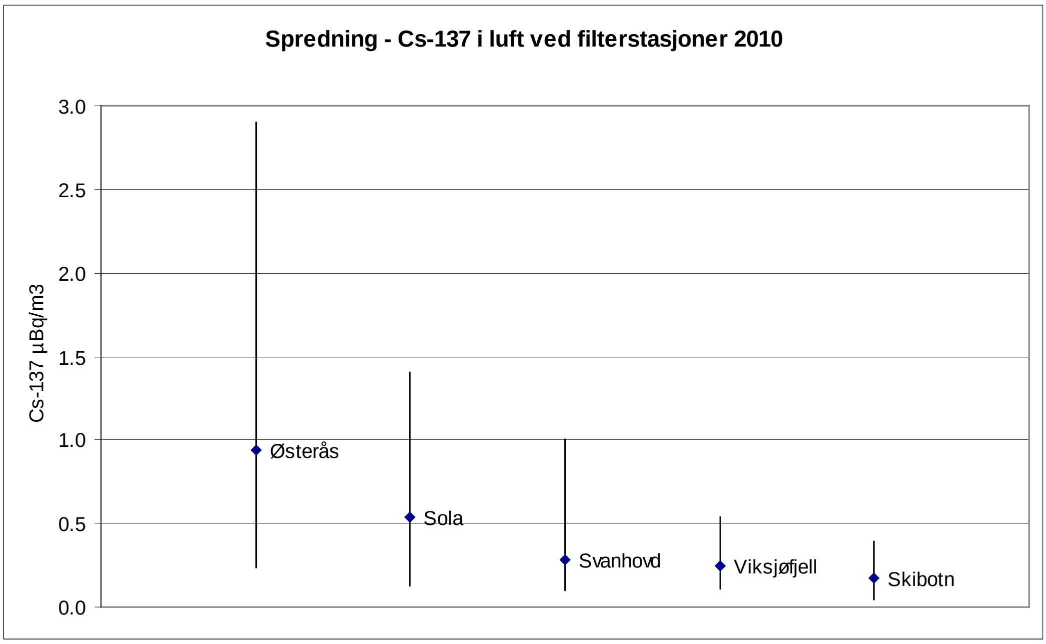
Overview of the subparameters

Parameters (name)	*Type ("S", "E", or "I")*	*Institution responsible for monitoring*	*Time series period*	*Have environmental quality objectives been set for this subparameters in the other monitoring programmes (i.e. the Norwegian mon.?*	*Priority ("e", "r" or "s")*
HCH	*impact +state*	*Norwegian Institute for Air Research*	*1996 - present*	*no*	e
HCB	*impact +state*	*Norwegian Institute for Air Research*	*1993 - present*	*no*	e
Chlordanes	*impact +state*	*Norwegian Institute for Air Research*	*1993 - present*	*no*	e
DDTs	*impact +state*	*Norwegian Institute for Air Research*	*1996 - present*	*no*	e
PCBs (minimum 28, 52, 101, 118, 138, 153,180)	*impact +state*	*Norwegian Institute for Air Research*	*1999 - present*	*no*	e

PBDEs [47, 66, 99, 100, 153, 154, 183, 196, 206, 209]	*impact +state*	*Norwegian Institute for Air Research*	*2006 - present*	*no*	e
HBCDD	*impact +state*	*Norwegian Institute for Air Research*	*2006 - present*	*no*	e
PFCs [PFOSA, PFOS, PFOA]	*impact +state*	*Norwegian Institute for Air Research*	*2006 - present*	*no*	e
Hg	*impact +state*	*Norwegian Institute for Air Research Murmansk dept of Hydromet*	*1994 - present*	*no*	e
PAH [16]	*impact +state*	*Norwegian Institute for Air Research Murmansk dept of Hydromet*	*1997 - present*	*no*	r
Other heavy metals (Cd, Pb, As, Ni, V, Cu, Cr, Zn)	*impact +state*	*Norwegian Institute for Air Research Murmansk dept of Hydromet*	*1994 - present*	*no*	r
Radioactivity - gamma emitters	*impact +state*	*Norwegian Radiation Protection Authority (NRPA)*	*1980-present*	*yes*	s

- **Short facts about the subparameters:** Most pollutants are of anthropogenic origin or caused by anthropogenic emissions.
- **Key subparameters:** All substances are found in the Arctic air. The deposition to the Arctic can be modelled to evaluate the pollution load to the Arctic.
- **Monitoring:** Monitoring is carried out on a weekly basis (high-volume samplers) at the Zeppelin mountain (Spitsbergen) and (since 2010) on Andøya (Nordland county, Northern Norway). At Russian meteorological stations samples for air pollution are also taken on weekly bases. Samples of radioactivity are collected from three monitoring stations in the northern and two in the southern part of Norway. The samples are measured on a weekly basis for gamma emitters by HPGe detectors by the NRPA (Norwegian Radiation Protection Authority).

The map above indicates the geographical placement of the air-filter stations for radiation monitoring, and the photo to the left shows the air-filter station at Østerås outside Oslo.



The figure above shows the activity concentration (µBq m^{-3}) of cesium-137in air-filter from Østerås, Sola, Svanhovd, Viksjøfjell and Skibotn in 2010 (maks, min, median)

- **Current status of the subparameters:** Most time series go back to the mid-nineties. Concentrations have decreased, leveled out, or are even increasing at times. The specific activity concentration of anthropogenic radioactivity on air filter under normal circumstances is low.
- **Quality objectives:** No quality objectives are set.
- **Other issues about the parameter:** The subparameters are important for emergency preparedness and are a part of a bigger worldwide monitoring network. The data used as environmental parameters are not included in the emergency preparedness part.

Contact person/responsible person: Bredo Møller, NRPA, Tor Johannessen and Camilla Fossum Pettersen, Norwegian Environment Agency, Olga Mokrotovarova, FGBU

Title: Pollution levels in the physical environment

Parameter: Pollution levels in sediments

About the parameter

Type of parameter: E

Priority of the parameter: e

Why should this parameter be included? Sediments consist of a mixture of mineralized and biological material which has settled at the seafloor. The concentration of radioactivity and pollutants in sediments will therefore reflect the pollution state in the area. Activity concentrations in sediments may be able to give us a better picture of the pollution situation in a local area. Pollutants may spread from sediments to water and biota. Sediments are impacted by both long-range pollution transport and pollution from local sources. Selected anthropogenic pollutants, including POPs, trace metals and radionuclides are transported via different pathways (mostly a combination of atmosphere, ocean currents, ice drift and rivers) into the Arctic and the Barents Sea. Radioactivity is a subparameter that is affected by pollution from the sea water and nuclear emergency situations.

Overview of the subparameters

Parameters (name)	***Type ("S", "E", or "I")***	***Institution responsible for monitoring***	***Time series period***	***Have environmental quality objectives been set for this subparameters in the other monitoring programs (i.e. the Norwegian mon. Programme?***	***Priority ("e", "r" or "s")***
Heavy Metals: As, Pb, Cd, Cu, Cr, Hg, Ni, Zn	*E*	*Institute of Marine Research (IMR), Norwegian Institute for Water Research (NIVA), Geological Survey of Norway (NGU)* *Sevmorgeo*	 *1995-2010*	*Yes* *No (Russia)*	***e***
THC, PAH	*E*	*Institute of Marine Research (IMR), Norwegian Institute for Water Research (NIVA),* *Sevmorgeo*	 *1995-2010*	*Yes* *No (Russia)*	*e*
PCB, HCH, DDT, HCB	*E*	*Institute of Marine Research (IMR), Norwegian Institute for*		*Yes*	*r*

		Water Research (NIVA), *Sevmorgeo*	 *1995-2010*	 *No (Russia)*	
Gamma emitting isotopes	E	*Norwegian Radiation Protection Authority (NRPA) and the Institute of Marine Research (IMR)* *Sevmorgeo*	*1999-2012* *1995-2010*	*Yes* *Yes (Russia)*	e

Heavy Metals: Heavy metals are often of anthropogenic origin but also occur naturally and can contribute to the contamination of the Barents Sea. It is important to know the background level of these substances to enable realistic estimates of the level of human impacts and the effect of these. Mercury is particularly important to monitor due to levels in the environment exceeding limit values for biota (EQS-values) in some cases.

THC, PAH: Pollution caused by discharges of oil or other hydrocarbons is measured as total level of hydrocarbons (THC) and levels of polyaromatic hydrocarbons (PAH). These are both used as indicators for oil pollution. PAH can however originate both from natural (e.g erosion of coalbearing bedrock, possible leakage of oil and gas from the seabed) and human made (e.g. offshore industry and wood-burning) sources. Due to expected increase in oil and gas activity in the area it is important to establish time series to see trends following increased activity.

Organic pollutants:
Mainly long-range transport. Because of high potential for bioaccumulation it is important to have good estimates for concentrations in the environment.

Radioactivity:
In the Northern Atlantic sediments are sampled every three years. Each sample contains approx. 200 gram freeze dried sediments. The samples are measured for cesium-137 by HPGe detectors either by the laboratory to NRPA (Norwegian Radiation Protection Authority) or the IMR (Institute of Marine Research). In addition, the samples are measured for anthropogenic and naturally occurring radionuclides for beta and alpha emitters by the NRPA (Norwegian Radiation Protection Authority). In the Russian part of the Barents Sea sampling for technogenic and naturally occuring radionuclides was done annually until 2012, and from 2013 – once every three years.

Monitoring:
Sediments are sampled with varying intervals. Sediments were sampled from 73 stations during 2003-2004.

- MAREANO – ongoing survey, started in 2006. 71 stations were sampled in 2006-2009.
- CEMP program (OSPAR) – 10 stations were sampled in 1994 and 2006.
- Tilførselsprogrammet (a Norwegian monitoring programme) – sediments were sampled from 8 stations in 2009.
- Regional environmental surveys from oil and gas industry started in 1998. Sediments are sampled every third year. In 2010, sediments were sampled from 88 stations.
- Russian State Offshore Monitoring Program 1999-2012. Sampling annually until 2012, and once every three years starting from 2013.

It is recommended that monitoring of bottom sediments should be conducted at least every five years (during the same season).

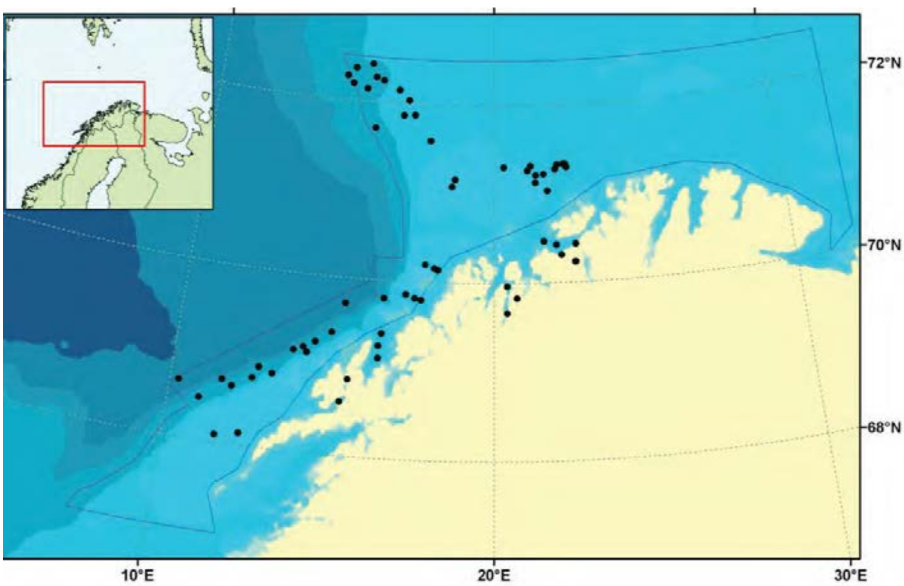


Figure 1: Sediment stations sampled by the Mareano programme in the period 2006-2009

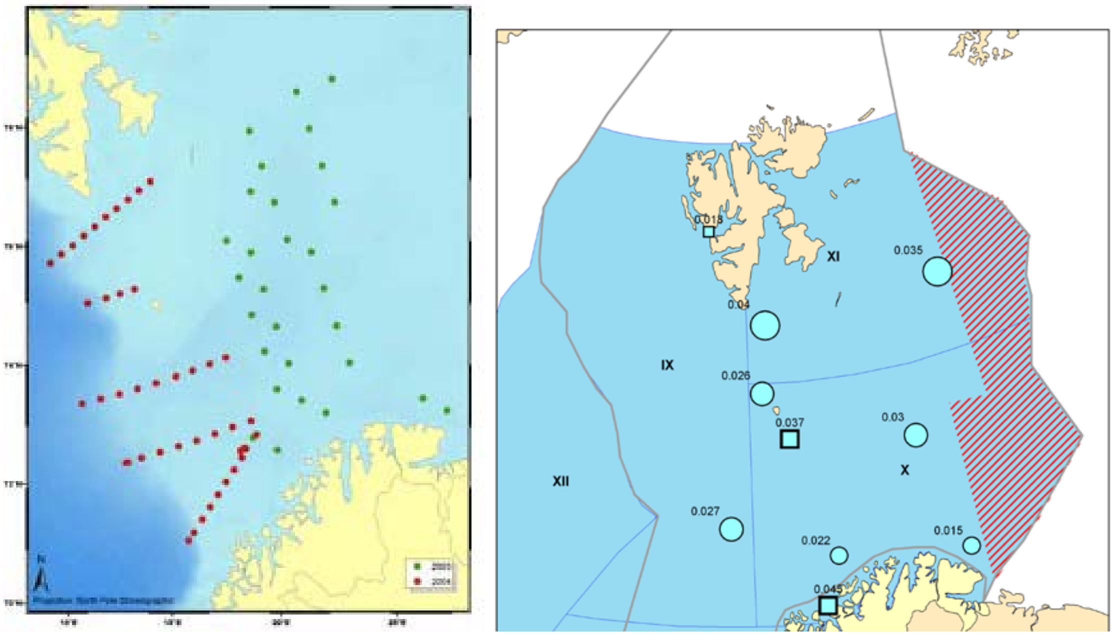


Figure 2: Sediment stations sampled by IMR in 2003-2004 (left) and by Tilførselsprogrammet in 2009 (right).

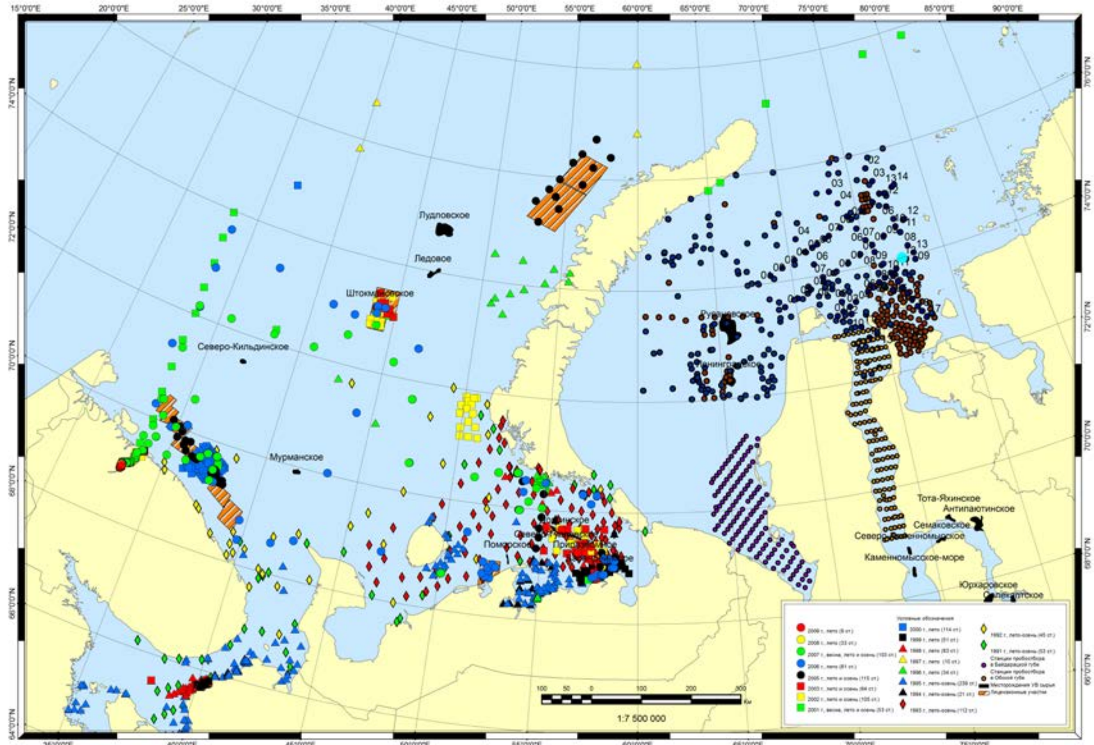
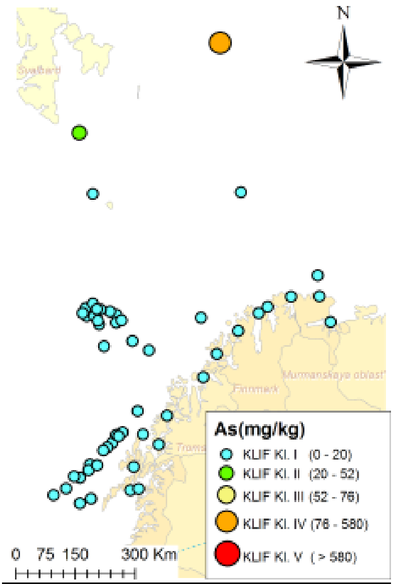


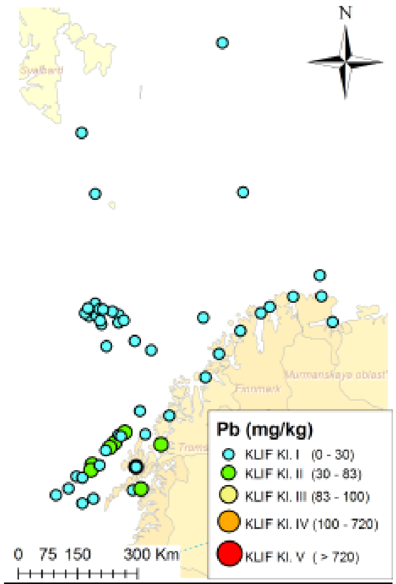
Figure 3: Sediment stations sampled by Sevmorgeo and VNIIOceangeology in 1995-2010 (heavy metals, THC, PAH, grain size, radioactivity (Cs-137, K-40 and others)

Current status of the parameter:

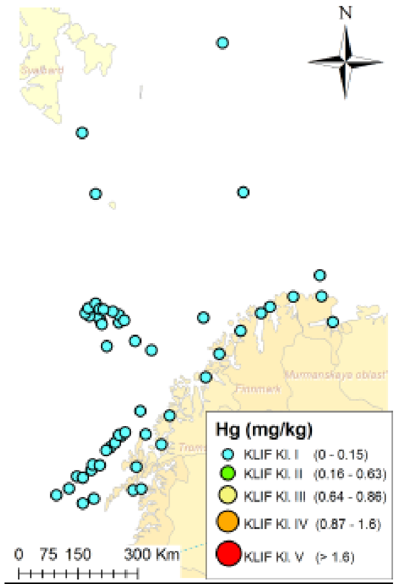
Arsenic sediments:



Lead in sediments:



Mercury in sediments



Cadmium in sediments PCB in sediments: HCB in sediments:

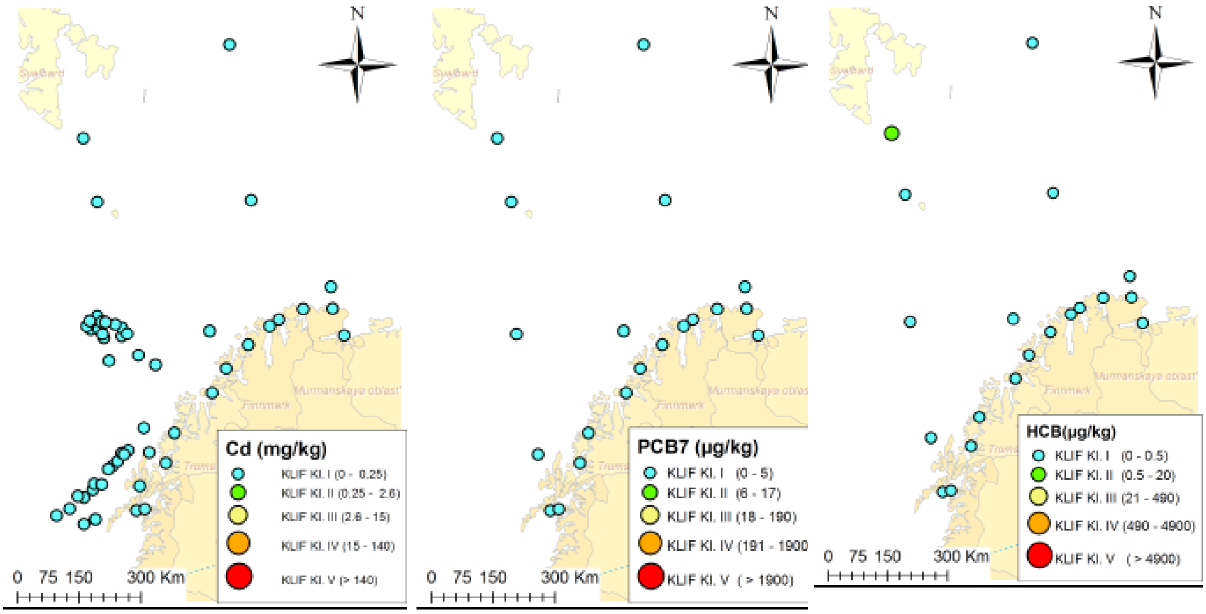


Figure 4: Levels of heavy metals and chloro-organic compounds in Barents Sea. Results from Mareano programme and Tilførselsprogrammet in the period 2006-2009.
(http://www.miljostatus.no/no/Tema/Hav-og-vann/havomrader/Barentshavet/Indikatorer-barentshavet/Indikator-Forurensning-i-sedimenter/)

Generally, the levels of heavy metals and chloro-organic compounds are low. An exception is the levels of lead which in some areas fall into level II in the Klif classification system (moderately polluted). The reason for the high arsenic levels in the northern Barents Sea is not known.

PAH in sediments:

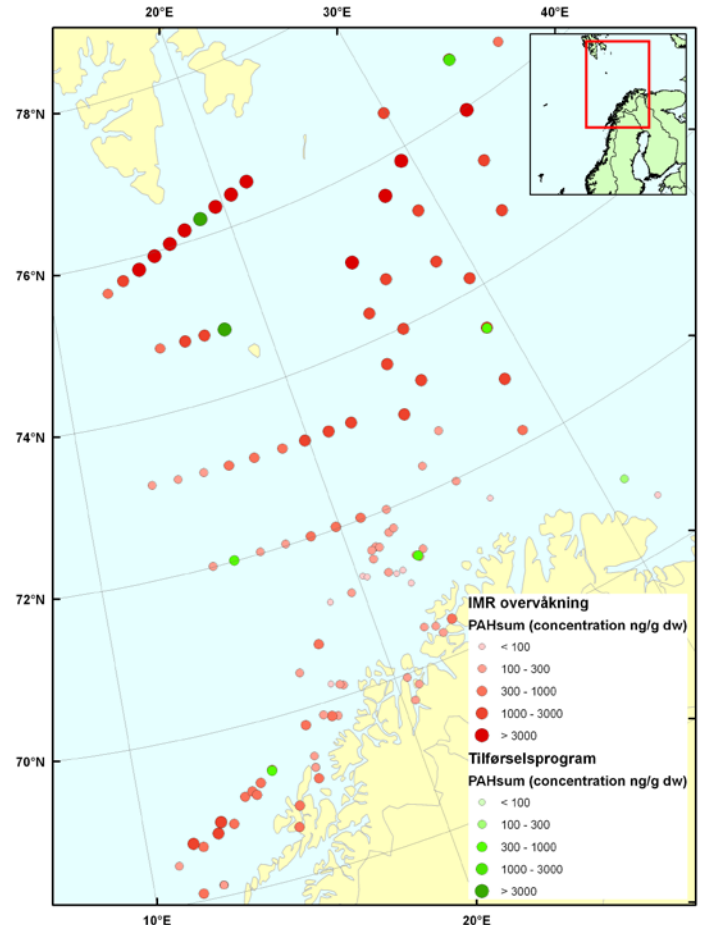


Figure 5: Levels of heavy metals and chloro-organic compounds in Barents Sea. Results from IMR, Mareano survey and Tilførselsprogrammet in the period 2003-2009.

PAH levels in southern parts of the area are relatively low. South of Svalbard the levels are higher, caused by weathering of minerals containing coal.

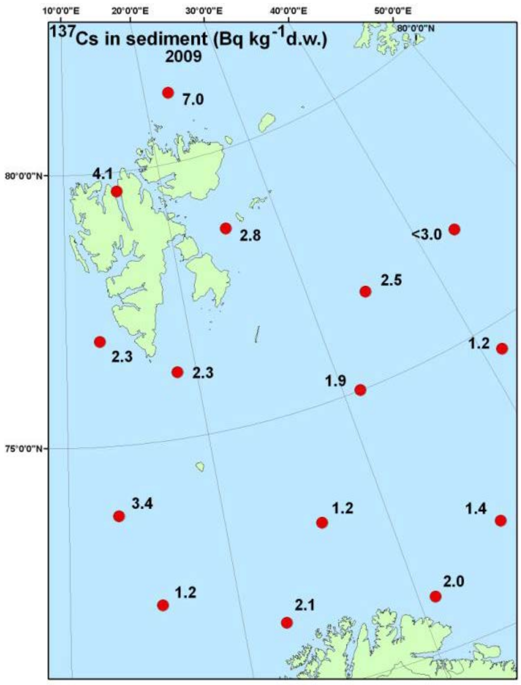


Figure 6: Levels of cesium137 in the sediments.

The activity concentration of cesium-137 in sediments from the North Atlantic ocean is low, and in the map the activity of cesium-137 in 2009 is shown.

Quality objectives:

Background levels for naturally occurring substances. Below detection limit for manmade substances.

The OSPAR Strategy provides that:

"Radioactive substances are reduced to levels where the additional concentrations in the marine environment above historic levels, resulting from such discharges, emissions and losses, before 2020 are close to zero."

Contact person/responsible person: Gunnar C. Skotte and Camilla Fossum Pettersen, Norwegian Environment Agency, Hilde Elise Heldal, Institute for Marine Research, Oleg Korneev, Sevmorgeo.

Title: Population development and demography of seabirds (E)

Parameter: Breeding population numbers in selected colonies

About the parameter

- ***Type of parameter: E***
- ***Priority of parameter: e***
- ***Rationale :*** Knowledge of how the size of different populations vary in time and the factors that influence these dynamics is of fundamental importance to distinguish between changes caused by human activity and those primarily caused by natural fluctuations. Using standardized methods, counts of birds at breeding sites give a sound, statistical base upon which to document short- or long-term changes. However, to be able to assess any changes, documentation of other parameters is necessary. Such parameters include breeding success, adult survival and diet.

Overview of the subparameters

Subparameters (name)	***Institution responsible for monitoring***	***Time series period***	***Gaps in monitoring***	***Priority ("e", "r" or "s")***
European shag	*NINA/KSNR*	*1960-2011*		e
Common eider	*NPI/NINA/KSNR/SSNR*	*1960-2011*		e
Herring gull	*NINA/KSNR/SSNR*	*1960-2011*		e
Glaucous gull	*NPI/NPRA*	*1986-2011*		e
Black-legged kittiwake	*NPI/NINA/KSNR/NPRA*	*1930-2011*		e
Ivory gull	*NPI/NPRA*	*2006-2011*		e
Brünnich's guillemot	*NPI/NINA/TMU/KSNR*	*1960-2011*		e
Common guillemot	*NPI/KSNR*	*1960-2011*		e
Little auk	*NPI*	*2004-2011*		e
Atlantic puffin	*NINA/KSNR*	*1960-2011*		e

Subparameter 1 - European shag (Phalacrocorax aristotelis)

- **Short facts about the subparameter:** The European shag is a medium-sized, marine cormorant with a slender bill that has a yellow base at the lower mandible. Adult plumage is black with a metallic sheen and they grow a conspicuous crest in spring. Breeding occurs along the European coasts of the North Atlantic and the Barents Sea, and on the coasts of North Africa, the Mediterranean and the Black Sea. In the Barents Sea the species breeds along the Norwegian and Murman coasts. In winter European shags either reside at the breeding grounds or disperse southwards along the coastline.
- **Why this is a key subparameter:** The European shag represents the foraging guild coastal, diving, piscivorous species that depends on returning to shore after foraging order to dry of its wettable plumage. Long time series already exist on this species that could be valuable to continue to build on. This species is recommended for monitoring by the Circumpolar Seabird Group.
- **Monitoring:** The number of apparently occupied nests, diet, and adult survival is monitored in Norway.
- **Current status of the subparameter:** Overall population increase in Norway, although large inter-colony fluctuations.
- **Quality objectives:** No quality objectives set for this parameter.
  National red list, Norway: A reduction in the population of 15-30 % over 10 years makes the species qualifies for the category "Near Threatened".
  Management Plan Barents Sea (Monitoring group): Decrease in population of 20 % or more over five years, or unsuccessful breeding for five consecutive years, qualifies for management actions.
- **Reference level:**
- **Gaps in data coverage:** Demography/diet not monitored on the Russian side.
- **Other issues about the subparameter**:

Subparameter 2 - Common eider (Somateria molissima)

- **Short facts about the subparameter:** The common eider is a large diving duck that is easily distinguishable even at quite long distances because of the elongated profile of the head. The common eider has a circumpolar distribution and breeds in the arctic and boreal zones of the northern hemisphere. They nest along the coast of Europe including the arctic coasts of Russia as well as in arctic regions such as Svalbard. They winter largely within the breeding range, leaving only the most northerly regions.
- **Why this is a key subparameter:** The common eider feeds almost exclusively on benthic species and its distribution is hence limited to the coastal waters of the region where conflict with human activity (e.g. pollution, disturbance, etc.) is more likely than for species with a more pelagic way of life.
- **Monitoring**: The number of breeding pairs (number of nest or number of males) is monitored in the breeding colonies.
- **Current status of the subparameter:** Stable or declining populations in Norway and Russia.
- **Quality objectives:** No quality objectives set for this parameter.
  National red list, Norway: A reduction in the population of 15-30 % over 10 years makes the species qualifies for the category "Near Threatened".
  Management Plan Barents Sea (Monitoring group): Decrease in population of 20 % or more over five years, or unsuccessful breeding for five consecutive years, qualifies for management actions.
- **Reference level**:

- **Gaps in data coverage**: No monitoring established in Novaya Zemlya or Franz Josef Land.
- **Other issues about the subparameter***:*

Subparameter 3 - Herring gull

- **Short facts about the subparameter:** The herring gull, which has the typical features of the genus Larus, has a circumpolar distribution. The species has long broad wings and short pink legs. Adults are grey over the back and wings and the primaries have a black tip. The largest breeding concentrations are found in the North Atlantic. In the Barents Sea region herring gulls are common and they breed along the whole Norwegian coast, on islands off the Murman coast, in the White Sea and on Vaygach Island. The herring gull is a partial migrant and winter mainly in the North Sea, the English Channel and the Bay of Bothnia.
- **Why this is a key subparameter:** The Herring gull represents the foraging guild coastal, surface-feeding species. Long time series already exist on this species that could be valuable to continue to build on. This species is recommended for monitoring by the Circumpolar Seabird Group.
- **Monitoring**: The number of individuals/nests at breeding colonies is counted, breeding success and adult survival is monitored in Norway.
- **Current status of the subparameter:** Norwegian populations are increasing; however results are based on a small proportion of the total population.
- **Quality objectives:** No quality objectives set for this parameter.
  National red list, Norway: A reduction in the population of 15-30 % over 10 years makes the species qualifies for the category "Near Threatened".
  Management Plan Barents Sea (Monitoring group): Decrease in population of 20 % or more over five years, or unsuccessful breeding for five consecutive years, qualifies for management actions.
- **Reference level**:
- **Gaps in data coverage**: No monitoring established in Nenetski District or Novaya Zemlya.
- **Other issues about the subparameter***:*

Subparameter 4 - Glaucous gull

- **Short facts about the subparameter:** The glaucous gull is one of the largest gulls breeding in the Arctic and the only numerous avian predator in Svalbard, Franz Josef Land and Novaya Zemlya. It has a circumpolar distribution and breeds along the coast from the Kanin Peninsula and eastwards, and is common on Novaya Zemlya, Franz Josef Land and Svalbard. Barents Sea birds winter mainly in the northern part of the Atlantic Ocean.
- **Why this is a key subparameter:** The glaucous gull is an important avian predator in the Arctic ecosystem. Long time series already exist on this species that could be valuable to continue to build on. This species is recommended for monitoring by the Circumpolar Seabird Group.
- **Monitoring**: The number of apparently occupied nests, breeding success and adult survival is monitored in Norway.
- **Current status of the subparameter:** The population in Norway (Bjørnøya (Bear Island) and Hopen Islands) are strongly declining. Status in other parts of Svalbard uncertain.
- **Quality objectives:** No quality objectives set for this parameter.

National red list, Norway: A reduction in the population of 15-30 % over 10 years makes the species qualifies for the category "Near Threatened".
Management Plan Barents Sea (Monitoring group): Decrease in population of 20 % or more over five years, or unsuccessful breeding for five consecutive years, qualifies for management actions.

- **Reference level**:
- **Gaps in data coverage**: No monitoring established in Novaya Zemlya or Franz Josef Land.
- **Other issues about the subparameter***:*

Subparameter 5 - Black-legged kittiwake

- **Short facts about the subparameter:** The black-legged kittiwake is a small gull and the most pelagic of those that breed in the Barents Sea Region. It has a circumpolar distribution, breeding in the arctic and boreal zones of the northern hemisphere, and in the Barents Sea Region it breeds throughout. The species winter in central and western parts of the North Atlantic and in the North Sea.
- **Why this is a key subparameter:** The black-legged kittiwake represents the foraging guild pelagic, surface feeders. Kittiwakes breed throughout the region and are interesting in a regional study perspective. Long time series already exist on this species that could be valuable to continue to build on. This species is recommended for monitoring by the Circumpolar Seabird Group.
- **Monitoring**: The number of apparently occupied nests, breeding success, diet and adult survival is monitored in Norway. Population development and breeding success monitored at several sites along the Murman coast.
- **Current status of the subparameter:** Kittiwake numbers are declining and breeding success failing over large parts of their range.
- **Quality objectives:** No quality objectives set for this parameter.
  National red list, Norway: A reduction in the population of 15-30 % over 10 years makes the species qualifies for the category "Near Threatened".
  Management Plan Barents Sea (Monitoring group): Decrease in population of 20 % or more over five years, or unsuccessful breeding for five consecutive years, qualifies for management actions.
- **Reference level**:
- **Gaps in data coverage**: No monitoring established in Novaya Zemlya or Franz Josef Land.
- **Other issues about the subparameter***:*

Subparameter 6 - Ivory gull

- **Short facts about the subparameter:** The ivory gull is a high-Arctic, medium-sized gull, which is strongly associated with ice-covered waters. In the Barents Sea Region the ivory gulls breed in the northern parts; in Svalbard, Franz Josef Land, possibly on the northern parts of Novaya Zemlya. Ivory gulls follow the ice edge to wintering areas in southeast Greenland, the Labrador Sea and the Davis Strait or alternatively move eastwards to the Bering Sea.
- **Why this is a key subparameter:** The ivory gull belongs to the foraging guild pelagic, surface feeders and due to its strong and year-round association with pack-ice and its scavenging habits, it is probably vulnerable to changes in sea ice cover and the accumulation of high levels of organic contaminants. This species is recommended for monitoring by the Circumpolar Seabird Group.

- **Monitoring**: The number of breeding pairs and breeding success are monitored annually in Svalbard.
- **Current status of the subparameter:** Population development not known. Canadian population has declined substantially recently.
- **Quality objectives:** No quality objectives set for this parameter.
  National red list, Norway: A reduction in the population of 15-30 % over 10 years makes the species qualifies for the category "Near Threatened".
  Management Plan Barents Sea (Monitoring group): Decrease in population of 20 % or more over five years, or unsuccessful breeding for five consecutive years, qualifies for management actions.
- **Reference level**:
- **Gaps in data coverage**: No monitoring established in Franz Josef Land.
- **Other issues about the subparameter***:*

Subparameter 7 - Brünnich's guillemot

- **Short facts about the subparameter:** The high-Arctic species Brünnich's guillemot is one of the most numerous seabirds in the northern hemisphere. It has a circumpolar distribution and is found in artic and sub-arctic seas. In the Barents Sea Region it occurs in highest numbers in the northern areas, but colonies are also found on the Norwegian and Murman Coasts. Winter is spent in the Barents Sea or in the western or central Atlantic Ocean.
- **Why this is a key subparameter:** The Brünnich's guillemot represents the foraging guild pelagic, diving piscivores. The large population and Arctic species occurring of such high numbers makes it important to monitor its role in the ecosystem and the potential effects of climate change. Long time series already exist on this species that could be valuable to continue to build on. This species is recommended for monitoring by the Circumpolar Seabird Group.
- **Monitoring**: The number of breeding pairs, breeding success, diet and adult survival is monitored in Norway.
- **Current status of the subparameter:** Declining populations in Norway and Russia.
- **Quality objectives:** No quality objectives set for this parameter.
  National red list, Norway: A reduction in the population of 15-30 % over 10 years makes the species qualifies for the category "Near Threatened".
  Management Plan Barents Sea (Monitoring group): Decrease in population of 20 % or more over five years, or unsuccessful breeding for five consecutive years, qualifies for management actions.
- **Reference level**:
- **Gaps in data coverage**: No monitoring established in Novaya Zemlya or Franz Josef Land.
- **Other issues about the subparameter***:*

Subparameter 8 - Common guillemot

- **Short facts about the subparameter:** The common guillemot is the largest of the extant auk species. It has a circumpolar boreo-low arctic distribution. In the Barents Sea Region it is found in colonies along the Norwegian and Murman coasts, on Novaya Zemlya and on Svalbard. In winter common guillemots stay in the region or move south along the Norwegian coast.
- **Why this is a key subparameter:** The common guillemots represent the foraging guild

pelagic, diving piscivores. Its response to fluctuating fish stocks may be an indicator of ecosystem changes. Long time series already exist on this species that could be valuable to continue to build on. This species is recommended for monitoring by the Circumpolar Seabird Group.

- **Monitoring**: The number of breeding pairs, breeding success, diet and adult survival is monitored in Norway. Annual counts are also performed on Kharlov Island.
- **Current status of the subparameter:** The species is declining in a number of colonies in Norway.
- **Quality objectives:** No quality objectives set for this parameter.
  National red list, Norway: A reduction in the population of 15-30 % over 10 years makes the species qualifies for the category "Near Threatened".
  Management Plan Barents Sea (Monitoring group): Decrease in population of 20 % or more over five years, or unsuccessful breeding for five consecutive years, qualifies for management actions.
- **Reference level**:
- **Gaps in data coverage**: No monitoring established in Novaya Zemlya.
- **Other issues about the subparameter***:*

Subparameter 9 - Little auk

- **Short facts about the subparameter:** The little auk is one of the smallest alcids and possibly the most numerous seabird species in the world. It breeds in the high-Arctic and in the Barents Sea Region it is found on all the high-Arctic archipelagos, but not on mainland Norway or Russia. The regions' little auks move to the West Atlantic in winter or some populations may remain in the region.
- **Why this is a key subparameter:** The little auk represents the foraging guild pelagic diving planktivor. Its large population, its Arctic affiliation and being the only strictly planktivor species in the system makes this an interesting study species. This species is recommended for monitoring by the Circumpolar Seabird Group.
- **Monitoring**: Breeding success, diet and adult survival is monitored in Norway.
- **Current status of the subparameter:** Population development not known.
- **Quality objectives:** No quality objectives set for this parameter.
  National red list, Norway: A reduction in the population of 15-30 % over 10 years makes the species qualifies for the category "Near Threatened".
  Management Plan Barents Sea (Monitoring group): Decrease in population of 20 % or more over five years, or unsuccessful breeding for five consecutive years, qualifies for management actions.
- **Reference level**:
- **Gaps in data coverage**: No monitoring established in Novaya Zemlya or Franz Josef Land.
- **Other issues about the subparameter***:*

Subparameter 10 – Atlantic Puffin

- **Short facts about the subparameter:** The Atlantic puffin breeds on both sides of the North Atlantic from the north-eastern parts of North America and Britanny in the south to Greenland, Svalbard and Novaya Zemlya in the north. The wintering area of the Barents Sea population is not known, but many birds probably winter in the Barents Sea and further to the south in the northeast Atlantic.

- **Why this is a key subparameter:** The Atlantic puffin represent the foraging guild pelagic, diving piscivores. Its response to fluctuating fish stocks may be an indicator of ecosystem changes. Long time series already exist on this species that could be valuable to continue to build on. This species is recommended for monitoring by the Circumpolar Seabird Group.
- **Monitoring**: The number of breeding pairs (occupied burrows), breeding success, diet and adult survival is monitored in several colonies in Norway. Annual counts are also performed in colonies on the Murman coast.
- **Current status of the subparameter:** Stable or declining populations in Norway and Russia.
- **Quality objectives:** No quality objectives set for this parameter.
  National red list, Norway: A reduction in the population of 15-30 % over 10 years makes the species qualifies for the category "Near Threatened".
  Management Plan Barents Sea (Monitoring group): Decrease in population of 20 % or more over five years, or unsuccessful breeding for five consecutive years, qualifies for management actions.
- **Reference level**:
- **Gaps in data coverage**: No monitoring established in Svalbard and Novaya Zemlya.
- **Other issues about the subparameter***:*

Contact person/responsible person: Hallvard Strøm, NPI, Maria Gavrilo

Title: Population development and demography of seabirds (E)

Parameter: Diet

About the parameter

- ***Type of parameter: E***
- ***Priority of parameter: e***
- ***Rationale :*** Population size is a result of reproduction, survival and dispersal (immigration/emigration). Data on seabird diet are important in explaining *why* populations change and in the prediction of how they might change, and an effort should be made to collect such data in as many colonies as possible.
- ***Comments:*** *the parameter needs to be further developed*

Overview of the subparameters

Subparameters (name)	*Institution responsible for monitoring*	*Time series period*	*Gaps in monitoring*	*Priority (“e”, “r” or “s”)*
European shag	*NINA/KSNR*	*1960-2011*		e
Common eider	*NPI/NINA/KSNR/SSNR*	*1960-2011*		e
Herring gull	*NINA/KSNR/SSNR*	*1960-2011*		e
Glaucous gull	*NPI*	*1986-2011*		e
Black-legged kittiwake	*NPI/NINA/KSNR*	*1930-2011*		e
Ivory gull	*NPI*	*2006-2011*		e
Brünnich’s guillemot	*NPI/NINA/TMU/KSNR*	*1960-2011*		e
Common guillemot	*NPI/KSNR*	*1960-2011*		e
Little auk	*NPI*	*2004-2011*		e
Atlantic puffin	*NINA/KSNR*	*1960-2011*		e

Subparameter 1 – European shag

- **Short facts about the subparameter:**
- **Why this is a key subparameter:**
- **Monitoring:**
- **Current status of the subparameter:**
- **Quality objectives:**
- **Reference level:**
- **Gaps in data coverage:**
- **Other issues about the subparameter:**

Contact person/responsible person: Hallvard Strøm, NPI, Maria Gavrilo

Title: Population development and demography of seabirds (E)

Parameter: Reproductive success

About the parameter

- ***Type of parameter: E***
- ***Priority of parameter: e***
- ***Rationale :*** Population size is a result of reproduction, survival and dispersal (immigration/emigration). Data on reproductive success are important in explaining *why* populations change and in the prediction of how they might change, and an effort should be made to collect such data in as many colonies as possible.
- ***Comments:*** the parameter needs to be further developed

Overview of the subparameters

Subparameters (name)	***Institution responsible for monitoring***	***Time series period***	***Gaps in monitoring***	***Priority ("e", "r" or "s")***
European shag	*NINA/KSNR*	*1960-2011*		e
Common eider	*NPI/NINA/KSNR/SSNR*	*1960-2011*		e
Herring gull	*NINA/KSNR/SSNR*	*1960-2011*		e
Glaucous gull	*NPI*	*1986-2011*		e
Black-legged kittiwake	*NPI/NINA/KSNR*	*1930-2011*		e
Ivory gull	*NPI/NPRA*	*2006-2011*		e
Brünnich's guillemot	*NPI/NINA/TMU/KSNR*	*2006-2011*		e
Common guillemot	*NPI/KSNR*	*1960-2011*		e
Little auk	*NPI*	*2004-2011*		e
Atlantic puffin	*NINA/KSNR*	*1960-2011*		e

Subparameter 1 – European shag

- **Short facts about the subparameter:**
- **Why this is a key subparameter:**
- **Monitoring:**
- **Current status of the subparameter**
- **Quality objectives:**
- **Reference level:**
- **Gaps in data coverage:**
- **Other issues about the subparameter:**

Contact person/responsible person: Hallvard Strøm, NPI, Maria Gavrilo

Title: Sea ice biota diversity, biomass and production

About the indicator:

- ***Type of indicator:*** **E**

- ***Priority of the indicator*** **e**

- ***Rationale:*** The importance of ice-related ecosystems is significant. Ice algae is the prime food source for the majority of the ice fauna, thus fuelling the ice-related part of the ecosystem, and the significance increases further north due to lower pelagic production. The sympagic-pelagic-benthic coupling is of great importance in the Arctic. Reduced sea ice, especially a shift towards less multiyear sea ice, will affect species composition as well as biomass and production One-year old sea ice has to be colonized every year, as opposed to multiyear ice which in addition normally has ice specialists not occurring in younger sea ice. Changes in species composition, biomass and production may therefore lead to changes that spread to higher trophic levels. Furthermore, if the sea ice disappears there will be a shift from a system dependent on sea ice species towards a system dependent on phytoplankton species.
Change in species composition, biomass and production of ice biota affects quality and quantity of food transferred to higher trophic levels. In addition, the phytoplankton bloom at the ice edge furnishes probably about half of the annual new production in arctic shelf areas. Zooplankton utilizes this production, but to what extent is dependent on how well the blooming of phytoplankton and zooplankton coincide. The probability for a "mismatch" increases with early phytoplankton.

- ***Comment:*** Indicators and parameters need to be developed before they can be operative. The indicator "sea ice biota diversity, biomass and production" will probably be split into several indicators (for example sea-ice protists (i.e. diatoms, dinoflagellates and flagellates), meiofauna, macrofauna, Arctic cod) with respective parameters. Ongoing work in CBMP. See below for possible parameters being considered.

Overview of the parameters

Parameters (name)	***Type („E", „I", or „A")***	***Institution responsible for monitoring***	***Time series period***	***Priority („e", „r" or „s")***
Ice algae biomass	*E*	*CBMP*		e
Ice algae species composition	*E*	*CBMP*		e
Ice algae chlorophyll-a concentration	*E*	*CBMP*		e
Ice algae diversity indicator	*E*	*CBMP*		e
Macrofauna species composition	*E*	*CBMP*		e
Macrofauna abundance and biomass	*E*	*CBMP*		e

Parameter 1 – Ice algae biomass

- **Short facts about the parameter:** Ice algae are unicellular autotrophic eukaryotes that are adapted to live in sea ice. Ice algae constitute the second source of primary production in Arctic seas, with the highest relative contribution in the central Arctic Ocean. Ice algae production accounts for up to 57% of the total annual primary production in the central Arctic Ocean and up to 25% in Arctic shelf regions.
- **Why this is a key parameter:** Ice algae are an important energy and nutritional source for invertebrates. The nutrient and light conditions in which sea ice algae thrive induce them to synthesize enhanced concentrations of essential polyunsaturated fatty acids, a vital constituent of the diet of grazing marine organisms. Furthermore, sedimentation of ice algae to the bottom has been related to rich benthic production in ice covered shelf seas. Ice algae biomass is a measure of how much biomass is available for higher trophic levels. Loss of sea ice and earlier ice-break up in the Arctic shelf areas will constrain ice-algae production and thus a reduction in ice algae biomass can be expected. On the other hand, increasing extent of annually formed sea ice over the central Arctic Ocean, with vanishing and restricted multi-year ice may result in higher biomass of sea-ice-associated algae. Higher likelihood of upwelling events along the transitional zone between ice-edge and coastal regions of the Arctic Ocean may contribute to enhance primary production and eukaryote biomass accumulation in annually formed sea ice during the vernal season. Changes in ice algae biomass may have implication for the grazer community relying on this primary production as a food source in spring and for the export of organic matter from the ice to the benthos.
- **Monitoring:** Ice algae biomass is estimated from ice cores. Ice cores are usually cut into smaller section and melted ice core water is analyzed for species composition and abundance. Ice algae biomass is given as mass Carbon per area (g C m^{-2}). Carbon content is estimated from species specific cells counts which are converted to carbon using a conversion factor (species- and area-specific). Ice algae biomass is not systematically monitored at the moment. Estimates of ice algae biomass are available from opportunistic sampling efforts on specific missions and programs (scientific cruises, drift ice stations, etc.)
- **Current status of the parameter:** Not available.

Parameter 2 – Ice algae species composition

- **Short facts about the parameter:** Ice algae are unicellular autotrophic eukaryotes that are adapted to live in sea ice. They range in size from 0.2 -200 µm and are often segregated into the pico (<0.2 µm), nano (2-20 µm) and micro-sized fractions (20-200 µm). Ice algae species assemblages are often dominated by diatoms. *Melosira arctica, Fragilariopsis cylindrus, F. oceanica* and *Nitzschia frigida* are depicted as truly sympagic taxa from Arctic sea ice. However, there is no clear border that distinguishes an ice algae species from a pelagic phytoplankton species as many species found in the ice are also found in the water column. Accounts of ice algae species composition often also encompass some non-autotrophic eukaryotes, excluding amoebae, ciliates, foraminiferans and radiolarians.
- **Why this is a key parameter:** Sea ice algae are an important energy and nutritional source for invertebrates. Ice algae species are adapted to cope with a rather extreme environment (low temperatures, large variability in salinity). Reduce the abundance of specific ice algae species and changes in the species and size composition will have implications for the

productivity and nutritional quality of the ice algae community and consequently for the productivity and population success of the grazer community.

- **Monitoring:** Ice algae species composition is determined from ice cores and water samples taken directly under the ice. Species are counted and identified by microscopy. Genetically analyses of bulk water samples are also becoming more common. Ice algae species composition is not systematically monitored at the moment. Species composition is available from opportunistic sampling efforts on specific missions and programmes (scientific cruises, drift ice stations, etc.). See also: Poulin M, Daugbjerg N, Gradinger R, Ilyash L, Ratkova T, von Quillfeldt C. (2011) The pan-Arctic biodiversity of marine pelagic and sea-ice unicellular eukaryotes: a first-attempt assessment. Mar Biodiv 41:13-28.
- **Current status of the parameter:** Not available.

Parameter 3 – Ice algae chlorophyll-a concentration

- **Short facts about the parameter:** Ice algae chlorophyll a concentration is an estimate of ice algae biomass. Ice algae chlorophyll a concentration can be used to compare biomass between different location and between the phytoplankton and ice algae.
- **Why this is a key parameter:** Sea ice algae are an important energy and nutritional source for invertebrates accounting for up to 57% of the total annual primary production in the central Arctic Ocean and up to 25% in Arctic shelf regions. The nutrient and light conditions in which sea ice algae thrive induce them to synthesize enhanced concentrations of essential polyunsaturated fatty acids, a vital constituent of the diet of grazing marine organisms. Furthermore, sedimentation of ice algae to the bottom has been related to rich benthic production in ice covered shelf seas. Chlorophyll a concentration of ice algae is a measure of its available biomass. Changes in sea ice extent, loss of multi-year ice and increase of first year ice will affect light conditions and thereby ice-algae production which may have implication for the grazer community relying on this primary production as a food source in spring and for the export of organic matter from the ice to the benthos.
- **Monitoring:** Ice algae chlorophyll a concentration is estimated from ice cores. Ice cores are usually cut into smaller section and melted ice core water is analysed for chlorophyll a/ phaeopigment concentration. Chlorophyll a concentration is given as mg Chl a per m^2. Ice algae chlorophyll a concentration is not systematically monitored at the moment. Estimates of ice algae biomass are available from opportunistic sampling efforts on specific missions and programmes (scientific cruises, drift ice stations, etc.)
- **Current status of the parameter:** Not available.

Parameter 4 – Ice algae diversity indicator

- **Short facts about the parameter:** Ice algae diversity indices are a quantitative measure that reflects how many different ice algae species are in a dataset (i.e. area, sample, etc.) and simultaneously takes into account how evenly individuals are distributed among those species. For a given number of species the value of a diversity index is maximized when all species are equally abundant. Commonly used diversity indices are the Simpson Index and the Shannon Index.
- **Why this is a key parameter:** Sea ice algae are an important energy and nutritional source

for invertebrates. Changes in sea ice extent, loss of multi-year ice, increase of first year ice will change species composition of ice associated algae with implications for the productivity and nutritional quality of the ice algae community and consequently for the productivity and population success of the grazer community. Species indices give an estimate on changes in abundance and species composition and can be used to compare ice algae communities in different regions and with the pelagic community.

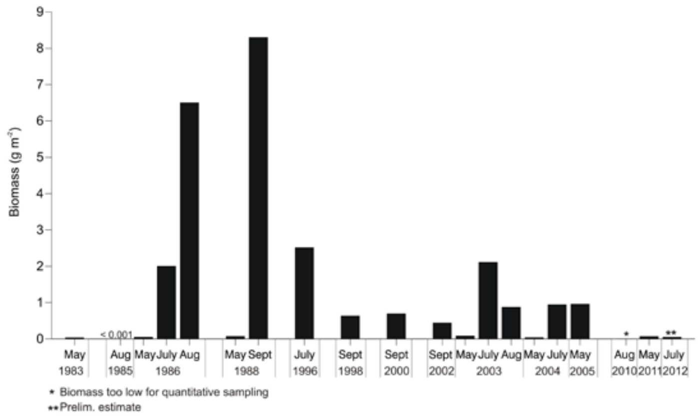
- **Monitoring:** Ice algae species diversity indices are calculated from abundance and species composition estimates retrieved from analysis of ice cores and of water samples taken directly under the ice. Species are usually counted and identified by microscopy.Ice algae species diversity indices are not systematically calculated at the moment. Species compositions are available from opportunistic sampling efforts on specific missions and programs (scientific cruises, drift ice stations, etc.) and indices can be calculated from published species lists.
- **Current status of the parameter:** Not available.

Parameter 5 – Macrofauna species composition

- **Short facts about the parameter:** Sea ice macrofauna (> 5 mm) consists mainly of crustaceans, and in particular gammarid amphipods, which are adapted to live on and within the lower layer of sea ice. Autochthonous sea ice species spend their entire life cycle associated with the ice and the most common species here are the amphipods *Gammarus wilkitzkii, Apherusa glacialis, Onisimus nanseni* and *O. glacialis*. *G. wilkitzkii* in particular is associated with multi-year ice due to its multi-year life cycle while *A. glacialis* is more common in first year ice. The sea ice macrofauna community comprises also allochthonous species that may spend part of their life cycle in the pelagic or benthic ecosystem.
- **Why this is a key parameter:** Sea ice macrofauna are the main grazers in all arctic sympagic environments and due to their size and biomass they represent an important energetic link to higher trophic levels (polar cod, sea birds, seals). Since the dominating species are autochthonous to the sea ice ecosystem (i.e. they rely on sea ice as a habitat for their entire life cycle) loss of sea ice (in particular multiyear ice) will affect the abundance and population success and thus the species composition. This may results in loss of species diversity which may have implications for higher trophic levels.
- **Monitoring:** Sea ice macrofauna species are sampled by divers using suction pumps or hand nets. Macrofauna can also be caught by baited traps attached under the ice. Sea ice macrofauna species composition is not systematically monitored at the moment. Species compositions are available from opportunistic sampling efforts on specific missions and programmes (scientific cruises, drift ice stations, etc.). Norwegian scientist have been most active in the marginal ice zone north of Svalbard (mainly summer-autumn); Russian data are available from drift ice stations in the central Arctic Ocean (spring).
- **Current status of the parameter:** Observations from Russian drift ice stations indicate loss in species diversity as fewer species can be found now compared to sampling efforts made in the 1970s.

Parameter 6 – Macrofauna abundance and biomass

- **Short facts about the parameter:** Sea ice macrofauna (> 5 mm) consists mainly of crustaceans, and in particular gammarid amphipods, which are adapted to live on and within the lower layer of sea ice. Autochthonous sea ice species spend their entire life cycle associated with the ice and the most common species here are the amphipods *Gammarus wilkitzkii, Apherusa glacialis, Onisimus nanseni* and *O. glacialis*. *G. wilkitzkii* in particular is associated with multi-year ice due to its multi-year life cycle while *A. glacialis* is more common in first year ice. The sea ice macrofauna community comprises also allochthonous species that may spend part of their life cycle in the pelagic or benthic ecosystem.
- **Why this is a key parameter:** Sea ice macrofauna are important grazers in all arctic sympagic environments and due to their size and biomass they represent an important energetic link to higher trophic levels (polar cod, sea birds, seals). Since the dominating species are autochthonous to the sea ice ecosystem (i.e. they rely on sea ice as a habitat for their entire life cycle) loss of sea ice (in particular multiyear ice) will affect the abundance and population success and thus the species and size composition of the sympagic community. This may results in loss of biomass with implications for higher trophic levels.
- **Monitoring:** Sea ice macrofauna is sampled quantitatively under the ice by divers using suction pumps or hand nets. All species in a specific area are caught and abundance can be estimated from species counts (individuals per m^2). Biomass is estimated by species specific measurements of wet and/or dry weight (g m^{-2}). Sea ice macrofauna biomass and abundance is not systematically monitored at the moment. Abundance and biomass estimates are available from opportunistic sampling efforts on specific missions and programs (scientific cruises, drift ice stations, etc.). Norwegian scientist have been most active in the marginal ice zone north of Svalbard (mainly summer-autumn); Russian data are available from drift ice stations in the central Arctic Ocean (spring).
- **Current status of the parameter:**



The figure shows estimated biomass of main autochthonous ice macrofauna species (*G. wilkitzkii, A. glacialis and Onisimus spp*) sampled in the marginal ice zone north of Svalbard by scientist of the Norwegian Polar Institute and UNIS since 1983. Due to the patchy distribution of ice fauna under the ice and the limited spatial and temporal sampling resolution there is a large variability in the data set. However, observations made by scientist in recent years (2010-2012) indicate that sea ice macrofauna has become less abundant and sampling ice fauna quantitatively has become rather challenging. In particular the large sized species *G. wilkitzkii* is less abundant (which effects the total biomass) as multi-year ice can hardly be found north of Svalbard anymore which restricts sampling efforts to first year ice in an advance state of degradation.

Contact person/responsible person: Cecilie H. von Quillfeldt, NPI, Igor Melnikov, Shirshov's Institute and Haakon Hop, NPI

Title: Sea Ice cover in the Barents Sea

About the indicator

- ***Type of indicator: E***
- ***Priority of indicator: e***
- ***Rationale :*** Sea ice is one of the most important components of the Barents Sea climate system. The ice distribution in the Barents Sea is influenced by the Atlantic, the Kara Sea and the central Arctic Ocean (Arctic Basin). Two opposing currents determine the sea-ice cover, ice edge configuration and ice concentration in the Barents Sea. Most of the sea ice in the Barents Sea is formed locally, but a significant fraction is imported from adjacent regions of the Arctic Basin through the straits between Svalbard and Novaya Zemlya. Ice flux is directed into the Barents Sea throughout the year with a maximum in the winter (March-April) and values close to zero in the summer (August-September). This adds to the seasonal variability related to thermodynamic ice growth and melt.

  The sea ice in the Barents Sea is also important for its ecosystem. Because of the ecosystem, the Barents Sea plays a crucial role for regional economies and local communities. Due to the warm Atlantic Water the Barents Sea has high biological production compared to other Arctic marginal seas. The spring bloom of phytoplankton can start as early as April or May close to the ice edge, where freshwater from the melting ice forms a stable layer on top of the sea water. In addition to the fishing industry, large reserves of oil and gas reserves have been found in the Barents Sea, and it is an important route for fishing, trade and navy vessels. All human activity in this area is affected by the climate and its variability.

  The area of sea-ice cover is often defined in two ways, i.e., sea-ice "extent" and sea-ice "area". The former is defined as the areal sum of sea ice covering the ocean (sea ice + open ocean), whereas the latter "area" definition counts only sea ice covering a fraction of the ocean (sea ice only). Thus, the sea-ice extent is always larger than the sea-ice area.

Overview of Parameters

Parameters (name)	***Type (“E”, “A”, or “I”)***	***Priority (“e”, “r” or “s”)***
Sea Ice area	*E*	e
Ice thickness	*E*	e
Snow thickness on sea ice cover	*E*	e
Ice age	*E*	s
Iceberg occurrence	*E*	s

Contact person/responsible person: Sebastian Gerland, NPI Olga Pavlova, NPI

Title: Sea Ice cover in the Barents Sea
Parameter: Ice age

About the parameter

- ***Type of parameter: E***
- ***Priority of parameter: s***
- ***Rationale :*** The age of the ice is another key descriptor of the state of the sea ice cover, since older ice tends to be thicker and more resilient than younger ice. Sea ice rejects salt over time and becomes less salty resulting in a higher melting point.
  A simple two-stage approach classifies sea ice into first year and multiyear ice. First-year is ice that has not yet survived a summer melt season, while multi-year ice has survived at least one summer and can be several years old.

Overview of the subparameters

Subparameters (name)	*Institution responsible for monitoring*	*Time series period*	*Gaps in monitoring*	*Priority ("e", "r" or "s")*
Satellite	*NPI*	*Since 1988*	*No*	s
In situ				s

*Subparameter 1 – **Ice age (satellite)***

- **Short facts about the subparameter:**
- **Why this is a key subparameter:**
- **Monitoring:** We use monthly mean sea ice concentration from the National Snow and Ice Data Center (NSIDC, Boulder, USA).The data are provided in the polar stereographic projection at a grid cell size of 25 x 25 km for the period 1979-present. For details see http://nsidc.org/data/nsidc-0051.html. Multiyear ice fractions are provided by the Bootstrap algorithm. DMSP SSM/I Daily and Monthly Polar Gridded Bootstrap Sea Ice Concentrations in polar stereographic projection currently include Defense Meteorological Satellite Program (DMSP) -F8, -F11, and -F13 daily and monthly sea ice concentrations. Using the Bootstrap algorithm, data gridded at a resolution of 25 x 25 km, begin 25 June 1987. Processing is ongoing. See http://nsidc.org/data/nsidc-0002.html.
- **Current status of the subparameter:** Data is processed continuously.
- **Quality objectives:** No environmental objectives could be defined.
- **Reference level:**
- **Gaps in data coverage:** No gaps in the period of satellite observations.
- **Other issues about the subparameter:**

Subparameter 2 – in situ

Not performed

Contact person/responsible person: Sebastian Gerland, NPI, Olga Pavlova, NPI, Vidar Lien, IMR

Title: Sea Ice cover in the Barents Sea
Parameter: Ice thickness

About the parameter

- ***Type of parameter: E***
- ***Priority of parameter: e***
- ***Rationale :*** Sea ice thickness is an important climate-related variable. A better knowledge of the ice thickness distribution enables to assess the ice volume of sea ice in the Barents Sea, and it helps the assessment of changes in ice dynamics and vice versa.
  While ice concentration is often used as a marker for climate change, knowledge on ice thickness is often lacking. Only when knowing ice thickness, one can determine the variable is sea ice volume which can be determined by multiplying concentration with thickness and integrating over the ocean surface.
  It is also important for navigators on icebreakers since there is an upper limit of thickness of ice any ship can sail through.

Overview of the subparameters

Subparameters (name)	***Institution responsible for monitoring***	***Time series period***	***Gaps in monitoring***	***Priority („e", "r" or "s")***
Altimeter satellite	*NPI*	*2012- (?)*		s
In situ	*NPI*	*1966-*		e
airborne				s
Moored upward looking sonars				s

Subparameter 1 – **Ice thickness** ***(Altimeter satellite)***

- **Short facts about the subparameter:**
- **Why this is a key subparameter:**
- **Monitoring:** The European Space Agency's Cryosat-2 satellite was launched in April 2010 on a quest to map the thickness and shape of the Earth's polar ice cover. Its single instrument - a SAR/Interferometric Radar Altimeter is able to measure the difference between the height of the surface of sea ice and the water in open leads, the "freeboard" of the ice. Currently, the operation of CryoSat is under calibration and validation. Corresponding use for monitoring in the Barents Sea might become possible in the near future.
- **Current status of the subparameter:**
- **Quality objectives:** Environmental objective can't be defined for this subparameter.
- **Reference level:**
- **Gaps in data coverage:**
- **Other issues about the subparameter:**

*Subparameter 2 - **Ice thickness (In situ)***

- **Short facts about the subparameter:**
- **Why this is a key subparameter:** Sea ice thickness variability as a climate indicator provides more quantitative information on the state of the ice cover than solely sea ice extent. It is measured as a part of NPIs sea ice monitoring at the island of Hopen by personnel of the Hopen Radio base of met.no since 1966.
- **Monitoring:** The regular sea ice monitoring by the island of Hopen (at approximately 50, 100 and 150 m from the shore) was initiated in 1966. It includes in situ measurements of ice and snow thickness, and freeboard at several sites. Ice thickness and freeboard are measured conventionally from drill holes using a Kovacs thickness-gauge tape measure or a measurement stick with a notch. The snow thickness is measured with a metal stake. Drillings are made approximately every 2 weeks as long as it is possible to access the sites. At each site on each occasion, three holes are drilled in the corners of a triangle with 10 m side length to account for variability at the site. The data from the three holes are measured and later averaged.
- **Current status of the subparameter:**
- **Quality objectives:**
- **Reference level:**
- **Gaps in data coverage:**
- **Other issues about the subparameter:**

Subparameter 3 and 4

Airbourne – not performed
Moored upward looking sonars – not performed, limited data available

Contact person/responsible person: Sebastian Gerland, NPI, Olga Pavlova, NPI

Title: Sea Ice cover in the Barents Sea
Parameter: Iceberg occurrence (Iceberg activity)

About the parameter

- ***Type of parameter: E***
- ***Priority of parameter: s***
- ***Rationale :*** Based on the principles of rational and effective use of information in order to achieve 'the greatest good to the greatest number for the longest time' the following structure of iceberg analysis is presented.
  Hazards that have a long or short-term negative impact on the environment, as well as creating the preconditions for the emergence situations for the offshore and onshore facilities related with icebergs and other ice formations activity. That is why it seems sensible to observe the iceberg activity in the Barents Sea as a hazard factor.

Overview of the subparameters

Subparameters (name)	***Institution responsible for monitoring***	***Time series period***	***Gaps in monitoring***	***Priority ("e", "r" or "s")***
The number of icebergs observed (A)	*SEVMORGEO*	*1950-1990*	*Last 10 years data seek*	e
The number of months in which episodes of observation were recorded (M)	*SEVMORGEO*	*1950-1990*	*Last 10 years data seek*	r
The number of episodes (E) defined by the dates of observation, during which icebergs were recorded	*SEVMORGEO*	*1950-1990*	*Last 10 years data seek*	e
A calculated value (D) determining the average number of fixations of icebergs in one episode of observations	*SEVMORGEO*	*1950-1990*	*Last 10 years data seek*	e
Iceberg shape	*SEVMORGEO*	*1950-1990*	*Last 10 years data seek*	s

Sub parameters A, M, E, D and the iceberg's shape

The idea of studying the iceberg activity starts from dividing the investigated region (the Barents Sea region as a whole for example) by trapezoids* which in the same time formed by latitude and longitude lines of 2 and 4 degrees scale respectively. So the map of a studied region will look as a system of a trapezoids with lateral sides of latitude scale of 2 degrees and longitude of 4 degrees (the scales are appropriate). In each trapezoid the following subparameters are estimated using recorded data of observed icebergs:

- The number of observed icebergs (A);
- The number of months in which episodes of observation were recorded (M);
- The number of episodes (E) defined by the dates of observation, during which icebergs were recorded;
- A calculated value (D) determining the average number of fixations of icebergs in one episode of observations D=A/E;
- Iceberg shape.

*- *It is not necessary to use the trapezoid, but due to the fact that the map projection to the plane surface resembles a trapezoid, the trapezoid figure was chosen.*

Subparameter 1-The number of recorded observations of icebergs during the whole period of observation (A).

- **Short facts about the sub parameter:** The subparameter is estimated using the long-term recorded data. The amount of icebergs observed is to be visualized in the trapezoids (described above) on the map of the studied area.
- **Why this is a key sub parameter:** This parameter is a key tool to represent the time-spatial distribution of iceberg activity in the studied area.
- **Monitoring**: Satellites. Physical observation from the vessel deck and land. Air survey. Radio goniometry.
- **Current status of the subparameter:** Data on iceberg observations are available for the period between 1950-1990. Access can be discussed.
- **Quality objectives:** Not defined.
- **Reference level:** Potentially readily available for any level.
- **Gaps in data coverage:** For a proper temporal-spatial distribution of iceberg activity pattern records for the last 10-15 years are needed. Could be gathered from the scientific organizations via negotiations.
- **Other issues about the subparameter:**

Subparameter 2 - The number of months in which episodes of observation were recorded (M)

- **Why this is a key sub parameter:** This parameter could be used to determine the most active seasons in the particular area from the point of iceberg threat.
- **Monitoring:** Calculated from the available data.
- **Current status of the subparameter:** Data on iceberg observations are available for the period between 1950-1990. Access can be discussed.
- **Quality objectives:** Not defined.
- **Reference level:** Potentially readily available for any level.
- **Gaps in data coverage:** For a proper temporal-spatial distribution of iceberg activity pattern records for the last 10-15 years are needed. Could be gathered from the scientific organizations via negotiations.
- **Other issues about the subparameter:** -

Subparameter 3 - The number of episodes (E) defined by the dates of observation, during which icebergs were recorded

- **Why this is a key sub parameter:** This parameter reflects the the iceberg activity. It is different from sub parameter A. Basically, the parameter corresponds to the frequency of iceberg activity.
- **Monitoring:** Calculated from the available data.
- **Current status of the subparameter:** Data on iceberg observations are available for the period between 1950-1990. Access can be discussed.
- **Quality objectives:** Unknown.
- **Reference level:** Potentially readily available for any level.
- **Gaps in data coverage:** For a proper temporal-spatial distribution of iceberg activity pattern records for the last 10-15 years are needed. Could be gathered from the scientific organizations via negotiations.
- **Other issues about the subparameter:**

Subparameter 4- A calculated value (D) determining the average number of fixations of icebergs in one episode of observations

- **Why this is a key sub parameter:** The meaning of the value D is a reflection of the intensity of the episodes and can be viewed as a measure of simultaneous iceberg hazard
- **Monitoring:** Calculated from the available data. D=A/E
- **Current status of the subparameter:** Data on iceberg observations are available for the period between 1950-1990. Access can be discussed.
- **Quality objectives:** Not defined.
- **Reference level:** Potentially readily available for any level.
- **Gaps in data coverage:** For a proper temporal-spatial distribution of iceberg activity pattern records for the last 10-15 years are needed. Could be gathered from the scientific organizations via negotiations.
- **Other issues about the subparameter:**

Subparameter 5- Iceberg shape

- **Why this is a key sub parameter:** The sub marameter reflects the the specific structure of iceberg hazards.
- **Monitoring:** Physical observation from the vessel deck and land. Air survey. Radio goniometry.
- **Current status of the subparameter:** Data on iceberg observations are available for the period between 1950-1990. Access can be discussed.
- **Quality objectives:** not defined
- **Reference level:** Potentially readily available for any level.
- **Gaps in data coverage:** For a proper temporal-spatial distribution of iceberg activity pattern records for the last 10-15 years are needed. Could be gathered from the scientific organizations via negotiations.
- **Other issues about the subparameter:** -

Having the coordinates of icebergs observed in different years we may form a grid map with trapezoids in which the particular amount of icebergs fell during the whole period observation. For example in the trapezoid bounded with latitude of 75-77°N and longitude of 30-35°E fall 184 icebergs during 1950-1990. Using the above stated subparameter and data we define other subparameters (M,E,D.)

Once these subparameters are estimated using the long term period for each year of observation (for example it is possible to collect the data starting from 1898) for each trapezoid, we may assign one or another activity level in terms to take these into account while any activity (building, resource exploitation, navigation, science activity etc) in the potential studying area. This tool is possible to apply if we will form a double array using the two parameters E and D. The value E will vary from 5 to 24 (for example) for the whole period of observation and will correspond the iceberg activity (less 5 – minor, from 5 to 18 –normal, from 18 to 24 high, more than 24 abnormal). We do the same for D subparameter corresponding to intensity of episodes. So in the end we might have trapezoids with indicated iceberg activity in each of it using the double array of sub parameters. All this information, together with easily understandable maps (which can be updated jointly) and even models of iceberg activity to be developed, can be a useful tool in terms of estimation of risks and hazards on any level.

Other issues for all sub parameters:

1. *An example of data base:*

Day	Month	Year	Icebergs/Ice fileds	Latitude (N)		Longitude (E)		Shape code
				Degrees	Minutes	Degrees	Minutes	
16	8	1978	3	76	32	33	30	99
16	8	1978	3	77	32	29	24	2
5	10	1978	1	79	10	45	30	2
16	10	1978	1	78	16	46	31	2
22	2	1979	1	75	36	23	30	2
24	2	1979	1	78	25	40	9	10
19	3	1979	1	78	16	39	24	10

2. *An Example of double array*

	Minor iceberg activity, $E \leq 5$	Normal iceberg activity, $5 < E \leq 18$	High iceberg activity $18 < E \leq 24$	Abnormal iceberg activity $E > 24$
Low episode intense, D < 3	Trapezoide1(XºN;YºE) Lower iceberg activity			
Normal episode intense, $3 \leq D < 9$				
High episode intense $9 \leq D < 15$				Abnormal iceberg activity
Anormal episode intense $D \geq 15$				TrapezoideN(XºN;YºE)

Furthermore, the tools to describe the iceberg activity threat can be developed broadly.

Contact person/responsible person: Alexander Ovsyannikov, SC Sevmorgeo

Title: Sea Ice cover in the Barents Sea
Parameter: Sea Ice area

About the parameter

- ***Type of parameter: E***
- ***Priority of parameter: e***
- ***Rationale :*** Sea-ice area is a parameter which can be used for studying climate changes in the Arctic Ocean. The decline in sea-ice area in the Arctic are widely cited and many studies have shown that the most substantial changes during the recent decades have taken place in the Eurasian Arctic, in particular in the Barents Sea.

Overview of the subparameters

Subparameters (name)	*Institution responsible for monitoring*	*Time series period*	*Gaps in monitoring*	*Priority ("e", "r" or "s")*
Sea ice area (satellite)	*NPI*	*Since 1979*	*no*	e
Extent (satellite)	*NPI*	*Since 1979*	*no*	e
Concentration (satellite)	*NPI*	*Since 1979*	*no*	e
Concentration (airborne)		*Potentially in future*		r
Concentration (in situ)		*Potentially in future*		r
Timing of ice formation	*NPI*	*Since 1979*	*no*	r
Timing of ice retreat	*NPI*	*Since 1979*	*no*	r

*Subparameter 1 - **Sea ice area (satellite)***

- **Short facts about the subparameter:**
- **Why this is a key subparameter:** The sea-ice area is sensitive parameter and reflects the changes of both dynamic and thermodynamic sea ice processes. The sea-ice area is the integral sum of areas actually covered by sea ice.
- **Monitoring:** Sea-ice area is the sum of the grid cell areas multiplied by the ice concentration for all cells with ice concentrations of at least 15%. For calculation of the sea-ice area in the Barents Sea (box bounded by latitudes 72˚N and 82˚N and longitudes 10˚E and 60˚E) we use monthly mean sea ice concentration from the National Snow and Ice Data Center (NSIDC, Boulder, USA).The data are provided in the polar stereographic projection at a grid cell size of 25 x 25 km for the period 1979-present. For details see http://nsidc.org/data/nsidc-0051.html
- **Current status of the subparameter:** In most years, the largest sea-ice area in the Barents Sea occurs in April, and in September it reaches its minimum. The Barents Sea ice area is also characterized by a large interannual variability (see Fig.1).

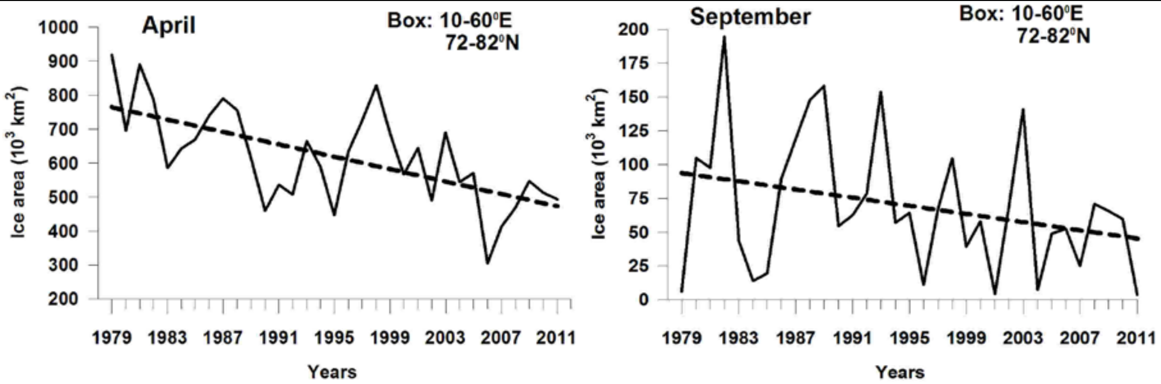


Fig. 1. Barents Sea sea-ice area (solid line) for the period 1979-2011 in April and September. Dashed line shows the linear trends.

- **Quality objectives:**
- **Reference level:** The main feature of the sea-ice area development in the Barents Sea between 1979 and 2011 is a clear negative trend (see Figs. 1). Based on a linear regression analysis, the rate of decadal decrease in April and September are -11.5% and -15.7%, respectively.
- **Gaps in data coverage:** No gaps in the period of satellite observations.
- **Other issues about the subparameter:**

*Subparameter 2 - **Sea ice extent (satellite)***

- **Short facts about the subparameter:**
- **Why this is a key subparameter:** The sea-ice extent is a very sensitive parameter and reflects the changes of practically the all dynamic and thermodynamic sea ice processes. The sea-ice extent is calculated as the areal sum of sea ice covering the ocean where sea-ice concentration exceeds a threshold, usually 15%.
- **Monitoring:** Sea-ice extent is the cumulative area of all grid cells that have at least 15% sea ice concentration.For calculation of the sea-ice extent in the Barents Sea (box bounded by latitudes 72˚N and 82˚N and longitudes 10˚E and 60˚E) we use monthly mean sea ice concentration from the National Snow and Ice Data Center (NSIDC, Boulder, USA). The data are provided in the polar stereographic projection at a grid cell size of 25 x 25 km for the period 1979-present. For details see http://nsidc.org/data/nsidc-0051.html
- **Current status of the subparameter:** In most years, the largest sea-ice extent in the Barents Sea occurs in April, and in September it reaches its minimum. The Barents Sea ice extent is also characterized by a large interannual variability (see Fig.1).

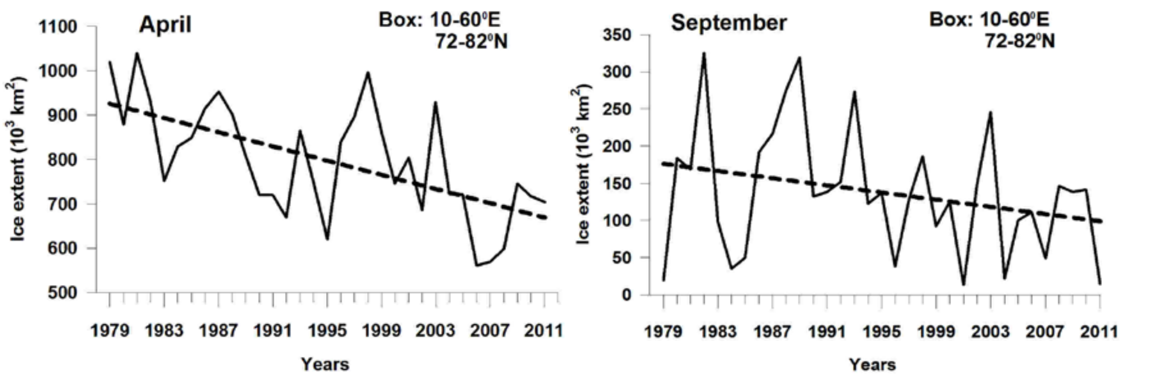


Fig. 1. Barents Sea sea-ice extent (solid line) for the period 1979-2011 in April and September. Dashed line shows the linear trends.

- **Quality objectives:**
- **Reference level:** The main feature of the sea-ice extent development in the Barents Sea between 1979 and 2011 is a clear negative trend (see Figs. 1). Based on a linear regression analysis, the rate of decadal decrease in April and September are -8.5% and -13.3%, respectively.
- **Gaps in data coverage:** No gaps in the period of satellite observations.
- **Other issues about the subparameter:**

*Subparameter 3 - **Sea ice concentration (satellite)***

- **Short facts about the subparameter:**
- **Why this is a key subparameter:** Sea ice concentration can be used to determine ice area and ice extent, both of which are important markers of climate change. Sea ice concentration is the percentage of an area that is covered with sea ice.
- **Monitoring:** We use monthly mean sea ice concentration from the National Snow and Ice Data Center (NSIDC, Boulder, USA).The data are provided in the polar stereographic projection at a grid cell size of 25 x 25 km for the period 1979-present. For details see http://nsidc.org/data/nsidc-0051.html
- **Current status of the subparameter:**
- **Quality objectives:**
- **Reference level:**
- **Gaps in data coverage:** No gaps in the period of satellite observations.
- **Other issues about the subparameter:**

*Subparameter 4 –**Timing of ice formation***

- **Short facts about the subparameter:**
- **Why this is a key subparameter:** This subparameter shows changes of sea-ice area seasonality in the Barents Sea.
- **Monitoring:** We calculate the number of days between the minimum and maximum sea-ice area in the Barents Sea (box bounded by latitudes 72˚N and 82˚N and longitudes 10˚E and 60˚E). For calculation of the sea-ice area in this box we use monthly mean sea ice concentration from the National Snow and Ice Data Center (NSIDC, Boulder, USA).The data are provided in the polar stereographic projection at a grid cell size of 25 x 25 km for the period 1979-present. For details see http://nsidc.org/data/nsidc-0051.html
- **Current status of the subparameter:**
- **Quality objectives:**
- **Reference level:**
- **Gaps in data coverage:** No gaps in the period of satellite observations.
- **Other issues about the subparameter:**

Subparameter 5 – ***Timing of ice retreat***

- **Short facts about the subparameter:**
- **Why this is a key subparameter:** This subparameter shows changes of sea-ice area seasonality in the Barents Sea.
- **Monitoring:** We calculate the number of days between the maximum and minimum sea-ice area in the Barents Sea (box bounded by latitudes 72˚N and 82˚N and longitudes 10˚E and 60˚E). For calculation of the sea-ice area in this box we use monthly mean sea ice concentration from the National Snow and Ice Data Center (NSIDC, Boulder, USA).The data are provided in the polar stereographic projection at a grid cell size of 25 x 25 km for the period 1979-present. For details see http://nsidc.org/data/nsidc-0051.html
- **Current status of the subparameter:**
- **Quality objectives:**
- **Reference level:**
- **Gaps in data coverage:** No gaps in the period of satellite observations.
- **Other issues about the subparameter:**

Contact person/responsible person: Sebastian Gerland, NPI, Olga Pavlova, NPI, Vidar Lien, IMR

Title: Sea Ice cover in the Barents Sea
Parameter: Snow thickness on sea ice cover

About the parameter

- ***Type of parameter: E***
- ***Priority of parameter: e***
- ***Rationale :*** Sea ice is typically covered by snow. In the polar regions, sea ice and its associated snow cover is a major regulator of the heat, mass and momentum between the atmosphere and ocean. While the three parameters sea-ice area, extent and concentration are routinely measured from satellite instruments, the snow cover thickness is not well measured and is highly uncertain.

Overview of the subparameters

Subparameters (name)	*Institution responsible for monitoring*	*Time series period*	*Gaps in monitoring*	*Priority (“e”, “r” or “s”)*
In situ	*NPI*	*Since 1966*		e
Airborne				r

Subparameter 1 - **Snow thickness on sea ice cover (*in situ*)**

- **Short facts about the subparameter:**
- **Why this is a key subparameter:**
- **Monitoring:** The regular sea ice monitoring by the island of Hopen (at approximately 100 m and 150 m from the shore) was initiated in the 1960s. It includes in situ measurements of ice and snow thickness, and freeboard at several sites. Since a few years, the measurement procedure was revisited and new standards established. Before that, especially snow thickness measurements are more sporadic. Ice thickness, freeboard and snow thickness are now measured conventionally from drill holes using a Kovacs thickness-gauge tape measure or a measurement stick with a notch. The snow thickness is measured with a metal stake. Drillings are made approximately every 2 weeks as long as it is possible to access the sites. At each site on each occasion, three holes are drilled in the corners of a triangle with 10 m side length to account for variability at the site. The data from the three holes are measured and later averaged. Usually, three sets of holes are drilled 50, 100 and 150 m from the shore.
- **Current status of the subparameter:**
- **Quality objectives:**
- **Reference level:**
- **Gaps in data coverage:**
- **Other issues about the subparameter*:***

Subparameter 2 - airborne

Not performed

Contact person/responsible person: Sebastian Gerland, NPI, Olga Pavlova, NPI

Title: Seabird communities/assemblages at sea (E)

About the indicator

- ***Type of indicator: E***

- ***Priority of indicator: r***
  The indicator is under development. A longer time series will provide a basis for setting the reference level, and link the development of the indicator to specific changes in the ecosystem

- ***Rationale:*** The purpose of the indicator is to identify changes in the seabird community in the Barents Sea. Distribution and abundance of seabirds at sea is sensitive to changes in the ecosystem in open waters. In particular, changes in fish stocks, fish larvae and zooplankton distribution are important. The indicator is updated at the Institute of Marine Research's (IMR) ecosystem surveys in the Barents Sea in the autumn (August-September). The different species are identified and counted by observers on board the cruise vessel.

  The indicator reflects both changes in population size and changes in habitat use. In relation to the dynamics observed in the breeding colonies, the dynamics at sea is larger, and the indicator reflects to a greater degree the changes in habitat use.

  Comments: the parameter needs to be further developed

Overview of Parameters

Parameters (name)	***Type (“E”, “A”, or “I”)***	***Priority (“e”, “r” or “s”)***
Spatial-seasonal distribution of seabird communities	*E*	r

Contact person/responsible person: Hallvard Strøm, NPI, Maria Gavrilo

Title: Vulnerable and endangered species (VES) (E,I)

About the indicator

- ***Type of indicator: E,I***
- ***Priority of indicator: e***
- ***Rationale:*** Healthy ecosystem is based on biodiversity. To maintain it, vulnerable and endangered species must be consistently monitored. They are important in terms of genetic, scientific, educational and esthetic value. They experience direct impact from anthropogenic activity as well as from the changing environmental conditions that affect their distribution and population numbers.

Overview of Parameters

Parameters (name)	***Type (“E”, “A”, or “I”)***	***Priority (“e”, “r” or “s”)***
Total number of VES for the main categories (mammals, birds, fish), their relative abundance and population trend	*E, I*	e
Distribution of VES	*E,I*	e
By-catch of VES	*I*	e
Species of special interest	*E,I*	e

Contact person/responsible person: Stas Fomin, WWF Russia, Julia Tchernova, NPI

Title: Vulnerable and endangered species (VES) (E,I)

Parameter: By-catch of VES

About the parameter

- ***Type of parameter: I***
- ***Priority of parameter: e***
- ***Rationale :*** Monitoring of VES by-catch allows to collect data on incidental takings, estimate full impact on population and draw attention to by-catch reduction efforts.

Overview of the parameter

Parameters (name)	*Institution responsible for monitoring*	*Time series period*	*Gaps in monitoring*	*Priority ("e", "r" or "s")*
By-catch of VES	*PINRO, IMR*	*PINRO – 2011* *IMR*		e

By-catch of VES

- **Why this is a key parameter:** to evaluate impact on the species we must know how many individuals are caught accidentally. By-catch data can also be valuable for estimation of population size and species territorial distribution.
- **Monitoring:** current agreements with fishing vessels to collect and report information on by-catch to have reliable estimates .
- **Environmental objective:** it is necessary to obtain reliable information on numbers of by-catch, allowing making realistic population estimates, which could possibly lead to implementation of some management steps to minimize the impact on the species.

Contact person/responsible person: Stas Fomin, WWF Russia, Maria Gavrilo, NPRA, Maria Tsiganova, VNII Prirody, Julia Tchernova, NPI

Title: Vulnerable and endangered species (VES) (E,I)

Parameter: Territorial distribution of VES

About the parameter

- ***Type of parameter: E,I***
- ***Priority of parameter: e***
- ***Rationale :*** Knowledge of spatial distribution of VES is critical to making meaningful management decisions and establishing boundaries to protect the species if/when there are changes in their preferred habitat, which is particularly important in light of the growing industrial activities and changing environmental conditions.

Name	***Institution responsible for monitoring***	***Time series period***	***Gaps in monitoring***	***Priority (“e”, “r” or “s”)***
Territorial distribution of VES	*IMR ecosystem cruise NPI MMBI PINRO VNIIPrirody*			e

Territorial distribution of VES

- **Why this is a key parameter:** territorial distribution can be reflective of the state of the population and changes in the environment and possibly - experienced negative impact, coming from either human activities or environmental changes.
- **Monitoring:** currently, monitoring of some of the VES conducted by the NPI, sightings are recorded by IMR, PINRO and MMBI. Many species are hard to monitor due to their vast geographic range and/or logistical challenges (hard or impossible to tag, rare encounters, hard to properly identify, etc) One approach is currently taken for some species is sighting database, where tourists and other “accidental” observers can submit information for the species, that can be reliably identified by non-scientists. It’s been suggested to utilize monitoring opportunities arising during the seismic work or geophysical surveys; visual observations should be backed by photo and video records. Number, location and behaviour of individuals should be recorded for marine mammals and possibly other VES in case of positive identification.
- **Environmental objective:** to have an overview of the distribution and habitat use by VES, which can be indicative of human impact, changes in habitat use due to the environmental changes and changes in the prey base and otherwise reflect ecosystem changes; can be critical for the successful protection of the species, particularly due to the further increasing industrial activities in the Barents Sea.

Contact person/responsible person: Stas Fomin, WWF Russia, Maria Gavrilo, NPRA, Maria Tsiganova, VNIIPrirody, Julia Tchernova, NPI

Title: Vulnerable and endangered species (VES) (E,I)

Parameter: Species of special interest

About the parameter

- ***Type of parameter: E,I***
- ***Priority of parameter: e***
- ***Rationale :*** Species that need special attention due to their population status and/or different level of protection in Norway and Russia. They experience direct anthropogenic impacts via former or current harvesting and are strongly influenced by changing environmental conditions.

Overview of the subparameters

Subparameters (name)	***Institution responsible for monitoring***	***Time series period***	***Gaps in monitoring***	***Priority ("e", "r" or "s")***
Relative Abundance of Bowhead whales:	*NPI*	*2008 (IPY)-*		e
Golden redfish	*IMR*			e
Abundance of harbour seals	*IMR, MMBI, . PINRO, NPI (Svalbard)*	*Norway: 1994-8; 2003-2006 Russia: 1990-2007; Svalbard – intermittent 5-yr intervals*	*See text*	e
Abundance of grey seals on the Barents Sea coast	*IMR, PINRO, MMBI*	*Norway: 1990-1991; 1998-2003; 2006 Murmansk Obl.:*1986-1992		e

Subparameter 1 – Relative Abundance of Bowhead whales

- **Why this is a key subparameter:**
  Bowhead whales (*Balaena mysticetus*) have been identified as key monitoring species in CAFF's Circumpolar Biodiversity Monitoring plan, because they are distributed throughout the circumpolar Arctic, and they are heavily reliant on sea ice. Arctic cetaceans are sentinel species that reflect the "health" of the system below them in the food chain. Earlier mismanagement (overharvesting) in the Barents Region has put the population at risk in this area. Despite protection over a very long period, this population is still classified as CR (Critically Endangered). Further risks should be minimized and mitigated where possible.

a)Relative abundance measured using passive acoustic recorders	*E*	*NPI*	*Bowhead whales targeted starting in 2008*	*IWC, IUCN*	E
b)Summer distribution	*E*	*NPI*	*Sighting programme formalized*		E

(and relative abundance) measured from sighting reports			*and operational from 2004-present+*		
c)Seasonal distribution and identification of key habitats	*E*	*NPI*	*Passive acoustic monitoring on-going since 2008. Intermittent coverage via ship surveys and atellite tracking commencing in the late 1990s*		E

a)Relative abundance measured using passive acoustic recorders

- **Short facts about the subparameter:** Historically bowhead whales were distributed throughout the northern Barents Sea and were extremely numerous in Svalbard. Over-harvesting took this species to the brink of extinction. The few remaining whales are difficult to survey within their vast range using conventional aerial or boat surveys, particularly because they often spend a lot of their time in heavy ice cover. Thus, we resorted to PAM (Passive Acoustic Monitoring) in an attempt to get a relative abundance index and some idea of their seasonal distribution. This PAM will be supplemented by intermittent ship work and satellite tracking.
- **Why is this a key subparameter:** It is a key parameter because this species undoubtedly had a significant role in the ecosystem before it was "hunted down", and because the population in the Barents sea is now on the brink of extinction.
- **Monitoring:** Commenced in 2008, when the first AURAL recorder was placed in Fram Stait, at the Southern Whaling Grounds, where historical whalers suggested that the whales were found in late winter/early spring (breeding time). The presence of bowheads during the entire winter in the region was confirmed. Over 50 different songs were recorded – giving some optimism regarding potential recovery of this population.
- **Current status of the parameter:** A second AURAL was placed further east in 2009 and provided valuable contrasting data – suggesting that the preferred wintering conditions were quite specific (restricted to areas with very heavy ice). Two more AURALs will be deployed in summer 2013.
- **Quality objectives:** The low cost, year-round nature of the PAM data collection provides the opportunity to create a meaningful array within the Barents Sea that might allow seasonal distributional tracking of rare cetaceans and a crude measure of abundance. PAM is increasingly popular in ocean monitoring. A value-added factor is that PAM devices also document (increasing) ocean noise that may be disruptive during sensitive periods (calving, mating etc.)
- **Other issues about the subparameter:** PAM should be used in combination with intermittence traditional surveys and satellite tracking to have a reasonably complete monitoring programme (see below). The acoustic recording document the presence of other cetacean species, including belugas, narwhal, fin, minke etc. so provide a crude monitoring tool for the cetacean community (though some species are more acoustically active than others).

b) **Relative abundance and distribution as measured from sighting reports**

- **Short facts about the subparameter:** Bowhead whales have been monitored in the Svalbard area via cooperation with marine tourist operators since 2004. Top-quality guide/naturalists report sightings of all marine mammal species. Rare or otherwise unusual records are confirmed via photographic evidence. Tours are increasing to Franz Josef Land – so a similar system is recommended for adoption by Russian colleagues.
- **Why is this a key subparameter:** Seasonal distribution changes are likely to be among the first observed responses (plastic responses) to climate change. In Svalbard, multiple vessels circumnavigate Spitsbergen weekly, providing amazingly intense sighting coverage. Bowheads and belugas are easily identified, and when present, quite easy to spot.

- **Monitoring:** Commenced in an organized fashion on a broad scale in 2004. The data base contains approximately 10,000 marine mammal records, including some few bowhead sightings.
- **Current status of the subparameter:** It is an on-going system.
- **Quality objectives:** This is a low cost monitoring system that provides good qualitative data and an opportunity to track phenology shifts, species additions etc.
- **Other issues about the subparameter:** It is difficult to assess "effort" beyond knowing the number of boats vs the number of boats reporting. Observer quality clearly differs somewhat from year to year and boat to boat in the sighting surveys. The PAM monitoring is very reliable, though analyses are somewhat time consuming.

***c)* Seasonal distribution and behavior via satellite tracking**

- **Short facts:** Designations of protected areas, or sensitive areas for industrial development, shipping lanes etc. should be based on minimizing conflict with endemic arctic cetaceans in marine areas. It is therefore essential that there is temporal tracking of key areas for these animals because they may shift with changing environmental conditions.
- **Why is this a key subparameter:** satellite tracking should be performed intermittently in order to identify key habitats (breeding areas etc.) and a broader seasonal distribution pattern than the finer spatial scale (near shore Svalbard) sighting programme permits.
- **Monitoring:** Only a single bowhead has been tagged with a tracking device to date – but this single record clearly documented the value of this approach.
- **Current status of the subparameter:** Currently the focus for tracking is on other species – but this system should be intermittent (every 3-5^{h} years for example) employed.
- **Quality objectives***:* Satellite tracking is a powerful tool for distributional and behavioral studies.
- **Other issues about the subparameter:** Satellite tracking provides vast amounts of data about the animals and can also be designed to sample environmental parameters that have explanatory value (for this and other programmes).

Contact person/responsible person: Kit Kovacs, NPI

Subparameter 2 – Golden redfish

- **Short facts about the subparameter:** Golden Redfish (*Sebastes marinus*) live at 100-500 m depth on the continental shelf along the coast and in certain places in the fjords. They feed on zooplankton in the early years, then switch to krill, capelin, herring and cod. Young fish represents an important food source for cod and halibut.
- **Why this is a key subparameter:** Redfish are affected by both natural factors such as sea temperature and the presence of predators that eat redfish, as well as human activities, including fisheries.Redfish are classified as endangered on the Norwegian Red List 2010. Population is very low and still declining. ICES consider the stock as very weak, and recommends ban on fishing, closure areas and strict rules for bycatch.
- **Monitoring:** The indicator describes the size of the population of redfish and how it changes over time. Stocks are monitored by researchers from the Norwegian Institute of Marine Research during annual cruises, and using data collected from fisheries. The data are included in a model used to estimate the size of spawning stock. The results of this model, including the size of the spawning stock is made available for the International Council (ICES) for their stock assessments. Assessment is annual. This is supported by regular surveys: Ecosystem survey, winter survey, slope surveys (egga-sør and egga-nor).

- **Area:** ICES area I & II, Norwegian and Barents Sea continental shelves and slopes.
- **Current status of the subparameter:** Cruise results and catch rates from trawl fishery shows a clear reduction in the occurrence of redfish, and indicates that the stock is near its all-time low. The stock recruitment has been low since the late 1990s. Despite the fact that there are indications of stronger year classes after 2003, it is not expected that these cohorts will contribute to the spawning stock until 2015. Given the low reproduction rate of redfish, it is expected that population' poor status will persist for many years.
- **Quality objectives**:
- **Reference level:**
- **Gaps in data coverage:**
- ***Other issues about the subparameter:***

Contact/responsible person: Benjamin Planque, IMR

Subparameter 3 - Abundance of harbour seals

- **Short facts about the subparameter:** Harbour seals are small piscivorous seals inhabiting coastal waters. Their abundance was estimated at about 1300 in the two northernmost Norwegian counties in 2003-2006. Complete surveys have not been conducted in the Russian part of the Barents Sea region, but abundance is thought to be in the low hundreds. As final hosts to the codworm (*Pseudoterranova decipiens*), harbour seals may promote codworm infestation rates in commercial local fish populations. Except for a in a few isolated localities , Norwegian harbour seals are legally hunted in order to reduce the codworm problem as well as other potential conflicts with coastal fisheries and fish farms. High hunting quotas are thought to have contributed to a decline of more than 10% in Norwegian harbour seals between 1996-99 and 2003-2006. Based on this change, harbour seals were listed as vulnerable in the 2010 Norwegian redlist. In Northwest Russia, harbour seals are redlisted in the category "rare" and have been legally protected from hunting since 1990. Nevertheless, some poaching is thought to occur and is suspected to have contributed to a severe reduction in observations of harbour seals in one of the main colonies in Ivanovskaya Bay on the Barents Sea coast. Harbour seals in Svalbard are Red Listed because of relatively small size of this isolated population. They are monitored via ship or aerial survey at 5-10 year intervals.
- **Why this is a key subparameter:** Both Russian and Norwegian management objectives for harbour seals are based on commitments to preserve viable populations of the species within its current range. The conservation value of northern harbour seals is strengthened by recent genetic analyses documenting a rich and unique gene pool in harbour seals from Northern Norway (Andersen et al. 2010) compared to the larger populations in the North Sea area. Conservation interests are, however, challenged in both countries and monitoring of actual abundance is needed to ensure viable populations and preservation of genetic diversity in the future.
- **Monitoring:** In Norway, aerial photo surveys and visual counts of moulting animals are used to obtain minimum estimates of harbour seal abundance. In Russia, counts have generally been restricted to breeding colonies in Ivanovskaya Bay in the Eastern part of the Kola Peninsula. Norway: 1996-1997, 2003-2006, 2011-2013, approximately every 5 years as required by the current Norwegian Management plan. Some deviations may occur due to occasional lack of funding or difficult field conditions (bad weather). Russia: 1990 - 2007

- **Area:** Norway: East Finmark; Russia: monitoring of minimum numbers of harbour seals in Ivanovskaya Bay.

- **Current status of the subparameter:** Survey results suggest a decline in overall harbour seal abundance in mainland Norway from 7500 individuals in 1996-99 to 6700 individuals in 2003-2006 (Nilssen et al. 2010). This decline is also reflected in the Barents Sea region as illustrated by results for East Finnmark in Fig. 1. Preliminary data from new surveys suggests possible recoveries in some areas with low hunting pressures. More counts are, however, needed before conclusions can be made about the overall situation in Norway. In Russia, minimum numbers of observed harbour seals in Ivanovskaya Bay were markedly reduced in the late 1990s and remained low to the last data point in 2007 (Fig. 2). Svalbard harbour seals are showing an opposite trend, spreading in distribution and also increasing in numbers. This population is protected from shooting.
-

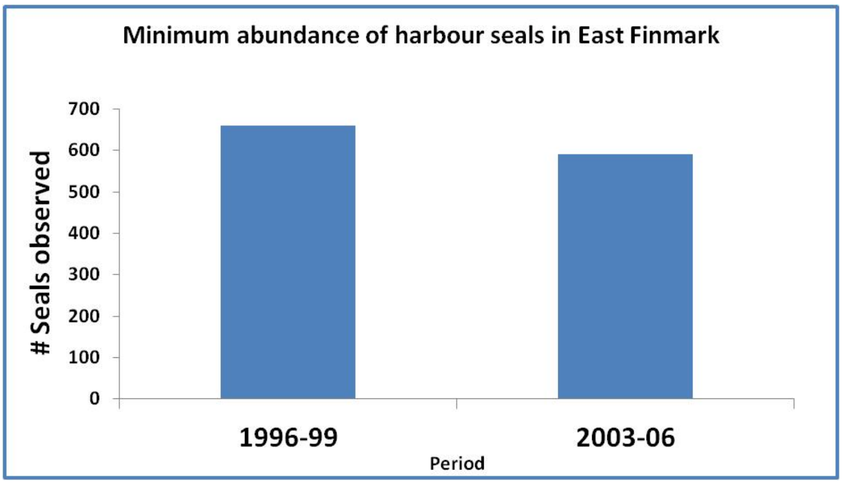


Fig. 1 Minimum abundance of harbour seals in East Finnmark based on maximum counts of seals hauled out during the moulting period (Numbers from Nilssen and Bjørge, 2011).

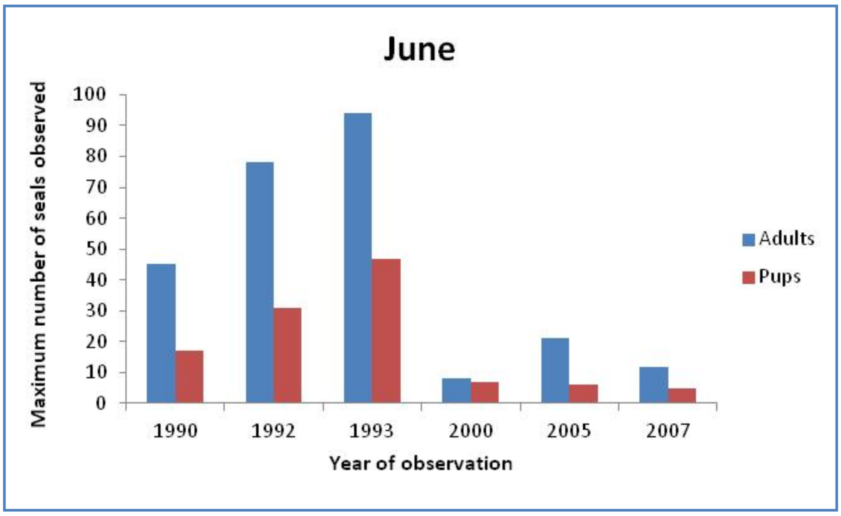


Fig. 2 Minimum numbers of harbour seals in Ivanovskaya Bay based on maximum counts during the breeding and lactation periods (based on data from Zyryanov and Egorov, 2010)

- **Quality objectives**: According to a recently adopted Norwegian management plan (Directorate of Fisheries, 2010), the overall management objective for harbour seals is to stabilize regional abundances at the 2006 level. The Russian management objective is not officially stated but the species currently has a highly protected status, similar to Svalbard.

- **Reference level:** In Norway, the reference level for harbour seal abundance is set at the 2006 level. In Russia, no overall reference level has been defined, but the data from Ivanovskaya Bay could be used to produce a reference level.
- **Gaps in data coverage:** Norwegian authorities aim to update the abundance estimate for harbour seals with intervals of about 5 years. It takes several years to get full coverage and a new counting cycle is expected to be completed in 2013 on the mainland. Surveys were flown most recently in Svalbard in 2010. No Russian data are available after 2007.
- ***Other issues about the subparameter:*** Counts of moulting and lactating harbour seals are subject to potential errors, because a variable proportion of the animals will be in the water, where they are less likely to be counted. Efforts are made to reduce these errors by studying of haul-out behavior and counting more than once in the same area.

References

Andersen, L.W.A. Lydersen, C. Frie, A.K. Rosing-Asvid, A. Hauksson, E. and Kovacs, K. 2008. A population on the edge: genetic diversity and population structure of the world's northernmost harbour seals (*Phoca vitulina*). Biological Journal of the Linnean Society, 2011, 102, 420–439.

Nilssen, K.T., Skavberg, N.-E., Poltermann, M., Haug, T., Härkönen, T., Henriksen, G. 2010. Status of harbour seals (*Phoca vitulina*) in mainland Norway. *NAMMCO Sci. Publ.*8: 61-70.

Nilssen, K.T. and Bjørge, A. 2011. *Status for Kystsel, anbefaling Jaktkvoter 2012*. [In Norwegian] (Status of coastal seals, quota recommendations for the 2012 hunt). Document presented at a meeting in "Sjøpattedyrutvalget" (The national Marine mammal committee) in Oslo 19-20 October 2011.

Zyryanov, S.V. and Egorov, S.A.2010. Status of the harbour seal (Phoca vitulina) along the Murman coast of Russia. NAMMCO Sci.Publ.8:37-46.

Contact person/responsible person: Anne Kirstine Frie, IMR, Vladislav Svetochev, Kit M. Kovacs, NPI

Subparameter 4 - Abundance of grey seals on the Barents Sea coast

- **Short facts about the subparameter:** Grey seals are large piscivorous coastal seals with a more offshore distribution than harbour seals. Based on differences in breeding phenology, grey seals in Troms and Finnmark counties are thought to be distinct from grey seals further south in Norway and are treated as a separate management unit. The total abundance of this breeding population was estimated at about 2000 animals in 2011 (Øigård et al., 2012).Grey seals in Northwest Russia show the same breeding phenology as in Northern Norway and their abundance was estimated at about 3400 individuals in 1994 (Haug et al., 1994). Grey seals have been completely protected from hunting in Russia since 1975 and are listed as "rare" in redlists for Murmansk and Arkhangelsk counties. In Norway, the species is listed in the "least concern" IUCN category and are subject to a significant hunt. The Norwegian redlist status is based on the overall national situation. According to a recent modeling study, current removal levels in Northern Norway are, however, only sustainable for the local populations if 50-55% of the hunted animals are assumed to originate from Russian colonies.
- **Why this is a key subparameter:** Regular monitoring of grey seal abundance in both Norway and Russia is necessary in order to understand the local and regional effects of the Norwegian grey seal hunt. Experience from the Northwest Atlantic shows that grey

seal populations may grow very large and play a major role in the ecosystem. In other areas, however, grey seal populations have gone almost extinct due to overhunting.

- **Monitoring:** Estimation of grey seal abundance in both Norway and Russia is based on pup counts. Total population abundance is derived from population models also incorporating data on catches and female reproductive rates.
  Norway: 1990-1991, 1998-2003, 2006, 2013, approximately every 5 years as required by the current Norwegian Management plan. Some deviations may occur due to occasional lack of funding or difficult field conditions (bad weather). Russia: estimate based on counts made during the period 1986-1992. There have been some recent counts in some of the Russian grey seal colonies.
- **Current status of the subparameter:** Pup production estimates from Troms and Finnmark have increased by about four fold over the period 1990-2006 (Fig.1). Taking into account catch data for the same period, this level of increase only appears possible if about 50% of the hunted animals originate from external breeding populations – most likely from larger colonies in Russia. Potential effects of increased removals after 2006 cannot be evaluated yet due to lack of recent pup production data.

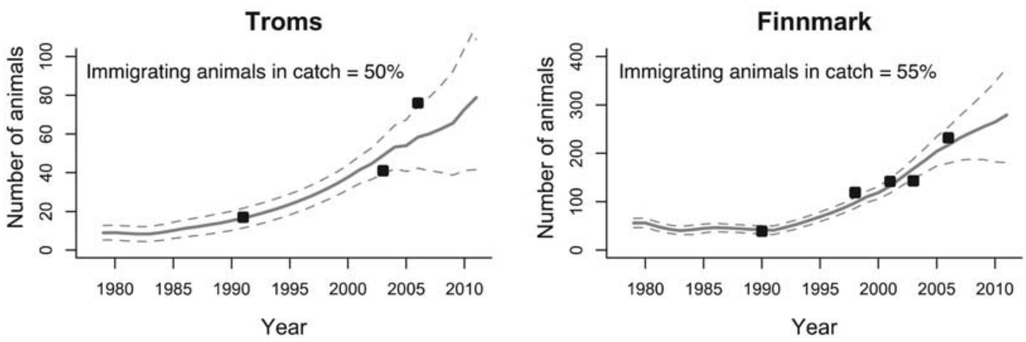


Fig.1 Modelled trend in grey seal pup production in Troms and Finnmark Counties (full grey line) with 95% confidence intervals (dashed grey lines). Black squares show total pup counts from surveys. (From Øigård *et al.* 2012)

- **Quality objectives:** A recently adopted Norwegian management plan states that the management objective for Norwegian grey seals is to maintain a total grey seal population which produces 1200 pups per year. This is slightly less than was counted in the most recent survey (1269 pups). The management plan also states, that viable populations should be maintained within the "natural" distribution area of the species, which presumably includes all of the current distribution area. The Russian management objective is not explicitly stated, but the species currently has a highly protected status.
- **Reference level:** The Norwegian reference level for grey seals is the 2006 national pup production level. In Russia, no overall reference level has been defined.
- **Gaps in data coverage:** According to the Norwegian management plan for grey seals, abundance estimates should be updated with intervals of about 5 years. A new estimate is therefore overdue, but has been postponed due to lack of funding. In Russia, no complete counts have been conducted since 1994.
- ***Other issues about the subparameter:*** In addition to surveys of abundance, grey seals in the Barents Sea region are studied with respect to genetic population structure (collaborative study), movements (Russian satellite tagging study) and diet (Norwegian scat based study).

References

Haug,T., Henriksen, G., Kondakov, A., Mishin, V.Nilssen, K.T. and Røv, N. 1994. The status of grey seals Halichoerus grypus in North Norway and on the Murman coast, Russia. Biological Conservation 70: 59-67.

Øigård, T.A., Frie, A.K., Nilssen, K.T. and Hammill, M.2012. Modelling the abundance of grey seals (*Halichoerus grypus*) along the Norwegian coast. ICES Journal of Marine Science 69: 1436-1447

Contact person/responsible person: Anne Kirstine Frie, IMR, Vladislav Svetochev

Title: Vulnerable and endangered species (VES) (E,I)

Parameter: Total number of VES in main categories (mammals, birds and fish), their relative abundance and population trend.

About the parameter

- ***Type of parameter: E,I***
- ***Priority of parameter: e***
- ***Rationale :*** Biodiversity is essential for the rich and well functioning ecosystem. Long-term monitoring of dynamics of total number of VES as well as monitoring of population trend allows evaluation of effectiveness of conservation efforts and ecosystem vulnerability and resilience. Changes in total number of VES as well as in population numbers can be reflective of the anthropogenic impact, changing environmental conditions and increasing stress for the Barents Sea ecosystem as a whole. Changes in population can also be indicative of local adverse conditions and increased human influence.

Overview of the subparameters

Subparameters (name)	***Institution responsible for monitoring***	***Time series period***	***Gaps in monitoring***	***Priority ("e", "r" or "s")***
Number of VES in mammals, their relative abundance and population trend	*Norwegian Biodiversity Information Centre NPI VNIIPRirody MMBI*			e
Number of VES in birds, their relative abundance and population trend	*Norwegian Biodiversity Information Centre NPI VNIIPrirody*			e
Number of VES in fish, their relative abundance and population trend	*Norwegian Biodiversity Information Centre IMR PINRO*			e

Subparameter 1 - Number of VES in mammals, their relative abundance and population trend

- **Why this is a key subparameter:** Population size and observed population trend can be indicative of a population well-being, and particularly important when it comes to vulnerable and endangered species as it reflects human impact and success of conservation and management efforts. Total number of VES allows to monitor overall health and stability of the ecosystem and to monitor human impact on the particular species or populations.

- **Monitoring:** ecosystem surveys carried out by IMR record sightings of VES. In Russia, PINRO and MMBI as well as VNIIPrirody. Norwegian Biodiversity Information Centre (Artsdatabanken) keeps track and updates list of the species regularly. Red book in Russia lists vulnerable and endangered species. Must be noted that there are some species that have different protection status in Norway and Russia.
- **Environmental objective:** to have an overview of VES populations in the Barents Sea to be able to monitor their state and population trend, take proper management and conservation steps when needed.

Subparameter 2 – Number of VES in birds, their relative abundance and population trend

- **Why this is a key subparameter:** Population size and observed population trend can be indicative of a population well-being, and particularly important when it comes to vulnerable and endangered species as it reflects human impact and success of conservation and management efforts. Total number of VES allows to monitor overall health and stability of the ecosystem and to monitor human impact on the particular species or populations.
- **Monitoring:** ecosystem surveys carried out by IMR record sightings of VES. In Russia, PINRO and MMBI as well as VNIIPrirody. Norwegian Biodiversity Information Centre (Artsdatabanken) keeps track and updates list of the species regularly. Red book in Russia lists vulnerable and endangered species. It must be noted that there are some species that have different protection status in Norway and Russia.
- **Environmental objective**: to have an overview of VES populations in the Barents Sea to be able to monitor their state and population trend, take proper management and conservation steps when needed.

Subparameter 3 – Number of VES in fish, their relative abundance and population trend

- **Why this is a key subparameter:** Population size and observed population trend can be indicative of a population well-being, and particularly important when it comes to vulnerable and endangered species as it reflects human impact and success of conservation and management efforts. Total number of VES allows to monitor overall health and stability of the ecosystem and to monitor human impact on the particular species or populations.
- **Monitoring:** ecosystem surveys carried out by IMR record sightings of VES. In Russia, PINRO and MMBI as well as VNIIPrirody. Norwegian Biodiversity Information Centre (Artsdatabanken) keeps track and updates list of the species regularly. Red book in Russia lists vulnerable and endangered species. Must be noted that there are some species that have different protection status in Norway and Russia.
- **Environmental objective:** to have an overview of VES populations in the Barents Sea to be able to monitor their state and population trend, take proper management and conservation steps when needed.

Contact person/responsible person: Stanislav Belikov, VNIIPritody, Maria Gavrilo, NPRA, Maria Tsiganova, VNIIPrirody, Julia Tchernova, NPI, Stanislav Fomin, WWF Russia

Title: Water masses properties and volume transport in the Barents Sea

About the indicator

- ***Type of indicator: E***
- ***Priority of indicator: e***
- ***Rationale:*** Water masses properties and volume transports play a key role in the functioning of the Barents Sea ecosystem. The southern part of the Sea is influenced by inflow of warm coastal and Atlantic waters entering the region along the coast of northern Norway, while the northern Barents Sea is influenced by cold Arctic waters. Interactions between different water masses produce numerous frontal zones in the Sea; the Polar front is most important among them. Water mass properties are largely determined by seasonal and interannual fluctuations in volume (and heat) fluxes across the sea boundaries. Due to unique properties of water masses, the Barents Sea is rich in marine life, being one of the most productive fishing grounds in the world. Monitoring of water mass properties and volume fluxes is of major importance for management and sustainable use of resources of the Sea.

Overview of Parameters

Parameters (name)	***Type (“E”, “A”, or “I”)***	***Priority (“e”, “r” or “s”)***
Frontal zones	*E*	e
Area of water masses	*E*	e
Volume flux across the south-western (Norway-BjørBear Island) and north-eastern boundaries (Novaya Zemlya-Frans Josef Land)	*E*	e
Volume flux across the other boundaries and transects	*E*	r

Contact person/responsible person: Oleg Titov, PINRO

Title: Water masses properties and volume transport in the Barents Sea

Parameter: Area of water masses

About the parameter

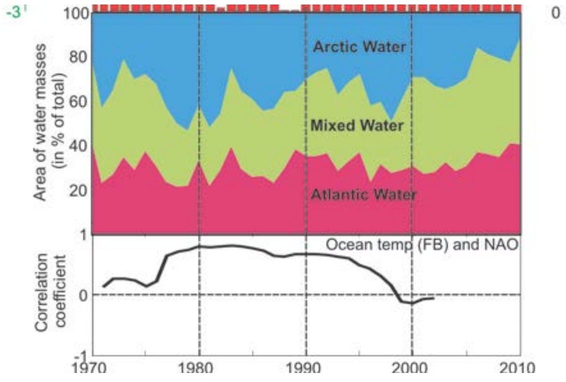
- ***Type of parameter: E***
- ***Priority of parameter: e***
- ***Rationale:*** Temperature restricts the spatial distribution of many species and as a consequence, the area of the different water masses determines the area available for the species with certain temperature preferences.

Overview of the subparameters

Subparameters (name)	***Institution responsible for monitoring***	***Time series period***	***Gaps in monitoring***	***Priority ("e", "r" or "s")***
Use in situ S and T (calculation from PINRO/IMR) from ecosystem surveys	*PINRO and IMR*	*1970-present*		e

Subparameter 1

- **Short facts about the subparameter:** Area occupied by different water masses defined by specific temperature and salinity criteria.
- **Why this is a key subparameter:** The area of the various water masses determines the area available to species with temperature-specific preferences.
- **Monitoring:** Area is calculated based on temperature and salinity maps obtained by objective analysis of CTD-observations during ecosystem cruises covering the entire Barents Sea.
- **Current status of the subparameter:**



The figure shows the expansion of the warm and saline Atlantic Water at the expense of the colder and fresher Arctic Water. (The correlation coefficient figure is not relevant, but is kept so that the year axis can be seen)

- **Quality objectives:**
- **Reference level:** Reference level should be based on climatic period compatible with climatic period for other parameters.
- **Gaps in data coverage:**
- **Other issues about the subparameter:**

Contact person/responsible person: Randi Ingvaldsen, Vidar S. Lien, IMR

Title: Water masses properties and volume transport in the Barents Sea

Parameter: Frontal zones

About the parameter

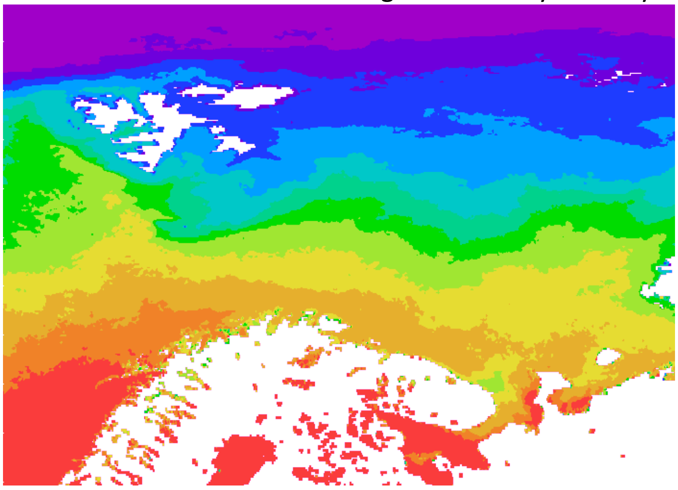
- ***Type of parameter: E***
- ***Priority of parameter: e***
- ***Rationale:*** There are numerous frontal zones in the Barents Sea formed by the convergence of currents and interaction of different water masses. The Polar Front is the most pronounced frontal zone separating southern and northern parts of the sea dominated by warm Atlantic and cold Arctic waters, correspondingly. Frontal zones are areas where vertical mixing is intensified compared to other areas, and more nutrients, stimulating primary production, are brought into the photic zone from deep layers. The Polar Front separates habitats of warm-water and cold-water marine species and also acts as a natural barrier for northward migrations of boreal fish species. Short-term and interannual variability in parameters of frontal zones is still poorly studied.

Overview of the subparameters

Subparameters (name)	***Institution responsible for monitoring***	***Time series period***	***Gaps in monitoring***	***Priority ("e", "r" or "s")***
Sharpness and location from satellite	*NERSC*	*1980 - present time*		e
New: use in situ S and T (calculation from PINRO/IMR) from ecosystem surveys	*PINRO*			r

Subparameter 1 - Sharpness and location from satellite

- **Short facts about the subparameter:** The Polar front is formed between warm and saline Atlantic waters and cold, fresher Arctic waters in the middle of the Barents sea. Its position and sharpness varies at seasonal and inter-annual scales.
- **Why this is a key subparameter:** The fronts are the boundaries between water masses and hence influence distribution and transport of mass, heat and biota.
  Seasonal and inter-annual dynamics may be a tracer of atmospheric forcing and hence and indicator of changing climate. Simultaneously location of the front influences strength of the air-sea interaction.
  It is relatively easy and cheap to estimate from satellite data.
- **Monitoring:** The front is visible as sharp transition between cold and warm waters with enhanced primary production (usually expressed as higher values of chlorophyll). Therefore location of the front is estimated based on spatial distribution of sea surface temperature derived from infrared or microwave satellite Earth observing data or phytoplankton chlorophyll derived from optical EO data. SST is calculated from IR or microwave satellite data. IR data has higher spatial resolution (1 km) but is limited by clouds. Microwave data has resolution about ¼ degree but is not limited by clouds. Images are available daily but due to clouds IR data has to be averaged over week.
- **Current status of the subparameter:** SST is being effectively estimated from satellite data since 1981. Several satellite missions provide IR and microwave data and 30 years of observations are already collected. More satellites to carry IR and microwave sensors onboard to be launched by space agencies are planned and expected. The figure below shows spatial distribution of SST in the surface waters (from 0 deg C to 10 deg K) of the Barents sea in summer as averaged over ten years July – October 2012.

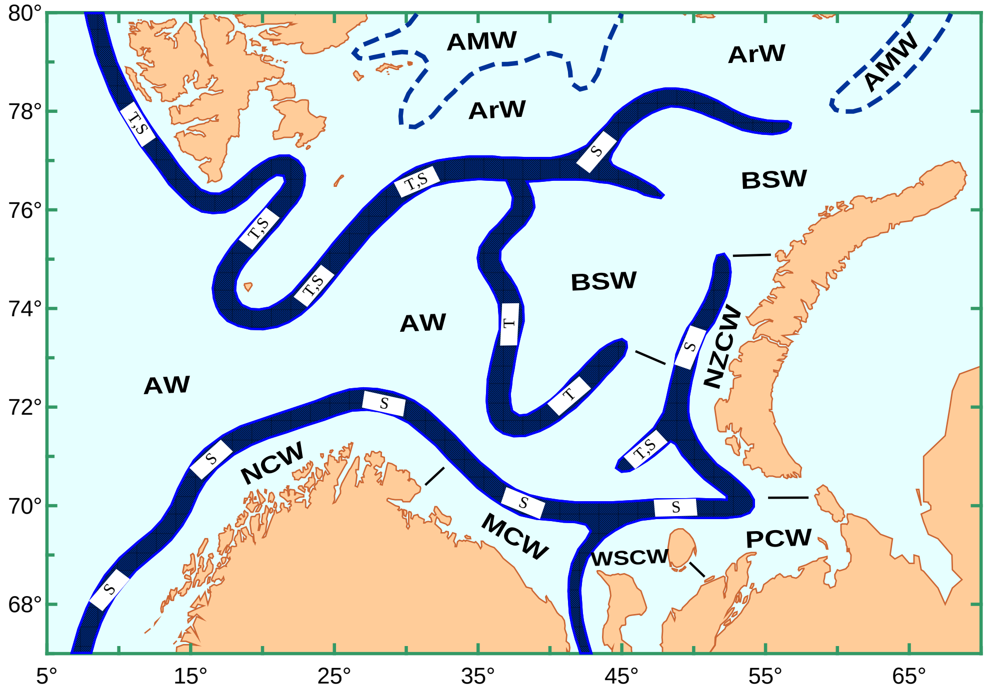


- **Quality objectives:** Have not been set.
- **Reference level:** Mean location during 20 years of observations (1980 - 2000).
- **Gaps in data coverage:** Gaps due to cloud cover disappear when averaging over a month
- **Other issues about the subparameter:**

Subparameter 2 - Use in situ S and T (calculation from PINRO/IMR) from ecosystem surveys

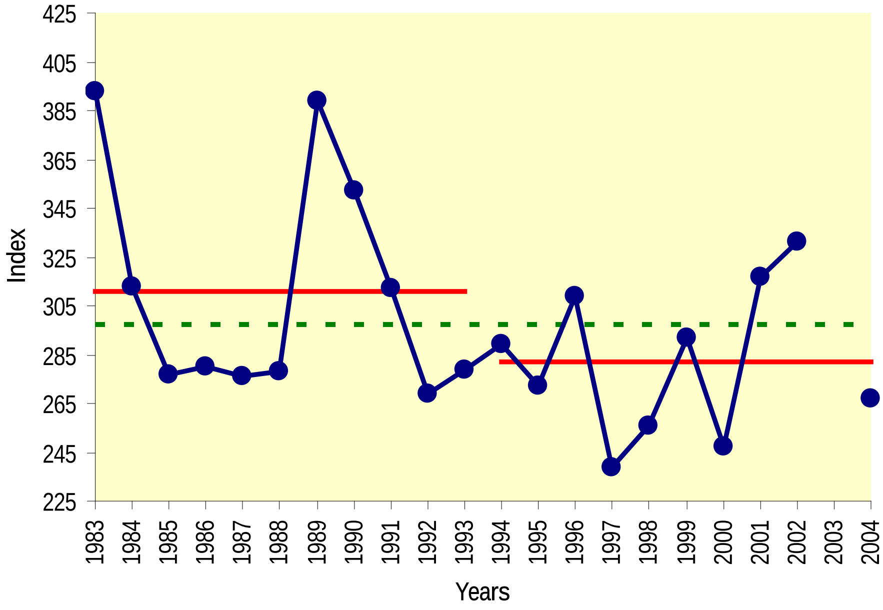
- **Short facts about the subparameter**:
  The Barents Sea frontal zones have a complicated spatial structure. In some areas only the thermal frontal zone is traceable while in other parts of the Sea only the haline front can be

observed. In the central part of the Barents Sea the thermal frontal zone is pronounced while the haline front is absent. In the south, east and northeast the haline frontal zone is well pronounced. In the northwestern Barents Sea positions of thermal and haline frontal zone coincides.



The water masses and the frontal zones in the Barents Sea (Ozhigin and Ivshin, 1999): T – thermal fronts; S – haline fronts; T,S – thermohaline fronts; AW – Atlantic Water; AMW – Atlantic Modified Water; ArW – Arctic Water; BSW – Barents Sea Water; NCW – Norwegian Coastal Water; MCW – Murman Coastal Water; WSCW – White Sea Coastal Water; PCW – Pechyora Coastal Water; NZCW – Novaya Zemlya Coastal Water.

- **Why this is a key subparameter**: The frontal zones are considered as areas of increased biological activity on several trophic levels.
- **Monitoring:** Horizontal gradients and positions of the thermal and haline frontal zones are calculated based on the data acquired during joint IMR/PINRO ecosystem surveys in August-September.
- **Current status of the subparameter:**



- Interannual variations of the frontal zone length index at the 50 m depth in August-September, its mean value for the period 1983-2004 (green dotted line) and mean values in 1983-1993 and 1994-2004 (red lines) (Titov et al., 2007)
- **Quality objectives:** Have not been set.
- **Reference level:** Have not been defined.
- **Gaps in data coverage:**
- **Other issues about the subparameter:** Spatial and temporal variability in parameters of the Barents Sea frontal zones is still poorly studied.

Contact person/responsible person: Oleg Titov, PINRO, Anton Korosov, NERSC

Title: Water masses properties and volume transport in the Barents Sea

Parameter: Volume flux across the south-western (Norway-Bear Island) and north-eastern (Novaya Zemlya-Franz Josef Land) boundaries

About the parameter

- ***Type of parameter: E***
- ***Priority of parameter: e***
- ***Rationale:*** The heat transport associated with the advection of warm and saline Atlantic Water and less saline Coastal Water in the southwest greatly affects the climatic state of the Barents Sea and to a large degree determines the sea-ice cover. Furthermore, the inflowing water carries nutrients, zoo- and ichtyoplankton from the Norwegian Sea into the Barents Sea. Human induced climate change influences the temperature of the inflowing water masses. The inflow in the southwest is to a large degree balanced by the outflow in the northeast, transporting modified Barents Sea Water towards the St. Anna Trough and Arctic Ocean.

Overview of the subparameters

Subparameters (name)	*Institution responsible for monitoring*	*Time series period*	*Gaps in monitoring*	*Priority ("e", "r" or "s")*
Current meters (LADCP, ship transects)	*IMR*			e
Current meters / ADCP moorings SW Barents Sea	*IMR*	*1997 - present*		e
New current meter and ADCP moorings in NE Barents Sea	*PINRO*	*1991/92, 2007/08*		e
Numerical models	*IMR*	*1959- 2011*		r

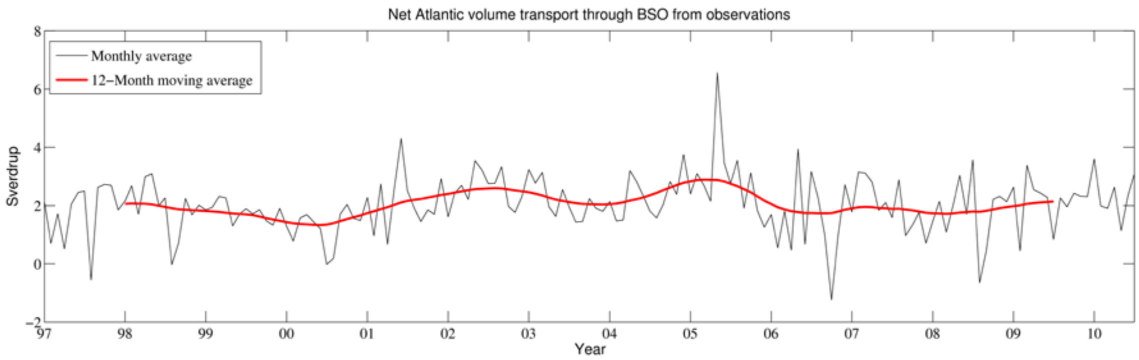
Subparameter 1 – Current meters (LADCP, ship transects)

- **Short facts about the subparameter:** Along track ADCP measurements along hydroraphic sections in the southwestern Barents Sea.
- **Why this is a key subparameter:** Monitors the exchanges between the Barents Sea and the Norwegian Sea.
- **Monitoring**: IMR-operated research vessels obtain ADCP measurements during hydrographic section surveys.

- **Current status of the subparameter:** Data are available, but need postprocessing.
- **Quality objectives**: No objectives possible to establish.
- **Reference level:** No reference level.
- **Gaps in data coverage:**
- **Other issues about the subparameter:**

Subparameter 2 – Current meters / ADCP moorings in SW Barents Sea

- **Short facts about the subparameter**: Five oceanographic moorings containing ADCP current meters covering the opening between Norway and Bjørnøya (Bear Island) and measuring velocity, temperature and salinity.
- **Why this is a key subparameter:** Monitors the advection of Atlantic Water into the Barents Sea and hence the heat flow entering the Sea, as well as acting as a proxy for advection of nutrients, zoo- and ichtyoplankton into the Sea.
- **Monitoring:** Acoustic Doppler Current Profilers (ADCPs) sample velocity between Norway and Bear Island at 20 min sampling interval. Volume transports are calculated from the velocity measurements. Moorings operated by IMR and data recovered yearly.
- **Current status of the subparameter:**



Observed net Atlantic volume transport through the opening between Norway and Bear Island from 1997-2011 (positive towards east). Black line shows monthly averages and red line shows 12-month moving averages.

- **Quality objectives:** No objectives possible to establish.
- **Reference level:** Should define climatic reference period (e.g. 2000-2009) for volume and heat transport to avoid reference level changing with each update.
- **Gaps in data coverage:**
- **Other issues about the subparameter:**

Subparameter 3 – New current meter and ADCP moorings in NE Barents Sea

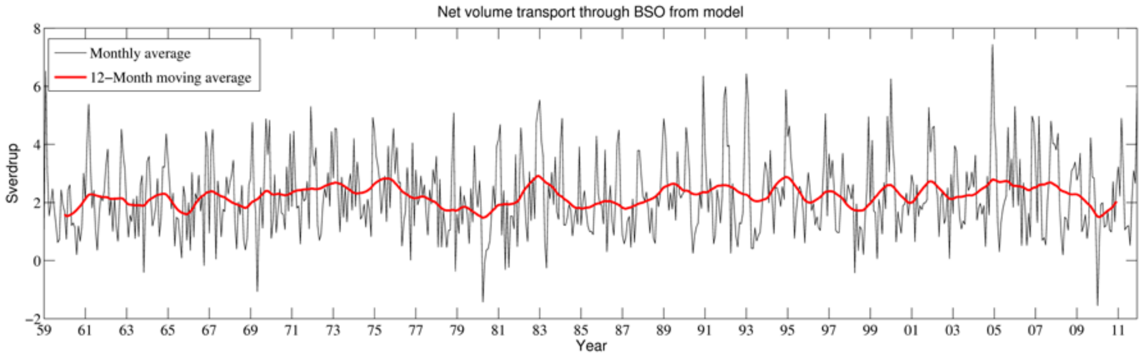
- **Short facts about the subparameter:** Oceanographic moorings containing ADCP current meters covering the opening between Nowaya Zemlya and Franz Josef Land and measuring velocity, temperature and salinity.
- **Why this is a key subparameter:** Monitors the advection of modified waters from the Barents Sea to the Arctic and the inflow of Arctic Waters to the Barents Sea from the

northeast.

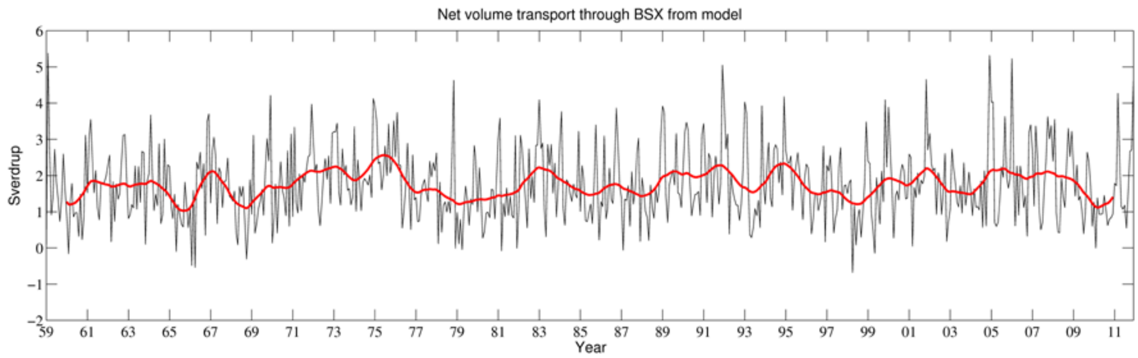
- **Monitoring:** Acoustic Doppler Current Profilers (ADCPs) sample velocity at 20 min sampling interval. Volume transports are can be calculated from the velocity measurements. Moorings would be operated by PINRO and data recovered yearly.
- **Current status of the subparameter:** Moorings not deployed.
- **Quality objectives:** No objectives possible to establish.
- **Reference level:** No reference level (due to lack of data).
- **Gaps in data coverage:** Only data from 1991-92 and 2007-08 exist, but 2007-08 data are unavailable.
- **Other issues about the subparameter:**

Subparameter 4 – Numerical models

- **Short facts about the subparameter:** Volume and heat transports through southwestern (Norway – Bear Island) and northeastern (Novaya Zemlya – Franz Josef Land) openings derived from a general circulation ocean model. Values can be given at yearly, monthly or daily temporal resolution.
- **Why this is a key subparameter:** Extends temporally on the observations providing information on volume and heat transports not monitored by direct observations.
- **Monitoring:** Numerical ocean model run in hindcast mode for the period 1959 – 2011 (will be continuously updated until present).
- **Current status of the subparameter:** Model archive for the period 1959 – 2011 exists and will be continuously updated.



Modelled net volume transport through the opening between Norway and Bjørnøya (Bear Island) from 1959-2011 (positive towards east). Black line shows monthly averages and red line shows 12-month moving averages.



Modelled net volume transport through the opening between Nowaya Zemlya and Franz Josef Land from 1959-2011 (positive towards east). Black line shows monthly averages and red line shows 12-

month moving averages.

- **Quality objectives:** No objectives possible to establish.
- **Reference level:** Should define climatic reference period (e.g. 1980-2009) for volume and heat transport.
- **Gaps in data coverage:**
- **Other issues about the subparameter:**

Contact person/responsible person: Randi Ingvaldsen, Vidar S. Lien, IMR

Title: Water masses properties and volume transport in the Barents Sea

Parameter: Volume flux across the other boundaries and transects

About the parameter

- ***Type of parameter: E***
- ***Priority of parameter: r***
- ***Rationale:*** Spitsbergenbanken is the most productive area of the Barents Sea. Advection through the Bjørnøya – Svalbard opening may be of importance for the ocean-shelf exchange of nutrients that supplies the Spitsbergenbanken to sustain the high biological activity. The advection through the other openings (northern and southeastern boundaries) mostly concerns direct exchanges with the Arctic Ocean (northern boundary) and the Kara Sea (southeastern boundary), with the former being important for the exchanges of cold and relatively fresh surface water masses but also warm Atlantic Water in the northern Barents Sea, while the latter is important for the freshwater content of the Barents Sea.

Overview of the subparameters

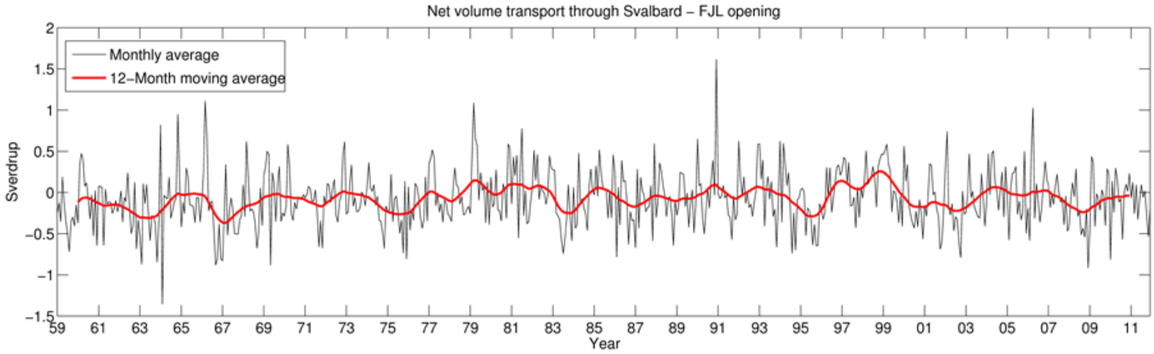
Subparameters (name)	*Institution responsible for monitoring*	*Time series period*	*Gaps in monitoring*	*Priority ("e", "r" or "s")*
Current meters and ADCP: mooring Bjørnøya (Bear Island)-Svalbard				e
Numerical models	*IMR*	*1959- 2011*		r

Subparameter 1 – Current meters and ADCP: mooring Bjørnøya - Svalbard

- **Short facts about the subparameter:** Mooring sampling velocity through the opening between Bjørnøya (Bear Island) and Svalbard.
- **Why this is a key subparameter:** Monitor the ocean-shelf exchanges that may be of great importance to sustain the high productivity on the Spitsbergenbanken.
- **Monitoring:** Acoustic Doppler Current Profilers (ADCPs) to sample velocity. Volume transport can be calculated from the velocity measurements.
- **Current status of the subparameter:** No mooring deployed.
- **Quality objectives:** No objectives possible to establish.
- **Reference level:** No reference level.
- **Gaps in data coverage:**
- **Other issues about the subparameter:**

Subparameter 2 – Numerical models

- **Short facts about the subparameter**: Volume and heat transports through the northwestern, northern and southeastern openings derived from a general circulation ocean model. Values can be given at yearly, monthly or daily temporal resolution.
- **Why this is a key subparameter**: Yields estimates of volume and heat transports through key sections not monitored by direct observations.
- **Monitoring:** Numerical ocean model run in hindcast mode for the period 1958 – 2011 (will be continuously updated until present).
- **Current status of the subparameter**: Model archive for the period 1959-2011 exists and will be continuously updated until present.



Modelled net volume transport through northern boundary in the Barents Sea during the period 1959 – 2011 (positive northward). Black line shows monthly averages and red line shows 12-month moving averages.

- **Quality objectives:** No objectives possible to establish.
- **Reference level:** Should define climatic reference period (e.g. 1980-2009) for volume and heat transport.
- **Gaps in data coverage:**
- **Other issues about the subparameter:**

Contact person/responsible person: Randi Ingvaldsen, Vidar S. Lien, IMR

Title: Zooplankton diversity, abundance and biomass

About the indicator

- ***Type of indicator: E***
- ***Priority of indicator: e***
- ***Rationale:*** In the Barents Sea ecosystem, zooplankton forms a link between phytoplankton (primary producers) and fish, mammals and other organisms at higher trophic levels. It is thus important to monitor this group to understand dynamics in the ecosystem. The most abundant zooplankton species are calanoid copepods, krill, and hyperiid amphipods which form the major diet of herring, capelin, polar cod, and juveniles of other fish species.

Overview of Parameters

Parameters (name)	***Type (“E”, “A”, or “I”)***	***Priority (“e”, “r” or “s”)***
Species composition of zooplankton	*E*	*e*
Average zooplankton biomass (3 size classes) in autumn survey of the entire Barents Sea	*E*	*e*
Species abundance of zooplankton	*E*	*e*
Relative abundance of *Calanus* species	*E*	*e*
Spatial distribution of total zooplankton biomass in autumn survey of the entire Barents Sea	*E*	e
Species composition of krill	*E*	*e*
Krill abundance	*E*	*e*
Jelly fish biomass	*E*	*s*

Contact person/responsible person: Per Arneberg, IMR, Tor Knutsen, IMR

Title: Zooplankton diversity, abundance and biomass

Parameter: Relative abundance of *Calanus* species

About the parameter

- ***Type of parameter: E***
- ***Priority of parameter: e***
- ***Rationale :*** *Calanus* species are key elements in the Barents Sea ecosystem. They typically constitute most of the biomass of mesozooplankton and are thus an important link between primary producers and higher trophic levels in the ecosystem. They are also considered to be vulnerable to effects from climate change. In a warming climate, geographic distribution is expected to shift north and eastwards in the Barents Sea. The Atlantic species *Calanus finmarchicus* may expand into areas where the Arctic species *Calanus glacialis* and *Calanus hyperboreus* dominate today. *C. finmarchicus* is less rich in lipids than the two Arctic species, and such shifts may have considerable effects on species at higher in the food web. From the south, *Calanus helgolandicus* may spread into areas dominated by *C. finmarchicus* today. *C. helgolandicus* have lower nutritional value than *C. finmarchicus* and also a different seasonal activity pattern. The sum of this is that *C. helgolandicus* may be a considerably poorer food source for juvenile and pelagic fish and other species than *C. finmarchicus*. A shift from dominance from *C. finmarchicus* to *C. helgolandicus* may thus have considerable effects on the entire ecosystem. Indeed evidence of such changes has been found in the North Sea, where for example recruitment of cod has been poor the last decade.

Overview of the subparameters

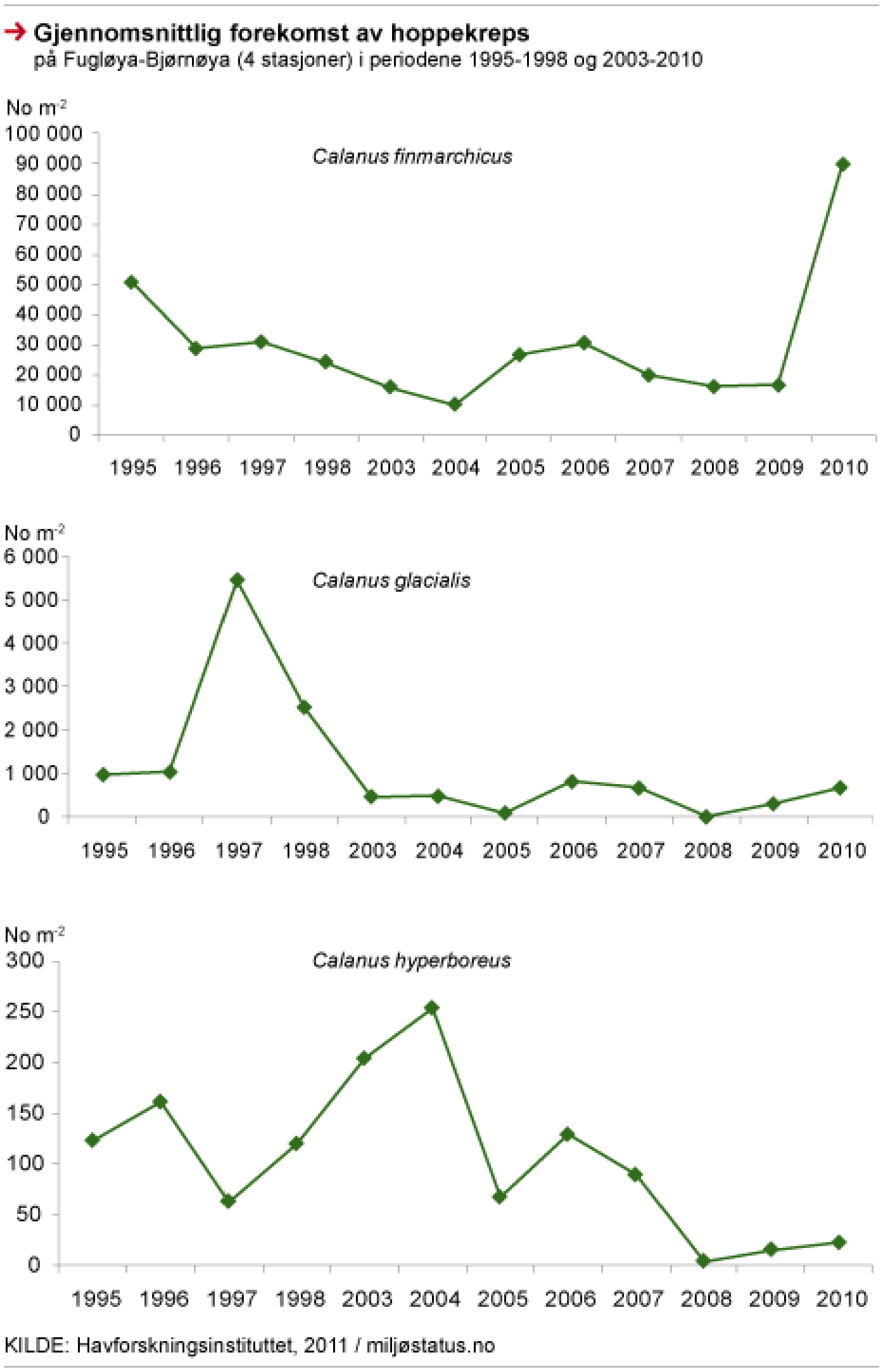
Subparameters (name)	*Institution responsible for monitoring*	*Time series period*	*Gaps in monitoring*	*Priority ("e", "r" or "s")*
Fugløya-Bjørnøya (Bear Island)	*IMR*	*1995-*		e
Kola section	*PINRO*	*1959-*	*1994-2007*	e
Kongsfjorden-section	*NPI*	*1996 -*	*1998 and 2005*	e
Rijpfjorden transect	*NPI*	*2004 -*	*2005, 2009*	e
Vardø-N	*IMR*	*2012-*	*No samples analyzed for species composition*	e

Subparameter 1 – Fugløya – Bjørnøya section

- **Short facts about the subparameter:** The Fugløya –Bjørnøya (Bear Island) section is located in the western entrance of the Barents Sea.
- **Why this is a key subparameter:** The western part of the Barents Sea is the area where an increase in abundance of *Calanus helgolandicus* may be observed first. This subparameter is already reported for the Norwegian management plan.
- **Monitoring:** Sampling is done using Norwegian WP2 nets. The numbers of sampled stations are normally 5 to 8 depending on weather conditions and can cover coastal, Atlantic, and mixed Atlantic/Arctic water.
- **Methods:** The methods being used are mostly the same as for the Ecosystem Survey during

autumn. However, the sampling program on the transects are run 5-6 times per year to obtain seasonal information on the zooplankton (and phytoplankton) development, which is not possible to achieve from a yearly autumn coverage of the Barents Sea. Currently the aim is to cover the Fugløya-Bjørnøya (Bear Island) transect 6 times per year, in a nearly straight line between Fugløya and Bjørnøya (70°30'N - 74°15'N). This is done in January, March, April/May, June, August and October. On the Fugløya-Bjørnøya (Bear Island) transect there are a total of 20 fixed oceanographic stations, and on eight (8) stations zooplankton is sampled using vertical net tows with the WP2-net as outlined above. To obtain information on the vertical structure in different seasons, two hauls are conducted at each station, one from bottom-0 m and a second haul from 100-0m.

- **Current status of the subparameter:** The figure below shows data on abundance of the three species *Calanus finmarchicus, Calanus glacialis* and *Calanus hyperboreus*. In addition, observations show that more individuals of *Calanus helgolandicus* where found in 2008 compared with 2007 while very few found when the monitoring begun, suggesting that spread of this species into the Barents Sea may have started.



- Figure 1: Average distribution of calanus, at Fugløya-Bjørnøya (four stations) during 1995-1998 and 2003-2010.

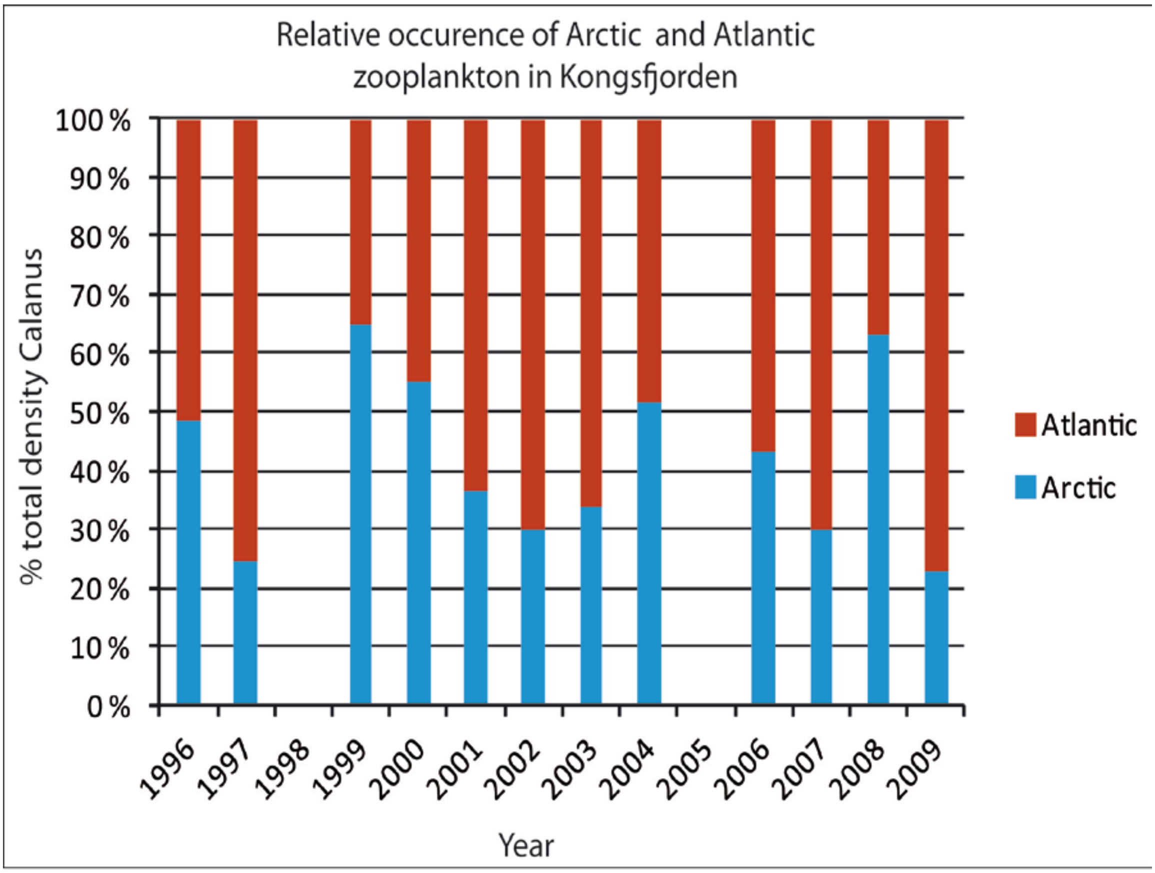
- **Quality objectives:** No quality objectives exist.
- **Reference level:** To be further discussed.
- **Gaps in data coverage:** No gaps.

Subparameter 2 – Kola section

- **Short facts about the subparameter:** The Kola section is located in the southern part of the Barents Sea, northwards from the Kola Peninsula.
- **Why this is a key subparameter:** Changes in abundance of *Calanus* species are expected to differ across the Barents Sea. The Kola section represents an important part of the Barents Sea and is therefore important to include in the monitoring.
- **Monitoring:** During 1959-1993 sampling was conducted two times per year at the Russian ichthyoplankton survey (May and June). Since 2008 sampling has been done only one time per year (May). The last 2-3 years sampling has been done in May (survey of herring) and August (the ecosystem survey). There are 6-8 stations per one sampling set. Sampling is done using Juday net.
- **Current status of the subparameter:**
- **Quality objectives:** No quality objectives exist.
- **Reference level:** To be further discussed.
- **Gaps in data coverage:** Species composition was not examined during the years 1994-2007.

Subparameter 3 – Kongsfjorden section

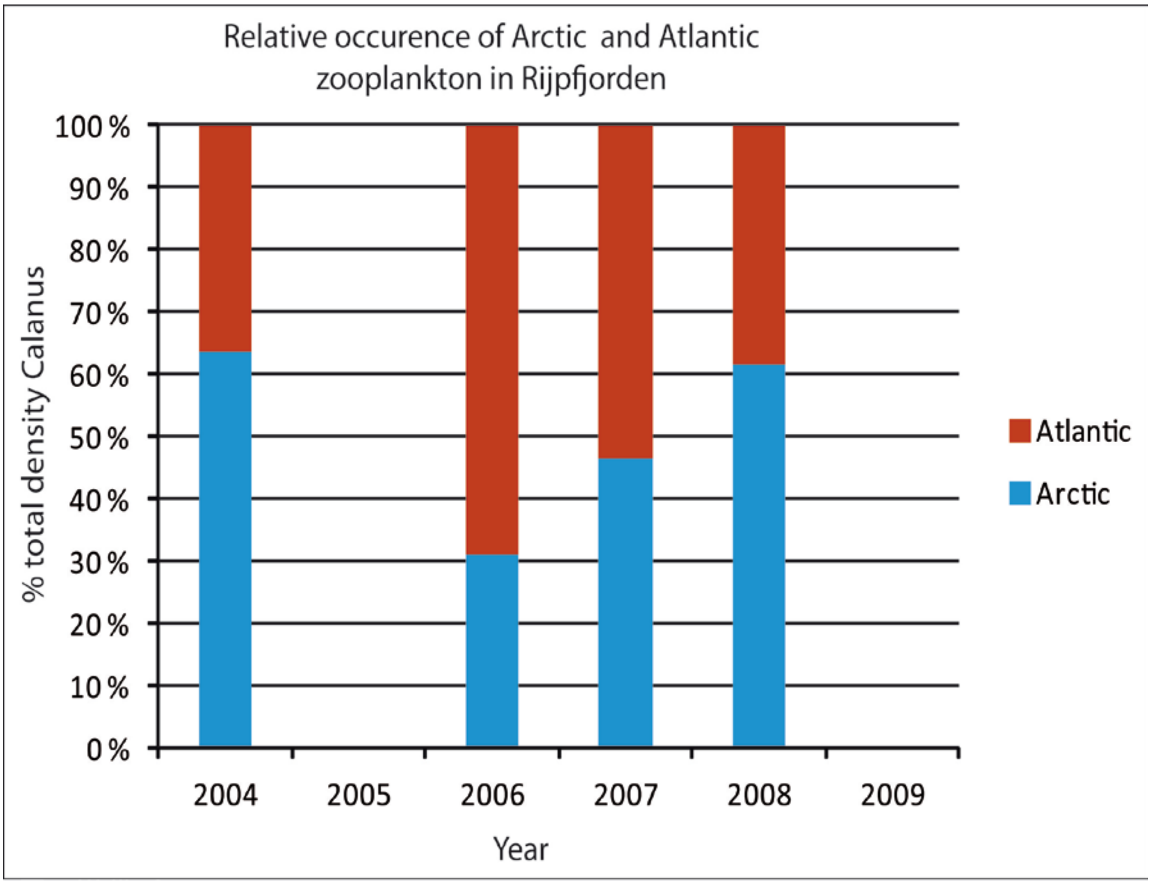
- **Short facts about the subparameter:** Kongsfjorden is located at the west coast of Spitsbergen, in Svalbard. It is close to the northern branch of the Atlantic current. The fjord can be dominated by both Arctic and Atlantic water masses.
- **Why this is a key subparameter:** In a warming climate, Kongsfjorden is a location where effects on an Arctic ecosystem can be detected early.
- **Monitoring:** Samples are taken at fixed stations inside the fjord summer (typically late July – early August).
- **Current status of the subparameter:**



- The figure (from MOSJ) shows the trend in the relative quantities of the Atlantic and Arctic *Calanus* species in Kongsfjorden, measured in summer. For each year, the figure shows the proportion of the total *Calanus* density made up of the Atlantic species, *Calanus finmarchicus*, on the one hand and the two Arctic species, *Calanus glacialis* and *Calanus hyperboreus*, on the other. *Calanus glacialis* is by far the more common of the two Arctic species. Both *Calanus glacialis* and the Atlantic *Calanus finmarchicus* maintain separate populations in Kongsfjorden. However, there are also large densities of *Calanus finmarchicus* in the Atlantic water bodies outside Kongsfjorden, where the northernmost branch of the Gulf Stream passes. The Atlantic water flows into Kongsfjorden to varying degrees and this probably explains why the density of *Calanus finmarchicus* in the fjord varies considerably from year to year. The Arctic species (especially *Calanus glacialis*) dominate in Kongsfjorden in ”cold” years when the influx of Atlantic water is low, as in 1999, 2000 and 2008. The density of *Calanus finmarchicus* rises in ”warm” years with a strong influx of Atlantic water. For instance, unusually strong flows of Atlantic water in winter since 2005/2006 have led to Kongsfjorden remaining largely ice-free in winter since 2006. Except in 2008, *Calanus finmarchicus* has dominated since then.
- **Quality objectives:** No quality objectives exist.
- **Reference level:** To be further discussed.
- **Gaps in data coverage:** Gaps are caused by shortage of funding.

Subparameter 4 - Rijpfjorden transect

- **Short facts about the subparameter:** Rijpfjorden is located in the northeastern part of Svalbard. The fjord is dominated by Arctis water masses. Atlantic water masses may also come into the fjord from the sub ducted northeastern branch of the Atlantic current north of Svalbard.
- **Why this is a key subparameter:** Rijpfjorden represents a high Arctic system, and effects of climate warming on zooplankton communities are expected to longer time to develop here than in Kongsfjorden.
- **Monitoring:** Samples are taken at fixed stations inside the fjord summer (typically late July – early August).
- **Current status of the subparameter:**



- The figure (taken from MOSJ) shows the trend in the relative densities of the Atlantic and Arctic *Calanus* species in Rijpfjorden, measured in summer or early autumn. For each year, the figure shows the proportion of the total *Calanus* density made up of the Atlantic species, *Calanus finmarchicus*, on the one hand and the two Arctic species, *Calanus glacialis* and *Calanus hyperboreus*, on the other. *Calanus glacialis* is by far the more common of the two Arctic species. Whereas it has a separate population in Rijpfjorden, the most important source for *Calanus finmarchicus* in the fjord is most probably the influx of Atlantic water from water bodies north of Svalbard. This influx, which varies considerably from year to year, also influences the time when the ice breaks up in Rijpfjorden. The density of the Atlantic *Calanus finmarchicus* is therefore related to both the influx of Atlantic water and the time when the ice breaks up. For instance, there were comparatively large densities of *Calanus finmarchicus* in the fjord in 2007 when the influx of Atlantic water was strong and the ice melted early, whereas *Calanus glacialis* and *Calanus hyperboreus* dominated the following year when the influx was less and the ice remained longer.
- **Quality objectives:** No quality objectives exist.
- **Reference level:** To be further discussed.
- **Gaps in data coverage:** Gaps in data exists because of lack of funding and because the fjord may be inaccessible in years with dense sea ice cover in the area.

Subparameter 5 – Vardø N

- **Short facts about the subparameter:** The section is located in the eastern part of the

Norwegian sector of the Barents Sea.

- **Why this is a key subparameter:** This subparameter is a suggested new subparameter to trace and allow a better understanding of taxonomic changes in the northern part of the Barents Sea, a transition region between the Barents Sea and Arctic Ocean now considered under particular influence of global warming.
- **Monitoring:** Samples will be collected from the northern part of the present day Vardø-Nord section and from the extended Vardø-Nord section being sampled for the first time in 2012.
- **Method:** The methods being used are mostly the same as for the Ecosystem Survey during autumn. However, the sampling programme on this transect are twice a year to obtain some seasonal information on the zooplankton (and phytoplankton) development, which is not possible to obtain from a yearly autumn coverage of the Barents Sea. However, samples from the Vardø-Nord transect will also be very valuable in a climate change context as this transect covers the the wole central part of the Barents Sea from the Norwegian coast to the northern shelf areas bordering the Arctic Ocean. Currently the aim is to cover the Vardø-Nord twice a year. To obtain information on the vertical structure in different seasons, two hauls are conducted at each station, one from bottom-0 m and a second haul from 100-0m.
- **Area and time period:** The standard Vardø-Nord transect consist of 22 oceanographic stations from geographical position 70°24'N to 76°30'N, following the meridian 31°13'E. The extended Vardø-Nord section is identical to the standard section, but an additional northern part consisting of 12 stations from geographical position 77°00'N to 81°00'N following the meridian 34°00'E. Zooplankton sampling is conducted on 9 stations out of the 22 original stations on the standard section, while on the extended section at total of 7 out of 12 stations are sampled for zooplankton.
- The standard transect is sampled in March, while the full transect including the extended part is sampled in August-September every year.

  Comment: Currently there are not sufficient internal resources at IMR to follow up the intensions with respect to the taxonomic work necessary to for this indicator
- **Current status of the subparameter:** Samples have been taken, but species identifications have not been done.
- **Quality objectives:** No quality objectives exist.
- **Gaps in data coverage:** As mentioned, species identifications have not been done on the samples collected. It would require a considerable amount of resources to do this.
- Requires priority and funding.

Contact person/responsible person: Per Arneberg, IMR, Tor Knutsen, IMR

Title: Zooplankton diversity, abundance and biomass

Parameter: Average zooplankton biomass (3 size classes) in autumn survey of the entire Barents Sea

About the parameter

- ***Type of parameter: E***
- ***Priority of parameter: e***
- ***Rationale:*** This parameter gives vital information about the amount of food available for zooplankton eating organisms in the Barents Sea. As mentioned elsewhere, zooplankton is key organisms in the ecosystem.

Overview of the parameter

Subparameters (name)	*Institution responsible for monitoring*	*Time series period*	*Gaps in monitoring*	*Priority ("e", "r" or "s")*
Average biomass across the entire Barents Sea	*PINRO* *IMR*	*2003-2006* *2004-*	*No*	e

Parameter 1 - Average biomass across the entire Barents Sea

- **Short facts about the parameter:** Biomass of all zooplankton is measured in the entire Barents Sea.
- **Why this is a key parameter:** Estimates of zooplankton biomass gives important information the amount of food available for higher trophic levels.
- **Monitoring:** Samples are taken in a web of stations covering the whole Barents Sea in the autumn survey using Norwegian WP2. Biomass of different size fractions is analysed mainly by IMR. PINRO did such analysis using Russian Juday nets only during some years – approximately in 2003-2006, during other years – only total biomass of zooplankton has been estimated.

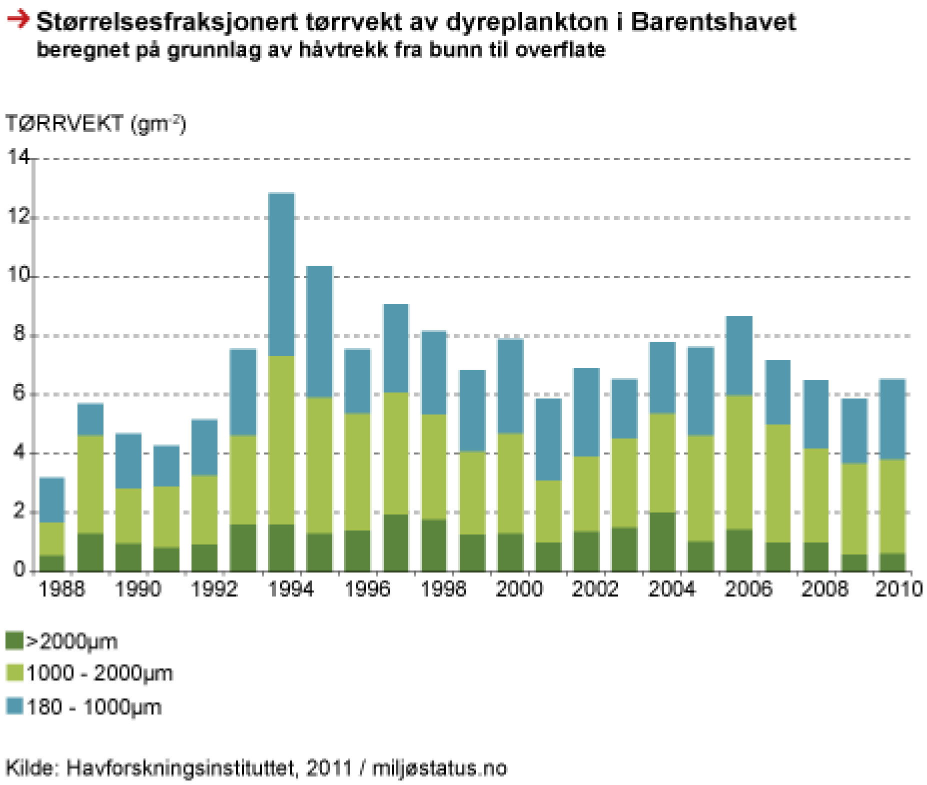
  Methods: Zooplankton sampling on Norwegian vessels is carried out by 56 cm diameter WP2 plankton nets (Unesco, 1968), having a 0.25 m^2 opening and 180 µm mesh size, using vertical hauls from bottom-0 m, now omitting the 100-0m hauls that was originally part of the sampling program. Samples are normally split in two, one part was fixated in 4% borax neutralized formalin for species analysis and the other one was size-fractioned as follows; >2000 µm, 2000-1000 µm and 1000-180 µm size categories. All size-fractionated samples are weighed after drying at 60°C for 24 hours. For large organisms like medusae and ctenophores their volume fraction are determined by displacement volume onboard the vessels. From the >2000 µm size fraction krill, shrimps, amphipods, fish and fish larvae are counted and their lengths measured separately before drying. *Chaetognatha*, *Pareuchaeta* sp. and *Calanus hyperboreus* from the >2000µm size fraction are counted and dried separately, but individual sizes are not measured. All dry weights are determined after additional drying at the IMR laboratory when the samples are returned to Bergen.

[The sampling on the Russian vessel is carried out by vertically stratified hauls using a Juday net with a 0.1 m^2 opening and 180 µm mesh size. Depth intervals for plankton sampling are the layers from bottom-0m, 100-50 m and 50-0m].

Area: The area covered during the joint Norwegian-Russian Ecosystem Survey in autumn (August-September), includes the entire Barents Sea from the Norwegian and Russians coasts in the south to the slope facing the Norwegian Sea and west of Svalbard in the west. In addition, the shelf region north of Svalbard all the way to the east of Franz Josefs land and to Novaya Zemlya in the East.

Period: August and September. Once every year.

- **Current status of the parameter:**



- This figure presenting only Norwegian data shows the status and development of the subparameter. Data are average dry weight of zooplankton in the entire water column in the entire Barents sea (only Norwegian data). Data are shown for different size fractions of zooplankton. Biomass of zooplankton has declined since 2006. Combining Russian and Norwegian data for the entire Barents Sea gives an estimate of average zooplankton biomass of 6.7 g dry weight m^{-2} in 2011 for the whole area. This is less than what was found in 2008 (7.15 g m^{-2} dry weight), 2007 (7.7) and 2006 (8.4).
- **Quality objectives:** No quality objectives exists.
- **Reference level:** To be further discussed.
- **Gaps in data coverage:** No gaps.

Contact person/responsible person: Per Arneberg, IMR, Tor Knutsen, IMR

Title: Zooplankton diversity, abundance and biomass

Parameter: Spatial distribution of total zooplankton biomass in the entire Barents Sea

About the parameter

- ***Type of parameter: E***
- ***Priority of parameter: e***
- ***Rationale:*** This parameter gives vital information about the amount of food available for zooplankton eating organisms and how this is distributed geographically in the Barents Sea. As mentioned elsewhere, zooplankton is key organisms in the ecosystem.

Overview of the parameter

Subparameters (name)	*Institution responsible for monitoring*	*Time series period*	*Gaps in monitoring*	*Priority ("e", "r" or "s")*
Distribution of biomass in the entire Barents Sea	*PINRO and IMR*	*2004-*	*No gaps*	e

Parameter 1 - Distribution of biomass in the entire Barents Sea

- **Short facts about the parameter:** Biomass of all zooplankton is measured in a web of stations covering the entire Barents Sea.
- **Why this is a key parameter:** Distribution of biomass gives important information the amount of food available for higher trophic levels and how this is distributed geographically in the Barents Sea.
- **Monitoring:** Samples are taken in a web of stations covering the whole Barents Sea in the autumn survey using Norwegian WP2 and Russian Juday nets. It must be taken into account that catchability of these sampling gears is different. This must be addressed carefully when this parameter is developed.

  Methods: Zooplankton sampling on Norwegian vessels is carried out by 56 cm diameter WP2 plankton nets (Unesco, 1968), having a 0.25 m^2 opening and 180 µm mesh size, using vertical hauls from bottom-0 m, now omitting the 100-0m hauls that was originally part of the sampling program. Samples are normally split in two, one part was fixated in 4% borax neutralized formalin for species analysis and the other one was size-fractioned as follows; >2000 µm, 2000-1000 µm and 1000-180 µm size categories. All size-fractionated samples are weighed after drying at 60°C for 24 hours. For large organisms like medusae and ctenophores their volume fraction are determined by displacement volume onboard the vessels. From the >2000 µm size fraction krill, shrimps, amphipods, fish and fish larvae are counted and their lengths measured separately before drying. *Chaetognatha*, *Pareuchaeta* sp. and *Calanus hyperboreus* from the >2000µm size fraction are counted and dried separately, but individual sizes are not measured. All dry weights are determined after additional drying at the IMR laboratory when the samples are returned to Bergen.

  [The sampling on the Russian vessel is carried out by vertically stratified hauls using a Juday net with a 0.1 m^2 opening and 180 µm mesh size. Depth intervals for plankton sampling are the layers from bottom-0m, 100-50 m and 50-0m].

Area: The area covered during the joint Norwegian-Russian Ecosystem Survey in autumn (August-September), includes the entire Barents Sea from the Norwegian and Russians coasts in the south to the slope facing the Norwegian Sea and west of Svalbard in the west. In addition, the shelf region north of Svalbard all the way to the east of Franz Josef Land and to Novaya Zemlya in the East.

Period: August and September. Once every year.

- **Current status of the parameter:** The horizontal distribution of mesozooplankton in 2011 is shown in Figure 1. Average zooplankton biomass was clearly below the long-term mean in 2011. Particularly low biomass was observed in the central parts of the Barents Sea. In the western part of the Barents Sea, well defined areas of higher zooplankton abundance were observed in Storfjorden just south of Spitzbergen and south of Bjørnøya . For the latter region, this was relatively similar to what was observed in 2009 and 2010. Another region with high mesozooplankton biomass was west of Novaya Zemlya and east of approximately 38.E, in the Russian sector of the Barents Sea. Although biomass levels were high in the north-eastern corner of the Russian sector, close to Franz Josef Land, they were considerably lower in 2011 compared with the two preceding years.

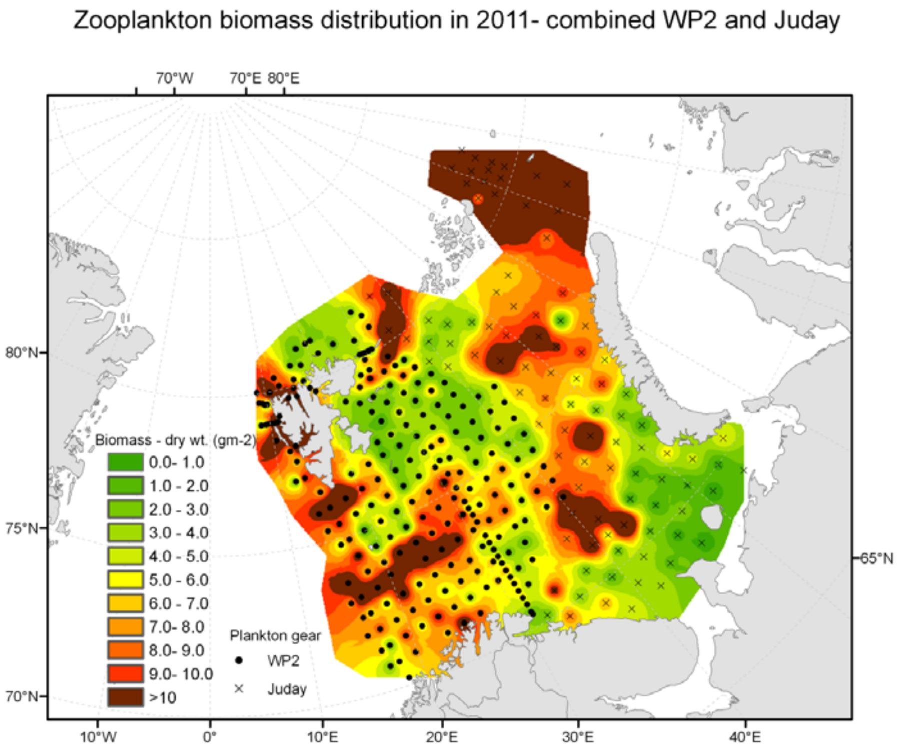


Figure 1. Distribution of zooplankton dry weight (g m^{-2}) from bottom-0 m in 2011. Data based on Norwegian WP2 and Russian Juday net samples (IMR/PINRO). Source: Arneberg, P., Titov, O., Filin, A., and Stiansen, J. E. (Eds.) 2013. Joint Norwegian-Russian environmental status report on the Barents Sea Ecosystem – update for current situation for climate, phytoplankton, zooplankton, fish and fisheries in 2011. IMR/PINRO Joint Report Series, 2013(3), 56 pp. ISSN 1502-8828.

- It must be developed how the results of the monitoring should be presented. Possible alternatives are (1) time series of values describing centre of distribution (2) series of maps or a combination of these.

- **Quality objectives:** No quality objectives exist.
- **Reference level:** To be further discussed between the Russian and Norwegian specialists.
- **Gaps in data coverage:** No gaps.

Contact person/responsible person: Per Arneberg, IMR, Tor Knutsen, IMR

Title: Zooplankton diversity, abundance and biomass

Parameter: Jellyfish biomass

About the parameter

- ***Type of parameter: E***
- ***Priority of parameter: s***
- ***Rationale:*** Gelatinous zooplankton should be monitored because they may be important predators on meso-zooplankton and thus competitors with juvenile and pelagic fish and other species feeding on meso-zooplankton.

Parameters (name)	***Institution responsible for monitoring***	***Time series period***	***Gaps in monitoring***	***Priority („e", "r" or "s")***
Biomass of jellyfish (gelatinous zooplankton)	*IMR and PINRO*	*1980 -*		s

Parameter 1 – Biomass of jellyfish

- **Short facts about the parameter:** Gelatinous zooplankton is a term often used expression by non-specialists in reference to classes of organism that are jelly-like in appearance. The term "jellyfish" is commonly used in reference to marine invertebrates belonging to the class *Scyphozoa, phylum Cnidaria*. Neither of these terms implies any systematic relationship to vertebrate fish. The term "jellyfish" is also often used in reference to relatives of true scyphozoans, particularly the *Hydrozoa* and the *Cubozoa*. In the Barents Sea ecosystem, however, comb-jellies (*phylum Ctenophora*) and cnidarians (*phylum Schyphozoa*) are predominant species of "gelatinous zooplankton". Both comb-jellies (*Ctenophora*) and "true" jellyfish are predators and many compete with plankton-eating fish, as copepods often are significant prey items for both groups. Along with increased temperatures, and changes in other components of the Barents Sea ecosystem, research interest has increased to understand how these changes effect abundance and distribution of gelatinous zooplankton and their prey.
- **Why this is a key parameter:** Estimates of biomass can give information about the effect jellyfish have as competitors in the ecosystem.
- **Monitoring:** In 2010 and 2011, the majority of hauls were conducted as standardized stepwise hauls in the 40-20-0 m depth interval, but a few hauls were operated deeper. The catches were adjusted for time of trawling. It is assumed that the results mainly reflect the occurrence of the larger Scyphozoan medusa like the genus *Aurelia* and *Cyanea*. The occurrence of Ctenophora ("comb-jellies") cannot be verified due to lack of proper taxonomic classification. Both *Ctenophora* and smaller "jellyfish" are however caught in the WP2 net, but this gear has limitations with respect to the small volume sampled. Initial trials using a larger vertically operated WP3 net (UNESCO, 1968) has been initiated and is probably what should be applied in the future. Methods for the years before 2010 are described in Eriksen E, Prozorkevich D, Trofimov A, Howell D (2012) Biomass of Scyphozoan Jellyfish, and Its Spatial Association with 0-Group Fish in the Barents Sea. PLoS ONE 7(3):

e33050. doi:10.1371/journal.pone.0033050.

- **Current status of the parameter:** Data for the years 2010 and 2011 are shown below.

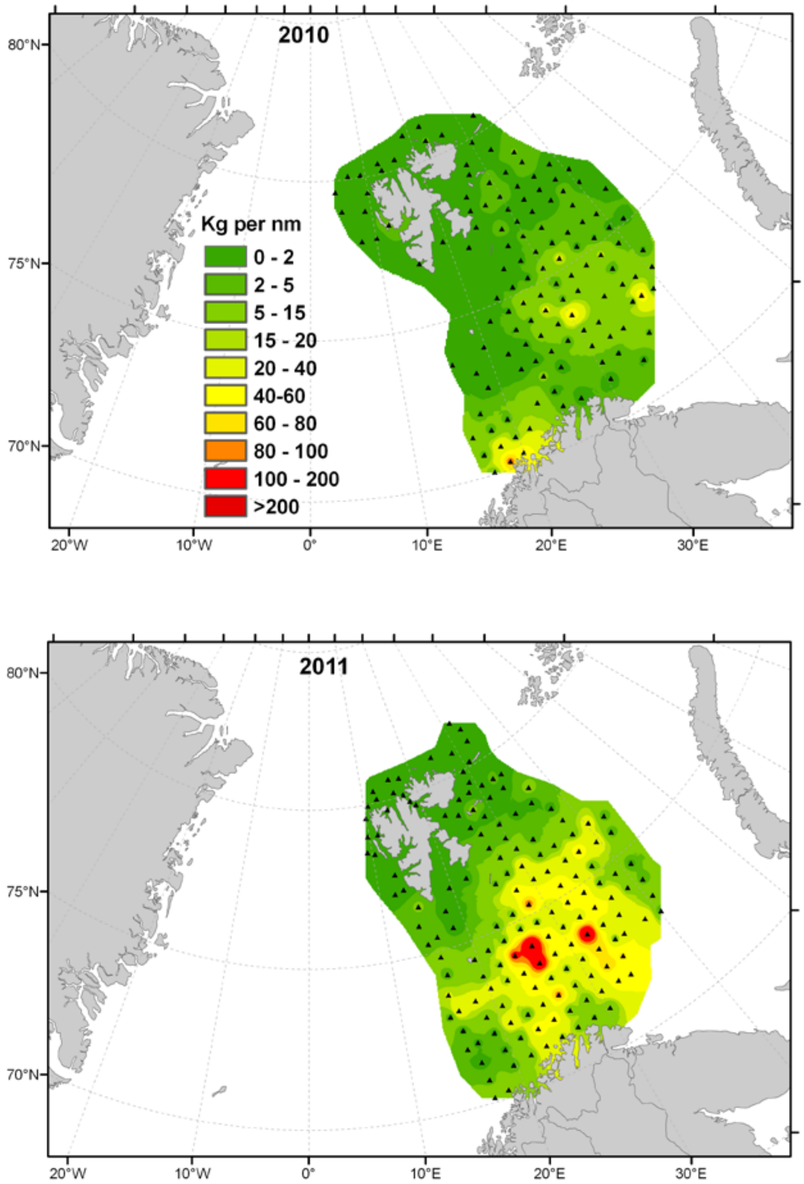


Figure 1. Distribution of catches of gelatinous zooplankton in pelagic Harstad trawl in 2010 and 2011. Numbers are standardized to kg·trawl distance^{-1}. Source: Arneberg, P., Titov, O., Filin, A., and Stiansen, J. E. (Eds.) 2013. Joint Norwegian-Russian environmental status report on the Barents Sea Ecosystem – update for current situation for climate, phytoplankton, zooplankton, fish and fisheries in 2011. IMR/PINRO Joint Report Series, 2013(3), 56 pp. ISSN 1502-8828.

- **Environmental objectives:** No objectives exist.
- **Reference level:** To be developed.
- **Gaps in data coverage:** None.

Contact person/responsible person: Per Arneberg, IMR

Title: Zooplankton diversity, abundance and biomass

Parameter: Krill abundance

About the parameter

- ***Type of parameter: E***
- ***Priority of parameter: e***
- ***Rationale:*** Krill constitute an important part of the zooplankton community and are important to monitor to understand how the zooplankton community functions as food source for higher trophic levels as well as for understanding other aspects of dynamics in the zooplankton community.

Overview of the parameter

Subparameters (name)	*Institution responsible for monitoring*	*Time series period*	*Gaps in monitoring*	*Priority (“e”, “r” or “s”)*
Krill abundance	*PINRO*	*1952 -*	*no gaps*	e

Parameter 1 – Krill abundance

- **Short facts about the parameter:** The parameter should show abundance of species that can be assumed to be ecologically important. It must be developed how this data should be reported. A possibility is to report abundance of Arctic vs Atlantic/boreal species to reveal possible changes caused by climate change. Data should be presented separately for different regions of the Barents Sea because changes in abundance of krill species is expected to differ between regions of the Barents Sea.
- **Why this is a key parameter:** Rationale is the same as described in the box above.
- **Monitoring**: Data on krill are collected during the Russian demersal survey in October-December since 1952. The sampling gear is trawl net. This survey covers most of the Barents Sea excluding the north and northeast parts.
- **Current status of the parameter:** The data has not been reported in the form suggested above. Below is shown overall abundance of krill in two parts of the Barents Sea.

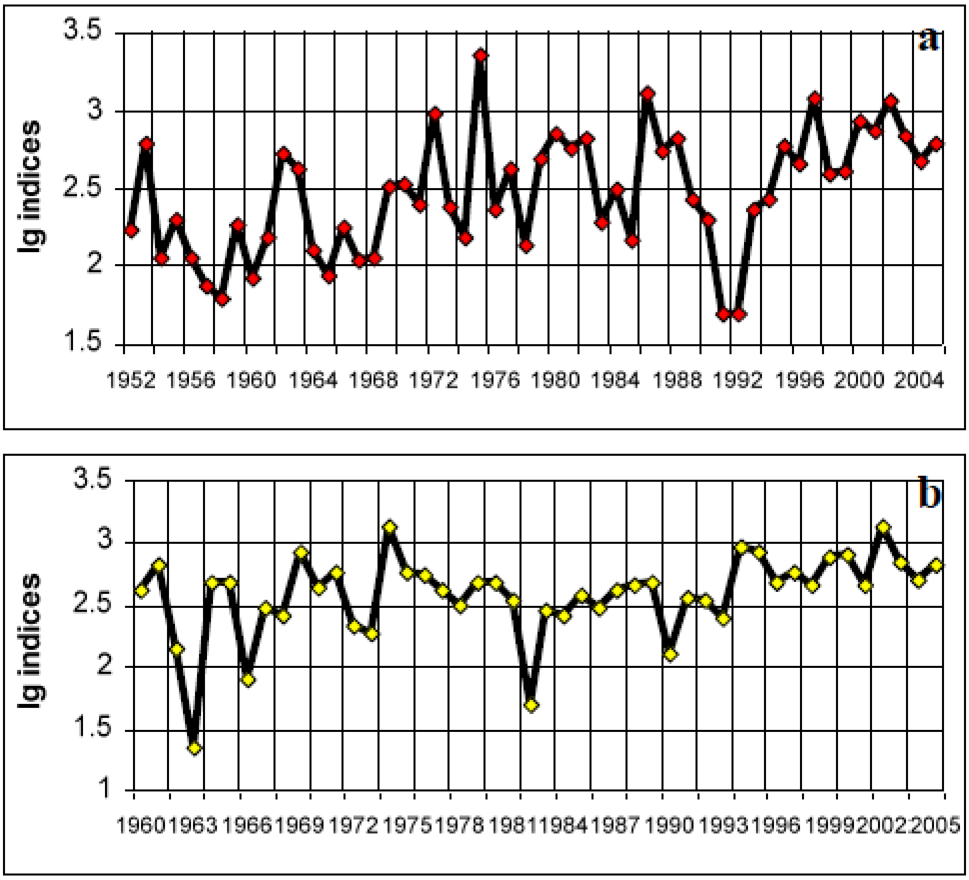


Fig 1: Variation in abundance indices of krill in the southern (a) and northwestern (b) parts of the Barents Sea (data from macroplankton survey conducted by PINRO).

- **Environmental objectives:** No objectives exist.
- **Reference level:** To be developed.
- **Gaps in data coverage:** There are no gaps, but in some years not all of the area was covered by the survey.

Contact person/responsible person: Per Arneberg, IMR, Tor Knutsen, IMR

Title: Zooplankton diversity, abundance and biomass

Parameter: Species composition of krill

About the parameter

- ***Type of parameter: E***
- ***Priority of parameter: e***
- ***Rationale:*** Krill constitute an important part of the zooplankton community and are important to monitor to understand how the zooplankton community functions as food source for higher trophic levels as well as for understanding other aspects of dynamics in the zooplankton community.

Overview of the parameter

Subparameters (name)	*Institution responsible for monitoring*	*Time series period*	*Gaps in monitoring*	*Priority (“e”, “r” or “s”)*
Species composition of krill	*PINRO*	*1952 -*	*1993-1999 (approximately, will be checked)*	e

Parameter 1 – Species composition of krill

- **Short facts about the subparameter:** The subparameter will include registrations of all species of krill. It has to be developed how this data should be reported. A possibility is to report occurrence of Arctic vs Atlantic/boreal species to reveal possible changes caused by climate change. Data should be presented separately for different regions of the Barents Sea because changes in species composition of krill are expected to differ across the Barents Sea.
- **Why this is a key subparameter:** Rationale is the same as for the entire parameter, which is described above.
- **Monitoring:** Data are colleted during the Russian demersal fish survey in October-December since 1952 using trawl net. Most of the Barents Sea is covered excluding the north and northeast parts. Approximately 30-40 % of all krill samples collected in this survey were used for species composition analysis.
- **Current status of the subparameter:** Data have not been reported in the form suggested above.
- **Environmental objectives:** No objectives exist.
- **Reference level:** No reference level has been set.
- **Gaps in data coverage:** Probably the years 1993-1999.

Contact person/responsible person: Per Arneberg, IMR

Title: Zooplankton diversity, abundance and biomass

Parameter: Species abundance

About the parameter

- ***Type of parameter: E***
- ***Priority of parameter: e***
- ***Rationale:*** Zooplankton species abundance may be affected by climate change. Significant changes in species composition (and relative occurrence of species) can have considerable effects on species feeding on zooplankton and through that indirectly also on other species in the ecosystem. The accumulated effects on the ecosystem as a whole may be large.

Overview of the subparameters

Subparameters (name)	*Institution responsible for monitoring*	*Time series period*	*Gaps in monitoring*	*Priority ("e", "r" or "s")*
Fugløya-Bjørnøya (Bear Island)	*IMR*	*1995-*		e
Kola section	*PINRO*	*1959-*	*1994-2007*	e
Kongsfjorden-section	*NPI*	*1996 -*	*1998 and 2005*	e
Rijpfjorden transect	*NPI*	*2004 -*	*2005, 2009*	e
Vardø-N	*IMR*	*2012-*	*No samples analysed for species composition*	e

Subparameter 1 - Fugløya-Bjørnøya

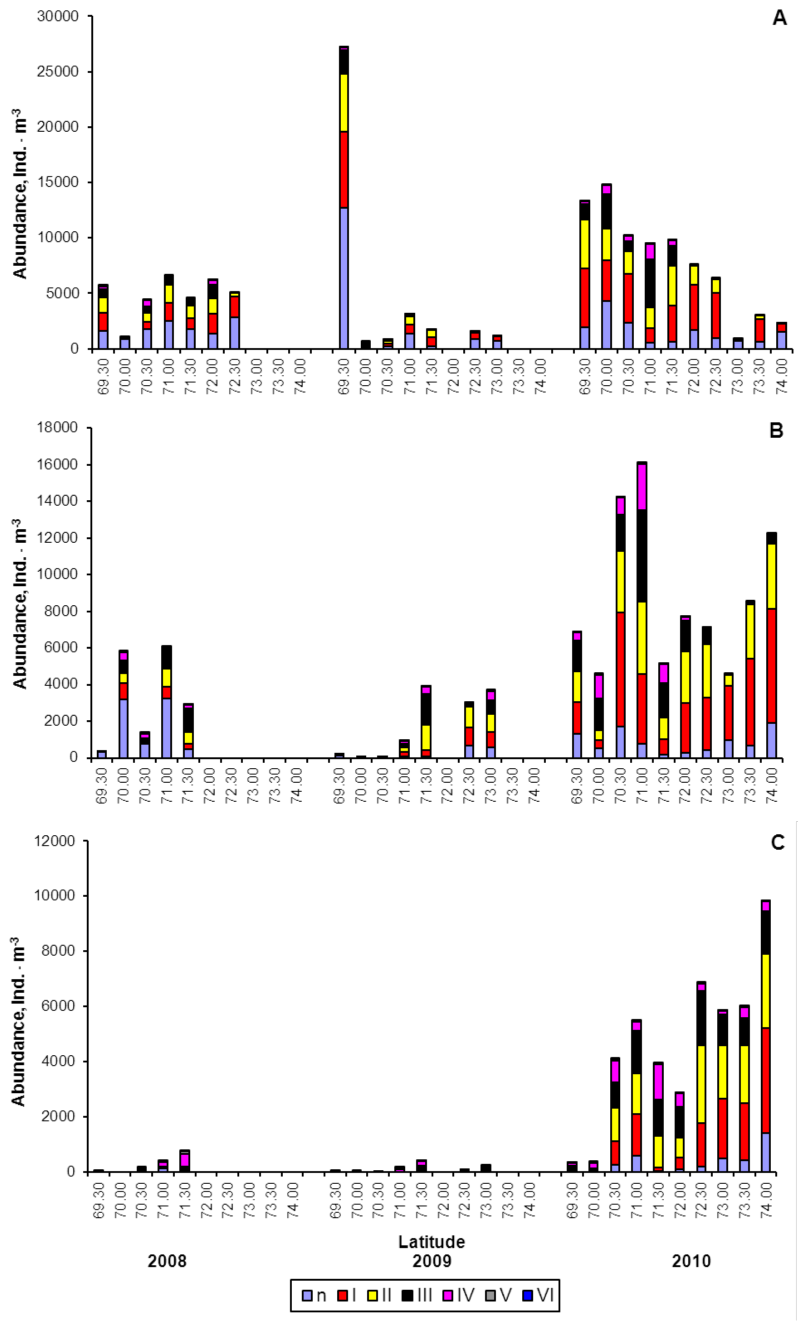
- **Short facts about the subparameter:** The Fugløya – Bjørnøya (Bear Island) section is located in the western entrance of the Barents Sea. All subparameters in this parameter will include abundance of species of zooplankton that can be assumed to be ecologically important. It has to be developed how this data should be reported. A possibility is to report abundance of Arctic vs Atlantic/boreal species to reveal possible changes caused by climate change. The subparameter overlaps with the subparameter describing relative abundance of *Calanus* species.
- **Why this is a key subparameter:** Changes in abundance of zooplankton species is expected to differ between regions of the Barents Sea. The Fugløya – Bear Island section covers the western entrance of the Barents Sea where changes in abundance of Atlantic/boreal species may be detected early.
- **Monitoring:** Sampling is done using Norwegian WP2 nets. The numbers of sampled stations are normally 5 to 8 depending on weather conditions and can cover coastal, Atlantic, and mixed Atlantic/Arctic water.

  Methods: The methods being used are mostly the same as for the Ecosystem Survey during autumn. However, the sampling program on the transects are run 5-6 times per year to obtain seasonal information on the zooplankton (and phytoplankton) development, which is not possible to achieve from a yearly autumn coverage of the Barents Sea. Currently the aim is to cover the Fugløya-Bjørnøya transect 6 times a year, in a nearly straight line between Fugløya and Bjørnøya (70°30'N - 74°15'N). This is done in January, March, April/May, June, August and October. On the Fugløya-Bjørnøya transect there are a total of 20 fixed oceanographic stations, and on eight (8) stations zooplankton is sampled using vertical net tows with the WP2-net as outlined above. To obtain information on the vertical structure in different seasons, two hauls are conducted at each station, one from bottom-0 m and a second haul from 100-0m.

- **Current status of the subparameter:** Data have not been reported in the form suggested above. Data on abundance of three *Calanus* species are shown for the parameter "Relative abundance of *Calanus* species".
- **Environmental objectives:** No objectives exist.
- **Reference level:** Suggested reference level is average of values from the first ten years of the data series. This should be further discussed between some specialists on the Russian and Norwegian side.
- **Gaps in data coverage:** No gaps.

Subparameter 2 - Kola transect

- **Short facts about the subparameter:** The Kola section is located in the southern part of the Barents Sea, northwards from the Kola Peninsula.
- **Why this is a key subparameter:** Changes in abundance of zooplankton species are expected to differ across the Barents Sea. The Kola section represents an important part of the Barents Sea and is therefore important to include in the monitoring.
- **Monitoring:** During 1959-1993 sampling was conducted two times per year at the Russian ichthyoplankton survey (May and June). Since 2008 sampling has been done only one time per year (May). The last 2-3 years sampling have been done in May (survey of herring) and August (the ecosystem survey). There are 6-8 stations per one sampling set. Sampling is done using Juday net. Species identifications are done routinely for the most important species (like *Calanus finmarchicus*) but not for all species. It may be possible to make identifications of all species.
- **Current status of the subparameter:** Below is shown abundance data for *Calanus finmarchicus* in late May – early June in 2008 – 2010.



- Fig 1: Ambudance data for *Calanus finmarchicus* in late May – early June in 2008 – 2010.

- **Environmental objectives:** No objectives exist.
- **Reference level:** Suggested reference level is average of values from the first ten years of the data series. This should be further discussed between some specialists on the Russian and Norwegian side.
- **Gaps in data coverage:** 1994 - 2007.

Subparameter 3 - Kongsfjorden-section

- **Short facts about the subparameter:** Kongsfjorden is located at the west coast of Spitsbergen, at Svalbard. It is close to the northern branch of the Atlantic current. The fjord can be dominated by both Arctic and Atlantic water masses.

- **Why this is a key subparameter:** In a warming climate, Kongsfjorden is a location where effects on an Arctic zooplankton species may be detected early.
- **Monitoring:** Samples are taken at fixed stations inside the fjord summer (typically late July – early August).
- **Current status of the subparameter:** No other data exists than those described in the parameter "Relative abundance of *Calanus* species".
- **Environmental objectives**: No objectives exist.
- **Reference level:** Suggested reference level is average of values from the first ten years of the data series. This should be further discussed between some specialists on the Russian and Norwegian side.
- **Gaps in data coverage:** Gaps are caused by shortage of funding.

Subparameter 4 - Rijpfjorden transect

- **Short facts about the subparameter:** Rijpfjorden is located in the northeastern part of Svalbard. The fjord is dominated by Arctis water masses. Atlantic water masses may also come into the fjord from the sub ducted northeastern branch of the Atlantic current north of Svalbard.
- **Why this is a key subparameter:** Rijpfjorden represents a high Arctic system, and effects of climate warming on zooplankton communities are expected to take longer time to develop here than in Kongsfjorden.
- **Monitoring:** Samples are taken at fixed stations inside the fjord summer (typically late July – early August).
- **Current status of the subparameter:** No other data exists than those described in the parameter "Relative abundance of *Calanus* species".
- **Environmental objectives:** No objectives exist.
- **Reference level:** Suggested reference level is average of values from the first ten years of the data series. This should be further discussed between some specialists on the Russian and Norwegian side.
- **Gaps in data coverage:** Gaps in data exists because of lack of funding and because the fjord may be inaccessible in years with dense sea ice cover in the area.

Subparameter 5 - Vardø-N

- **Short facts about the subparameter:** The section is located in the eastern part of the Norwegian sector of the Barents Sea.
- **Why this is a key subparameter:** This subparameter is a suggested new subparameter to trace and allow a better understanding of taxonomic changes in the northern part of the Barents Sea, a transition region between the Barents Sea and Arctic Ocean now considered under particular influence of global warming.
- **Monitoring:** Samples will be collected from the northern part of the present day Vardø-Nord section and from the extended Vardø-Nord section being sampled for the first time in 2012. **Method:** The methods being used are mostly the same as for the Ecosystem Survey during autumn. However, the sampling program on this transect are twice a year to obtain some seasonal information on the zooplankton (and phytoplankton) development, which is not possible to obtain from a yearly autumn coverage of the Barents Sea. However, samples from the Vardø-Nord transect will also be very valuable in a climate change context as this transect covers the the wole central part of the Barents Sea from the Norwegian coast to

the northern shelf areas bordering the Arctic Ocean. Currently the aim is to cover the Vardø-Nord 2 times per year. To obtain information on the vertical structure in different seasons, two hauls are conducted at each station, one from bottom-0 m and a second haul from 100-0m.

Area and time period: The standard Vardø-Nord transect consist of 22 oceanographic stations from geographical position 70°24'N to 76°30'N, following the meridian 31°13'E. The extended Vardø-Nord section is identical to the standard section, but an additional northern part consisting of 12 stations from geographical position 77°00'N to 81°00'N following the meridian 34°00'E. Zooplankton sampling is conducted on 9 stations out of the 22 original stations on the standard section, while on the extended section at total of 7 out of 12 stations are sampled for zooplankton.

The standard transect is sampled in March, while the full transect including the extended part is sampled in August-September every year.

- **Current status of the subparameter:** Samples have been taken, but species identifications have not been done.
- **Environmental objectives**: No objectives exist.
- **Reference level:** Suggested reference level is average of values from the first ten years of the data series. This should be further discussed between some specialists on the Russian and Norwegian side.
- **Gaps in data coverage**: As mentioned, species identifications have not been done on the samples collected. It would require considerable amount of resources to do this.

Contact person/responsible person: Per Arneberg, IMR, Tor Knutsen, IMR

Title: Zooplankton diversity, abundance and biomass

Parameter: Species composition

About the parameter

- ***Type of parameter: E***
- ***Priority of parameter: e***
- ***Rationale:*** Zooplankton species composition may be affected by climate change. Significant changes in species composition can have considerable effects on species feeding on zooplankton and through that indirectly also on other species in the ecosystem. The accumulated effects on the ecosystem as a whole may be large.

Overview of the subparameters

Subparameters (name)	***Institution responsible for monitoring***	***Time series period***	***Gaps in monitoring***	***Priority (“e”, “r” or “s”)***
Fugløya-Bjørnøya (Bear Island)	*IMR*	*1995 -*		e
Kola section	*PINRO*	*1959-*	*1994-2007*	e
Kongsfjorden-section	*NPI*	*1996 -*	*1998 and 2005*	e
Rijpfjorden transect	*NPI*	*2004 -*	*2005, 2009*	e
Vardø-N	*IMR*	*2012-*	*No samples analyzed for species composition*	e

Subparameter 1 - Fugløya-Bjørnøya

- **Short facts about the subparameter:** The Fugløya – Bjørnøya (Bear Island) section is located in the western entrance of the Barents Sea. All subparameters in this parameter will include registrations of all species of zooplankton. It has to be developed how this data should be reported. A possibility is to report occurrence of Arctic vs Atlantic/boreal species to reveal possible changes caused by climate change. It also has to be clarified whether relative abundance of *Calanus* species (another zooplankton parameter) should be reported together with this data.
- **Why this is a key subparameter:** This indicator is already included in the Norwegian Management Plan for the Barents Sea. The indicator was originally intended to express the biodiversity in different water masses of the Barents Sea, and is currently based on standard analysis of the mesozooplankton species composition at the Fugløya-Bjørnøya (Bear Island) section. Such monitoring of the zooplankton species composition could give early warning signals with respect to ecosystem change (dominance of native species), and the abundance of rare or introduced species.
- **Monitoring:** Sampling is done using Norwegian WP2 nets. The numbers of sampled stations are normally 5 to 8 depending on weather conditions and can cover coastal, Atlantic, and mixed Atlantic/Arctic water.
- **Methods:** The methods being used are mostly the same as for the Ecosystem Survey during

autumn. However, the sampling program on the transects are run 5-6 times per year to obtain seasonal information on the zooplankton (and phytoplankton) development, which is not possible to achieve from a yearly autumn coverage of the Barents Sea. Currently the aim is to cover the Fugløya-Bjørnøya transect 6 times per year, in a nearly straight line between Fugløya and Bjørnøya (70°30'N - 74°15'N). This is done in January, March, April/May, June, August and October. On the Fugløya-Bjørnøya transect there are a total of 20 fixed oceanographic stations, and on eight (8) stations zooplankton is sampled using vertical net tows with the WP2-net as outlined above. To obtain information on the vertical structure in different seasons, two hauls are conducted at each station, one from bottom-0 m and a second haul from 100-0m.

- **Current status of the subparameter:** Number of observations of southern species, including observations of *Calanus helgolandicus* has increased in the recent years.
- **Quality objectives:** No quality objectives exist.
- **Reference level:** No reference level has been set.
- **Gaps in data coverage:** No gaps.

Subparameter 2 - Kola transect

- **Short facts about the subparameter:** The Kola section is located in the southern part of the Barents Sea, northwards from the Kola Peninsula.
- **Why this is a key subparameter:** Changes in species composition of zooplankton are expected to differ across the Barents Sea. The Kola section represents an important part of the Barents Sea and is therefore important to include in the monitoring.
- **Monitoring:** During 1959-1993 sampling was conducted two times per year at the Russian ichthyoplankton survey (May and June). Since 2008 sampling has been done only one time per year (May). The last 2-3 years sampling has been done in May (survey of herring) and August (the ecosystem survey). There are 6-8 stations per one sampling set. Sampling is done using Juday net. Species identifications are done routinely for the most important species (like *Calanus finmarchicus*) but not for all species. It may be possible to make identifications of all species.
- **Current status of the subparameter:**
- **Quality objectives:** No quality objectives exist.
- **Reference level:** No reference level has been set.
- **Gaps in data coverage:** There are no data for the years 1994-2007. Not all species are identified in the samples.

Subparameter 3 - Kongsfjorden-section

- **Short facts about the subparameter:** Kongsfjorden is located at the west coast of Spitsbergen, in Svalbard. It is close to the northern branch of the Atlantic current. The fjord can be dominated by both Arctic and Atlantic water masses.
- **Why this is a key subparameter:** In a warming climate, Kongsfjorden is a location where effects on an Arctic ecosystem can be detected early.
- **Monitoring:** Samples are taken at fixed stations inside the fjord summer (typically late July – early August)
- **Current status of the subparameter:** Data for species occurrence exists, but have not yet been reported, except for relative occurrence of *Calanus* species.
- **Quality objectives:** No objectives exist.
- **Reference level:** No reference level has been set.

- **Gaps in data coverage:** Gaps are caused by shortage of funding

Subparameter 4 - Rijpfjorden transect

- **Short facts about the subparameter:** Rijpfjorden is located in the northeastern part of Svalbard. The fjord is dominated by Arctis water masses. Atlantic water masses may also come into the fjord from the sub ducted northeastern branch of the Atlantic current north of Svalbard.
- **Why this is a key subparameter:** Rijpfjorden represents a high Arctic system, and effects of climate warming on zooplankton communities are expected to longer time to develop here than in Kongsfjorden.
- **Monitoring:** Samples are taken at fixed stations inside the fjord summer (typically late July – early August).
- **Current status of the subparameter:** Data for species occurrence exists, but have not yet been reported, except for relative occurrence of *Calanus* species.
- **Quality objectives:** No objectives exist.
- **Reference level:** No reference level has been set.
- **Gaps in data coverage:** Gaps in data exists because of lack of funding and because the fjord may be inaccessible in years with dense sea ice cover in the area.

Subparameter 5 - Vardø-N

- **Short facts about the subparameter:** The section is located in the eastern part of the Norwegian sector of the Barents Sea.
- **Why this is a key subparameter:** This subparameter is a suggested new subparameter to trace and allow a better understanding of taxonomic changes in the northern part of the Barents Sea, a transition region between the Barents Sea and Arctic Ocean now considered under particular influence of global warming.
- **Monitoring:** Samples are collected from the northern part of Vardø-Nord section and from the extended Vardø-Nord . The latter part of the section was sampled for the first time in 2012.
  Method: The methods being used are mostly the same as for the Ecosystem Survey during autumn. However, the sampling programme on this transect are twice a year to obtain some seasonal information on the zooplankton (and phytoplankton) development, which is not possible to obtain from a yearly autumn coverage of the Barents Sea. However, samples from the Vardø-Nord transect will also be very valuable in a climate change context as this transect covers the the wole central part of the Barents Sea from the Norwegian coast to the northern shelf areas bordering the Arctic Ocean. Currently the aim is to cover the Vardø-Nord twice a year. To obtain information on the vertical structure in different seasons, two hauls are conducted at each station, one from bottom-0 m and a second haul from 100-0m.
  Area and time period: The standard Vardø-Nord transect consist of 22 oceanographic stations from geographical position 70°24’N to 76°30’N, following the meridian 31°13’E. The extended Vardø-Nord section is identical to the standard section, but an additional northern part consisting of 12 stations from geographical position 77°00’N to 81°00’N following the meridian 34°00’E. Zooplankton sampling is conducted on 9 stations out of the 22 original stations on the standard section, while on the extended section at total of 7 out of 12 stations are sampled for zooplankton. The standard transect is sampled in March, while the full transect including the extended part is sampled in August-September every year.
- **Current status of the subparameter:** Samples have been taken, but species identifications

have not been done.

- **Quality objectives:** No quality objectives exist.
- **Reference level:** No reference level has been set.
- **Gaps in data coverage:** As mentioned, species identifications have not been done on the samples collected. It would require a considerable amount of resources to do this.
- ***Other issues about the subparameter:***

Contact person/responsible person: Per Arneberg, IMR