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NORSK POLARINSTITUTT

Gunnar Sander, Inger Hanssen-Bauer, Arne Bjørge and Pål Prestrud

The Environmental Monitoring of Svalbard and Jan Mayen – MOSJ

Documentation of the system and the first assessments of the state of the environment

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Norsk Polarinstitutt er Norges sentrale statsinstitusjon for kartlegging, miljøovervåking og forvaltningsrettet forskning i Arktis og Antarktis. Instituttet er faglig og strategisk rådgiver i miljøvernsaker i disse områdene og har forvaltningsmyndighet i norsk del av Antarktis.

The Norwegian Polar Institute is Norway's main institution for research, monitoring and topographic mapping in the Norwegian polar regions. The institute also advises Norwegian authorities on matters concerning polar environmental management.

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Preface

The Environmental Monitoring of Svalbard and Jan Mayen (MOSJ – the Norwegian acronym for Miljøovervåking av Svalbard og Jan Mayen) is a monitoring system that presents results from various monitoring programmes in a standardised manner and makes overall assessments of the state of the environment athwart these programmes. One reason why the system has been devised is to evaluate how the environment is faring relative to the national goals for the environment in the Polar Regions and, on that basis, put forward recommendations regarding the need to use new cross-sectoral measures. MOSJ is administered by environmental management, but the work is performed in cooperation with a number of research institutions.

It has taken a long time to build up MOSJ from its start in 1999 (see pages 9 - 10). Four years later, the main part of the ongoing monitoring selected for the system was presented on http://miljo.npolar.no/mosj/start.htm This formed the basis for making the first overall assessments of the state of the environment as regards the topics of climate, marine and terrestrial environments. The climate assessment would consider changes in the geophysical conditions, whereas the climatic effects would be discussed in the other two reports. A principal author with a research background was chosen for each theme:

- Climate: Inger Hanssen-Bauer, senior researcher at the Norwegian Meteorological Institute
- Ocean: Arne Bjørge, divisional manager at the Norwegian Institute of Marine Research
- Land: Pål Prestrud, Director of CICERO (formerly Director of Research at the Norwegian Polar Institute)

The authors were given a set of questions as a guide to what they should supply answers to, a budget and freedom to organise their work as they chose fit, including which co-authors they wanted to draw into it. The three authors chose to tackle their tasks somewhat differently. However, a common feature was that the drafts of their assessments were presented at a meeting in Tromsø on 20.5 –21.5.2003 to which suppliers of data and users of MOSJ from management bodies were invited. During the summer of 2003, the principal authors revised their assessments in the light of the comments they received.

This report has been written to present the assessments of the state of the environment in a single publication, not just on the web pages where they have been available since they were completed (Parts 2-4). At the same time, we wanted to publish a documentation of MOSJ as the system has developed to date (Part 1). Its main aspects are based on the suggestions made by Hansen & Brodersen (1998), but the system has been further developed and concretised since then and its content has therefore changed somewhat.

These three assessments of the state of the environment have given us a chance to test MOSJ in the form the system was envisaged to have. Some elements we had planned to include still remain to be covered, and we have a number of ideas for improvements. Or to put it metaphorically, the house has been erected, some rooms are not fully completed, and rebuilding plans are already in place, but everything is now ready for use!

MOSJ is a result of the work of a great many people, and it is almost impossible to thank everyone individually. The system would not have functioned without the contributions of all those who carry out environmental monitoring in the northern regions. The institutions and individuals responsible for this major, joint effort are listed on page 21. The principal authors and their co-authors have made an impressive effort compiling and assessing the material embodied in MOSJ to prepare the reports from which we will derive much benefit in the years to come. The steering group comprised of Bjørn Fossli Johansen, Susan Barr, Else Løbersli, Linn Bryhn-Jacobsen and Sissel Aarvik have done a valuable job in pushing the work ahead and rooting it more broadly. Colleagues at the Norwegian Polar Institute are thanked for constructive contributions to develop the system, improve methods and choose indicators. I wish, in particular, to single out Lise Øvrum from the Section for Environmental Data, who has performed an inestimable task constructing practical databases that enable such a large system to be administered. She has also designed the MOSJ home pages.

Gunnar Sander
Project Manager for MOSJ
Norwegian Polar Institute

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Summary

The MOSJ system

The Environmental Monitoring of Svalbard and Jan Mayen (MOSJ) is a system for integrated monitoring of the environment on these islands and in adjacent seas. The system must:

- Be based on indicators for the state of the natural environment and cultural heritage sites and for activities and processes that impact them.
- Compile selected information from thematic monitoring programmes for Svalbard, Jan Mayen and adjacent seas.
- Make the information readily available on the Internet.
- Present quality-assured and interpreted data in a systematic, standardised manner.
- Prepare regular reports on the state of the environment in the area, which sum up the principal trends in the development and assess them against national environmental targets to be able to offer advice on the need for cross-sectoral responses.
- Be a basis for day-to-day decisions on the use and protection of nature and cultural heritage sites.
- Help to coordinate monitoring in the area and ensure that relevant monitoring needs are met and data are acquired in a cost-effective manner and using standardised methods to ensure high quality.

MOSJ was established following an initiative from the Ministry of the Environment in 1999. It is run by a steering group composed of representatives from the environment directorates and the Governor of Svalbard. MOSJ is managed by the Norwegian Polar Institute in cooperation with a number of institutions which carry out the monitoring.

MOSJ takes up important challenges in Norwegian environmental policy in the northern regions: climate changes, long-transported pollution, biodiversity and archaeological and historical monuments and sites. The general, cross-sectoral, national environmental goals stated in the White Papers on “The Government’s Environmental Policy and the State of the Environment” is reflected in the choice of themes and the selection of indicators.

A principal objective of MOSJ is to supply regular assessments of the state of the environment in the northern regions. These must evaluate the extent to which the national environmental goals are achieved or whether there is a trend that gives grounds for concern. The assessments must point out where there is a need to implement corrective measures and which sectoral bodies are responsible for this. They must also point out requirements for research and monitoring that can provide a better basis for assessing the state of the environment. The first such assessments were made in 2003 for the climate and for the state in the sea and on land in Svalbard.

Climate changes are observed

Observations of the climate made at Norwegian Arctic stations reveal that the climate became warmer during the first part of last century, up to the 1930s, and that this pattern returned from the 1960s up to the present day. In this latter period, the air temperatures in the Arctic have increased more than the global mean temperature. This warming is also resulting in increased precipitation, reduction in the ice cover, particularly in summer, fresher surface water and indications of reduced formation of deep water.

Globally, the trend in the Arctic since 1960 is explained as part of a global warming which is partly caused by human emissions of greenhouse gases. However, it is difficult to draw firm conclusions on a regional level, particularly in such a dynamic area as this part of the Arctic. Important observations are, nevertheless, qualitatively in line with the picture which the best climate models reveal of what will take place as a consequence of human-induced global warming.

The strategic goal of stabilising the concentrations of greenhouse gases is considered to be good, but the level on which these concentrations are stabilised is decisive. Inertias in the climate system mean that it will take many decades before any stabilisation becomes noticeable. It is therefore vital that effective international climatic measures are urgently implemented.

Measurements of the ozone layer at Ny-Ålesund reveal great variations. Preliminary results indicate a reduction during the 1990s. However, the series of measurements is too short to say whether this is a natural or a human-induced change.

Increases in tourist traffic are worrying

On the whole, the state of the Svalbard environment is good. Hunting of reindeer, Arctic foxes and ptarmigan does not seem to be affecting the populations other than locally. Of the terrestrial species that are being monitored, only the brent goose is endangered. However, the increasing tourist traffic gives cause for concern relative to the environmental goals that have been set for the archipelago. Vessels disembark tourists throughout Svalbard. It is recommended that this trend is followed closely to assess in greater detail the effects on the vegetation and animal life. Nevertheless, we know that the cultural heritage is already suffering damage today.

Threatened species in the sea

A political goal is that the utilisation of resources must not result in species becoming endangered or made extinct. None of the species in the sea that are harvested today are threatened by biological extinction; neither fish, seals nor minke whales. Nevertheless, it is pointed out that the long-term yield of, for example, cod, Greenland halibut and shrimps, will be lower than it could have been if quotas had been lower.

A number of species that are now protected in Norway are still endangered. The bowhead whale, which was almost made extinct by over-exploitation in the past, is still critically endangered. It is assumed that the polar bear population is growing following its protection in 1973, and the walrus, which was protected as long ago as 1952, also seems to be making a gradual recovery. New threats, such as pollutants and climate change, may worsen the situation for several species in the years to come.

Global sink

The ocean and air currents mean that the Arctic functions as a global sink for pollution from the entire globe. Special conditions in the Arctic ecosystems mean that even low levels of pollutants in the sea become concentrated in animals, fish and birds, and the levels increase the higher they stand in the food chain. Polar bears, glaucous gulls and whales are therefore particularly vulnerable. Climate changes and imbalance in the harvesting of fish, birds and mammals may help to worsen the effects of pollution. The assessment documents the need to reduce pollutants and recommends that Norway should enhance its international effort to have hazardous emissions and discharges reduced.

Gaps in knowledge

Environmental monitoring is essential to obtain a picture of changes in the natural environment. Policy, management and research all derive great benefit from a long-term effort made to document what is taking place and why. However, the assessments point out a number of shortcomings with regard to what is being monitored in the northern regions. The current effort does not permit the issuing of an early warning of what is taking place in important non-commercial species, due to lack of data about populations and because scarcely any monitoring of pollutants in animals is taking place. There is also a need to improve the long-term acquisition of climate data in the northern regions and to understand how climate variables may impact the ecosystems and their components, such as vegetation.

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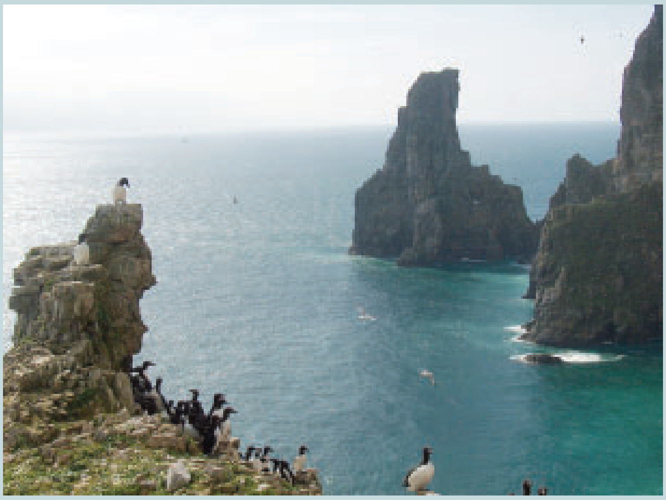
The Environmental Monitoring of Svalbard and Jan Mayen – MOSJ

Part 1: A documentation of the system

By Gunnar Sander



Photos: G. Sander

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1. MOSJ – a brief history

1.1 MOSJ developed from the monitoring of biological diversity

The roots of MOSJ (the Norwegian acronym for Miljøovervåking av Svalbard og Jan Mayen - Environmental Monitoring of Svalbard and Jan Mayen) can be traced back to the work done by the Norwegian Polar Institute in the "Miljøundersøkelser på Svalbard" (Environmental investigations in Svalbard) at the end of the 1980s (Hansson et al. 1989). That systematised the ways in which important human activities affect the natural environment. The methodology employed was an adaptation of methods used in Canadian environmental impact assessments[1] and comprised a flexible system of analysis with continuous procurement of information.

The Directorate for Nature Management took the initiative to have the monitoring carried out when it proposed a strategy for monitoring biological diversity in Norway (Direktoratet for naturforvaltning 1995). It recommended that the monitoring should be based on types of habitat. Eight working groups were appointed to put this strategy into effect using seven types of habitat in mainland Norway and the Polar Regions. The report on monitoring of biological diversity in the Norwegian Arctic (Hop et al. 1998) embodies the most important principles and proposals for monitoring subsequently applied by MOSJ. The need to monitor the biological diversity in the Arctic was viewed in relation to the threats, including changes in the climate and the ozone layer. Existing monitoring in marine, terrestrial and limnic ecosystems was then assessed relative to these requirements, and conclusions were drawn regarding prioritised suggestions for monitoring[2].

At the same time, the Norwegian Ministry of the Environment asked the Polar Institute to prepare a study of the environmental monitoring of Svalbard and Jan Mayen. The most important conclusion drawn from that work was that the monitoring taking place in the region lacked coordination (Hansen & Brodersen 1998). The report maintained that this prevented both an efficient utilisation of the monitoring effort and an overall assessment of the data with a view to devising the environmental policy. MOSJ was therefore suggested as a *system* for integrating the monitoring – not a new monitoring *programme*. The system was to be operated by state-run management institutions in cooperation with research groups in a permanent and dynamic process. It was suggested that initially the monitoring should involve pressures which affect the environment (15 indicators), biological diversity in marine, terrestrial and limnic environments (30 indicators) and cultural heritage relics (2 indicators). The cost of both setting up MOSJ as a system based on existing activity and starting new monitoring was estimated.

1.2 Pilot phase

The Norwegian Polar Institute was commissioned by the Ministry of the Environment to establish MOSJ as a system in 1999. A project manager was appointed in the spring and a steering group was set up in June.

Data for the indicators which had been selected were put before a meeting in November 1999. The intention was to evaluate them and put forward ideas which could be used later to assist with assessments. Instead, the meeting discussed improvements to the monitoring. The reason was obvious; environmental monitoring in the northern regions had not progressed as far as many people had thought. Many of the activities described by Hansen & Brodersen (1998) were isolated research projects or time series that scientists had worked on. Too few could be characterised as systematic monitoring. It was therefore concluded that there was a need to revise the selection of indicators and parameters.

Figure 1
MOSJ covers Svalbard, Jan Mayen and neighbouring marine areas

However, the main features of the MOSJ system itself were retained.

1.3 Development to date

In autumn 2000, the MOSJ steering group decided on a new list of prioritised indicators and parameters, and proposed three areas for intensive monitoring, Kongsfjorden-Brøggerhalvøya, Longyearbyen-Adventdalen and Storfjorden.

In September 2001, another meeting was held to review the state of the environment. Based on these discussions, assessments were drawn up regarding pollution and traffic with respect to cultural heritage sites. It was difficult to reach any conclusions regarding climate, the marine environment and the terrestrial environment due to the way these procedures were organised and because MOSJ still lacked considerable data on these topics.

The MOSJ web site was gradually developed during 2001 and 2002, and has meant a great deal for the systematisation and presentation of the data. An initial version was constructed using a traditional design for each individual page. The pages are now generated dynamically from the content of a database where all the MOSJ data are stored.

The most recent assessment of the state of the environment so far made began in 2002 and was completed the following year. Its results are in Parts 2 - 4 of this report.

2. Structure and objectives

2.1 MOSJ is organised in the environmental management sector

The Ministry of the Environment assigned the responsibility for MOSJ to the Norwegian Polar Institute as a permanent task that is included in the annual Letter of Commissions from the Ministry. Within the Polar Institute, the Section for Environmental Management has the secretarial responsibility and is in charge of the day-to-day follow-up of the work, in close cooperation with the Section for Environmental Data, which handles the data and manages the web pages. The Department for Research provides internal advice on the system and carries out monitoring.

The work is organised by a steering group that meets when there is a need to discuss the development of the system and at important milestones. Its members come from the offices of the Governor of Svalbard and the environmental directorates: the Norwegian Polar Institute (chair), the Directorate for Nature Management, the Directorate for Cultural Heritage and the State Pollution Control Authority (the persons appointed are listed in Appendix 1). The County Governor of Nordland, who has management responsibility for Jan Mayen, was also represented initially, but chose to withdraw at an early stage because little monitoring proved to be directed at Jan Mayen.

Sectoral responsibility for the environment requires that all sectors take charge of acquiring environmental information relating to their own activities. Contact with the suppliers of data is based on the principle that publicly funded monitoring and data acquisition must be freely available for re-use in other contexts. However, organising the data for MOSJ requires some additional working up, particularly when the data are to be included for the first time. This is based on the goodwill of the institutions. The Institute of Marine Research, with its extensive marine monitoring, is the largest contributor to MOSJ outside the environmental management sector. Other major contributors are the Norwegian Institute for Air Research (NILU), the Norwegian Meteorological Institute, the Norwegian Institute for Nature Research (NINA), the Governor of Svalbard and the Polar Institute’s own scientists (see the detailed lists in Appendices 1 and 3).

2.2 MOSJ objectives

The Environmental Monitoring of Svalbard and Jan Mayen (MOSJ) is a system for integrated monitoring of the environment on these islands and in adjacent seas. The system must:

- Be based on indicators for the state of the natural environment and cultural heritage sites and for activities and processes that affect them.
- Compile selected information from thematic monitoring programmes for Svalbard, Jan Mayen and adjacent seas.
- Make the information readily available on the Internet.
- Present quality-assured and interpreted data in a systematic, standardised manner.
- Prepare regular reports on the state of the environment in the area, which sum up the principal trends in the development and assess them against national environmental goals to be able to offer advice on the need for cross-sectoral responses.
- Be a basis for day-to-day decisions on the use and protection of nature and cultural heritage sites.
- Help to coordinate monitoring in the area and ensure that relevant monitoring needs are met and data are acquired in a cost-effective manner and using standardised methods to ensure high quality.

The target groups are management bodies working in northern regions, and the general public. As the data are being imparted via the Internet, with the general public as the target, emphasis is placed on popularising and simplifying the scientific matter. With its concern directed at monitoring, MOSJ is, nevertheless, narrower in scope and somewhat more specialised than ”State of the Environment Norway” and ”Miljøinfo Svalbard” (Environmental Info Svalbard). These web sites give a broader and more generalised knowledge of the environment and have links to MOSJ for more detailed facts derived from the monitoring.

2.3 Delimitation must take care of functional contexts

MOSJ takes in data from both the land areas in Svalbard and Jan Mayen and the monitoring of the atmosphere that is based on observation platforms on these islands. However, a limitation has been drawn here; MOSJ has so far not included any indicators that will cast light on the state of the environment within the settlements in Svalbard. It is, nevertheless, intended that the pressure which the settlements put on the surrounding natural environment will be covered.

It is more difficult to define permanent delimitations for which marine areas MOSJ must cover. Initially, it was said to be ”the coastal waters” around the islands (Hansen & Brodersen 1998). This proved problematical because few data series had such a geographical breakdown and there is a limit to what these areas can reveal relative to national environmental goals and other relevant issues. The guiding principle MOSJ is now following is that *the delimitation of the system must take care of functional*

The activities in the MOSJ system

MOSJ has been devised by the environmental management sector in cooperation with research institutions. Results from the monitoring of the desired indicators are supplied quality assured and interpreted. The material is presented in a standardised manner and is regularly updated when new data arrive. At somewhat longer intervals, the indicators and assessments are used to evaluate the state of the environment, placing special emphasis on the extent to which national, political, environmental goals are attained. There are two feedback loops from this activity:

- The left-hand loop has its origin in the assessment of the political environmental goals. Should there provetobediscrepancy between the desired state and the actualsituation, MOSJ must advise that responses are called for. The specific formulation of measures and means must, however, be undertaken by the sectoral authorities which have responsibility. If these responses are effective, they will lead to changes in the pressures induced by human activities and, in the next instance, to a changed state of the environment. By degrees, this will be able to be picked up by monitoring included in MOSJ.
- The right-hand loop has its origin in knowledge that is lacking to evaluate the state of the environment, or flawsin the environmental monitoring. This will result in recommendations regarding the need for research, improved monitoring of specific aspects ora revision of MOSJ, for instance with changes in the selection of indicators and parameters.

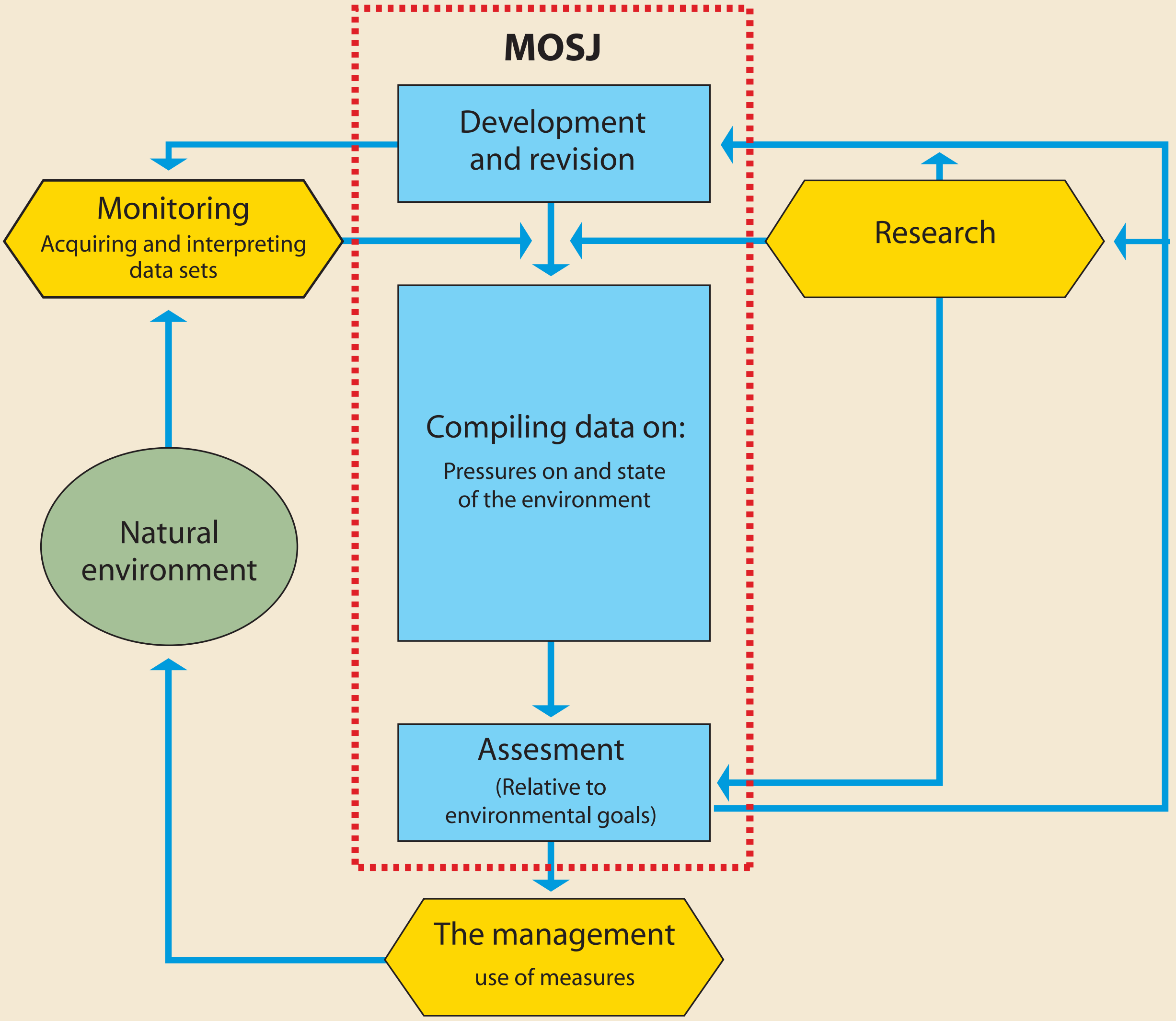

Figure 2
The core activities in the MOSJ system are marked with blue inside the red frame. The angular yellow boxes denote activities outside the system itself, which either supply or receive information.

Text box 1

contexts. We will therefore need to be pragmatic and define the delimitations from theme to theme:

- The climate system requires a comparatively wide study area – in both the sea and the atmosphere. The ocean currents flowing in and out of the Arctic provide important signals about climatic trends. MOSJ embraces oceanographic sections west of Svalbard and all the way to Greenland (the Fram Strait). Discussion is also taking place as to whether sections southwards and eastwards to the mainland should be included to take in the flow into the Barents Sea.
- A number of fish, bird and mammal populations roam over large areas. In the case of fish, we have therefore presented selected data on populations for what the annual reports of the Norwegian Institute of Marine Research refer to as the ”Barents Sea Ecosystem”. This covers the entire Barents Sea – including the Russian part – and often also the waters along

the coast in the Lofoten – Vestfjord area, where important stocks spawn. This means that data on catches in the same area must also be presented. Moreover, we present a more detailed geographical breakdown of both the catch and the stock data if these exist (e.g. shrimps). In the case of birds and mammals, in principle it may also be relevant to include data on, for instance, over-wintering areas, although this has not yet taken place.

- Some pressures, such as pollution or climatic signals like the North Atlantic Oscillation (NAO), may derive from distant regions. This may mean that data from there must be used to explain phenomena observed through monitoring taking place in MOSJ. We have elected to say that such data are supporting data that may be drawn in when necessary to help to interpret data series and evaluate the state of the environment, but not be permanent MOSJ parameters.

It has proved difficult to acquire monitoring data from Jan Mayen. Nowadays, only meteorological data from there are used in MOSJ, besides data on catches and stocks of seals in the neighbouring West Ice. This is a reflection of the minimal amount of monitoring taking place on this remote Norwegian island. We could have elected to present more data in MOSJ from the monitoring of fisheries in the area. However, we would then have encountered the problem that we would have had to include the entire ”Norwegian Sea Ecosystem” to obtain functional contexts. This would take MOSJ far beyond its geographical focus.

In practice, we can therefore say that MOSJ has its geographical focus on Svalbard, the Barents Sea and the waters surrounding Svalbard (the fishery protection zone), but with pragmatic detours beyond this when scientifically necessary (Figure 1).

2.4 MOSJ evaluates environmental goals and advises on measures

The left-hand loop represents the primary, external usefulness of MOSJ for the management sector. The right-hand loop may be said to be more internally directed towards the system itself, the research and the environmental monitoring. It was not before the assessments of the state of the environment in 2003 that the work had progressed far enough for the system to be able to demonstrate its external usefulness.

The flow chart for MOSJ activities (Figure 2) is explained in text box 1. The assessments of the state of the environment are the core activity in MOSJ. Together with interpretations of the individual indicators, they provide additional information which experience shows is essential as a supplement to purely indicator-based environmental reporting (OECD 2003). The thematisation of these assessments has varied from time to time (see section 1.3). In 2003, they were made for the climate, sea and land. They are primarily intended to give answers on:

- Goals
  Are the political goals for the northern regions, as stated in the White Papers on ”The Government's Environmental Policy and the State of the Environment” (Miljøverndepartementet 1999, 2001, 2003), being achieved? Or, in more general terms: Do trends exist that give grounds for concern?
- Responses
  If the goals are not being attained, or worrying trends are visible, is there a need to put responses in place? Who is responsible for that?
- Gaps in knowledge
  If the basis for assessing goals and trends is too poor, what kind of new or improved monitoring should be initiated, and what aspects of MOSJ should be improved? What kind of research should be started?

Even though the principal emphasis in the assessments should be based on the indicators used in MOSJ, the use of other relevant knowledge is also encouraged.

The process of making assessments of the state of the environment has evolved over time. To an increasing extent, MOSJ has asked special authors to take responsibility for writing the assessments. It is vital that these authors are independent of the management sector so that they can be free to evaluate the results that have been achieved and give advice on the need for changes. In addition, a meeting is held between the authors and representatives of the bodies which have supplied data. Representatives from the management body have also taken part in this meeting. However, the authors are responsible for the ultimate results.

MOSJ aims to implement this kind of assessment at intervals of 3-4 years. The work will be accommodated to the publications of the White Papers on ”The Government's Environmental Policy and the State of the Environment”. The topics may vary according to what is relevant from a scientific viewpoint and as regards environmental policy.

2.5 Environmental indicators are presented in a standardised fashion

MOSJ is an indicator-based system for reporting the state of the environment (see text box 2).

2.5.1 Enquiry pages

The MOSJ system presents all the indicators in a standardised manner, as illustrated in Figure 3. This is the first image that meets a reader on the web pages when he or she clicks on an indicator. The intention is that the reader will not just be presented with the indicator alone through a figure, but also be given the essence of *why* the indicator is relevant (the introduction above the figure that summarises the description of the indicator) and *what*

Indicator-based reporting on the environment

Reports on the state of the environment are largely built around indicators. An **indicator** is a parameter or a value derived from parameters, which gives simplified and concentrated information with a significance extending beyond that directly associated with the parameter value. For instance, the state of a population of a key species in an ecosystem, or an area, will be able to say something about the qualities of a larger entity, not just the species itself.

A **parameter** is a variable that acquires a value by being measured or observed. Several parameters can be combined to obtain more compressed presentations of what one wishes to show with the indicator (e.g. in the form of an index, thematic maps or figures).

The objectives of indicator-based reporting on the state of the environment are to reduce the number of measurements that are essential to acquire a good impression of the situation and to improve communication with the users. Indicators are, however, just one tool and must be supplemented by interpretations and analyses (Smeets & Weterings 1992, OECD 2003).

Text box 2

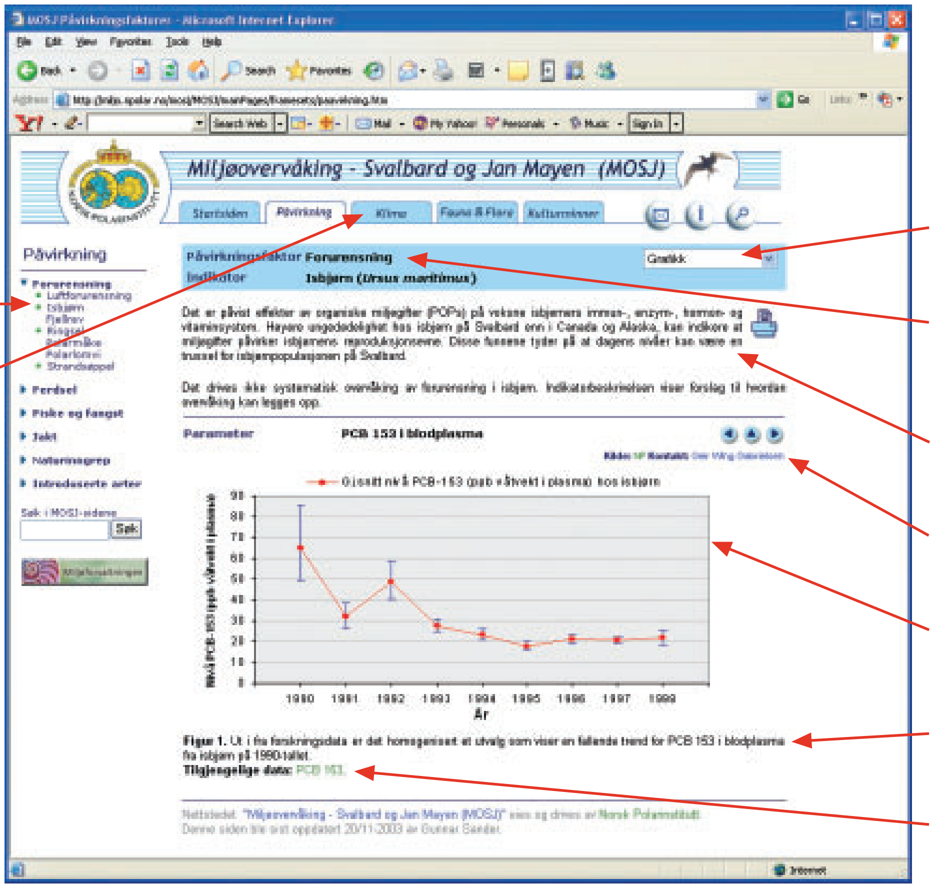

Figure 3
A screenshot that shows how an indicator is presented in MOSJ

the indicator illustrates (the caption beneath that gives the essence of the interpretation). Hence, it should be possible to leaf through the indicators and quickly grasp the most important information.

2.5.2 Descriptions of indicators provide data about the data

Each indicator is documented by a description that contains metadata – "data about the data". This is an important element in the quality assurance of MOSJ and must give users the background information they need to understand what the data represent.
It deals with the reason for the monitoring, the methods used to acquire the data, formal systems for quality assurance, limitations in the methodology, the year the monitoring started, the intervals and so on. It is, moreover, contact information for those commissioning the monitoring and those carrying it out. Appendix 2 lists in detail what the data suppliers are asked to provide in their description of the indicator.

2.5.3 Data tables and access to data

Environmental monitoring will largely wish to be transparent and to meet legally required demands regarding public accessibility to information on the environment. In keeping with this, MOSJ has a policy to publish the numerical values for the parameters that are included. This will ensure access to the data, as has been called for in a number of contexts (e.g. Norges forskningsråd 2003-04). The parameters will often show aggregated values or just a selection of what is monitored. The descriptions of the indicators will summarise this broader data material, who may be contacted to gain access to it, and guidelines from the data supplier for gaining access to the data.

2.5.4 Interpretation of data

It is intended that MOSJ will not only present indicators in isolation, but also explain what they show. The interpretations must transform numbers into useful information by giving popularised explanations of three questions:

1. How is the environmental situation described by the data judged today and over time? Is there a trend in the data? If so, what is it?
2. What are the causes of the situation and the trend?
3. Which impacts will the situation and the trend have?

Evaluations of data require the existence of something to compare them with. One approach is to compare the conditions to similar ones elsewhere, i.e. to look at geographical variation. Circumpolar comparisons will often be most relevant for MOSJ because the environmental conditions are comparatively similar, whereas north-south gradients give contrasts. However, MOSJ has so far put most emphasis on time trends, i.e. the variation over time at the place where the monitoring is taking place.

Preferably, a system for evaluation should also be available that places the observations relative to threshold values, target figures and the like. This is possible in some thematic monitoring that is included in MOSJ (e.g. the annual evaluation of the spawning and total stocks of fish provided by the Institute of Marine Research). In Sweden, a broadly based system for such assessments exists athwart major monitoring programmes. It is based either on comparisons of geographical variation or deviation from a predetermined reference situation (Naturvårdsverket). Evaluation will, however, often also be attached to impacts (cf. Question 3 above). The feasibility of demonstrating a trend depends on how the

It takes a long time to detect trends

Figure 3
Sampling blood from a polar bear. Photo: G. Bangjord.

The Norwegian Polar Institute performed a statistical analysis of samples of pollutants in polar bears taken over eight years (Henriksen et al. 2001). The samples were taken from blood (Figure 3), fatty tissue and milk, and initially showed no trends over time due to a large scatter in the data. Hence, the first task was to find out which kinds of samples gave the least scatter. This proved to be blood serum. All the serum samples were then analysed to find out what other causes than pollution levels could explain the variation from year to year. Nutrition, reproductive status and the time and place of the sampling were determined to play systematic roles. Only when the scientists were left with samples that were standardised for these factors was it possible to detect a trend – which, in fact, was the first time series for contamination in polar bears. However, this required no more than approximately half the samples collected.

An analysis of what caused the undesirable scatter in the results clearly indicated how to standardise future sampling to ensure enhanced cost effectiveness. But how many samples need to be taken each year and how many years is it necessary to keep on sampling before it is possible, with a reasonable degree of probability, to detect a trend that actually exists? The essence in the answer to this is the random variation that will always exist between years. In the case of polar bears, an annual change of 5 % in the contamination levels is unlikely to be detected before a minimum of 7-8 years sampling. To be 90 % certain, 14 years with 20 samples a year are needed. Increasing the number of samples per year beyond a minimum of about 10 will be of little help. At best, this would mean 1-2 years less before the trend becomes apparent. Keeping going a sufficient number of years is the only thing that helps.

A corresponding analysis of data from the mercury monitoring currently taking place in the Arctic nations shows that it will take, on average, 17 years of annual sampling before the data have sufficient statistical power to detect trends in an acceptable manner (Bignert et al. 2004).

These examples show that it will usually take a long time to detect trends with certainty, at any rate in the case of small changes. Consequently, a long-term obligation must be present when the monitoring of time trends begins.

Text box 3

Quality assurance of environmental monitoring

High quality in a monitoring programme requires good planning. The National Environment Protection Board in Sweden recommends that environmental monitoring should be designed through a stepwise process:

1. Formulation of the aim of the monitoring based on its objective For the most important measurement variables (the parameters), quantitative demands on statistical power should be made,i.e. demands on the scale of the change that must be detected,which areas this must be measured for and the desired level of significance. Certain types of analysis also require good diagnostic power.
2. Choice of variables (parameters): Measurement variables (dependent variables), input variables (independent variables) and intermediate variables.
3. Choice of sampling strategy: The whole population or a selection, localities, times and frequency.
4. Design of the data acquisition: Detailed decisions regarding methodology and the network of stations.
5. Data handling: Storage, accessibility and presentation of data.
6. Special measures for quality assurance

The general quality control means that the monitoring must be regularly evaluated for all the factors as a basis for decisions to change, extend or terminate the programme (Inghe 2002).

Text box 4

monitoring is planned relative to the scatter in the data acquired[3]. A large scatter (high variance) gives a low probability of being able to detect a trend rapidly. Hence, a very important part of the development of methodology in monitoring is that analyses are performed to find out which underlying factors cause undesirable scatter, and the sampling must subsequently be standardised with regard to selection of locality, timing, type of selection, etc. (Henriksen et al. 2001, Naturvårdsverket). MOSJ users must therefore be aware that a negative finding (no trend detected) may arise because the monitoring has not taken place long enough or has not been designed well enough to detect a trend that is actually present. The objective of the monitoring determines how serious such a statistical “error” is. However, those who commission monitoring are seldom specific and explicit enough regarding the statistical power they require, and a wise sampling strategy is not often worked out beforehand with the scientists doing the work. Here, there is potential for better targeted and more cost-effective environmental monitoring.

2.6 Quality assurance and coordination of monitoring

The monitoring undertaken in the MOSJ system is controlled by the various sectors and bodies commissioning the work. The extent to which these follow up recommendations on how the monitoring should be designed will vary (text box 4); hence, the quality will also vary. The quality assurance of the monitoring has been discussed by the steering group, the authors of reports on the state of the environment and at meetings with the suppliers of the data, particularly questions regarding how standardisation of the monitoring can give better statistical power and lower costs. MOSJ has a potential to work more systematically by taking up such questions and help to exchange experience and achieve common standards across the thematic monitoring programme.

The basis for starting MOSJ was the need to coordinate ongoing monitoring in the northern regions. To some extent, this has taken place through a common presentation and use of data to evaluate

Table 1
National targets and key figures for the environmental effort in the Polar Regions (performance area 8) from White Paper no. 25 (2002-03)

Goals	
Environmental conservation work in the Polar Regions	**Key figures**
Strategic objective The large continuous wilderness areas on Svalbard and in the Antarctic shall together with the cultural heritage in these areas be protected against major developments and environmental pressures. Svalbard shall become one of the best managed wilderness areas in the world, and the settlements shall be soundly managed in order to protect the environment and promote human welfare. Norway will work to ensure that its neighbouring Arctic seas remain some of the cleanest in the world, and that their resources are used within limits that will ensure the maintenance of biological diversity both in the short term and in the long term.	
National performance target 1 Cooperation in the Nordic region, in areas adjacent to Norway and in the Arctic region shall lead to improvements in the state of the environment, protect and enhance the natural heritage and cultural monuments in these areas, and help to reduce and prevent transboundary pollution that may have an impact on the environment or economic activity in Norway.	
National performance target 2 Cooperation shall help to enable the authorities and industry and commerce in Russia to exercise greater control over their own environmental problems and to integrate Russia's environmental authorities into international and regional cooperation.	
National performance target 3 The use of the resources in neighbouring Arctic seas shall not lead to species, stocks or populations becoming endangered or made extinct.	*For state*: The situation for populations of a selection of seabirds that are vulnerable to pressures arising from resource use in the Barents Sea. For pressure: Annually reported harvests of selected marine populations relative to population sizes and ICES quota recommendations.
National performance target 4 Populations of species that are currently believed to be endangered or otherwise adversely affected by land use, harvesting and/or pollution shall be conserved and if possible restored.	1. Levels of selected pollutants in selected Arctic populations of animals. 2. Number of species whose category on the Red List for Svalbard and Jan Mayen changes as a consequence of human activity, apportioned according to threat factors.
National performance target 5 Efforts shall be made to retain the extent of continuous wilderness areas on Svalbard. By 2003, a representative cross- section of Svalbard's natural environment shall be protected against major developments and environmental pressures by the establishment of specially protected areas. Steps shall be taken to give adequate protection to marine areas of particular conservation value.	*For state*: 1. Proportion of the area protected in the various biogeographic zones in Svalbard. 2. Marine areas around Svalbard subject to protection and other measures that conserve natural assets. *For pressure*: Area of natural environment affected by major developments in Svalbard.
National performance target 6 Steps shall be taken to preserve a representative selection of archaeological and historical monuments and sites on Svalbard and Jan Mayen as scientific source material and as a source of emotional and aesthetic experience for future generations. Losses of archaeological and historical monuments and sites as a result of human activity shall not exceed an average of 0.1 per cent of the total per year.	Percentage loss of recorded archaeological and historical monuments and sites according to the cultural heritage database at the Office of the Governor of Svalbard.
National performance target 7 Transport and travel on Svalbard shall not cause serious or permanent damage to the vegetation or disturb animal life. Opportunities for experiencing the natural environment undisturbed by motor traffic shall also be ensured in areas that area easily accessible from the settlements.	*For state*: 1. Damage caused by travel in selected areas. 2. Extent of areas without motor traffic that are easily accessible from the settlements in Svalbard. *For pressure*: Scale of motor traffic in Svalbard (cruise vessels, helicopter flying and snowmobile driving).

national environmental goals. The system has, however, so far not filled the role it was envisaged for more comprehensive coordination across sectors and thematic programmes. This is largely due to organisational and financial factors, which are dealt with in more detail in sections 2.1 and 3.8.

3. Choice of indicators in MOSJ

3.1 MOSJ forms part of strategic environmental reporting

The Norwegian White Paper on "Environmental Policy for a Sustainable Development" (Miljøverndepartementet 1997) laid down a cross-sectoral system to follow up results. The environmental challenges were thematised in eight performance areas:

1. Sustainable use and protection of biological diversity
2. Outdoor recreation
3. Cultural heritage and cultural environments
4. Water pollution (nutrients and oil)
5. Chemicals that are hazardous to health and the environment
6. Waste and recycling
7. Climate change, air pollution and noise
8. International environmental cooperation and environmental con servation in the polar regions

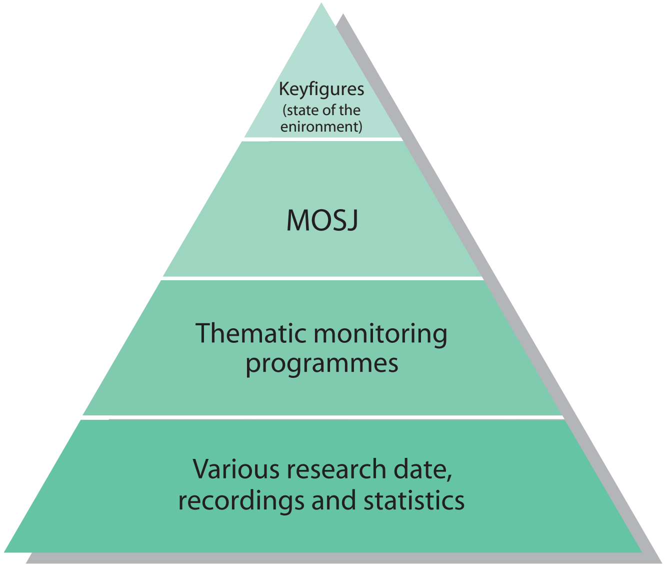

Figure 4
MOSJ is in discourse on both national, strategic, environmental reporting and the acquisition of more detailed information from thematic monitoring and research.

Strategic goals and national performance goals were set for each of these. In addition, every sector must determine sectoral working goals to render their efforts concrete. The performance goals must be verifiable. Indicators were therefore selected – in this context called key figures – which are intended to evaluate the extent to which the goals are achieved. The Government reported on the trend in three White Papers: ”The Government’s Environmental Policy and the State of the Environment” (Miljøverndepartementet 1999, 2001, 2003). The administrative system for compiling the information from the sectors for, among other purposes, these White Papers – the performance documentation system – is still being prepared.

The strategic task of MOSJ is to supply information to performance area 8 in the national system for documentation of environmental policy results. Table 1 shows the strategic objective for this performance area and the seven performance goals with the associated key figures (Miljøverndepartementet 2003). MOSJ must acquire data for, and present, these key figures. Some of the key figures and associated analyses will generally also be presented in the White Papers dealing with the State of the Environment. In other words, this is a further narrowing of the selection of indicators, or a kind of ”key indicators” (OECD 2003). In addition, the goals, chiefly from performance area 8, form the basis for the assessments which MOSJ makes of the state of the environment. A good assessment requires that all the relevant sectors contribute monitoring data in line with the principles for their environmental responsibility.

The targets and key figures have remained unaltered in the three White Papers so far put before the Norwegian Parliament. Experience to date shows that a few of the targets are difficult to verify due to the way they are formulated. It is also difficult to acquire data for several of the key figures. The Norwegian Polar Institute has therefore proposed several changes.

3.2 MOSJ compiles thematic monitoring

Specialist bodies in all the sectors need much more in-depth knowledge about the environment than the key figures are able to give. In many spheres, they have therefore initiated more comprehensive monitoring. In general terms, we may call this thematic monitoring. The motivation may, for example, be to:

- follow up international agreements
- meet demands laid down in the legislation governing the sectors
- verify environmental standards, threshold values and quality demands
- follow up sectoral environmental goals
- draw up strategies and prioritise responses
- evaluate the effects of responses implemented
- follow up orders regarding monitoring of their own discharges or emissions given in response to internal controls or health, environment and safety (HES) monitoring in the industrial sector

To provide early warning of new environmental problems or problems in other areas than those on which focus is placed through the key figures is another justification for monitoring more than just key figures.

MOSJ derives many of its indicators from thematic monitoring programmes. Among these are the monitoring of fisheries and fish stocks, long-transported pollution in the atmosphere and precipitation, meteorological programmes and reindeer monitoring. Our selection of indicators does not only include key figures, we also seek to widen our scope without going into too much detail.

Performance area 8 is geographically oriented and thus differs from the others, which are defined thematically. This gives MOSJ a special challenge in that it must try to draw an overall picture of the state of the environment in the geographical area that is covered and link together items of knowledge from a variety of disciplines and themes. MOSJ is therefore also an example of an integrated regional environmental assessment, like the Arctic Council, for example, wishes to develop[4].

3.3 MOSJ seeks to integrate research and monitoring

3.3.1 Good environmental monitoring must be based on research

Management authorities can set targets and present problems which indicate what it is relevant to monitor and what information users require from the monitoring. However, it is research that can tell us *what is best* to monitor, for instance when we wish to find indicator species that can give a representative picture of

Figure 5: Research must be closely integrated with monitoring. (After Naturvårdsverket 2003)

an ecosystem. Good environmental monitoring must therefore be founded on research.

Research is also essential for finding out *how* the monitoring must be performed. It is vital to evolve standardised methods for acquiring, analysing and presenting data so that monitoring has adequate quality to solve a problem. Trends can only be detected from data when we have long, quality-assured time series. The choice of methods also has a great deal to say for the costs.

Research is also needed to be able to *interpret* and explain the data acquired. This may also entail using analysis tools and models that fill out data sets in space and time, or making projections and scenarios for future trends.

These are important reasons why research must be closely integrated with monitoring programmes (Figure 5).

Environmental research

MOSJ has always endeavoured to have a close relationship with research. Researchers have helped to design the system, select relevant indicators and interpret them. However, developing methodology has not been given equal priority. Financial and organisational constraints frequently make it difficult to link research to monitoring. Several monitoring programmes have such limited funding that it is difficult to have the data that are acquired properly analysed and to improve the methods. It is also rare for research funds to be directly linked to monitoring programmes.

3.3.2 Research and monitoring may have different priorities

Despite great mutual benefits, environmental monitoring and research are different activities that may have different motivations and priorities (see text box 5).

One area where conflict may arise is the need environmental monitoring has for rapid reporting. This can be incompatible with the desire of the individual researcher to publish his or her findings in scientific journals first. Moreover, the desire of the management authority for open access to monitoring data may conflict with that of researchers and research institutions to use publications and data strategically when positioning themselves for new tasks. Such problems have arisen in MOSJ work because some data stem from research financed partly by unreliable funding. Nevertheless, there is growing recognition, also in research circles, that data should be freely accessible (Norges forskningsråd 2003-04). The problem will, moreover, be reduced if what is defined as national environmental monitoring is commissioned and financed by public authorities which place clear demands on reporting and publishing, as seems to be the case in Sweden (Naturvårdsverket 2003).

Definitions of environmental monitoring and research

Environmental monitoring is the systematic acquisition of environmental data using established methods, and the assessment and reporting of the data. The objective is to document the state of the environment and variations in time and space (trends) and, at the same time, to distinguish between what is induced by human activities and what has natural causes.

Handling of the data throughout the production chain is included in the definition, from the acquisition of the data, their quality assurance (including standardisation), storage and documentation to the reporting of the data to the users.

(Based on Samordningsgruppa for miljøovervåking 2001)

Research and Development work is creative activity performed systematically to acquire more knowledge – including knowledge about people, cultures and societies, and also covers the use of this knowledge to find new applications. R & D activity is often divided into basic research, applied research and development work.

(Based on OECD definitions.)

Text box 5

The DPSIR Framework

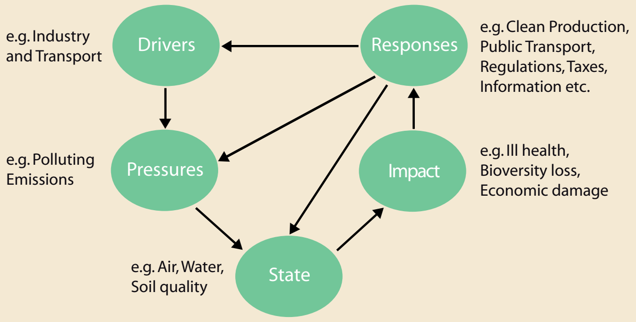

Figure 6
The DPSIR framework for environmental reporting. Source: European Environmental Agency (EEA).

DPSIR is a framework for organising information about the state of the environment. It is a system-analytical reflection on the interconnection between society and the natural environment. Social driving forces lead to activities that exert pressures on the environment. The activities will affect the state of the environment so it will change. Hence, impacts on environmental qualities or society may arise that trigger responses. The responses may be directed against every link in this chain. The acronym DPSIR stands for Driving forces – Pressures – States – Impacts – Responses. An advantage of this approach is that it presents the underlying causes of the environmental state. The intention is to make the causal relationships apparent and help to set in effective responses.

The concept was originally evolved by OECD as a PSR framework (Pressure – State – Response). The European Environmental Agency (EEA) developed it to include driving forces and impacts. The concept now has a dominant position in international environmental reporting (the UN system, the World Bank, the EU, the Nordic Council of Ministers), but some agencies use the PSR, some the DPSIR framework. In Norway, the presentations on, for example, the ”State of the Environment Norway” portal are built up around the DPSIR framework.

Descriptive indicators are used for each of the steps in this cause and effect chain. However, indicators may also be used normatively; for example, indicators for goal attainment to show how far politically adopted goals or standards have been attained (see the key figures in Table 1). Connections may also be made between different links in the chain to focus on the processes, for instance indicators for environmental efficiency which, in particular, connect pressures and driving forces as an expression of the environmental impact per unit of value. An example is the emission of CO2 per unit of gross domestic product (Smeets & Weterings 1992, OECD 2003).

Text box 6

Whereas research is innovative and investigative in its search for new knowledge, monitoring is in many ways conservative and careful through its demand on established methods. It takes time to evolve and gain acceptance for standardised methods, and monitoring will therefore lose a great deal of valuable information if we are too restrictive towards including research data. This may, in particular, have an effect on the possibility for monitoring to identify new environmental problems, whether these are defined as known problems at new places or completely unknown problems. This topic has been discussed repeatedly in MOSJ fora. Many suggestions for indicators made by Hansen & Brodersen (1998) proved to derive from research or screening using, in part, untested methods, unknown representability and short duration. We have therefore now gone a long way towards demanding that established methods lie behind them before we accept data into MOSJ. However, it is possible to consider whether we may have gone too far.

3.4 MOSJ and the DPSIR framework

MOSJ has based its reporting on the PSR framework (see text box 7), but only includes indicators for pressure and state. Climate is shown separately, since it is difficult to place unambiguously using such a simple distinction.

MOSJ does not present indicators for response. The reason for this is that reporting of responses and the use of measures in the various sectors must first and foremost take place through the performance documentation system and the sectoral action plans for the environment, which every Ministry draws up. Nor are there any indicators for driving forces, because the intention is to concentrate the system around the scientific segments of the DPSIR chain.

An important characteristic of MOSJ is that the indicators form individual building blocks that can be combined freely. There are generally many reasons for the trend we can see in an indicator. The link between cause(s) and effects takes place first through the *interpretations* that accompany each indicator. Here, we ask for the preceding and succeeding links in the cause and effect chain. Why does the trend which we are seeing take place? What impacts will it have? It is first in this way that the indicators are placed together in an analysis. Here, MOSJ differs from the reporting performed by, for example, the European Environmental Agency (EEA).

In the interpretations, details in the far more complex mechanisms than the broad categories of the PSR framework can also be detected by using supporting parameters. We may be able to detect both state and impact, even though they are not differentiated in the MOSJ scheme. We will also be able to refer to both driving forces and responses, even though no indicators for these are included in MOSJ. However, even an analytical scheme divided into five elements, like the DPSIR framework, is far too restricted to grasp what really takes place in the interplay between nature and society. The framework compels one to put forward just the most important mechanisms in each link.

Thorough analyses of threats to nature in the Arctic and different cause and effect chains lie behind the selection of indicators in MOSJ (Hansson et al. 1989, Hansen et al. 1996, Hop et al. 1998, Hansen & Brodersen 1998). At the same time, new knowledge about important relationships will continually be generated, and new priorities will be made in environmental policy. The system therefore has to be dynamic.

3.5 Themes reflect prioritised environmental challenges

The principal problems focused upon in MOSJ reflect important, major priorities in Norwegian environmental policy: climate change, pollution, biodiversity and archaeological and historical monuments and sites. The inclusion of cultural heritage protection in Norwegian environmental management helps to bring out an interesting conflict of views on the nature of the landscape in Svalbard. Is it undisturbed wilderness, or a cultural landscape marked by centuries of human use? Irrespective of which of these perspectives one adopts, there are aspects of present-day use that play a role in the damage of valuable assets.

To cast light on these problems, MOSJ covers the following main themes, which are arranged as follows in relation to pressures and state:

Themes that reveal pressures:

- Pollution
- Travel
- Hunting
- Fishing and trapping
- Disturbance of the terrain
- Introduced species

Climate and UV radiation

- The atmosphere
- Sea
- Land

Themes that reveal the state:

- Plant and animal life in the sea (marine)
- Plant and animal life on land (terrestrial)
- Cultural heritage sites (archaeological and historical monuments and sites)

3.6 Criteria for selecting indicators

A number of recommendations about criteria exist for the selection of environmental indicators. One example is from the OECD (Table 2). An attempt has also been made to develop criteria for MOSJ (Hansen & Brodersen 1998). In practice, such criteria have not been used in *formal* evaluations of proposed indicators. They have, nevertheless, played an important role in the discussions about what to select. Important factors have been:

- The relevance has been taken care of by putting high priority on key figures and looking after the needs which, not least, the Governor of Svalbard has in day-to-day management.
- Indicators that describe human-induced pressures, or are as sumed to be sensitive to these, have been given high priority. Some obvious links between pressures and state are also taken care of; for example, population monitoring takes place for the same species in which pollution is measured.
- Processes that are assumed to control the development of climate in the region and factors that give clear signals of climate change.
- Key species that are especially valuable in Arctic ecosystems or representative for several species.

Table 2
OECDs three basic criteria for selecting environmental indicators: policy relevance, analytical soundness and measurability. These describe an ideal indicator, since not all criteria can be complied with in practice (OECD 2003).

	An environmental indicator should
Policy relevance and utility for users	• provide a representative picture of environmental conditions, pressures on the environment or ociety's responses • be simple, easy to interpret and able to show trends over time • be responsive to changes in the environment and related human activities • provide a basis for international comparisons • be either national in scope or applicable to regional environmental issues of national significance • have a threshold or reference value against which to compare it so that users can assess the significance of the values associated to it
	An environmental indicator should
Analytical soundness	• be theoretically well founded in technical and scientific terms • be based on international standards and international consensus about its validity • lend itself to being linked to models, forecasting and information systems
	The data required to support the indicator should be
Measurability	• readily available or made available at a reasonable cost/benefit ratio • adequately documented and of known quality • updated at regular intervals in accordance with reliable procedures

- Rarity has been given lower priority than both human-induced pressures and key species for ecology. Hence, several Red List[5] and Responsibility[6] species are not included.
- Different types of ecosystems must be included.
- The methods must be documented and standardised.
- International recommendations, particularly from the Arctic Council's pollution (AMAP) and biodiversity (CAFF) programmes.
- Costs.

3.7 Selection of indicators in MOSJ

During its development, MOSJ has sought to find a balance between what is desirable and what is possible. The steering group has held thorough discussions on what it is desirable to include for the system to be able to fulfil its objective, but it has not had funds of its own to start new monitoring. For the most part, it has therefore been compelled to take in indicators and parameters from existing programmes. Appendix 3 summarises the indicators and parameters used in MOSJ in autumn 2003. The status, ”Not started”, in this table denotes what the steering group has wanted to include, but which it has so far been unable to include. The most important absences identified are:

- Pollutants, particularly in animals
  The selection reflects the situation that in the northern regions data are mainly found in research and preliminary screening. However, monitoring the air at Ny-Ålesund and radionuclides in the sea are regular activities that are now sufficiently long term that we can begin to distinguish trends over time. Monitoring of pollutants in commercial fish species (by the Institute of Marine Research) did not start until 2003, while that of other species, such as the top predators that are most exposed to the effects of persistent organic pollutants, has still not begun.
- Climate
  MOSJ has a comparatively large number of climate parameters. The parameters concerned with ice could be improved, both locally in the fjords and for the transport out of the Arctic Ocean. Work on this is in progress.
- Marine mammals
  Research is taking place on polar bears, walrus, ringed seals and harbour seals that will result in monitoring from 2004-05. A simplified observation programme was initiated in 2004 to supply data on white whales, bowhead whales and narwhals, for example.
- Benthos (bottom communities)
  No regular monitoring of benthos is taking place in the Svalbard area. Research data (e.g. photographs) from hard bottoms and soft bottoms are available, but better methods need to be devised to be able to obtain good monitoring series.
- Seabirds
  Work is concentrated on Bjørnøya (Bear Island). Spitsbergen is poorly covered, and nothing is taking place on Jan Mayen. A plan has been proposed to register the ivory gull population in 2005.
- Geese
  International research programmes that have generated time series are in progress. An attempt will be made to include these in MOSJ.
- Vegetation
  This is considered essential for studying climate change. No monitoring is taking place.

It is otherwise worth noting that limnic systems are almost completely lacking, but there is a desire to include measurements of pollutants in arctic char, which have been a topic of several research projects.

Several suggestions for supplements and changes to the MOSJ monitoring system were put forward when the state of the environment was assessed in autumn 2003. For instance, pollution in several species of whales and seals, damage due to travel, improved hunting statistics, more oceanographic profiles that can show the current flow in and out of the Barents Sea, snow cover and greenhouse gases (see Parts 2-4).
Lack of data is not peculiar to MOSJ. A survey of current environmental monitoring in Norway concluded that it was only possible to report ‘satisfactory’ for 51 of 82 key figures. There was also a lack of basic data to be able to comply with the obligations to report on several international environmental agreements and the Arctic Council’s AMAP and CAFF programmes. At the same time, caution is urged regarding concentrating too much of the funding for monitoring on following up key figures, since this can take place at the expense of other tasks which environmental monitoring should attend to (Samordningsgruppa for miljøovervåking 2001). Lack of data means that management authorities rely less on knowledge, and more of their work must be based on educated guesswork, with greater risks attached to the decisions.

3.8 Economy and opportunities for new monitoring

The Norwegian Polar Institute received an allocation from the Ministry of the Environment in 1999 to start MOSJ as a system. No separate funding has been provided subsequently which the MOSJ steering group has been able to use to begin monitoring in fields where monitoring needs have been identified. The steering group has limited possibilities to meet new requirements and these possibilities depend upon which body has responsibility and available funding:

- Monitoring internally in the Norwegian Polar Institute
  The organisation receives funds for monitoring through allocations from the Ministry of the Environment. The MOSJ work has had a strong bearing on what has been carried out in this field.

- Monitoring under the auspices of the other bodies represented in the steering group
  Recommendations from the steering group may influence the priorities of their monitoring in the same way as it has those of the Polar Institute. This has particularly taken place in the case of the Governor of Svalbard.

- Monitoring under the auspices of other Ministries than the Ministry of the Environment
  The steering group can put forward requests to the Ministries under which the respective sectors belong.

A broader organisation and effort on marine monitoring in the northern regions was proposed (”Environmental monitoring in the Norwegian Arctic“) in connection with the ”Protecting the Riches of the Seas” White Paper from the Ministry of the Environment (Miljøverndepartement 2002). The proposal was not followed up at the time. Improved monitoring of marine areas is a topic that will now be taken up in the Management Plan for the Barents Sea, on which several Ministries are cooperating[7]. This plan will probably also have to look into organisational and financial aspects of the monitoring. The work will be completed in 2006. However, the conclusion has already been reached that seabird monitoring should be improved, and a programme has partially begun[8].

Even though it is accepted that research data must not normally be used in environmental monitoring (Samordningsgruppa for miljøovervåking 2001), MOSJ has made use of a number of data sets that are funded by research grants. Indeed, several long time series that are very valuable for both research and management-directed monitoring are financed by research grants. The Research Council of Norway has performed a survey of existing, long time series and has suggested that the most important ones must be assured funding from several Ministries (Norges forskningsråd 2003-04). The outcome of this will have a bearing on the funding of monitoring included in MOSJ.

A committee appointed to review Norwegian policies in the northern regions has suggested a build-up of monitoring in both the Barents Sea and Svalbard (NOU 2003:32). Other possibilities for improving monitoring exist in the Environmental Fund being set up for Svalbard and in the follow-up of EUs Water Framework Directive.

4. Future development

An evaluation of MOSJ relative to the objective of the system shows that the majority of the goals are well on the way to being attained (see section 2.2). In a Norwegian context, MOSJ is in many ways a pilot project for integrated environmental monitoring on a comparatively large, regional scale. However, there is one important limitation. MOSJ has not achieved the coordinating function it was envisaged to have. Consequently, the problem of inadequate coordination of the monitoring taking place in the northern regions, which was the basis for proposing the establishment of the system, remains to be solved. However, MOSJ has created a good platform to achieve this.

The most important challenges in the time ahead are:

- Expand the monitoring
  The review in section 2.3.1 shows that monitoring is lacking in several desired fields. The indicators that are lacking reflect

Footnotes

[1] The method is known as ”Adaptive Environmental Assessment and Management” (AEAM). Some aspects are now commonly used in environmental impact assess ments, particularly in the petroleum sector, where AEAM is used as a participatory process to focus the reports on the most important consequences (”scoping”).

[2] National programme for mapping and monitoring of biological diversity for 2003-2007 is the ongoing continuation of these processes (see http://www.naturforvaltning.no/wbch3.exe?d=6585&toppgiff=dyrogplanter). It focuses first and foremost on municipal mapping on mainland Norway, including the coast. By degrees, monitoring will also be included. Both the open sea and the Arctic have so far been excluded from the programme.

[4] The two programmes of the Arctic Council, “Arctic Monitoring and Assessment Programme” (AMAP) and “Conservation of Arctic Flora and Fauna” (CAFF) point out the need to develop “integrated regional assessments, incorporating a greater range of impact factors” in an analysis of what the programmes will achieve by being better coordinated.

[5] A **Red List** is a survey of plant and animal species which in one way or another are threatened by extinction, exposed to substantial reduction or naturally rare. The species are considered to belong to one of several specifically defined categories of threat. The Norwegian Red List is found at
http://www.naturforvaltning.no/wbch3.exe?d=4379
The international Red List is found at http://www.redlist.org/

[6] **Responsibility species** are species which an individual nation has a special responsibility to manage because a large proportion of the population is found there.

[7] More information can be found at:
http://odin.dep.no/md/norsk/tema/svalbard/barents/bn.html

[8] SEAPOP is a joint initiative taken by several scientific organisations to update outdated data on seabirds and learn more about their populations. The programme seeks to coordinate parallel needs for knowledge among different bodies which need support for decision-making in issues that involve seabirds. Coordinating the activities will mean that the acquisition of data will be standardised, better quality assured and more cost effective. The programme started in 2004 with part-funding of the proposed activities.

the situation that several fields lack thematic monitoring programmes from which MOSJ can acquire information (e.g. pollutants and biological diversity). One way of solving the funding needs for environmental monitoring is that the sectors become more strongly involved.

- Better coordination of monitoring in the northern regions
  More could be achieved from the monitoring in the northern regions if the activities were better coordinated. This applies to logistics, prioritising of parameters, joint use and interpretation of data, quality assurance and development of methodology. MOSJ should be improved to play such a role in the future.
- Broader organisational foundation
  MOSJ has its origins in environmental management. However, several suppliers of data and relevant users come from other sectors. Broader cross-sectoral cooperation would increase the relevance of the system and help to improve coordination. Using data from foreign environmental monitoring, particularly that performed in Svalbard, can also add valuable data.
- Linking monitoring to models and forecasting systems
  The development of data models in research on climate and pollution, for example, has come a long way. However, they have not been as useful as desired because too few data are available to validate the models. The acquisition of data from monitoring can therefore help us to develop models that will be more and more capable of simulating reality. Model development should therefore be linked to monitoring. Improved models will enable us to fill out monitoring data in both time and space to supplement the relatively limited selection of data we will be able to acquire through monitoring. We will also be able to simulate future situations through extrapolations and scenarios, thus extending the basis for decision-making compared with just analysing the past and the present.
- Present the data geographically using a Geographical Information System (GIS).

Appendix 1

Members of the steering group, authors of assessments and institutions which supply data to MOSJ

Steering group for MOSJ

- Bjørn Fossli Johansen, Norwegian Polar Institute - chairman
- Susan Barr, Directorate for Cultural Heritage
  Formerly: Lyder Marstrander
- Else Løbersli, Directorate for Nature Management
  Formerly: Kikke Bøkseth and Ivar Myklebust
- Linn Bryhn-Jacobsen, State Pollution Control Authority
  Formerly: Gunnar Futsæter
- Sissel Aarvik, Office of the Governor of Svalbard
  Formerly: Stefan Norris

Inge Berg from the Office of the Governor of Nordland was a member until January 2000.

Project managers for MOSJ at the Norwegian Polar Institute

- Kristin Tangvik April 1999 - April 2000
- Gunnar Sander from March 2000
- Data bases and web pages: Lise Øvrum,
  Norwegian Polar Institute

Authors of assessments of the status of the environment in 2003:

Climate

- Inger Hanssen-Bauer, Norwegian Meteorological Institute
- Kåre Edvardsen, Norwegian Institute for Air Research
- Eirik J. Førland, Norwegian Meteorological Institute
- Terje Brinck Løyning, Norwegian Polar Institute
- Marine Arne Bjørge, Institute of Marine Research
- Mette Mauritzen, Institute of Marine Research
- Hallvard Strøm, Norwegian Polar Institute Terrestrial
- Pål Prestrud, CICERO (formerly Norwegian Polar Institute)

In addition, a number of representatives of bodies that supplied data took part in a meeting where the drafts of the assessments were presented.

Assigners

The following institutions are registered in our database as having given the assignments for the monitoring which is included in MOSJ:

Directorate for Nature Management, Ministry of Fisheries Directorate of Fisheries, Ministry of the Environment, Norwegian Space Centre, State Pollution Control Authority and Ministry of Education and Research

Several data series are also funded through research grants from the Research Council of Norway and other sources.

Suppliers of data

The list shows which institutions and persons supply data to MOSJ. The web pages show which indicators and parameters they are responsible for (see also Appendix 3).

- Institute of Marine Research
  Asgeir Aglen
  Michaela Aschan
  Petter Fossum, Harald
  Gjøsæter, Arne Hassel
  Tore Haug, Åge Høines
  Jarle Klungsøyr
  Reidar Toresen
- Norwegian Meteorological Institute
  Eirik Førland
  Inger Hanssen-Bauer
- Norwegian Institute for Air Research
  Torunn Berg
  Ole Anders Braathen
  Georg Hansen
  Britt Ann Høiskar
  Stein Manø
  Kjetil Tørseth
- Norwegian Institute for Nature Research
  Olav Strand
  Nigel Yoccoz

- Norwegian Polar Institute
  Andrew Derocher
  Anne Estoppey
  Eva Fuglei
  Geir Wing Gabrielsen
  Harvey Goodwin
  Jack Kohler
  Kit Kovacs
  Christian Lydersen
  Terje Brinck Løyning
  Fridtjof Mehlum
  Vladimir Pavlov
  Hallvard Strøm
  Stein Tronstad
  Jan Gunnar Winther
  Hans Wolkers
  Jon Børre Ørbæk
  Ronny Aanes
  Jon Aars

- Directorate for Cultural Heritage
  Lyder Marstrander

- Norwegian Radiation Protection Authority
  Anne Lene Brungott
  Trine Kolstad
  Anne Liv Rudjord

- Office of the Governor of Svalbard
  Bjarne Otnes
  Øystein Overrein
  Kristin Prestvold
  Jon Ove Scheie
  Sissel Aarvik

- University of Tromsø
  Rolf Ims
  Åshild Ønvik Pedersen

Store Norske Spitsbergen Kullkompani and Svalbard Reiseliv A/S are sub-suppliers of data to the Office of the Governor of Svalbard. MOSJ has also used publicly available statistics from Statistics Norway.

Appendix 2

Description of indicators for documentation of monitoring data

This form presents the guidelines for how the description accompanying each indicator is to be filled in.

1. Main groups

Data for MOSJ are divided into the following main groups (see http://miljo.npolar.no/mosj/mosj/Default.htm and the ”tabs” on the first page). These are:

1 Pressures

2 Climate

3 State of the natural environment

4 State of archaeological and historical monuments and sites (cultural heritage relics)

Write here which main group your parameter or indicator comes under.

2. Parameters

MOSJ is intended to consist of a limited selection of key parameters which may be important for environmental manage-ment work. Each parameter must be absolutely precisely defined. Describe specifically what is observed or measured and reported to MOSJ. If there is more than one parameter, list each one point by point. There is a gradual transition to how far you also must describe geography and methods under this item. Detailed descriptions of these should be given under items 5 and 8. However, regarding geography, it should be stated here whether the registration concerns selected areas (which areas may be stated under item 5, if there are many), or whether the data are representatively acquired to cover a larger area, such as the whole of Svalbard. Descriptions of methods should as far as possible be given under item 8.

If there is more than one parameter, you must be specific for each of them in the descriptions in several of the items below, provided the information is not identical for all of them. For instance, there may be different justifications for different parameters, different geography, different intervals, different lengths of time series, etc. In addition to the parameters included in MOSJ, it may be of interest to be informed of other parameters included in the monitoring programme, but not reported to MOSJ. This may be supplementary information to inform that more data can be found. In that case, state how people can acquire these data (see also items 11, 12, 13 and 14 below).

It is also possible to present more detailed data in MOSJ than just those chosen as parameters, which should be somewhat aggregated data (see, for example, the tables of data under ”Pressure/hunting/Svalbard reindeer”, where fairly complete statistics from reindeer hunting are given). Only some of this is shown in the parameter. It is also possible to show finer time resolution in the data tables than in the parameter (see item 6). This must be agreed upon when the initial establishment takes place, and be followed up on subsequent supplies of data.

3. Justification for selecting parameters

A justification must be given for the selection of each parameter (”Why is this interesting to monitor?”). This will form the basis for the introductions in the headings on the web pages where the figures are presented. The justifications may, for example, contain a brief description of the environmental problem it is desired to cast light upon and why the parameter concerned is appropriate for monitoring this. In particular, information should be given if the parameters:

- form the basis for ”key figures” used when reports are submitted for inclusion in the White Papers regarding ”The Government’s Environmental Policy and the State of the Environment” (see http://odin.dep.no/md/norsk/publ/stmeld/022001-040006/index-ved001-b-n-a.html particularly Table 1.8 – the Polar Regions)

- are included in the reports submitted to international environmental agreements (which?)

- are valuable data for early warning of environmental problems and discovery of new ones

- are included in voluntary, bilateral or multilateral commissions from, for example, EEA, AMAP and CAFF (state which)

4. Status

Is the monitoring of the parameter(s):

- ongoing?
- new?

In some cases, both may be appropriate. Scientific material is frequently acquired that may have been used to develop the basis for the parameter without it necessarily being fully adequate for what is to be reported in MOSJ. In such cases, describe the status as precisely as possible.

5. Locality (site)

Here, it must be stated where the parameter is measured or observed, geographically. State the coordinates, where relevant.

6. Interval

Here, we are seeking three kinds of information:

- The time resolution of the measurements or observations, or how frequently the parameter is measured or observed (e.g. every minute, every day, every year, every 5 years).
- Which time resolution is used in the reporting to MOSJ? Daily measurements may, for example, be aggregated and reported as mean annual values. However, we can show more detailed data under the data headings on the web pages than are reported as the parameter value. For instance, mean monthly values are available from all the meteorological stations, even though the parameter uses annual and seasonal means (see: ”climate/atmosphere/temperature and precipitation”). This enhances the usefulness of the system for those needing more data.
- How frequently are reports submitted to MOSJ? This does not take place *more frequently* than once a year. When reporting is more seldom, state the interval and which year the next delivery will come.

7. Length of time series

If this is an ongoing activity, it must be stated here how long the time series is. Information should also be given about any breaks in the time series, or limitations in its/their quality, in individual years or sets of observations which entail that they should not be used to calculate trends.

8. Method

The method used to perform measurements or observations must be described in detail here (e.g. at what time of year, where on the animal, the height above the ground, etc.). Give any references to more thorough descriptions of the method.

In addition to the example concerning air pollution, we would refer to the indicator description for Arctic fox under ”Fauna and flora” as a good example of a good description of method.

9. Limitations in the method

Any uncertainty regarding the results arising from the method used must be described here (uncertainty in the measurements or the methods used to acquire data, handling of samples, statistical uncertainty, etc.). If supplementary investigations are required, this must be stated.

10. Quality assurance

Any formal requirements regarding quality assurance made to the method of observation or measurement must be described here. Examples: Are they acquired in accordance with a documented quality assurance system, and do formal descriptions of the method, calibration and verification routines, protocols, certifications, standards, etc. exist? Refer, if appropriate, to the literature, in addition to giving a brief description.

11. Home institution and contact person

We wish to know both the:

- Assigner: Name of institution with web address and the person who may be contacted, with e-mail address and telephone number
- The institution performing the work: Name of institution with web address and the person who may be contacted, with e-mail address and telephone number

If no clear assigner exists – just the person performing the work – fill in just the institution performing the work.

The person to be contacted should normally be the one who supplies the data to MOSJ and to whom anyone wishing further information may apply. Several co-workers may be listed if desired. Each must be attached to an institution. Give details of the institution if it is not the same one as is stated as performing the work. The co-workers will be listed in the indicator description along with the actual contact person. In the figures, we will normally always give the name and e-mail address of the contact person. However, we are also able to mention one other person in connection with the figures (e.g. if an indicator has many parameters and responsibility for them differs slightly).

12. Possible limitations regarding access to data and raw data

Any limitations on the use of the data must be stated here. For example, ”always state the source”, ”contact the ’contact person‘ prior to any further use”, etc. It may also be stated whether it is possible to gain access to more detailed data or raw data.

13. Relevant links to web sites

References to relevant web sites must be given here. Links should always be given to specific sub-pages under ”State of the Environment Norway” www.environment.no if anything is stated there regarding circumstances which the indicator elucidates.

14. Relevant references

References to, for example, publications where the data are published and to scientific articles containing data, description of methods, etc., must be given here. Try to limit this to a few key publications. References must also be given in the interpretations of time series which must be supplied along with the data. Here, it will be most natural to mention references that directly concern the interpretation, not particularly the methods, which should be covered by references in the description of the indicator.

In addition, the suppliers of data are asked about costs (this information is used in the administrative work connected with the environmental monitoring) and about routines for submitting data. This information is not shown on the web pages.

Appendix 3

List of indicators

Here is a summary of all the MOSJ themes, indicators and parameters. The table also shows where monitoring is taking place and for which years data exist. Abbreviations are explained on page 27

Pressure indicatiors

1. Pollution

Theme/indicator/parameter	Institution*	Status*	Reported	Data for
a. Air pollution in Ny-Ålesund				
Organic pollutants: PCB sum 10 congeners	**A:** SFT; **P:** NILU, NP	Ongoing, data received	Annually	1993-2001
Organic pollutants: Sum DDT	**A***:* SFT; **P:** NILU, NP	Ongoing, data received	Annually	1995-2001
Organic pollutants: HCB	**A:** SFT; **P:** NILU, NP	Ongoing, data received	Annually	1993-2001
Organic pollutants: Sum	**A:** SFT; **P:** NILU, NP	Ongoing, data received	Annually	1993-2001
Organic pollutants: Sum chlordanes	**A:** SFT; **P:** NILU, NP	Ongoing, data received	Annually	1993-2001
Acidifying components : Sulphur (SO2 and SO4)	**A:** SFT; **P:** NILU, NP	Ongoing, data received	Annually	1980-2001
Heavy metals: Mercury (Hg), lead (Pb) and cadmium (Cd)	**A:** SFT; **P:** NILU, NP	Ongoing, data received	Annually	1995-2001
b. Polar bear (*Ursus maritimus*)				
PCB 153 in blood plasma	**A/P:** NP	Ongoing, data received	Annually	1990-1998
DDT, chlordanes, HCB, HCH, dieldrin, toxaphene, PBDE, mercury,	**A/P:** NP	Not started	Every 3 years	
Caesium, strontium, technetium	**A:** NRPA; **P:** NP	Not started	Screening	
c. Arctic fox (*Alopex lagopus*)				
Substances as for polar bear	**A:** NP; **P:** NP, SMS	Not started	Every 3 years	
d. Ringed seal (*Phoca hispida*)				
Toxaphene (congeners 26 and 50)	**A/P:** NP	Partly ongoing		1996-1996
PCB 153 in blubber	**A/P:** NP	Partly ongoing		1996-1996
Other substances as for polar bear	**A/P:** NP	Not started	Every 5 years	
e. Glaucous gull (*Larus hyperboreus*)				
Substances as for polar bear	**A/P:** NP	Not started	Every 3 years	
f. Brünnich's guillemot (*Uria lomvia*)				
Substances as for polar bear	**A/P:** NP	Not started	Every 5 years	
g. Shore rubbish				
Shore rubbish, annual quantities	**A/P:** SMS	Ongoing, data received	Annually	2001-2003
h. Radioactivity in air				
Gamma radiation	**A:** NRPA; **P:** NILU	Ongoing, data not received	Annually	1986-2003
i. Polar cod (*Boreogadus saida*)				
Organic pollutants, metals and radioactivityd		Not started		
j. Cod (*Gadus morhua*) Organic pollutants, metals and radioactivity	**A:** FID; **P:** HI	Ongoing, data not received	Every 3 years	
k. Radioactivity in seawater				
Technetium-99	**O:** MD; **U:** NRPA	Ongoing, data not received	Annually	1997-2003
l. Radioactivity in fish				
Caesium-137	**A:** FID; **P:** Mattilsynet, NIFES, NRPA	Ongoing, data not received	Annually	1996-2002
m. Arctic char (*Salvelinus alpinus*)				
Organic pollutants and mercury		Not started	Every 5 years	
n. Svalbard reindeer (*Rangifer tarandus platyrhynchus*)				
Metals	**A/P:** NP	Not started	Every 10 years	
o. Svalbard ptarmigan (*Lagopus mutus hyperboreus*)				
Metals	**A/P:** NP	Not started	Every 10 years	

2. Traffic

Theme/indicator/parameter	Institution*	Status*	Reported	Data for
a. Overnight stops in Longyearbyen				
Number of overnight stops at overnight accommodation	**A:** SMS; **P:** SR	Ongoing, data received	Annually	1995-2004
b. Cruise tourism				
Number of places where people go ashore and total number of people ashore, except in the settlements and Isfjorden	**A/P**: SMS	Ongoing, data received	Annually	1996-2004
c. Petrol consumption in Longyearbyen (snowmobiles)				
Number of litres of petrol sold	**A:** SMS; **P:** SNSK	Ongoing, data received	Annually	1995-2004
d. Use of snowmobiles				
Number of snowmobiles registered in Svalbard	**A/P:** SMS	Ongoing, data received	Annually	1973-2004
e. Use of helicopters				
Total annual flying hours by helicopters in Svalbard (excluding Russian)	**A/P:** SMS	Ongoing, data received	Annually	1985-2002
f. Individual travellers				
Number of travellers outside management area 10	**A/P:** SMS	Ongoing, data received	Annually	1998-2004
g. Snowmobiles: Number of hire days				

3. Fishing and trapping

Theme/indicator/parameter	Institution*	Status*	Reported	Data for
a. Harp seal (*Phoca groenlandica*)				
Harp seals taken in the	**A:** FID; **P:** East Ice, Fiskeridir.	Ongoing, data received	Annually	1946-2002
Harp seals taken in the West Ice	**A:** FID; **P:** Fiskeridir.	Ongoing, data received	Annually	1946-2002
b. Hooded seal (*Cystophora cristata*)				
Hooded seals taken in the West Ice	**A:** FID; **P:** Fiskeridir.	Ongoing, data received	Annually	1946-2002
c. Cod (*Gadus morhua*)				
Catch of Norwegian-Arctic cod divided according to age-classes	**A:** FID; **P:** Fiskeridir, HI	Ongoing, data received	Annually	1946-2002
d. Greenland halibut (*Reinhardtius hippoglossoides*)				
Catch of Norwegian-Arctic Greenland halibut	**A:** FID; **P:** Fiskeridir, HI	Ongoing, data received	Annually	1964-2002
e. Shrimps (*Pandalus borealis*)				
Catch of shrimps from the north-east Atlantic Ocean	**A:** FID; **P:** Fiskeridir, HI	Ongoing, data received	Annually	1970-2002
f. Capelin (*Mallotus vollosus*)				
Total catch of capelin stock in the Barents Sea	**A:** FID; **P:** HI	Ongoing, data received	Annually	1973-2002
g. Herring (*Clupea harengus*)				
Catch of herring	**A:** FID; **P:** HI	Ongoing, data received	Annually	1950-2002

4. Hunting

Theme/indicator/parameter	Institution*	Status*	Reported	Data for
a. Bag of polar bear (*Ursus maritimus*)				
Total bag of polar bear (dead and alive)	**A/P:** SMS	Ongoing, data received	Annually	1871-2004
b. Bag of Svalbard reindeer (*Rangifer tarandus platyrhynchus*)				
Number of reindeer shot	**A/P:** SMS	Ongoing, data received	Annually	1983-2004
c. Bag of Svalbard ptarmigan (*Lagopus mutus hyperboreus*)				
Number of ptarmigan shot	**A/P:** SMS	Ongoing, data received	Annually	1997-2004
d. Bag of arctic fox (*Alopex lagopus*)				
Number of arctic foxes taken	**A:** SMS; **P:** NP, SMS	Ongoing, data received	Annually	1997-2004

5. Disturbance of the natural environment

Theme/indicator/parameter	Institution*	Status*	Reported	Data for
a. Major man-made constructions and disturbance of the natural environment				
Major man-made constructions	**A/P:** NP, SMS	Partly ongoing	Every 10 years	1992-1997

6. Introduced species

Theme/indicator/parameter	Institution*	Status*	Reported	Data for
a. Sibling vole (*Microtus epiroticus*)				
Number of sibling voles caught	**A:** NINA; **P:** NINA, NP, UiTø	Ongoing, data received	Annually	1991-2002

Climate and UV radiation

1. Atmosphere

Theme/indicator/parameter	Institution*	Status*	Reported	Data for
a. Temperature and precipitation				
Air temperature	**A:** UFD; **P:** MI	Ongoing, data received	Annually	1912-2003
Precipitation	**A:** UFD; **P:** MI	Ongoing, data received	Annually	1912-2003
b. Total ozone and UV				
Total ozone	**A:** SFT; **P:** NILU, NP	Ongoing, data received	Annually	1979-2003
UV doses	**A:** SFT; **P:** NILU, NP	Ongoing, data received	Annually	1995-2004
c. Atmospheric radiation				
Annual total global radiation at Ny-Ålesund	**A/P:** NP	Ongoing, data received	Annually	1974-1999
Annual total net radiation at Ny-Ålesund	**A/P:** NP	Ongoing, data received	Annually	1974-1999
Annual total net short-wave radiation at Ny-Ålesund	**A/P:** NP	Ongoing, data received	Annually	1974-1999
Annual total net long-wave radiation at Ny-Ålesund	**A/P:** NP	Ongoing, data received	Annually	1974-1999

2. Sea

Theme/indicator/parameter	Institution*	Status*	Reported	Data for
a. Area covered by sea ice in the Norwegian and the Barents seas				
Area covered by sea ice in the Norwegian Sea and the Barents Sea in April	**A/P:** MI, NP	Ongoing, data received	Annually	1865-2000
b. Area covered by sea ice in Storfjorden and Kongsfjorden				
Area covered by sea ice in Storfjorden	**A:** NR; **P:** MI, NP	Ongoing, data received	Annually	1967-2002
c. Thickness of sea ice in the Fram Strait				
Thickness of sea ice in the Fram Strait	**A/P:** NP	Ongoing, data received	Annually	1990-2000
d. Ice transport through the Fram Strait				
Annual volume of ice flow	**A/P:** NP	Ongoing, data received	Annually	1950-2000
e. Sea temperature, salinity and current in the Fram Strait				
Sea temperature, 10-yearly mean values (summer and winter)	**A/P:** NP	Ongoing, data received	10 years	1950-2000
Water salinity, 10-yearly mean values (summer and winter)	**A/P:** NP	Ongoing, data received	10 years	1950-2000
Annual mean values for sea temperature, Fram Strait (80ºN, 9ºE)	**A/P:** NP	Ongoing, data received	Annually	1960-2000
Annual mean valuesfor water salinity, Fram Strait (80ºN, 9ºE)	**A/P:** NP	Ongoing, data received	Annually	1960-2000
Difference between maximum summer and winter temperatures at 79ºN in the Fram Strait	**A/P:** NP	Ongoing, data received	Annually	1950-1980
f. Sea temperature, salinity and current around Sørkapp				
g. Sea level				
Sea level at Barentsburg – annual mean	**A/P:** NP	Ongoing, data received	Annually	1949-2000
Sea level at Vardø – annual mean	**A/P:** NP	Ongoing, data received	Annually	1948-1998
Sea level at Tromsø – annual mean	**A/P:** NP	Ongoing, data received	Annually	1953-2001

3. Land

Theme/indicator/parameter	Institution*	Status*	Reported	Data for
a. Mass balance of glaciers near Ny-Ålesund				
Mass balance of Brøgger Glacier	**A/P:** NP	Ongoing, data received	Annually	1967-2000
Mass balance of Midtre Lovén Glacier	**A/P:** NP	Ongoing, data received	Annually	1968-2000
Mass balance of Kongsvegen Glacier	**A/P:** NP	Ongoing, data received	Annually	1987-2000
Annual variation in the mass balance of 3 glaciers	**A/P:** NP	Ongoing, data received	Annually	1967-2000
b. Snow distribution in Svalbard				

Fauna and flora

1. Animal and plant life, marine environment

Theme/indicator/parameter	Institution*	Status*	Reported	Data for
a. Polar bear (Ursus maritimus)				
Distribution in Svalbard and the western Barents Sea	**A:** MD; **P:** NP	Not started		
Population parameters in Svalbard (age distribution, demographic parameters)	**A:** MD; **P:** NP	Partly ongoing		
Diet in different areas and seasons	**A:** MD; **P:** NP	Not started		
Fitness and state of health, including diseases and parasites	**O:** MD; **U:** NP	Not started		
b. Walrus (*Odobenus rosmarus*)				
Population size NP	**A:** MD; **P:**	Partly ongoing	Every 3 years	
Use of resting places NP	**A:** MD; **P:**	Partly ongoing	Every 3 years	
c. Ringed seal (*Phoca pusa*)				
Number and density of ringed seals in selected fjords around Spitsbergen.	**A:** MD; **P:** NP	Partly ongoing	Every 5 years	
Population parameters – age structure and vital rates.	**A:** MD; **P:** NP	Partly ongoing	Every 5 years	

Theme/indicator/parameter	Institution*	Status*	Reported	Data for
Food intake locally and	**A:** MD; **P:** NP	Not started	Every 5 years	
State of body and "health status" of ringed seals in Svalbard	**A:** MD; **P:** NP	Not started	Every 5 years	
d. Harbour seal (*Phoca vitulina*)				
Population size and distribution	**A:** MD; **P:** NP	Partly ongoing	Every 3 years	
State and age composition	**A:** MD; **P:** NP	Not started	Every 6 years	
e. Harp seal (*Phoca groenlandica*)				
Production of pups in the West Ice	**A:** FID; **P:** HI	Ongoing, data received	Variably	1983-2000
Production of pups in the East Ice	**A:** FID; **P:** HI	Ongoing, data received	Variably	1998-2000
f. White Whale (*Delphinapterus leucas*)				
Distribution and numbers derived from observation journals	**A:** MD; **P:** NP	Not started	Annually	
g. Bowhead whale (*Balaena mysticetus*)				
Distribution and numbers derived from observation journals	**A:** MD; **P:** NP	Not started	Annually	
h. Narwhal (*Monodon monoceros*)				
Distribution and numbers	**A:** MD; **P:** NP	Not started	Annually	
i. Brünnich's guillemot (*Uria lomvia*) derived from observation journals				
Breeding population on Bjørnøya as percentage of the average	**A/P:** NP	Ongoing, data received	Every 1-3 years	1986-2001
Breeding population on Spitsbergen as percentage of the average	**A/P:** NP	Ongoing, data received	Every 1-3 years	2002-2002
Nesting period on Bjørnøya	**A/P:**	Ongoing, data received	Every 1-3 years	2002-2002
Chick growth on Bjørnøya	**A/P:** NP	Ongoing, data received	Every 1-3 years	2002-2002
Breeding success on Bjørnøya	**A/P:** NP	Ongoing, data received	Every 1-3 years	2002-2002
Adult survival on Bjørnøya	**A/P:** NP	Ongoing, data received	Every 1-3 years	2002-2002
Food choice on Bjørnøya	**A/P:** NP	Ongoing, data received	Every 1-3 years	2002-2002
j. Common guillemot (*Uria aalge*)				
Breeding population on Bjørnøya as percentage of the average	**A/P:** NP	Ongoing, data received	Annually	1988-2002
Nesting period on Bjørnøya	**A/P:** NP	Ongoing, data received	Annually	1988-2002
Chick growth on Bjørnøya	**A/P:**	Ongoing, NP	Annually data received	2000-2002
Breeding success on Bjørnøya	**A/P:** NP	Ongoing,	Annually	2000-2002
Adult survival on Bjørnøya	**A/P:** NP	Ongoing, data received	Annually	1988-2002
Food choice on Bjørnøya	**A/P:** NP	Ongoing, data received	Annually	1988-2002
k. Common eider (*Somateria mollissima*)				
Breeding population on the islands in Kongsfjorden	**A/P:** NP	Ongoing, data received	Annually	1981-2000
Average number of eggs in a clutch per year (Kongsfjorden)	**A/P:** NP	Ongoing, data received	Every 1-3 years	1981-2000
Number of moulting pairs along the coast	**A/P:** NP	Not started	Every 3-5 years	
l. Kittiwake (*Rissa tridactyla*)				
Population size on Spitsbergen in percentage of average	**A/P:** NP	Ongoing, data received	Every 1-3 years	1988-2001
Clutch size Bjørnøya	**A/P:** NP	Not started	Every 1-3 years	
Population size on Bjørnøya in percentage of average	**A/P:** NP	Ongoing, data received	Every 1-3 years	2002-2002
Nesting period on Bjørnøya	**A/P:** NP	Not started	Every 1-3 years	
Chick growth on Bjørnøya	**A/P:** NP	Not started	Every 1-3 years	
Breeding success on Bjørnøya	**A/P:** NP	Not started	Every 1-3 years	
Adult survival on Bjørnøya	**A/P:** NP	Not started	Every 1-3 years	
Food choice on Bjørnøya	**A/P:** NP	Not started	Every 1-3 years	
m. Glaucous gull (*Larus hyperboreus*)				
Breeding population on Bjørnøya as percentage of the average	**A/P:** NP	Ongoing, data received	Annually	1997-2002
Breeding success on Bjørnøya	**A/P:** NP	Ongoing, data received	Annually	1997-2002
n. Ivory gull (*Pagophila eburnea*)				
o. Hooded seal (*Cystophora cristata*)				
Pup production in the West Ice	**A:** FID; **P:** HI	Ongoing, data received	Variably	1997-2000
p. Zooplankton				
Average biomass of zooplankton in the whole Barents Sea	**A:** FID; **P:** HI	Ongoing, data received	Annually	1988-2001
Average biomass of zooplankton in area 6 (Svalbard)	**A:** FID; **P:** HI	Ongoing, data received	Annually	1988-2002
Average biomass of zooplankton in area 7 (Bjørnøya - Hopen)	**A:** FID; **P:** HI	Ongoing, data received	Annually	1988-2001
q. Shrimps (*Pandalus borealis*)				
Index (quantity estimate) for the shrimp stock in the Svalbard zone and the Barents Sea	**A:** FID; **P:** HI	Ongoing, data received	Annually	1984-2002
r. Cod (*Gadus morhua*)				
Spawning and total stocks of Norwegian-Arctic cod	**A:** FID; **P:** HI	Ongoing, data received	Annually	1946-2002
Biomass index for cod (3+) in the Barents Sea	**A:** FID; **P:** HI	Ongoing, data received	Annually	1981-2002
s. Greenland halibut (*Reinhardtius hippoglossoides*)				
Spawning and total stocks of Norwegian-Arctic Greenland halibut	**A:** FID; **P:** HI	Ongoing, data received	Annually	1964-2001
t. Bottom communities (*benthos*)				
u. Herring (*Clupea harengus*)				
Spawning and total stocks of Norwegian spring-spawning herring	**A:** FID; **P:** HI	Ongoing, data received	Annually	1950-2002
v. Capelin (*Mallotus vollosus*)				
Quantity estimate of the total capelin stock in the Barents Sea	**A:** FID; **P:** HI	Ongoing, data received	Annually	1973-2002

2. Animal and plant life, terrestrial environment

Theme/indicator/parameter	Institution*	Status*	Reported	Data for
a. Svalbard reindeer (*Rangifer tarandus platyrhynchus*)				
Development of Reindalen population	**A:** DN; **P:** NINA	Ongoing, data received	Annually	1979-2002
Development of Brøggerhalvøya population	**A/P:** NP	Ongoing, data received	Annually	1978-2005
b. Arctic fox (*Alopex lagopus*)				
Number of litters (Kongsfjord area)	**A:** NP; **P:** NP, SMS	Ongoing, data received	Annually	1993-2001
Average size of litters (Kongsfjord area)	**A:** NP; **P:** NP, SMS	Ongoing, data received	Annually	1993-2001
Lairs observed in Adventdalen/Sassen	**A:** MD; **P:** NINA, NP	Partly ongoing		
c. Svalbard ptarmigan (*Lagopus muta hyperborea*)				
Density of territorial cocks in April in selected monitoring areas	**A:** NP, SMS; **P:** UiTø	Ongoing, data received	Annually	2000-2004
d. Geese (*Barnacle*, Pink-footed and/or Brent)				
e. Vegetation				

Cultural heritage relics

1. Cultural heritage relics

Theme/indicator/parameter	Institution*	Status*	Reported	Data for
a. Number of recorded cultural heritage relics				
Number of recorded cultural heritage relics	**A/P:** SMS	Ongoing, data received	Annually	

2. Wear and tear from traffic

Theme/indicator/parameter	Institution*	Status*	Reported	Data for
a. Gravneset, Magdalenefjorden				
Gravneset, changes due to traffic (wear and tear)	**A/P:** SMS	Partly ongoing	Annually	1999-1999
b. Virgohamna				
Virgohamna, changes due to traffic (wear and tear)	**A/P:** SMS	Partly ongoing	Annually	1998-1998
c. Hiorthamn				
Hiorthamn, changes due to traffic (wear and tear)	**A/P:** SMS	Partly ongoing	Every 4 years	1997-1997
d. Smeerenburg				
Smeerenburg, changes due to traffic (wear and tear)	**A/P:** SMS	Partly ongoing	Every 3 years	1999-1999

3. Erosion

Theme/indicator/parameter	Institution*	Status*	Reported	Data for
a. Fredheim				
Fredheim, changes due to erosion	**A/P:** SMS	Partly ongoing	Every 3 years	1997-1997
b. Sallyhamn				
Sallyhamn, changes due to erosion	**A/P:** SMS	Partly ongoing	Every 4 years	1998-1998

*** The codes in front of the institution abbreviations mean**

A = Assigner/Institution responsible for commissioning
P = Performing institution

* Institution abbreviations

DN	Directorate for Nature Management
FID	Ministry of Fisheries
Fiskeridir	Directorate of Fisheries
HI	Institute of Marine Research
Mattilsynet	Norwegian Food Safety Authority
MD	Ministry of the Environment
MI	Norwegian Meteorological Institute
NAFO	Northwest Atlantic Fisheries Organization
NIFES	National Institute of Nutrition and Seafood Research
NIKU	Foundation for Cultural Heritage Research
NILU	Norwegian Institute for Air Research
NINA	Norwegian Institute for Nature Research
NP	Norwegian Polar Institute
NR	Norwegian Space Centre
NRPA	Norwegian Radiation Protection Authority
RA	Directorate for Cultural Heritage
SFT	State Pollution Control Authority
SMS	Office of the Governor of Svalbard
SNSK	Store Norske Spitsbergen Kullkompani
SR	Svalbard Reiseliv AS
SSB	Statistics Norway
UFD	Ministry of Education and Research
UiTø	University of Tromsø

* **Status**
The summary of the indicators shows both ongoing monitoring and desirable new monitoring (cf. the ”Status” column).

RAPPORTSERIE 123

The environmental monitoring of Svalbard and Jan Mayen – MOSJ

Part 2: Assessment of the state of the environment and responses: climate

By Inger Hanssen-Bauer, Kåre Edvardsen,
Eirik J. Førland and Terje Brinch Løyning


Photo: G. S. Jaklin


Photo: S. Gerland


Photo: A. Taurisano

Contents

1 Background

1.1 Problems

The global mean temperature rose by about 0.6°C during the 20th century (IPCC 2001). This warming took place in two periods, 1900-1945 and 1976-2000. In an article in *Nature*, Tett et al. (1999) concluded that variations in natural climate forcing (volcanic activity and solar radiation) can explain the warming before 1945, but cannot alone explain that which took place after 1970. Increasing concentrations of greenhouse gases in the atmosphere are, however, capable of explaining this last global warming. IPCC (2001) concluded that most of the warming in the last 50 years has probably been caused by human activity. Climate models indicate that the global mean temperature will continue to rise for the next 100 years in response to human emissions of greenhouse gases, and the rise in temperature will be greater in the Arctic than in other regions (Raisänen 2001). Monitoring of the climate development in the Arctic is therefore considered to be important.

Ozone depletion has been recorded over the Arctic in the last two decades, though not on the same scale as over the Antarctic. Some calculations undertaken with the help of models suggest that ozone depletion can also be expected in the Arctic during the next 20 years, but the development further into the future is very uncertain. It is therefore also important to monitor the ozone layer in the Arctic.

1.2 Basis for the assessment

The basis for this assessment is geophysical data listed on the ”Climate” page of the MOSJ Internet pages in October 2002. These include air temperature and precipitation measurements from Bjørnøya (Bear Island), Hopen, Svalbard Airport, Ny-Ålesund and Jan Mayen, radiation and ozone measurements from Ny-Ålesund, sea-ice observations from the Fram Strait and the Barents Sea, oceanographic observations (sea temperature, salt content and currents) from the Fram Strait, water-level measurements (sea level) at Barentsburg, Vardø and Tromsø, and the mass balance of glaciers in Svalbard. Stations and areas where measurements and observations are taken are shown in Figures 1 and 2.

Fig. 2.
Map of Svalbard showing the sites where measurements are taken for MOSJ.

The assessment is partly based on analyses of the development of the individual elements undertaken by those supplying the data, partly on our own analyses. It has been performed in the light of relevant scientific publications from the Arctic and elsewhere.

Fig. 1.
Map showing the area covered by MOSJ.

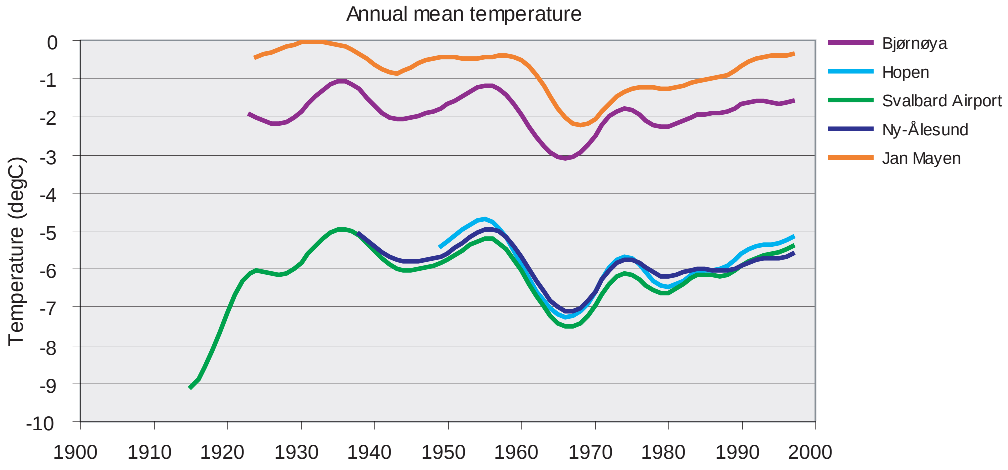

Fig. 3.
The annual mean temperature at Norwegian Arctic stations. The time series have been smoothed and show variations on a 10-year scale.

1.3 Participants

The following institutions are responsible for collecting and/or funding the data on which the assessment is based: the Norwegian Meteorological Institute (met.no), the Norwegian Institute for Air Research (NILU), the Norwegian Polar Institute (NPI), the National Pollution Control Authority (SFT), the Norwegian Mapping Authority – Hydrographic Survey of Norway Division, and the Roshydrome in Murmansk.

2 Status and features in the development

2.1 Introduction

This chapter presents the main features in the development over time of each individual MOSJ geophysical indicator and their covariation. Variations on a time scale of 10 years are illustrated with the help of smoothed time series. Linear trends are used to cast light on variations over time scales of 30-100 years. ”Statistical reliability” for the trends has been tested using a method described by Førland et al. (1997). By ”statistically reliable trends”, we mean here trends that with less than 5 % probability would arise as a result of fortuitous variations. Possible physical reasons for the trends observed are discussed at the end of the chapter.

2.2 Climatic variations in the atmosphere

2.2.1 Air temperature

Climate models indicate that the air temperature at the ground will largely be affected by human-induced increases in the greenhouse effect and that the rise in temperature on average will be greatest at high latitudes (IPCC 2001, Chap. 9 and 10). The air temperature is therefore an obvious climatic indicator to choose for MOSJ work.

The time series for the annual mean temperature at the Norwegian Arctic stations show quite a similar development over time (Fig. 3). The longest temperature series is from Svalbard Airport near Longyearbyen (Fig. 2), and started in 1912. A trend analysis of this series (Table 1) gives a positive trend of 0.14° C per 10 years from 1912 to 2000. The trend is not statistically reliable. This is partly because the 1930s were somewhat warmer than the 1990s, which is typical for the Atlantic sector of the Arctic (60° W-30° E) (Førland et al. 2002). The period can, however, be divided into three parts, all of which have statistically reliable trends, a warming from 1912 until the 1930s, a cooling from the 1930s until the 1960s and a new warming from the 1960s up to 2000.

Table 1
Linear temperature and precipitation trends at Svalbard Airport in various periods. Trends that are statistically reliable (5 % level) are shown in bold face. Units: °C per 10 years (temperature), mm per 10 years (precipitation).

	Linear trends in temperature, °C per 10 years				
Period	Year	Winter	Spring	Summer	Autumn
1912-2000	+0.14	+0.08	**+0.36**	+0.04	+0.11
1912-1940	**+1.83**	**+3.82**	**+1.67**	+0.31	+1.55
1930-1970	**-0.66**	**-1.66**	-0.32	-0.22	-0.45
1960-2000	**+0.49**	+0.77	**+0.61**	**+0.24**	+0.27
	Linear trends in precipitation, °C per 10 years				
Period	Year	Winter	Spring	Summer	Autumn
1912-2000	+5.3	0.0	+1.1	+2.6	+1.7

Temperature series from all seasons show the same direction in trend as the annual mean temperature, although not all the seasonal trends are statistically reliable (Table 1). The only season that shows a statistically reliable trend from 1912 until 2001 is spring, which has been warmer. There are no statistically reliable trends when it comes to the variability of the data series.

The average temperature in the circumpolar area north of 60° N shows the same periods of warming and cooling as the Norwegian stations (Jones & Moberg 2003). This average temperature, however, shows a statistically reliable, positive long-term trend. The vast majority of places on the Norwegian mainland have also shown statistically reliable warming over the last 100 years. This is because the warm period in the 1930s was comparatively less marked there than in the Arctic.

2.2.2 Precipitation

The climate models show generally greater differences as regards the influence of the enhanced greenhouse effect on precipitation than they do for temperature (Raisänen 2001). Nevertheless, it is considered likely that the precipitation at high northern latitudes will increase because of the enhanced greenhouse effect (IPCC 2001, Chap. 10). Precipitation is therefore an important climatic indicator in the Arctic.

In contrast to the temperature series, the precipitation series from Norwegian Arctic stations show quite a different development over time (Fig. 4). This is because precipitation varies over a smaller spatial scale than temperature does. However, the series do have features in common; all show a positive trend throughout the period, and the three longest have been trend tested and show a statistically reliable increase in the annual precipitation from the

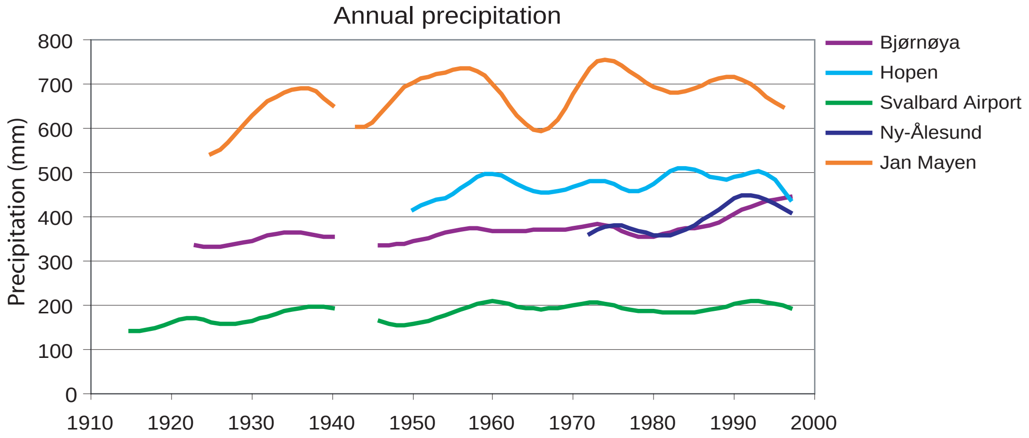

Fig. 4.
Annual precipitation at Norwegian Arctic stations. The time series have been smoothed and show variations on a 10-year scale.

onset of measurements up to 2000. Table 1 shows that at Svalbard Airport it is particularly the summer and autumn precipitation that has increased. However, this varies from station to station.

Other stations in the Atlantic sector of the Arctic also show a statistically reliable increase in precipitation through the 20th century, but a rise of over 2 % per 10 years is only found in the series from Svalbard Airport and Bjørnøya (Førland et al. 2002). The increase at these stations is also greater than the average increase in precipitation at high northern latitudes (Hulme 1995), and greater than the increase in precipitation on the Norwegian mainland during the last 100 years.

2.2.3 Radiation

Series of annual total global radiation, annual short-wave net radiation, annual long-wave net radiation and annual total net radiation from Ny-Ålesund (Fig. 2) are available from 1974, inclusive. The first two series show no trend, but long-wave net radiation shows a negative trend which is also reflected in the total net radiation. However, a number of problems exist. The data series have many large gaps, the station has been moved, and the instruments have been modernised. The data therefore need more careful examination to be reasonably certain that the negative trend in the long-wave radiation is not due to a calibration error, or some other form of discontinuity.

2.2.4 Atmospheric circulation

To be able to interpret the trends in the MOSJ indicators, it is essential to know the variation in the atmospheric circulation in the area. MOSJ has no indicator that covers the atmospheric circulation, but there are long time series for two indicators which influence the air currents in the region. The North Atlantic Oscillation (NAO) (Hurrel 1995) gives oscillations in the difference in air pressure between Iceland and the Azores. When the difference is large (positive NAO index), a comparatively large amount of mild, moist air is generally transported north-eastwards across the North Atlantic towards the eastern part of the Arctic. When the difference is small (negative NAO index), less warm air is transported. The average NAO index for December to March has proved to be a useful climatic index, and it is this winter value that is termed the NAO index below. The Arctic Oscillation (AO) (Thompson & Wallace 1998) is defined on the basis of the sea-level pressure field north of 20° N in winter, and it has been found that these two winter indices are highly correlated ($R \geq 0.8$). Both show a negative trend from 1900 to 1970, and quite a strong positive trend from the 1960s until 2000. Over this period as a whole there is no statistically reliable trend in these indices. Table 2 shows trends in the AO index in periods with statistically significant temperature trends.

Table 2
Linear trends in the AO winter index and the air temperature at Svalbard Airport. Trends that are statistically reliable (5 % level) are shown in bold face. Units: index unit per 10 years (AO), °C per 10 years (temperature).

PERIOD	AO-index	T, Svalbard Airport
1900-2000	+0.02	+0.14
1912-1940	-0.07	**+1.83**
1930-1970	**-0.21**	**- 0.66**
1960-2000	**+0.42**	**+0.49**

2.3 Climatic variations in the cryosphere

2.3.1 Mass balance of glaciers

More than 60 % of the land area in Svalbard is covered by glaciers. Hagen et al. (1993) estimated that the total volume of ice in Svalbard is approximately 7000 km^3. The storage of fresh water in these glaciers has great significance regionally, partly for the water balance in rivers and the influx of fresh water to fjords. However, melting of glaciers in Svalbard may also have global repercussions through sea-level rise and effects on the formation of deep water in neighbouring seas. Liestøl (1988) showed that most glaciers in Svalbard have been in almost continuous retreat since the end of the Little Ice Age. The glaciers on land have retreated between 1 and 2 km in the last hundred years (Hagen et al. 2003).

Mass balance measurements give more extensive and reliable information about changes in the state of glaciers than studies of glacier fronts. Mass balance is defined as the difference between accumulation and ablation (mostly melting and calving) of snow and ice over a specific period, and is a climatic indicator which is primarily dependent on precipitation in the form of snow, and on temperature. The net balance in Svalbard is significantly correlated with the summer temperature and to a lesser degree with the winter precipitation (Hagen et al. 2003). Regionally, the mass balance is also affected by the wind direction and the height above sea level. Sand et al. (2003) have uncovered large gradients in snow accumulation through the winter on Spitsbergen. From 1997 to 1999, approximately 40 % more snow fell on the east coast than on the west coast.

In Svalbard, systematic mass balance measurements have only been made on glaciers that take up approximately 0.5 % of the total ice-covered area (Hagen et al. 2003). The longest series of measurements have been made on two small glaciers (Austre Brøggerbreen and Midtre Lovénbreen) near Ny-Ålesund (Fig. 2). These measurements show a sinking mass balance since they started at the beginning of the 1960s (Fig. 5). All told,

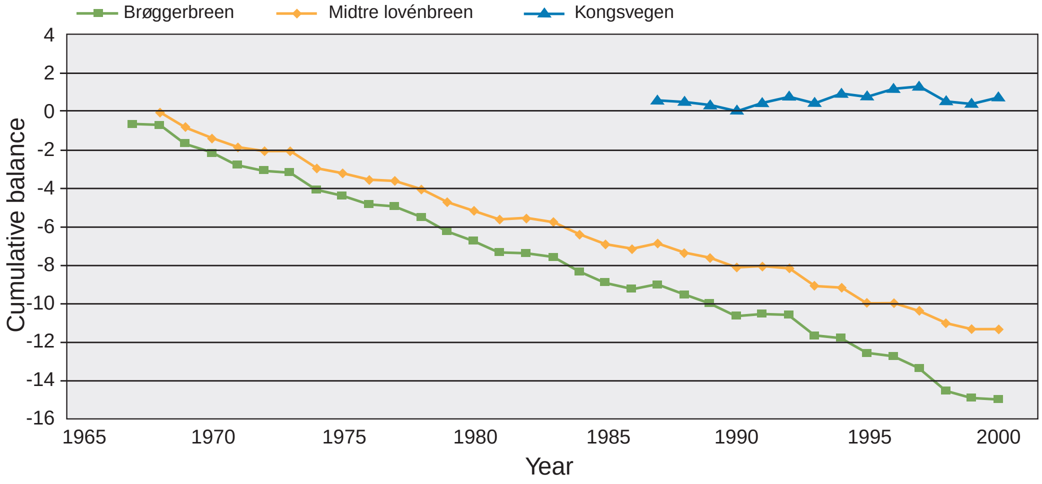

Fig. 5.
Cumulative net mass balance for three glaciers near Ny-Ålesund (Brøggerbreen (from 1967), Midtre Lovénbreen (from 1968) and Kongsvegen (from 1987).

approximately 10 % of the mass of these glaciers has been lost in this period. The winter balance has been stable, but there have been great variations in melting in summer. The Kongsvegen glacier stretches over a much greater span of altitude than the other two glaciers, which is the main reason for its weakly positive balance (Fig. 5).

2.3.2 Sea ice

The extent and thickness of sea ice are determined by processes in the sea and the atmosphere, which also contribute to determine the climate in this region. At the same time, the extent of the ice will itself have an effect on the climate in the Arctic. The presence of sea ice means that less solar radiation is absorbed in the sea. The ice also effectively blocks the heat exchange between the sea and the atmosphere. Changes in absorption and heat exchange between sea and atmosphere will greatly influence the climate regionally and globally.

The latest IPCC report (IPCC 2001, Chap. 2) emphasised that the extent of sea ice is a sensitive index for global warming. Measurements from satellites have recorded a reduction in the ice cover of –2.8 ± 0.3 % per decade from 1978 to 1996 (Parkinson et al. 1999). This reduction was greatest in the Eurasia Basin of the Arctic Ocean, and was most pronounced in summer. By combining satellite data with other data sets for ice distribution, the IPCC report (IPCC 2001) ascertained that the summer reduction, which is primarily responsible for the negative trend revealed by the satellite measurements, has been present throughout the second half of the 20th century. In autumn and winter, there has been only a weak, uncertain negative trend in the extent of pack ice since 1970. Analyses performed by Johannessen et al. (1999) show that the area covered by thick perennial ice has decreased more than twice as rapidly as the area of total ice cover and that the ice volume therefore depletes much more rapidly than the ice-covered area. The problems in establishing consistent, long data series of ice thickness have been demonstrated recently by Holloway & Sou (2002) who showed that the 50 % reduction in ice thickness in recent decades, which measurements from submarines had indicated, is incorrect. Their work revealed that internal redistribution of ice in the Arctic Ocean may explain why submarine measurements overestimated the reduction in ice thickness. The reduction in ice thickness is assumed to be on approximately the same scale as the reduction in its extent, i.e. about 10 % in the last 25 years.

Vinje (2001) used a combination of observations from vessels and satellites to map the extent of sea ice in April in the waters west and north of Norway from 1864 to 1998 (Fig. 6). These data are used by MOSJ. Despite great variations from year to year, there is a clear, statistically reliable negative trend throughout this period. For the area as a whole, the regression line suggests a reduction of 33 % over the entire period. Almost half of this reduction took place before 1900. Table 3, however, shows that the reduction is also statistically reliable after 1900.

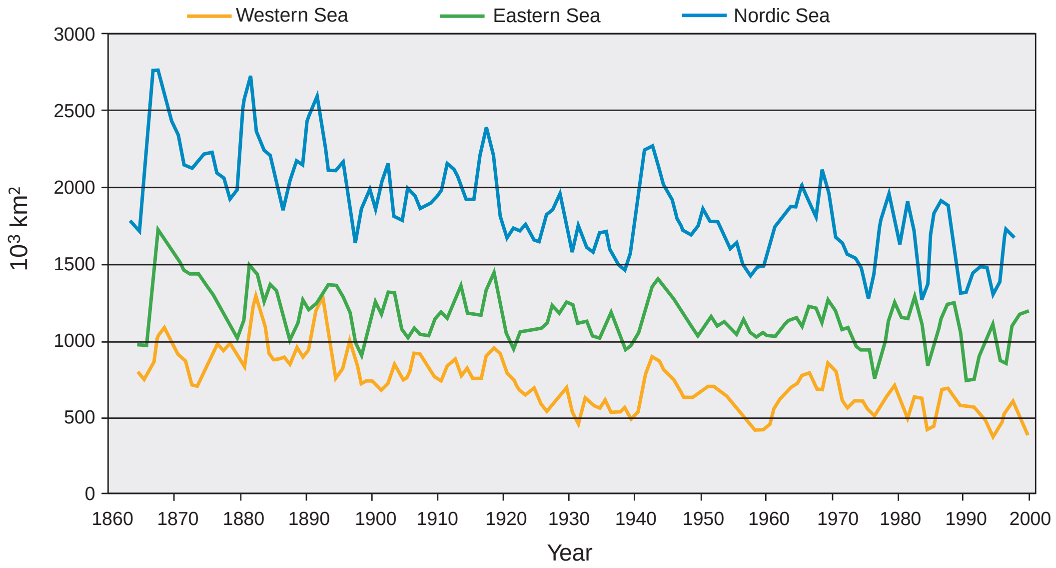

Fig. 6.
The extent of sea ice in April (maximum ice extent) in the area west and north of Norway ("Eastern Sea" = 30° W-10 ° E, "Western Sea" = 10° W-70 ° E, "Nordic Seas", here, means the whole area). The data have been compiled from satellite observations after 1966 and observations made from sealing vessels before 1966. (From Vinje 2001)

The regression lines for the sub-areas west and east of Spitsbergen show that the former has had a greater reduction (46 %) than the latter (24 %). Observations from vessels give, on average, slightly less (ca. 6 %) ice cover than satellite observations. If an adjustment had been made for this, the long-term trends would have become more pronounced.

Systematic measurements of the thickness of sea ice in the area we are concerned with are available from the Fram Strait from 1990 onwards (Vinje et al. 1998). These have been obtained using sonar equipment which records all the ice that drifts over the instrument. They suggest a weak (not statistically reliable) negative trend in ice thickness.

Table 3
Linear trends in the ice cover in April. Trends that are statistically reliable (5 % level) are shown in bold face. Units: 103 km^2 per 10 years (ice area), °C per 10 years (temperature).

PERIOD	Ice cover in April, western sub-area	Ice cover in April, eastern sub-area	T. Svalbard Airport
1900-2000	**-26.2**	**-17.1**	+0.14
1912-1940	**-123.4**	**-81.8**	**+1.83**
1930-1970	+25.5	+6.5	**-0.66**
1960-2000	**-55.2**	-32.6	**+0.49**

2.4 Climatic variations in the sea

2.4.1 The Nordic Seas

The interaction between sea and atmosphere in the North Atlantic is responsible for transport of heat that results in the Nordic countries being, on average, 5-10º C warmer than other areas of land at the same latitude. A major contribution comes from the heat transport in the sea, and variations in the ocean currents entering the Nordic Seas (the Greenland Sea and the Norwegian Sea, Fig. 1) may therefore be vitally important for the climate in our areas (Fig. 7). Data from the Nordic Seas are not yet included in the MOSJ project, but according to Blindheim et al. (2000) the distribution of the water masses here have gradually changed since 1960. This has manifested itself through the development of a layer of arctic water that originated in the Greenland Sea and has subsequently spread over the entire Norwegian Sea, and by the water layer of Atlantic origin having become fresher. In the waters closest to Norway, this has resulted in the polar front having moved eastwards, nearer the coast. The influence from the Arctic has resulted in cooling of the uppermost water layers.

According to Østerhus & Gammelsrød (1999), the deeper water layers in the Nordic Seas are becoming warmer. Data collected by the weather ship ”MIKE”, positioned at 66º N 2º E, have been analysed since measurements started in 1948, until 1997. Statistically reliable warming started in 1987 at a depth of 2000 m and in 1990 at 1200 m. The highest temperatures for the whole period from 1948 to 1997 were measured in 1997. The warming can be explained by the formation of deep water in the Greenland Sea having been reduced during the 1980s. This formation is part of a global thermohaline circulation, which is an important link in the global climate system (Aagaard & Carmack 1989).

2.4.2 Fram Strait

In the Fram Strait, between Spitsbergen and Greenland (Fig. 7), there is both northward transport of warm Atlantic water to the Arctic Ocean (the West Spitsbergen Current) and southward transport of pack ice and polar water (the East Greenland Current). Variations in the circulation here may have a great influence on the total volume and extent of pack ice, on heat transport to the Arctic Ocean (Steele & Morison 1993, Steele & Boyd 1998), and on the amount and location of deep-water formation in the Nordic Seas (Dickson et al. 1996).

Sporadic measurements of temperature and salinity in the Fram Strait started as early as the beginning of the 20th century. The Russians began more or less regular measurements in the 1950s. The measurements in the Fram Strait can be found on the MOSJ Internet pages (miljo.npolar.no/mosj/) as 10-year mean values. They show that the difference between summer and winter values has decreased. In winter, no statistically reliable temperature trend

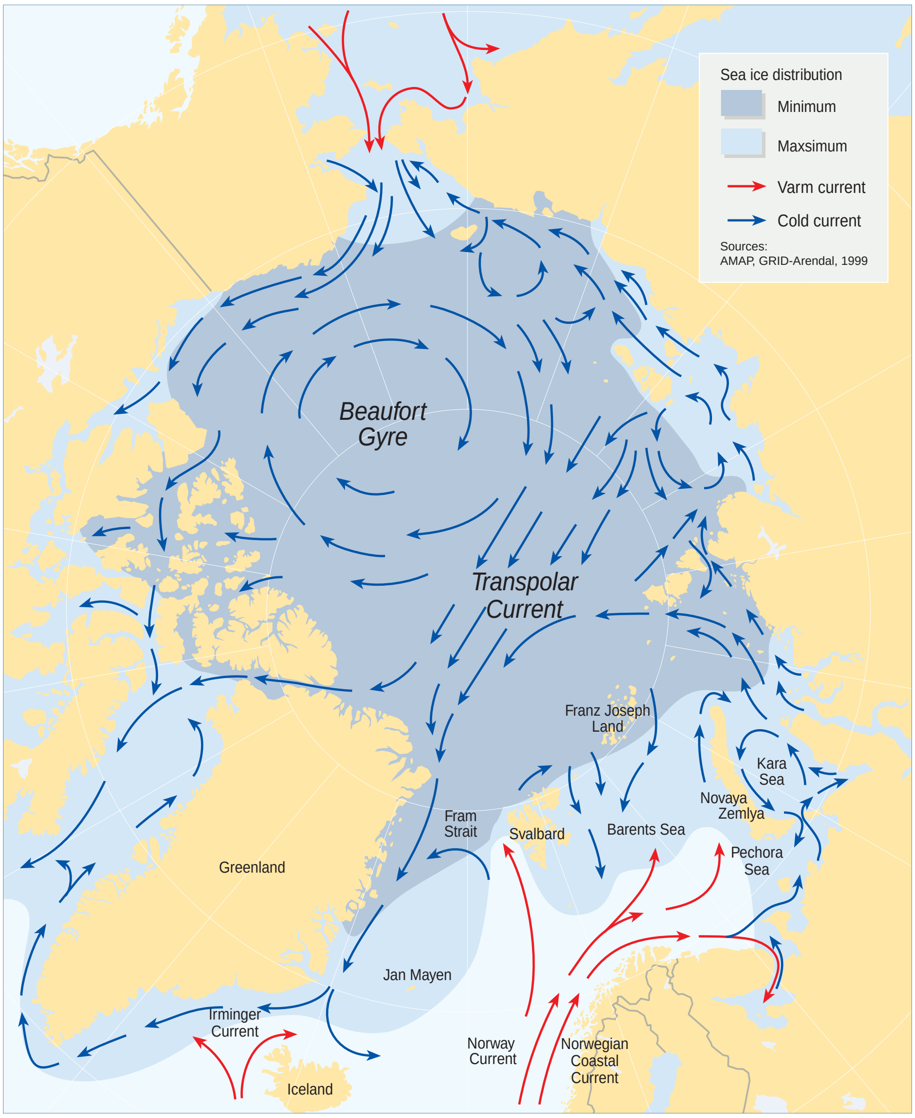

Fig. 7.
The most important ocean currents in the area covered by MOSJ.

exists, but the sea water became less saline from 1950 to 1980. In summer, the water masses became both colder and less saline from 1950 to 1990, whereas during the 1990s the surface water in summer became warmer and the reduction in salinity in the upper layers was most significant. Hence, the 1990s show statistically significant changes in summer for both the temperature (warmer) and the salinity (fresher) of the upper water layers compared with 1950-1990.

2.4.3 Water-level (sea-level) measurements at Barentsburg, Vardø and Tromsø

The water level in the sea is affected by many factors, including tidal water, air pressure, wind, ocean currents, the temperature and salinity of the sea water, the supply of fresh water, and land uplift after the last Ice Age. In the Arctic, variations in the ice cover will also affect the water level. Because the height of the water level is a result of many climatic indicators, water-level measurements at Barentsburg, Vardø and Tromsø are included in the MOSJ programme. The measurements at Barentsburg and Tromsø started around 1950. Those in Vardø began in 1984 and have therefore not been trend tested. A negative trend in the water level can be observed at both Barentsburg and Tromsø, and this was particularly marked from 1980 to 2000.

2.5 Relationships between variations in the atmosphere, ice and sea

Trend analyses of temperature series from Norwegian stations in the Arctic and the AO (Arctic Oscillation) index for December-March (Table 2) suggest that changes in the atmospheric circulation (rising AO index) may be partly responsible for the rise in temperature in the region from the 1960s to 2000. This fits into a regional pattern (Serreze et al. 2000). Rigor et al. (2000) estimated that more than half of the warming in eastern parts of the Arctic Ocean in the last 20 years may be associated with the AO. However, the warming earlier in the century cannot be explained in this way. This was pointed out by Hanssen-Bauer & Førland (1998), who found a weaker relationship between the atmospheric circulation and the rise in temperature in the Norwegian Arctic early in the 20th century than has been seen in the last 30-40 years. Correlation analyses (Table 4) also show that the relationship between temperature and the AO index, and likewise between the ice cover and the AO index, have been strongest in this last period. Correlation analyses between the air temperature and the extent of pack ice (Table 5) show that the air temperature correlates better with the area of ice than with the AO. This may imply that the relationship between the AO and the air temperature determines much of the influence of the AO on the extent of pack ice.

Hanssen-Bauer & Førland (1998) showed that the increase in precipitation in Svalbard during the 20th century can largely be linked to variations in atmospheric circulation. More local circulation indices than the NAO and AO indices must, however, be invoked to explain local shifts in precipitation.

It is well known that the extent of the pack ice over periods of weeks and months is largely determined by the regional wind field, and hence the distribution of pressure. Variations in the thickness and extent of the ice from year to year may also to some extent be caused by changes in the atmospheric circulation (Holloway & Sou 2002). Both Deser et al. (2000) and Smedsrud & Furevik (2000) stated that the changes in the sea ice in the Arctic from about 1960 are strongly linked to the AO. However, the heat transport in the sea through the Fram Strait and the Barents Sea will have an influence on the volume of ice (Steele & Morison 1993, Steele & Boyd 1998).

Transport in the sea may also be partly linked to the North Atlantic Oscillation (NAO). Variations in the NAO winter index may explain approximately 60 % of the variance in the annual volumetric outward flow of ice from the Fram Strait since 1976, and the result of the combined sea and ice models shows the same as the observations (Dickson et al. 2000). Nevertheless, great variations in the transport of ice and fresh water also occur that are not related to the NAO. One example is the large salt anomaly in the 1960s, which occurred in a period when the NAO winter index was extremely low. Such events are of comparatively short duration, but the flow of fresh water is comparable in volume to the maximum ice transport observed during the 1990s, for example. The increase in precipitation and the possible increase in fresh water reaching the Arctic Ocean from surrounding large rivers may have helped to change the transport of fresh water. Glacier meltwater may contribute locally, but the volume will be small in a global context. The freshwater budget in the Arctic affects the formation of deep water in the North Atlantic, and may therefore play a key role in global warming (Walsh et al. 1998).

The cooling of the uppermost water layer in the Nordic Seas may be linked with changes in the NAO index (Blindheim et al. 2000).

Table 4
Correlation coefficients between the AO winter index and temperature and ice data in various periods.

Period	T_{SvaL}/ AO	$T_{Bjørn}$/ AO	T_{JanM} / AO	IS_{west} / AO	IS_{east}/AO
1912*-1999	-0.25	-0.25	-0.12	-0.20	-0.49
1912-1940	-0.24			0.01	-0.44
1930-1970	-0.31	-0.26	-0.16	-0.13	-0.30
1960-1999	-0.33	-0.34	-0.25	-0.44	-0.61

*: Analyses which include data from Bjørnøya and Jan Mayen started in 1920 and 1921, respectively.

Table 5
Correlation coefficients between temperature and ice data.

Period	T_{SvaL}/ IS_{west}	T_{SvaL}/ IS_{east}	$T_{Bjørn}$ / IS_{west}	$T_{Bjørn}$ / IS_{east}	T_{JanM}/ IS_{west}	T_{JanM}/ IS_{east}
1912*-1999	-0.53	-0.54	-0.40	-0.43	-0.49	-0.33
1912-1940	-0.67	-0.75				
1930-1970	-0.50	-0.46	-0.49	-0.47	-0.59	-0.53
1960-1999	-0.49	-0.54	-0.39	-0.45	-0.62	-0.46

*:Analyses which include data from Bjørnøya and Jan Mayen started in 1920 and 1921, respectively.

There is also a close relationship between the breadth of the Norwegian branch of the North Atlantic Current, the Norway Current (Fig. 7), and the NAO winter index from the 1960s to 2000. The effect of the wind and the eastward shift of arctic water also seem to be the main reasons for the water masses in eastern areas having become fresher.

The reduced contrast between summer and winter observed in the Fram Strait may be caused by several factors. For instance, the maximum temperature of the sea water is connected with the intensity of the West Spitsbergen Current which, in turn, is determined by changes in the atmospheric circulation. Swift et al. (1997), Grotefendt et al. (1998), Blindheim et al. (2000) and Dickson et al. (2000) have all reported annual variations in the West Spitsbergen Current at Sørkapp, and in particular remarked on the relationship between annual variations in the temperature at Sørkapp and corresponding variations in the NAO winter index. At the beginning of the 1990s, a warming of the water layer of Atlantic origin was observed in the Eurasia Basin of the Arctic Ocean. Blindheim et al. (2000) thought that the rise in temperature in the West Spitsbergen Current since 1960 alone might explain the warming of the Arctic Ocean. Grotefendt et al. (1998) and Dickson et al. (2000) explained the warming in terms of a rise in the temperature and volume of the water masses feeding into the Arctic Ocean through the Fram Strait and from the Barents Sea. According to Dickson et al. (2000), there is a warmer and stronger influx of Atlantic Ocean water to the Arctic Ocean when the NAO index is high. The MOSJ data can confirm that the West Spitsbergen Current was more intense in the period with a high NAO index. The salinity decreased in both passages as the NAO moved from a negative phase in the 1960s to a positive phase in the 1990s. This was related to increased quantities of fresh water and a greater volumetric flow of ice through the Fram Strait from the Arctic Ocean (Vinje et al. 1998), and, moreover, less ice throughout this period (Deser et al. 2000).

The variations in the water-level measurements are strongly correlated with variations in the NAO index. The negative trend in the measurements may largely be explained by changes in atmospheric forcing and reorganisation of the thermohaline circulation in the Nordic Seas. Details regarding interpretations of water-level data may be found on the MOSJ web pages (http://miljo.npolar.no/mosj/).

We conclude that variations and trends over the last 30 years or so in air temperature, extent of sea ice, sea temperatures and salinity in the Nordic Seas, transport of Atlantic water into the Arctic Ocean, volume of ice transported from the Arctic Ocean and the water level have been partially connected with the NAO and AO indices. However, some of the variations cannot be linked with either the NAO or other circulation indices. There is, moreover, reason to assume that the relationships with the NAO are not robust in the long term. For instance, the warming of the Arctic before the 1930s was not linked to either the NAO or the AO.

2.6 Ozone layer

The ozone layer is situated high in the atmosphere, in what is called the stratosphere. The breakdown of ozone may occur because chlorofluorocarbons (CFCs) and halons reach the stratosphere due to human activities. A feature these substances have in common is that under special conditions they are able to break down ozone. The thickness of the ozone layer varies for natural reasons, too. Major volcanic eruptions, during which particles and gases are ejected all the way up to the stratosphere, may have a negative impact on the ozone layer. One of the largest volcanic eruptions in the 20th century took place in June 1991 in the Philippines when Pinatubo erupted violently. Large amounts of sulphur dioxide (SO_2) were emitted into the stratosphere where they gradually became oxidised to sulphuric acid, which collects in small droplets. Chemical reactions take place within these droplets and they activate passive chlorine and bromine compounds which, in turn, can break down ozone. A reduction in the quantity of ozone was observed following the Pinatubo eruption.

Instruments placed on Zeppelinfjellet in Ny-Ålesund have detected, and to some extent been able to quantify, the thinning of the ozone layer that has taken place in the Arctic during the 1990s. Some work is still required before the analysis is complete, but preliminary results show that the ozone layer has depleted during the 1990s relative to the mean for 1984-1991 (Høiskar et al. 2002). Figure 8 shows that ozone depletion in the Arctic varies greatly from year to year. In 1997, the thickness of the ozone layer above Ny-Ålesund was, at worst, reduced by approximately 40 % relative to the mean for 1984-1991, whereas no significant breakdown occurred in 1998.

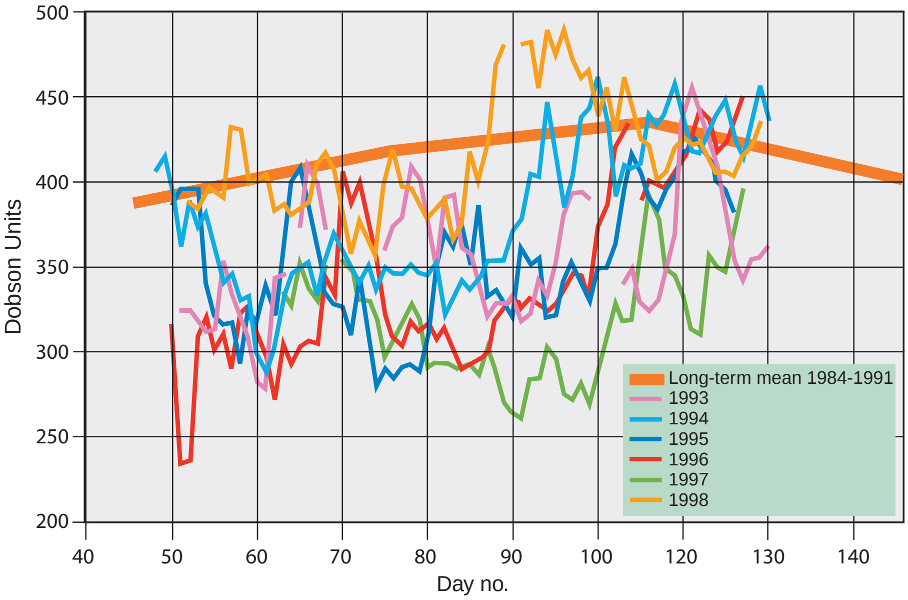

Fig. 8.
Ozone observations carried out by SAOZ (the DOAS instrument) in Ny-Ålesund. The thick red curve represents the long-term mean for 1984-1991. The figure clearly shows that all the years covered here have experienced substantially less ozone than normal, especially 1997 when the values also remained low longer than in the other years. (From Britt Ann K. Høiskar and Geir Braathen, NILU)

2.7 Possible links between climate and ozone problems

Ozone depletion results in less ultraviolet (UV) radiation being absorbed in the stratosphere. Hence, the temperature there becomes lower than it otherwise would be. This may influence the circulation in the higher atmospheric strata which, in turn, may affect the circulation in the lower layers of the atmosphere. One hypothesis is that ozone depletion may, in this way, have an effect on the AO and thus on the climate.

On the other hand, climate changes may influence the breakdown of ozone. An increase in the greenhouse effect gives higher temperatures at ground level, but lower temperatures in the stratosphere, since more heat radiates from there out to space. The lower temperature may result in more frequent formation of polar stratospheric clouds which, in turn, lead to breakdown of ozone. Changes in the circulation pattern of the atmosphere may also affect the thickness of the ozone layer.

A reduction in total ozone helps to increase the UV radiation on the Earth's surface. However, changes in cloud cover and snow cover also affect UV doses. Measurements show that clouds may reduce the monthly means of UV doses by up to 40 %, while reflection from snow on the ground can increase them by more than 20 % in April and May. Systematic changes in snow and cloud conditions may thus affect the UV doses even though the ozone layer remains unchanged. It is therefore vital that both ozone and UV radiation are measured very precisely.

UV radiation may periodically be an important regulatory factor for plankton production in the sea. Measurements on ice in Kongsfjorden show that the fjord is very transparent for UV radiation when little snow covers the sea ice in the period shortly before the marine spring bloom of plankton starts (Winther et al., submitted). If, at the same time, there are few clouds and low ozone values, episodes of abnormally high UV radiation may arise. Direct detrimental effects have been demonstrated on both phyto- and zooplankton, even though the organisms have a significant potential for UV protection. The quantity of dissolved organic material is decisive for UV effects in the sea. Changes in the supply and concentration of dissolved organic material, for instance as a consequence of altered temperature and precipitation conditions, may have far greater significance than a 20-30 % reduction in stratospheric ozone. Any reduction in primary production will necessarily have consequences higher up the food chain, and also influence the uptake of CO_2 in the sea.

2.8 Are the observed variations in climate and ozone human induced?

2.8.1 Climatic variations

Our understanding of the warming in the Arctic from 1900 up to the 1930s and the cooling from the 1930s to the 1960s is inadequate. However, on the global scale, we believe the climatic variations in this period can be explained by variations in natural climate forcing (Tett et al. 1999), and we do not have evidence to claim that these variations result from human influence. On the other hand, the warming in the Arctic from the 1960s up to the present day is part of a global warming that is at least partly caused by human emissions of greenhouse gases (IPCC 2001). The air temperature in the Arctic has typically risen more than the global mean temperature in this period, and this is probably partly a response to the feedback which the ice extent gives (see 2.3.2).

However, we have also seen that the warming of the Arctic over the last 30 years may be partly linked to a positive trend in the AO index. Trends in a number of other climatic variables may also be linked to the trend in the AO or other indications of atmospheric circulation. Hence, an important question is whether the variations in atmospheric circulation in general, and in the AO in particular, can be linked to human-induced climate changes. This is still not clear. The AO is basically an internal oscillation in the climate system, which can probably be influenced by both natural and anthropogenic climate forcing. Many climate models give some increase in the AO as a response to increasing concentrations of greenhouse gases, but only one fully linked climate model gives a trend in the AO of the scale observed in the last 30 years. Shindell et al. (1999) and Moritz et al. (2002) have suggested that this may be because the climate models have poor vertical solution high in the atmosphere (the stratosphere) and can therefore not reproduce a self-intensifying mechanism which is part of the AO and which involves reciprocal influences between the stratosphere and the lower strata in the atmosphere. Any changes in the ozone layer may also have an effect on the AO (see section 2.7), although Shindell et al. (1999) claimed that it is unnecessary to consider such changes to simulate the climate changes we have seen so far. More research is required before final conclusions can be drawn about this, and it is thus impossible to say how much of the climate change in the Arctic during the last 30 years has been caused by man.

Nonetheless, it must be remembered that the intensified warming we have seen over the Arctic, the increase in precipitation at high latitudes, the substantial reduction in the ice cover (particularly in summer), the fresher surface water in the Nordic Seas and indications of reduced formation of deep water are all qualitatively in agreement with the responses which the best climate models give for human-induced global warming.

2.8.2 Ozone variations

The short series of measurements at Ny-Ålesund provides no basis yet for ascertaining whether, and if so to what extent, man is responsible for the breakdown of ozone during the 1990s. However, the ozone breakdown, too, is qualitatively in agreement with the result of models which consider human emissions of substances that break down ozone.

3 Assessment in relation to national environmental targets

3.1 Introduction

A recent White Paper (St.meld. 24 (2000-01)) presents strategic objectives and key figures associated with problems of ozone and the climate. This chapter discusses this in the light of the scientific assessment.

3.2 Climate

The objective to stabilise the concentration of greenhouse gases is good, but the level on which the concentration is stabilised will be decisive for the climate (see, for example, IPCC 2001, p. 76). It must, moreover, be borne in mind that any such stabilisation will, at the earliest, become noticeable in the second half of the 21st century. Because of this sluggishness in the climate system, it is vital that climate measures are initiated as soon as possible.

The key figures are wisely defined. Since the climate models give the strongest warming signal in the Arctic, consideration should be given to the inclusion of key figures based on observations in this region. Such key figures might involve the extent of sea ice in April and August over both the whole Arctic and the waters north and west of Norway.

3.3 Ozone layer

This strategic objective is clearly formulated and the key figures are wise. The series of ozone measurements from Ny-Ålesund is still too short to form a basis for assessing the extent to which human activity has affected the ozone layer in the Arctic. It is most important that the measurements being undertaken on Zeppelinfjellet continue so that future analyses will be able to form a basis for assessing this.

4 Advice to management authorities regarding responses

Responses to reduce emissions

The problems of ozone and climate have a global dimension that must be solved through international cooperation. It is therefore important that international agreements to limit emissions of greenhouse gases and substances that break down ozone are initiated, supported and followed up. This work has progressed far in the case of ozone. Ratification of the Kyoto Protocol is a good start as regards climate, but on its own it is inadequate to achieve the above-mentioned strategic objective.

Responses aimed at accommodation and relieving damage

The routine issuing of warnings when the ozone layer is thin is a possible response aimed at reducing damage and inconvenience linked with ozone depletion in the Arctic. As regards the climate, changes in standards for which climate data form the basis should be continuously evaluated. Infrastructure like buildings and other constructions with a long lifetime must be able to withstand expected changes in wind force, wave height, temperature, permafrost, precipitation, snow loading and icing conditions.

5 Advice regarding gaps in knowledge

5.1 Climate monitoring

Monitoring of geophysical parameters is important for several reasons:

- Such data can provide early indications if changes are taking place that call for responses or accommodation.
- They can form the basis for analyses which can strengthen or weaken existing theories and models for changes in climate and the ozone layer.
- They can be used for further research into climate and ozone problems.

The MOSJ project is collecting data from many sources, and offers opportunities to achieve awareness of, and analyse, complex signals and uncover actual causal relationships. To enable MOSJ to function optimally, it is vital that all key data are included. Long data series are specially valuable. We believe the atmospheric and oceanographic measurements collected by the weather ship ”Polarfront” (66º N 2º E) at station MIKE should be included in the MOSJ project. Moreover, one or more indicators for snow, such as snow cover and snow depth, observed at the meteorological stations which are taking part in the MOSJ project should also be included. Consideration should, in addition, be given to the inclusion of an oceanographic section that provides indications of transport to and from the Barents Sea. The MOSJ data should also include the measurements of greenhouse gases and aerosols being undertaken in Ny-Ålesund.

For monitoring purposes, it is important that long data series are preserved and continued. Changes to measuring methods which give more ”correct” measurements may reduce the value of such series if old and new measurements are not comparable. To ensure continuity in long series, parallel measurements must be carried out in connection with changes that can influence the measurements. It is nevertheless vital that quality-improving, efficiency-raising and rationalising measures for the long-term series are continually assessed as new technology and methodology become available.

5.2 Climate research

Climate research has advanced far in recent years, but knowledge is still lacking in some areas. In the context of the MOSJ project, we believe the following topics are most important:

- The relationship between global warming and atmospheric circulation. In the last 30 years, the atmospheric circulation has changed systematically in the region we are concerned with. These changes affect not only the air temperature and precipitation, but also the extent and transport of sea ice, and processes in the sea. It is still uncertain whether the circulation changes observed can be linked to climate changes caused by man. This is an important question in relation to climate changes in the North because the prevailing circulation conditions may mean at least as much for the regional climate there as global warming in itself does.

- Interactions between atmosphere, sea and sea ice. Our understanding of these interactions is inadequate. We do not know to what extent variations in one element affect the others. The relative importance of the various elements probably depends upon the time scale.

- Oceanic circulation and the extent of sea ice. Ocean currents and ice cover are of great importance for the climate in the Norwegian Arctic. Different climate models give, in some cases, greatly varying results regarding this.

- Probable future regional climate changes. Even though what are considered to be the best climate models show a large measure of agreement when it comes to the global development of climate, there are still great regional variations. Climate scenarios have been worked out specially for the region considered here, and they should be compared with other scenarios to assess which signals are robust.

- Regional changes in fluxes of greenhouse gases and aerosols. Such changes may contribute to regional changes in radiative forcing which directly, or via its effect on the global circulation, influences the regional climate.

The realisation is increasing that funding must be made available for research into the effects of climate change. We fully share this view. However, to obtain the best possible basis for such studies there is a need for continued focus on process-oriented climate research and monitoring.

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RAPPORTSERIE 123

The environmental monitoring of Svalbard and Jan Mayen – MOSJ

Part 3: Assessment of the state of the environment: ocean

By Arne Bjørge, Mette Mauritzen and Hallvard Strøm


Photo: H. Wolkers


Photo: B. Frantzen


Photo: G. Sander


Photo: M. Westh Hammer

Contents

1. Background

This assessment is based on text and data available on the MOSJ web page (//miljo.npolar.no/mosj) on 1 May 2003. To cast additional light on some of the problems pertinent to MOSJ, some information has also been obtained from Havets ressurser 2002 and Havets miljø 2003 mangler i References, AMAP reports from 1997 and 2002, and various refereed scientific literature.

The assessment of the marine environment was originally intended not to exceed 15 pages. A stringent selection has therefore been made among the proposed pressures and indicators. On the other hand, the concepts used by fisheries management and the interplay between pressures and natural fluctuations and processes have been offered special attention. Emphasis has been placed on making the text understandable without special prior knowledge in the individual fields.

The section on the polar bear has been written by Mette Mauritzen and the rest of the text by Arne Bjørge. The authors are responsible for the selection of information and the subsequent compilations, evaluations and recommendations. References are not cited for information derived from the web pages of the Norwegian Polar Institute, or other national monitoring programmes. Geir Wing Gabrielsen and Hallvard Strøm have contributed written comments on the text.

2. Status and features in the development

The ocean surrounding Svalbard and Jan Mayen is often divided into three macro-ecosystems, the Norwegian Sea, the Barents Sea and the Arctic Ocean. Unlike the other two, the Barents Sea comprises shallow water, entirely underlain by the continental shelf. The Arctic Ocean is ice covered for most of the year, and even though some fishing takes place, the area is poorly accessible to the fishing fleet. Norwegian monitoring of the fisheries and the environment of the oceans primarily focuses on the Norwegian Sea and the Barents Sea, and the description that follows centres around these macro-ecosystems.

The Norwegian Sea and the Barents Sea are extremely dynamic areas of ocean where polar and Atlantic waters meet in a continuously shifting zone of mixing called the polar front. The polar front along with oceanographic conditions near the ice margin when the ice is melting in spring and summer are extremely important for marine production in these waters. Oceanographic and climatic fluctuations mean that the productive areas change from year to year, both in area and location. The intensity (temperature and volume per unit of time) in the North Atlantic Current determines the changes. This dynamic, but natural process, is the greatest pressure on the state of the marine ecosystems in the Norwegian Arctic, and has to be a key part of the assessment that follows.

In addition, man has been responsible for a number of disturbances to the environment that have had a significant impact. Of these, fishing and hunting together exert the most direct pressure on the trophic system, affecting both its structure and the flow of energy through the food webs. They are therefore an important element when we want to assess the state and development of the Arctic marine ecosystems. Traditionally, quotas have been fixed in relation to the size and yield of the individual stock. Ecological effects on other species or on the ecosystem as such have been given little attention as a basis for regulating fisheries. Ecological effects of fishing and hunting are broadly covered in section 2.3. Arctic waters are looked upon as being undisturbed and little polluted. This opinion is also exploited in the marketing of fishery products from northern waters. However, such marketing may cut both ways because several of the most hazardous environmental pollutants accumulate in arctic marine food chains. Focus on the pollutant situation linked with marketing of foodstuffs may therefore have a negative effect. The pollutants concerned derive from emissions from local sources within the region and, to a large extent, are transported from far afield. The Norwegian Food Control Authority has drawn up dietary recommendations that include up-to-date knowledge about the incidence of pollutants in marine species. These can be found on http://www.snt.no/nytt/kosthold/introduksjon/. Here, we will confine ourselves entirely to the ecotoxicological aspects of pollution.

Fluctuations in natural conditions, fishing and hunting, together with pollution, will be taken up again in the concluding discussion regarding pressures and the current state of the environment (section 2.3). The section on pressures (section 2.1) focuses mainly on fishing, hunting and environmental pollution.

2.1 Pressures

2.1.1 Fishing and hunting

About 55 populations of molluscs, crustaceans, fish and mammals form the commercial basis of the Norwegian fishing industry. Approximately 40 of these are systematically and regularly monitored, and reference points for their protection and harvesting are also determined. Demands made regarding the principles of sustainability and precaution arising out of the Rio Conference (Rio Convention) in 1992 form the basis for the management of Norwegian fisheries. To ensure that fishing is sustainable, i.e. the stock is protected from overfishing that may in the long term result in its collapse, a lower limit (B_{lim}) has been defined for the size of the spawning stock. This threshold value is based on historical data on stocks and simple assumptions regarding the link between spawning stocks and recruitment. Correspondingly, an upper limit (F_{lim}) has been defined for mortality caused by the fisheries. If this is exceeded for a long time, the spawning stock will pass beyond its biologically safe limit (Fig. 1).

The precautionary principle presumes the existence of a buffer between the actual size of the stock and the threshold value (B_{lim}). Reference values, B_{pa} and F_{pa} (pa = precautionary approach), have therefore been defined to ensure that the stock does not fall towards B_{lim}. Whereas B_{lim} and F_{lim} are based on empirical data, the determination of B_{pa} and F_{pa} will, among other things, depend on how great a risk the management authorities in question are willing to take.

The terms cited above have been devised for use in fisheries management and are not direct synonyms of terms used in a nature conservation context. If a spawning stock passes below B_{lim}, the probability will increase that recruitment will be poorer than if it was larger. Hence, B_{pa} and B_{lim} are primary threshold values at which the quotas must be temporarily limited or set to zero, i.e. the stock is threatened as a commercial resource for a period. The threshold values give no basis for concluding that the stocks are threatened by extinction in a biological sense. The concept of "biologically safe limits" therefore appears to have another content and purpose in fisheries management than in a nature conservation context (although these concepts have not been clearly defined in nature management).

Generally speaking, the stocks of fish resources were in a sound state in our northern waters in 2001-2002 (Fig. 2). However, in

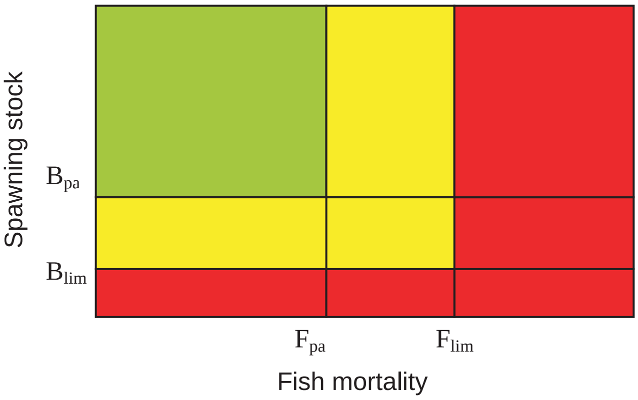

Fig. 1.
Schematic representation of reference values used in fisheries management. A stock in the green zone is within the precautionary principle area. If the stock is in the yellow zone, there is increasing likelihood that it will tip over into the red zone, which corresponds to "outside biologically safe limits".

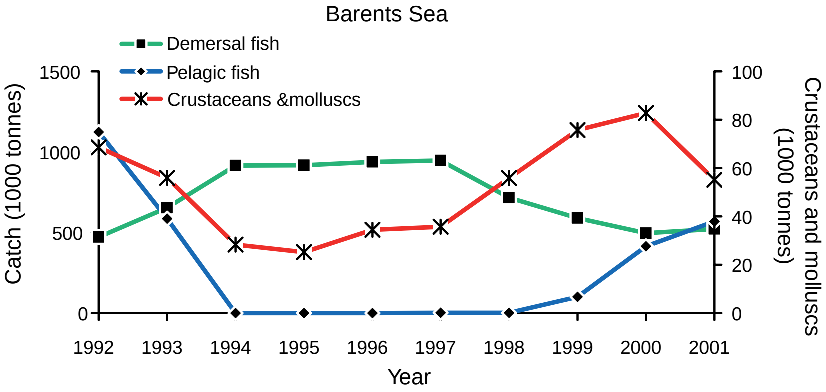

Fig. 2. The total catch of demersal fish, pelagic fish, crustaceans and molluscs in the Barents Sea in the last ten years. From Havets ressurser 2002. Iversen 2002

a period between 1994 and 1998, minimal fishing took place on the pelagic stocks in the Barents Sea. This was primarily because the capelin stock was in a "low period", significantly beneath B_{lim} i.e. outside biologically safe limits and "commercially extinct", even though this does not mean it was necessarily threatened by biological extinction.

Figures for the quantity of the individual stock fished in relation to the size of the stock and the quota fixed can be found in Havets ressurser 2003, and detailed catch statistics are published by the Directorate of Fisheries and Statistics Norway.

2.1.2 Pollution

In this assessment, emphasis is placed on two groups of environmental pollutants, persistent organic compounds and radioactivity. These groups have very different biological impacts and are dealt with separately. In addition, high concentrations of heavy metals, particularly mercury, have been recorded, among elsewhere in the muscles of minke whales in the Barents Sea and in char from the Svalbard region. Heavy metals are not a specifically Arctic problem and are not considered further in this assessment.

Persistent organic pollutants include industrial chemicals like polychlorinated biphenyls (PCBs) and hexachlorobenzene (HCB), herbicides like DDT, chlordane, aldrin/dieldrin, toxaphene, hexachlorocyclohexane (HCH, lindane), and by-products from industrial processes like polychlorinated dibenzo-dioxins (PCDDs), dibenzofurans (PCDFs), polybrominated biphenyls (PBBs) and polybrominated diphenyl ethers (PBDEs).

The physical properties of several of the most toxic persistent organic chlorine compounds result in them being picked up by the major circulation systems (both atmospheric and oceanic) in warm regions and transported to cold tracts where they are incorporated into the marine food chains. The food webs in polar regions are often highly lipid-based (fatty). The chemical properties of several of the most toxic persistent organic pollutants make them highly soluble in fats, thus helping them to accumulate in the food webs. According to Oehme et al. (1996), accumulation factors in excess of 10^5 have been observed in marine food webs. Atmospheric and oceanic transport means that polar regions (particularly the Arctic since pollutant emissions are highest in the Northern Hemisphere) will, over time, act as a "slop sink" for the persistent pollutants. If the use of a substance is banned, local sources will fall out and an initial reduction in the concentrations will be observed. Nevertheless, it can be expected that quantities of pollutants will continue to be transported to the Arctic from distant, diffuse sources for a long time.

PCBs (polychlorinated biphenyls) are synthetic products that do not occur naturally. They have several good industrial properties, for example as fluid insulation in transformers. However, they also have physical and chemical properties that make them into hazardous pollutants in the Arctic. The production of PCBs began as early as the 1920s and they achieved broad application in the industrialised countries. In the 1960s, concentrations of PCBs were recorded in the external environment and were associated with reduced reproductive abilities in, among others, seabirds and marine mammals. Restrictions in their use were introduced in North America and Europe from the early 1970s. PCBs are still reaching the natural environment, both because of leaks from waste dumps and due to the material being used in other parts of the world after the regional restrictions were introduced. PCB emissions are still taking place in Norway, too, partly due to shattering of glass when old double glazing is replaced.

Because focus was placed on the toxicity of PCBs as early as the 1960s, their harmful properties have been widely studied. PCBs consist of a group of chemical compounds that have related toxic properties. Reijnders et al. (1999) published a thorough survey of the toxic properties of PCBs and related compounds, and of their biological effects on marine mammals. The 2002 AMAP report also gives a good survey of their biological effects on seabirds and marine mammals.

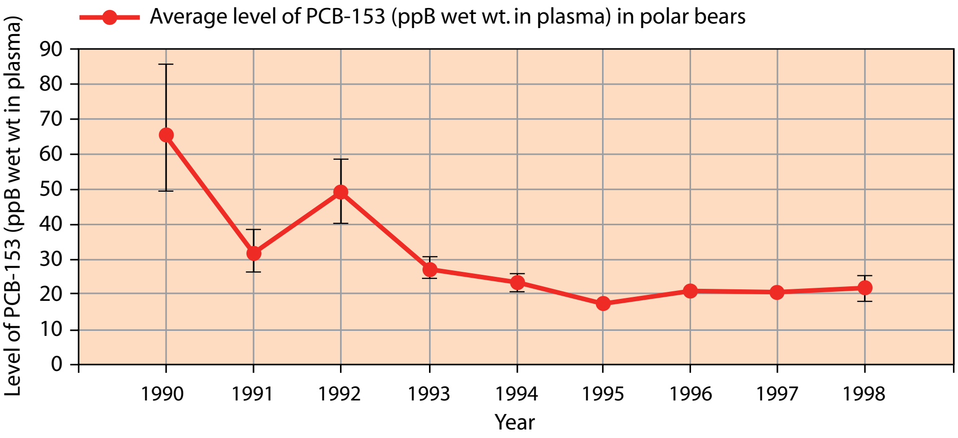

Fig. 3.
The average level ± standard deviation of PCB-153 in blood plasma from polar bears measured in the Norwegian Arctic in 1990 – 98. A linear regression model has been used that includes adjustments for lipid content in the plasma, nutritional status, age, easterly longitude for sampling and elimination through milk.

High concentrations of PCBs have been found in some species of seabirds and marine mammals in the Norwegian Arctic. However, few data sets show development over time. One time series on seabird eggs collected from 1973 to 1993 at various colonies in North Norway, Svalbard and on the Kola Peninsula coast shows a reduction in PCBs in several species of gulls and auks during this period. Another time series concerns PCB-153 in polar bears from 1990 to 1998 (Fig. 3). It shows a tendency for a drop in the concentration of PCB-153 during the first half of the series and a flattening out in the second half. The decrease in the first part of the series is statistically significant and can be interpreted as a result of the regional restrictions in the use of PCBs. More sampling is required to verify whether the concentration of PCBs has flattened out. However, large quantities are still in circulation in the environment. If the flattening proves to be real, continuous supply from old waste dumps and transport from distant sources, together with the persistence of the substance, may be likely explanations. The PCB level in polar bears in Svalbard is 2-6 times higher than in Alaska and Canada. This may be due to geographical distribution, the size of the regional emissions and differences in the large-scale circulation systems over the North Pacific and North Atlantic.

As part of the AMAP study, the Norwegian Institute of Marine Research undertook a broad investigation of the level of pollutants in lower trophic levels of the Barents Sea and coastal waters around Svalbard in 1991-1993. Both sediments and fish were studied and concentrations of PCBs and pesticides were measured in fish livers. Of the three species of fish studied, cod had the highest values. The differences between the species probably illustrate differences in feeding ecology and, hence, exposure. The average concentration in cod livers at five stations varied from 165 to 392 ng g^{-1} wet weight for PCBs, 98-223 ng g^{-1} for DDT, 75-166 ng g^{-1} for chlordane and 7-14 ng g^{-1} for HCH, respectively. It is worth noting that the highest PCB values were measured at stations dominated by water masses from the Norwegian Coastal Current. These water masses integrate local sources as far south as the North Sea and the outflow from the Baltic Sea. Whether this reflects geographical differences in PCB concentrations in the cod prey has still not been investigated, nor have geographical differences in relation to the cod migration pattern. If new sampling is undertaken, it will be interesting to see whether these geographical differences are also being maintained for a long time after the use of PCBs was banned in Europe. A study carried out by the Norwegian Polar Institute (also at low trophic levels) in the Barents Sea in 1998 to 2000 showed a rise in PCBs and pesticides with increasing trophic level. The results reflect geographical differences in that the highest concentration was found in species collected in the Arctic Ocean. Organic pollutant levels in zooplankton, fish and several species of seabirds were like those found in the Canadian Arctic.

The Institute of Marine Research has been monitoring ***radioactive isotopes*** in the sea and in marine biota as part of a national monitoring programme which started in 1999. In autumn 2002, two research vessels undertook a cruise which covered the Norwegian sector of the Barents Sea as far north as 76.5° N and the continental slope from Vesterålen northwards along the west side of Svalbard as far as 80° N. Both sediment and biological samples were collected to analyse for caesium (Cs), technetium (Tc), plutonium (Pu) and strontium (Sr). This monitoring aimed to check whether radioactivity is spreading from the Russian submarine “Komsomolets”, which was wrecked in 1989 and lies at a depth of 1660 m south-west of Bjørnøya (Bear Island), and to document any build up of radioactivity in the Arctic as a consequence of deliberate discharges from Sellafield in Great Britain. So far, no rise in the concentration of the nuclear decomposition product ^{137}C has been found in the sediment around the submarine which may indicate a leak from the “Komsomolets”. The analysis of samples of ^{99}Tc from the cruise in autumn 2002 is still incomplete. In practice, only Sellafield is the source of ^{99}Tc in our waters. Documentation of any build up of ^{99}Tc in the Barents Sea and near Svalbard will therefore be an important instrument in the task of halting the deliberate discharges. Samples of seaweed and sea water collected in Svalbard by the National Institute for Radiation Protection demonstrate a rise in ^{99}Tc during the period from 1997 to 2003.

2.2 Indicators

2.2.1 Zooplankton

Calanus finmarchicus is the species of zooplankton forming the largest biomass in the Norwegian Sea and the Barents Sea south of the polar front. Its close relation, *Calanus glacialis*, is common in arctic waters north of the polar front. These two species of copepods, together with some species of amphipods and krill, are the most important components of the zooplankton consumed by plankton-eating fish, birds and mammals. The zooplankton biomass showed a tendency to increase from 1989 to a peak in 1994, after which it became somewhat reduced until 2002 (Fig. 4).

Changes in the plankton biomass are primarily caused by variations in the influx of ocean currents from year to year. *C. finmarchicus* winters in deep water in the Norwegian Sea, but rises towards the surface in spring and may be carried by the current into the Barents Sea. In addition to variations in the pattern of ocean currents, the grazing of pelagic fish, comb jellies and jelly fish regulates the zooplankton population. The zooplankton in these waters are not harvested commercially, but the aquaculture industry is evaluating them as possible feed for its fish.

2.2.2 Shrimps

In the period from 1982 to 2002, the total stock of shrimps in the Barents Sea and the Svalbard region fluctuated between peak years when the biomass amounted to more than 300 000 tonnes and poor years when it was down to almost 150 000 tonnes. The peaks occurred about every seventh year in this period (Fig. 5).

Variations in the strengths of the year classes determine the development in the stock size, but fishing and consumption of shrimps by cod are thought to be important factors regulating the population. Attempts are being made to improve the estimates of the quantity consumed by cod.

Norway is the only nation in the North Atlantic region which does not fix a total quota for the shrimp catch. The catch is regulated through licences, minimum sizes and criteria for intermixing of fish in the catches. Shrimp catches have been comparatively large, despite the small size of the stock. This is mainly due to an increase in the capacity of the fishery. Information from Russia indicates reduced catches per hour of trawling as a consequence of a decrease in the stock. Good recruitment to the stock is expected in the years ahead, but comparatively large catches may weaken the good year classes. The distribution of sizes in the catches shows a shift towards younger shrimps. This is detrimental because female shrimps only become sexually mature at an age of five years and recruitment to the stock is directly dependent upon the number of mature females.

2.2.3 Capelin

Capelin have a short life span. They become sexually mature at the early age of 2-4 years, most spawn only once, and few reach an age of more than five years. The capelin stock has a comparatively high growth potential, partly because individuals mature early, but the population (particularly the spawning stock) in the form of biomass is liable to enormous fluctuations since it consists of very few year classes. This life-history strategy means that the capelin stock can grow rapidly when conditions are favourable, but has a corresponding facility for collapsing when conditions are poor for several successive years. These fluctuations may be very rapid. Figure 6 shows the trend in the capelin stock from 1973 to 2002 and illustrates its rapid and nearly total collapse in the mid-1980s, an almost explosive recovery from 1989 to 1990 and a new cycle of collapse and recovery during the 1990s.

Oceanographic conditions cause the fluctuations in the capelin stock, but increased grazing pressure on young capelin exerted by large year classes of herring in the 1980s (see section 2.2.4) contributed to the decline. Figure 6 also shows that the fishery in 1983-1986 must have affected the scale and speed of the collapse in the stock because the catches were roughly equal to the total stock. Prior to and during the collapse in the 1980s, larger catches were permitted than ICES recommended. From 1997 to 2003, the quotas fixed have followed the maxima recommended by ICES, and the total catches have sometimes been lower than the quota.

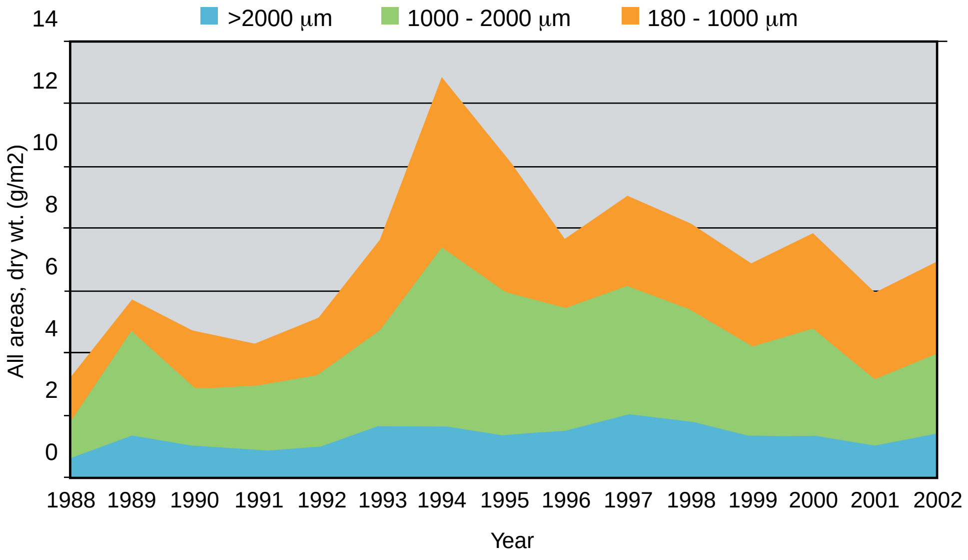

Fig. 4.
Mean values for size-fractioned zooplankton in six areas of the Barents Sea investigated in 1988-2002.

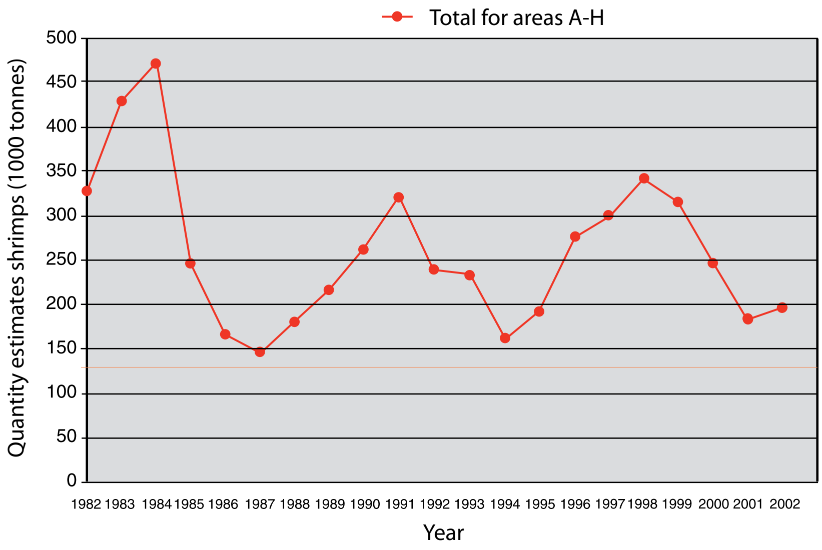

Fig. 5. Estimates of the quantity of shrimps in the Barents Sea in 1982-2002.

In 2002, the stock in the Barents Sea was declining again, chiefly as a result of two poor year classes (2000 and 2001). In addition, the growth of individuals was lower than in the previous years. The B_{lim} for capelin in the Barents Sea is stipulated at 200 000 tonnes, and the spawning stock in 2002 was 620 000 tonnes.

2.2.4 Herring

Norwegian spring-spawning herring become sexually mature at an age of 4-5 years and have a maximum life span of almost 25 years. However, herring seldom exceed an age of 15 years under the current harvesting rate. The herring stock contains far more year classes than the capelin stock, particularly the spawning portion of the stock. This functions as a buffer against rapid shifts in the stock as a consequence of one or a few unsuccessful year classes. The stock of Norwegian spring-spawning herring nevertheless collapsed during the late 1960s (Fig. 7). However, history has shown that the herring stock has been dominated by some unusually strong year classes, such as the 1904 and 1983 year classes. The latter formed the basis for the recovery of the stock after its collapse in the 1960s.

During the 1960s, the waters north of Iceland cooled, resulting in a lower production of plankton where the herring grazed. This must be assumed to have had an impact on the herring stock, but simultaneous massive overfishing contributed to its almost complete collapse from the mid-1960s. Following this, the established migration pattern also broke down. The herring used to grow up in areas along the Norwegian coast and in the Barents Sea, had grazing and wintering areas in the Norwegian Sea, and undertook a spawning migration from the Norwegian Sea to the Norwegian coast. Following the collapse, they remained in the grazing areas on the coast and particularly in the Barents Sea before migrating in to winter in the vicinity of Vestfjord, especially in Ofoten and Tysfjord. From there, they visited their spawning grounds along the coast. For a long period, the Norwegian spring-spawning herring hardly migrated out of the Norwegian economic zone. Consequently, they came completely under Norwegian jurisdiction and were ensured effective management and control, which has no doubt played an important part in rebuilding the stock. Improved monitoring and stringent, responsible regulation, especially by Norwegian management authorities, resulted in its recovery. This process really took off after one unusually strong year class (the 1983 year class) recruited to the sexually mature portion of the stock in 1987-88 (Fig. 7).

Only after the stock recovered did the herring resume their former migration to their grazing areas. They continually found more and more northerly grazing areas until this tendency was broken in 2002. An intriguing feature of the migration pattern was that only a small portion of the 1998 year class migrated to the wintering areas in Vestfjord in 2002. The remainder wintered in the open sea, as was the case prior to the collapse.

In 2002, the spawning stock was estimated to be between 5 and 5.5 million tonnes (B_{pa} = 5 mill. tonnes; B_{lim} = 0.85 mill. tonnes). The total quota for 2002 was fixed as recommended. Fish mortality in 2002 was equal to F_{lim}, which must be characterised as justifiable at a time when the spawning stock is increasing. The forecast for 2003 was that the spawning stock would be 6 million tonnes. There is therefore a basis for concluding that the stock is well within safe biological limits. However, if management is to remain sustainable, the coastal nations must reach consensus on a new herring agreement within the limits of recommended harvesting.

2.2.5 Cod

The stock of Norwegian arctic cod is substantially beneath its biological potential and the level expected to give the highest yield. The stock has been under 500 000 tonnes (which is B_{pa}) since the 1950s, except from 1992 to 1998 (Fig. 8). From a rock bottom of 120 000 tonnes in 1987, the spawning stock increased to 870 000 tonnes in 1992. The rise towards the end of this period was due to a low level of harvesting combined with the good growth of individuals and good recruitment. From 1993, the spawning stock has declined and reached a minimum of 220 000 tonnes in 2000. The decline since 1993 is a result of the low growth of individuals, increasing cannibalism and, not least, excessive fishing pressure. In 2003, the spawning stock is estimated to be 430 000 tonnes, but this increase is mainly because the fish have become sexually mature at a lower age.

From 1998 inclusive, the quota has been fixed significantly higher than recommended (Fig. 9). In retrospect, it has also transpired that the ICES recommendations were sometimes too optimistic, but there is nevertheless no doubt that the prime reason for the stock and the fishery now being outside safe biological limits is that management decisions since 1998 have not been in line with ICES recommendations. The last rise in the spawning stock was not due to a reduction in the fishing pressure, but to younger maturation which, under given conditions, may also be interpreted as a biological response to severe harvesting pressure.

For 2002, B_{pa} and B_{lim} were fixed at 500 000 and 112 000 tonnes, respectively, and F_{pa} and F_{lim} at 0.42 and 0.7, respectively. Actual fish mortality (F) was estimated to be 0.84. The catch relative to the recommended and fixed quotas is shown in figure 9. Even with the quota that was fixed, the stock is increasing and will ex-

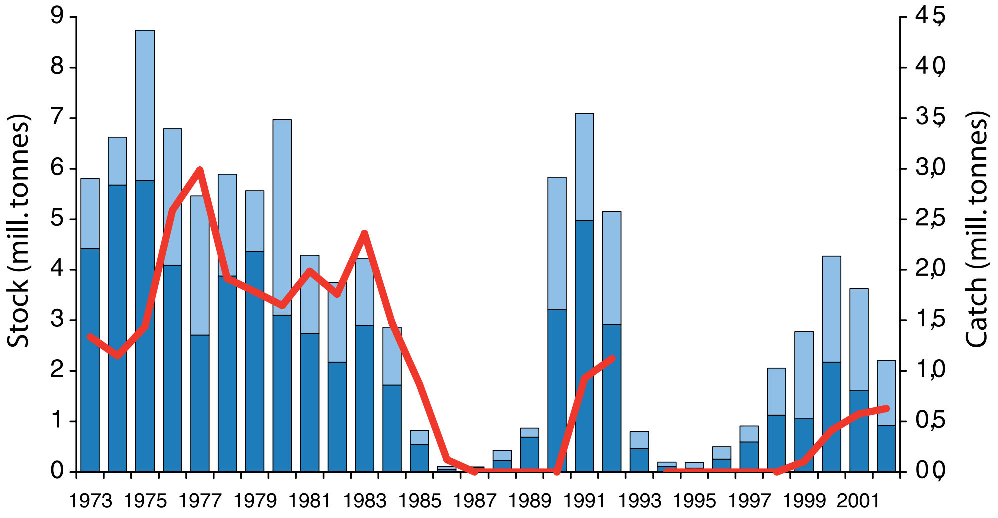

Fig. 6.
Trends in the total stock (solid bars), maturing stock (light-coloured parts of bars) and annual catches (line) of Barents Sea capelin in 1973-2002. From Havets ressurser 2003.

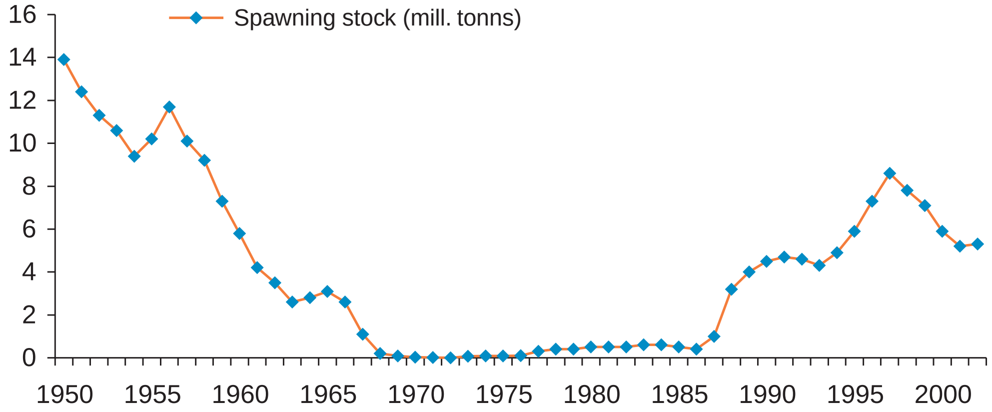

Fig. 7.
Trend in the spawning stock of Norwegian spring-spawning herring in the period from 1950 to 2002. Source: Havets ressurser 2003.

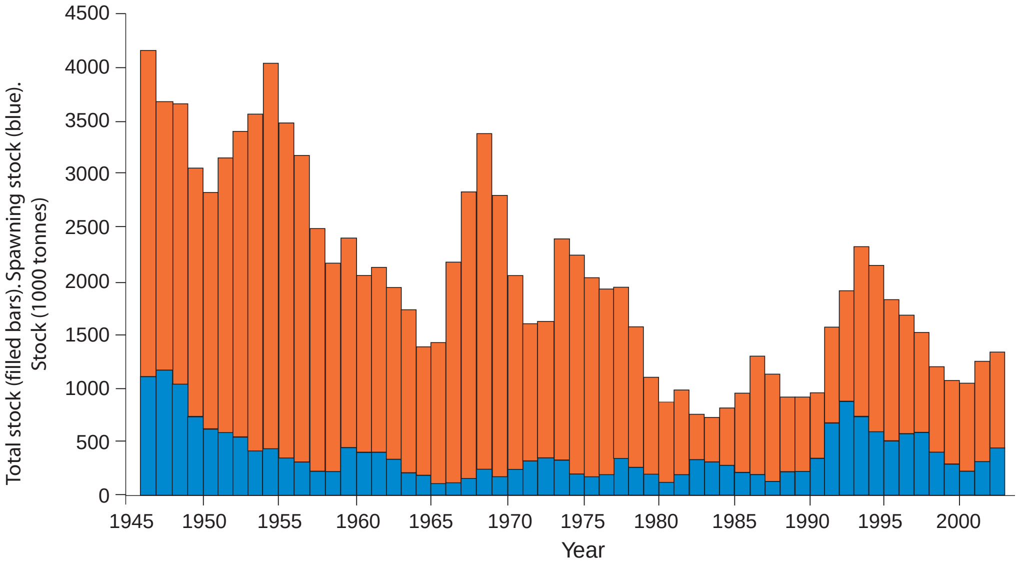

Fig. 8.
Trends in the total and spawning stocks of Norwegian arctic cod from 1946 to 2003.

ceed biologically safe limits owing to the addition from younger year classes.

2.2.6 Polar cod

Polar cod are not harvested by Norwegian fisheries. Russian vessels have fished them regularly since the 1970s, but the yield has varied. The stock was practically not fished in 1988-1992. However, this semi-pelagic species is a very important ecological component of northern and eastern parts of the Barents Sea and is therefore worth mentioning among important indicators. The pelagic component of the stock has been investigated in ice-free areas using acoustic techniques and has shown a tendency to increase from 1997 to 2001 (Fig. 10). A decline was recorded in 2002, but the 0-group index in 2002 was the highest ever recorded. No complete survey of either the stock or the 0-group takes place, and differences in the extent of the coverage may therefore produce variations from year to year in records of the stock and the 0-group.

2.2.7 Marine birds

MOSJ has identified six species of marine birds as indicators: common guillemot, Brünnich's guillemot, black-legged kittiwake, glaucous gull, ivory gull and common eider. The populations of four of these, the common guillemot, Brünnich's guillemot, black-legged kittiwake and common eider, are monitored regularly (Fig. 11).

Common guillemots occur principally on Bjørnøya (Bear Island), where the population is most definitely the largest in both Norway and the Barents Sea region. In 1986, it was estimated to amount to 245 000 breeding pairs. Unlike the Brünnich's guillemot, the common guillemot is a food specialist, and in the breeding season it lives primarily on pelagic species of fish - at Bjørnøya almost exclusively on capelin. The common guillemot population has declined dramatically in northern parts of the Norwegian Sea and in the Barents Sea, and the species is now listed in the ”Vulnerable” category of the Norwegian Red List. The population on Bjørnøya collapsed in the winter of 1986-87 owing to shortage of food, and only 10-15 % of the population (37 000 pairs) returned to the nesting ledges in 1987. The growth in the common guillemot population on Bjørnøya in recent years (Fig. 11A) must be viewed in the context of this most dramatic reduction in 1986-87. A rapid recovery was recorded the first two years, indicating that some of the breeding population survived the winter of 1986-87, but did not breed in 1987. The population was comparatively stable from 1989 to 1995, but grew again from 1996 to 2002. On the whole, it has recovered substantially since its collapse in 1986-87, but is still smaller than in 1986. However, the numbers of common guillemots in the seven selected monitoring sites are probably showing an artificially high growth rate because the species seems to be recolonising the steep cliffs before the open, flat areas, where it nested extremely densely prior to 1987.

After the little auk, the ***Brünnich's guillemot*** is the most abundant auk in Svalbard. Brünnich's guillemots breed over large parts of the archipelago, but have their main occurrences on Bjørnøya, Hopen and in the Storfjorden area (together over 70 % of the population). The Svalbard population is estimated to number 850 000 breeding pairs. Brünnich's guillemots make up the largest proportion (over 60 %) of the seabird biomass in the Barents Sea. The species is a generalist and an important predator on cape-

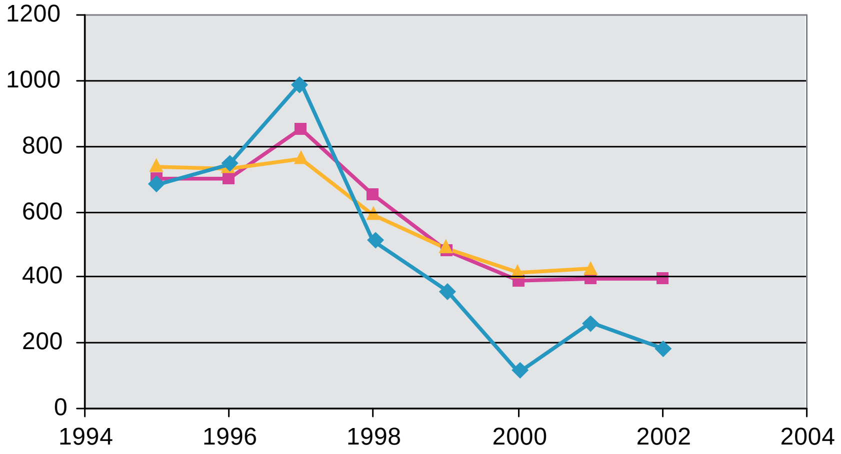

Fig. 9.
ICES quota recommendations for Norwegian arctic cod (◆), fixed quotas (■) and recorded catches (▲).

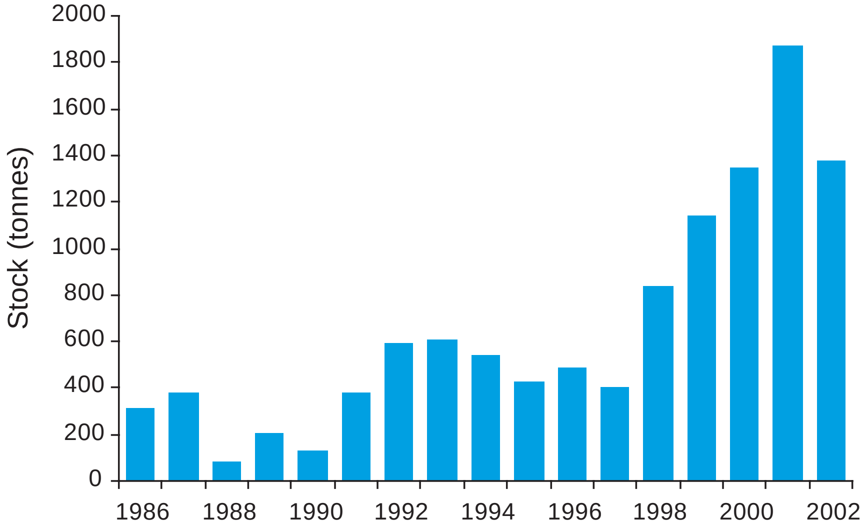

Fig. 10.
Trend in the stock of polar cod in 1986-2002 based on acoustic measurements of quantities.

lin, polar cod, pelagic amphipods and krill. The developments in the breeding population (Fig. 11B) in nine selected colonies in Svalbard are shown as the number of individuals on nesting ledges. The results of the monitoring in Spitsbergen show large annual variations in the breeding population, and no trend can be demonstrated in any of the colonies. The breeding population on Bjørnøya shows a significant negative trend during the period. However, this is the case in the sampling plots where the common guillemot shows a corresponding positive trend. This may suggest that the Brünnich's guillemot is losing out in competition with the common guillemot for space on the nesting ledges.

The ***common eider*** population in Svalbard was greatly decimated in the second half of the 19th century and the early 20th century due to extensive harvesting of eggs and down by local hunters and hunting expeditions. The collecting of eider eggs and down was banned in Svalbard in 1963. In 1973, 15 bird sanctuaries were set aside to protect the most important breeding islets for common eiders and geese. The breeding population is now estimated to be 17 000 pairs. Around 1980, the Norwegian Polar Institute started a project in Svalbard to investigate the status of the eider population, monitor its development and obtain background material to assess the effect of the management effort that had been implemented. The development of the breeding population recorded on the islands in Kongsfjorden is shown in Figure 11C. A considerable variation in the breeding population from year to year has been noted, and this is largely related to the date when the surrounding sea becomes ice free. The breeding population is larger in years when the ice departs early, because the birds are then less exposed to predation by arctic foxes, which need ice to enable them to reach the breeding islets.

Black-legged kittiwakes breed round the whole of Svalbard, but have their main occurrences on Bjørnøya, Hopen and in the Storfjorden area (together over 60 % of the population). The total population in Svalbard is estimated to be about 270 000 breeding pairs, and the species makes up approximately 13 % of the seabird biomass in the Barents Sea. Black-legged kittiwakes are responsible for about 11 % of the total consumption of food by seabirds in this area. The species is a pelagic gull which obtains its food on the surface of the sea. Important prey in the Barents Sea are pelagic species like the younger year classes of capelin and polar cod, along with crustaceans. The development in the breeding population of black-legged kittiwakes in eight selected colonies in Svalbard is shown as the number of breeding pairs (apparently occupied nests) in Figure 11D. No trends are available for any of the monitored colonies on Bjørnøya or Spitsbergen. There are indications of a decline in the breeding populations in four of the colonies, but the other five seem to be experiencing a positive development (Fig. 11D).

It has been proposed that the ***glaucous gull*** and the ivory gull should be taken up as indicator species in the MOSJ project, but funding problems have so far prevented any monitoring. However, there is cause for concern for the populations of both species. Studies on Bjørnøya have shown that the glaucous gull is highly exposed to fat-soluble pollutants. The values found there are the highest measured in this species in the Arctic. Various data sets collected in connection with the other seabird monitoring on Bjørnøya indicate a decline in the breeding population that is dra-

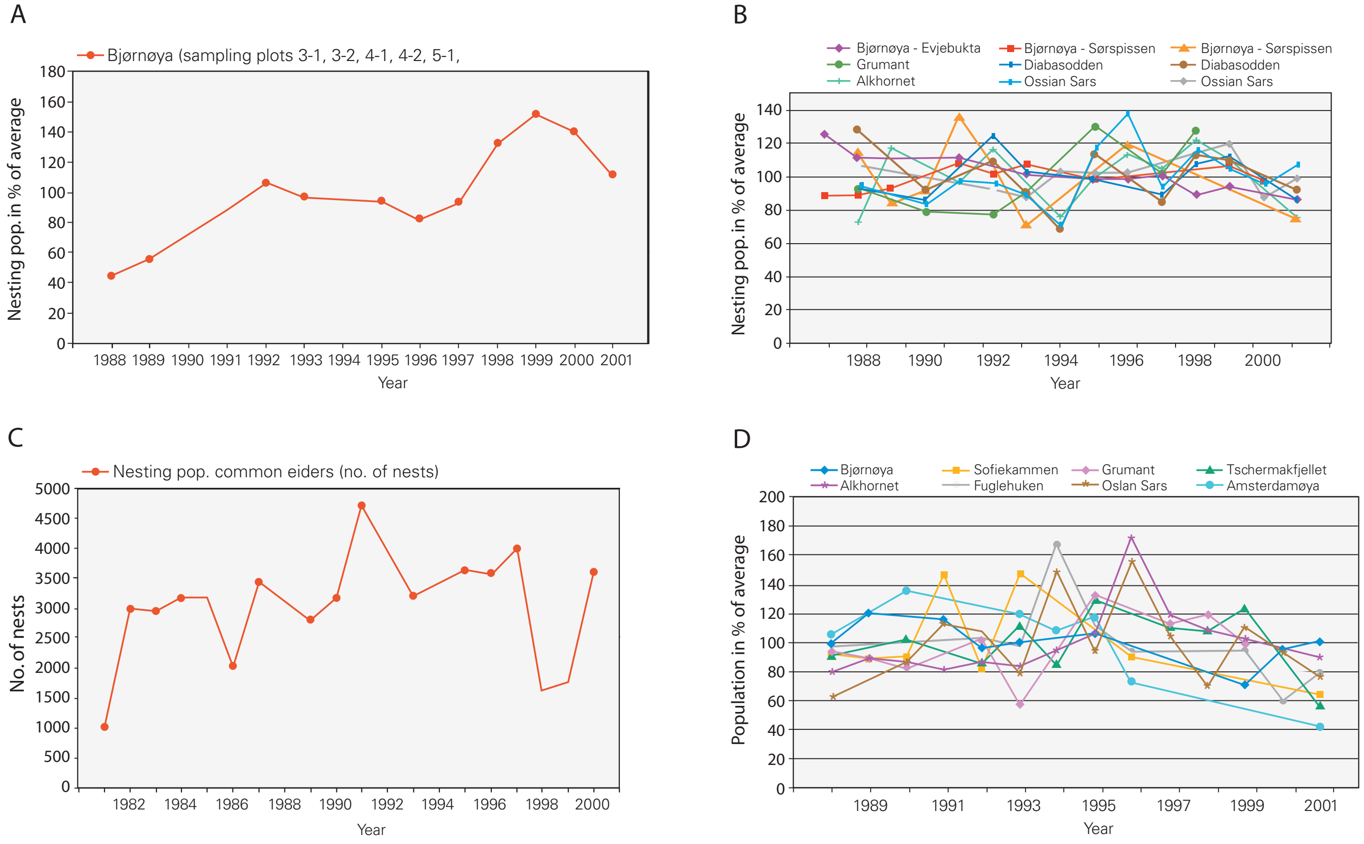

Fig. 11.
Recorded developments in the populations of the common guillemot (A), Brünnich's guillemot (B), common eider (C) and black-legged kittiwake (D).

matic in places, but more thorough analysis of the data is required to determine the status of the population with greater certainty.

The ***ivory gull*** is a high-arctic species associated with ice-filled waters throughout the year, apart from the nesting period. The species breeds in arctic parts of Canada, Greenland, Svalbard and Russia. The total population has been estimated at 14 000 pairs, but this figure is probably too high. The species occurs in limited numbers in Svalbard, where the population has been estimated at between 200 and 750 pairs. The ivory gull is a food generalist that lives on fish, crustaceans, blubber, meat and excrements from seals and polar bears. A decline in the population has been reported from the entire breeding area, but no cause has been proposed.

2.2.8 Seals

Six species of seals (harp seal, hooded seal, common harbour seal, ringed seal, bearded seal and walrus) occur in the waters around Svalbard and Jan Mayen. The harp seal and hooded seal populations are assessed by ICES about every other year, based on hunting data, records of individuals at the pupping grounds (at intervals of several years) and continuous records of recoveries of tagged individuals. These species are discussed below with a view to an overall discussion in relation to the pressures of fishing and hunting.

The population of approximately 500 individuals of the ***common harbour seal*** at Prins Karls Forland is the only population of the species in Svalbard and Jan Mayen. No time-series data are available, but plans exist for a monitoring programme. Because of lack of data, there is no basis for including the common harbour seal in the assessment.

Project-oriented research on population biology, ecology and pollutants has been carried out on the ***ringed seal*** in the Norwegian Arctic. Toxaphene and PCB-153 in blubber were analysed in samples taken in 1996. The research has, however, not been organised for monitoring use and no time-series data are available for pollutant concentrations or the population. Plans exist for a monitoring programme. Because of lack of data, there is still no basis for including the ringed seal in the assessment.

Walrus were abundant in the Svalbard area and on Bjørnøya before the species became in practice extinct in these areas after being hunted for 350 years until it was protected under the terms of the Svalbard Act in 1952. Telemetry studies carried out by the Norwegian Polar Institute indicate the presence of a common population between Svalbard and Franz Joseph Land, and surveys suggest that it numbers at least 1500. No time-series data are available. Because of lack of data, there is no basis for including the walrus in the assessment.

Based on empirical data, an estimate exists for the production of ***harp seal*** pups at Jan Mayen for eight years in the period from 1983 to 1991. The production in 2000 has been calculated at 76 700 (95 % CI[1] 48 000-104 000), corresponding to a population of 361 000 (95 % CI 210 000-629 000) one-year old and older animals. No conclusions regarding trends in the development of the population can be drawn on the basis of these estimates. In the 2002 pupping season, the Norwegian Institute of Fisheries and Aquaculture Research recorded the number of pups on the pupping grounds using aerial photography. ICES has still not quality assured these figures.

ICES recommends quotas for two years at a time, and the current hunting level is considered to be within biologically safe limits.

For a long time, there has been considerable uncertainty regarding the development of the ***harp seal*** population in the Barents Sea and the White Sea. Oceanographic conditions in the winter of 1986-87, together with the capelin collapse, led to an unusual westerly migration pattern for harp seals in the Barents Sea, bringing them into conflict with net fisheries in Norwegian waters, particularly in relation to the spring cod fishery off Finnmark. Almost 60 000 seals are known to have drowned in nets in 1987. Mortality due to starvation was also reported. There are therefore reasonable grounds to assume that the litters suffered relatively high mortality in 1986-88. The effect on the population is not well documented.

In 1988 and 2000, the Russians undertook aerial surveys of the pupping grounds in the White Sea. The pup production levels have been adjusted upwards after the aerial surveys began to use the stripe-transect technique and photographic documentation of cows and pups on the pupping grounds. Primarily based on these surveys, it has been estimated that 319 000 pups were born in 2000, corresponding to a population of 1 727 000 one-year old and older animals.

After the Second World War, the population was heavily hunted and was reduced to a minimum of about 500 000 in the mid-1960s. In 1965, a total quota of 34 000 animals was introduced. For several decades now, quotas have been fixed using the principle of "balanced hunting", but before 2000 they were based on a population estimate that was probably too low. It is therefore not unreasonable to assume that the population is close to a maximum size consistent with the carrying capacity of the Barents Sea (see section 2.4).

ICES recommends quotas for two years at a time, and the current hunting level is considered to be within biologically safe limits.

There is only one population of ***hooded seals*** in the north-east Atlantic, and it pups on the drift ice between Jan Mayen and East Greenland (Vestisen). In 1997, an aerial survey over the pupping grounds resulted in an estimated pup production of 24 000 (95 % CI 14 800-32 700). This must be considered a minimum figure because it has not been corrected for lack of coverage in space or time. Using model projection, it is estimated that 28 100 (95 % CI 16 000-40 000) pups were born in 2002, corresponding to a population of 102 000 (95 % CI 57 000-147 000) one-year old and older animals.

There is no basis for drawing conclusions regarding a trend in the development of the hooded seal population. ICES recommends quotas for two years at a time, and the current hunting level is considered to be within biologically safe limits.

2.2.9 Whales

Eleven species of whales occur regularly close to or north of the polar front in the Norwegian Arctic. The ***narwhal*** and ***beluga whale*** are high-arctic species that are characteristic for the Norwegian Arctic marine fauna. No standardised monitoring programme exists for these species. Due to lack of data there is no basis for including them in the assessment.

The ***bowhead whale*** used to be a characteristic species for the northern waters around Svalbard, but was in practice made extinct from the Norwegian Arctic by extensive, excessive hunting in the 18th and 19th centuries. A residual population of bowhead whales may possibly be found in the waters north of Svalbard. No monitoring data exist for this possible population which, if it exists, is extremely endangered. The University of Oslo and the Institute of Marine Research began a programme in 2003 aimed at clarifying the genetic affiliation (present and historical), number and migrations of this possible population. Due to lack of data, there is at present no basis for including the bowhead whale in the assessment.

The annual ***minke whale*** monitoring programme performed by the Institute of Marine Research has taken place since 1988, routinely using a standardised line-transect technique. However, all species of whales that occur in open water both north and south of the polar front are recorded. The data and results deriving from the programme are reported annually to the scientific committee of the International Whaling Commission (IWC). It has not been proposed to include either the minke whale or other whale species covered by this programme in the MOSJ project.

2.2.10 Polar bears

The polar bear occurs both in Svalbard and on the ice-covered seas around Svalbard. As a top predator in the marine ecosystem, the polar bear will be likely to be affected by changes in the lower trophic levels or its physical habitat, and these will therefore be reflected as changes in the size of its population, its demography or its geographical distribution. Since 1988, the polar bear in the Svalbard region has been the object of studies involving its capture, tagging and recapture, and about 150 females have also been equipped with satellite transmitters in the same period. Blood and fat samples of the bears have also been taken.

The telemetry studies show that there is a common population around Svalbard and in the Barents Sea. It is uncertain how far this population stretches westwards towards Greenland. Early in the 1980s, the population in Svalbard and the Barents Sea was estimated to number 3000 – 5000. This estimate is very uncertain and it is not known how the population has changed since then. In autumn 2004, the Norwegian Polar Institute will undertake counts in the Russian and Norwegian sectors to acquire a new estimate of the population size. Counts of dens have also been carried out in parts of Svalbard, and since 1995 on Hopen, too. The number of dens on Hopen seem to be strongly correlated with when the ice reaches Hopen in autumn. There are fewer dens when the ice comes late. It is uncertain whether this affects the polar bear population because it is not known whether the females equally willingly den in other areas, such as Edgeøya or Kong Karls Land, which are also important denning areas. The capture-tagging-recapture studies also provide information about sex and age distributions in the polar bear population. However, low recapture rates have made it impossible to discern trends in these distributions over time.

The polar bears in Svalbard and the Barents Sea carry high levels of organic pollutants like PCBs, and the levels increase from west to east. This geographical variation may be caused by actual geographical variations in PCB levels in the environment, or result from the polar bears in the two parts of the region having different living habits. The polar bears in Svalbard are more stationary and roam over smaller areas (about 50 000 km^2 a year) than those on the drift ice in the Barents Sea (about 300 000 km^2 a year). This probably results in higher predation rates among Barents Sea bears than bears in Svalbard, and hence higher accumulation rates for organic pollutants. A negative trend in PCB levels has been observed in polar bears from 1990 to 1998 (Fig. 3). During this period, the study area was moved from Storfjorden towards the eastern part of Storfjorden and Hopen, thus reducing the proportion of stationary Svalbard bears and raising the proportion of the more widely roaming Barents Sea bears. This complicated the interpretation of the variation in the PCB levels in the polar bears. To be able to distinguish between geographical and temporary trends in PCB levels, 25 % (55 of 221) of the samples collected were excluded from the statistical analyses, which demonstrates the importance of taking samples at the same locality over many years. Since we know little about the structure and size of the polar bear population, we do not know whether the high PCB levels have any effects on the population.

2.3 Overall assessment of pressures and the state of the environment

The situation for the fish stocks in the Barents Sea in 2002 must be characterised as normal. The pelagic fish stocks in the Barents Sea were within safe biological limits in 2002 and were also managed within safe biological limits. The cod stock, on the other hand, was outside safe limits and was fished in accordance with quotas that were fixed higher than recommended. However, the spawning stock of cod in 2002 was increasing and is expected to be brought within biologically safe limits by addition from younger year classes. The shrimp stock gave a good yield in 2002, but it gives cause for concern that ever younger age groups are fished. Some species, for example Greenland halibut and Iceland scallop, are far beneath their biological potential because of overfishing in the not too distant past. Over time, the total yield of the fish stocks in the Barents Sea should be able to be increased if limited fishing on depleted stocks takes place to substantially under F_{pa} until the stocks have passed B_{pa}.

The Norwegian Polar Institute has posed a number of questions that should be answered through the MOSJ assessment. To do so, it is essential to look at the development over a time scale of several decades to draw conclusions regarding the situation in 2002.

Increased heat transport to the Barents Sea and adjoining marine areas has resulted in a marked retreat of the sea ice. The ice distribution in winter showed a negative trend from 1958 to 1997, which was negatively correlated with the NAO (North Atlantic Oscillation) index (Deser et al. 2000). Year-to-year variations in the influx of warm, saline Atlantic water to the Norwegian Sea and the Barents Sea nevertheless form the basis for the dynamics in primary production and energy flow through the food webs, manifested by extreme fluctuations in the strength of the year classes of zooplankton and fish. Herring and capelin (and polar cod in the northern and eastern parts of the system) are important key species because they convert the zooplankton production into food that is available for fish-consuming species (cod, other predatory fish, common guillemots, harp seals, minke whales and many other species that are less investigated).

Ecological reasons seem to preclude the simultaneous existence of large stocks of capelin and herring in the Barents Sea. These species are to some extent food competitors, and herring also eat young capelin. Periods with enhanced influx of warm Atlantic water, resulting in the warming up of the Barents Sea, favour herring (and cod), whereas periods when the Barents Sea is cooling favour strong year classes of capelin. For reasons of population biology (see 2.2.3 and 2.2.4), herring may get weak year classes in years with unfavourable conditions, without the stock suffering collapse, whereas the capelin stock tends to collapse in periods which do not favour the species. This is part of the natural fluctuations in the Barents Sea. Species which feed on capelin, but are generalists in their food choice, shift their diet in line with these fluctuations (Fig. 12).

The cod is one of these generalists. Following the collapse in the capelin stock in the mid-1980s, amphipods took over as important food for the cod until capelin again became dominant in the diet from 1990 (Fig. 12). However, several other species which eat capelin are more specialised and in parts of the year are entirely dependent on herring and capelin, or their fry. Over time, several of these specialists have developed life-history strategies accommodated to fluctuations in the availability of food. Auks generally lay one egg a year, but on the other hand they have a very long life span and are able to reproduce for many years. They thus spread the risk over many years. Atlantic puffins are an example of this adaptation. When the herring stock was fished down in the 1960s, a great many years passed with very few herring fry in the sea off a number of the puffin colonies, for example on Røst in Lofoten. This has resulted in a decline in the puffin population to this day on Røst.


Photo: B. Frantzen

The collapse of the capelin stock in 1986-87 occurred when the herring stock was still small (but growing). It was a consequence of natural oceanographic conditions, but was quite clearly aggravated by overfishing in 1983-86. When capelin were not available in 1986 and 1987, species that were most dependent on them for food were most severely hit. The common guillemots breeding in Finnmark and on Bjørnøya were reduced by 90 %. Substantial mortality among adults on the open sea was also reported. Figure 11A shows the recovery of the common guillemot following this dramatic episode when 85-90 % of its population did not return to the breeding sites in 1987. The Brünnich's guillemot, which to some extent competes with the common guillemot for nesting sites, is not so specialised in its diet as the latter and was less severely hit by the collapse in the capelin stock. The negative trend now being observed for the Brünnich's guillemot at some breeding colonies on Bjørnøya is probably caused by its losing out in the competition for nesting sites with the common guillemot, whose population is recovering rapidly. The development in 2002 in the common guillemot and Brünnich's guillemot populations on Bjørnøya is an example of ecological effects of fishing in earlier years which, over time, are also transmitted to species that are not directly affected. Even though the capelin fishery has clearly had some effect on the changes in the bird populations, the extent to which natural fluctuations in the natural conditions are responsible is not clear.

A large part of the catch from fish stocks takes place at one or two trophic levels, and catches of plankton-eating, pelagic shoal fish are particularly important in an ecological context. Pelagic shoal fish (especially capelin, but also herring and polar cod) convert the zooplankton production into fish biomass, which is the food base for a number of fish-eating species like cod, common guillemots, harp seals and minke whales (as well as other less-studied species such as humpback whales, common rorquals and springers). The unusual harp seal migrations in the winter of 1987, when the seals fed on saithe and herring along the coast, resulted in a dramatic mortality in nets. In addition, many seals, particu-

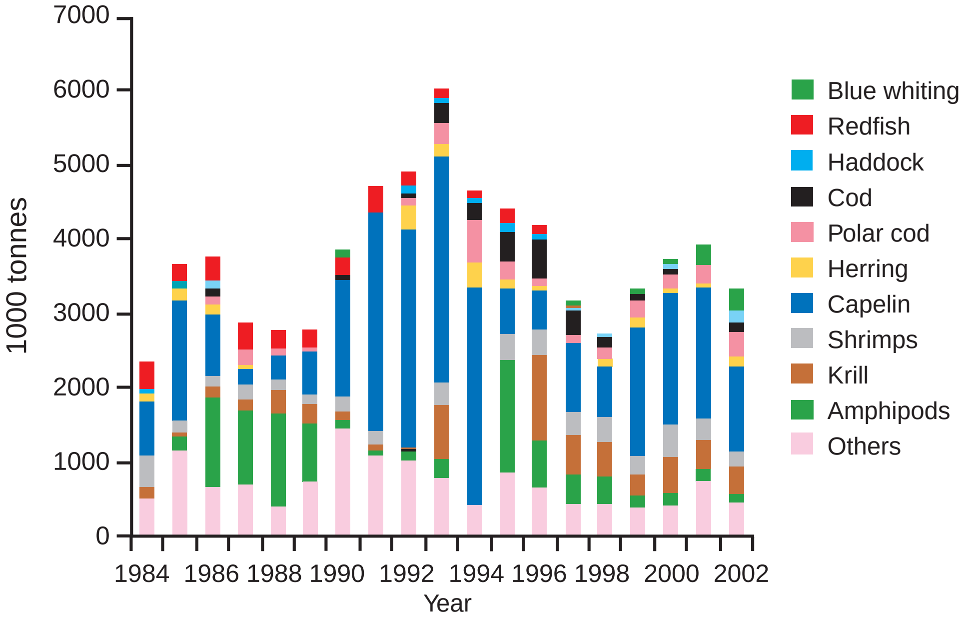

Fig. 12
Cod food selection in the Barents Sea in 1984-2002.

larly pups, died from starvation. This, together with the mortality of common guillemots the same year, are ecological effects that can be linked to the fisheries.

By definition, an ecosystem is all biotic and abiotic components that act together to form a functional entity. A disturbance in an ecosystem will therefore a priori affect the entire ecosystem, with all the components that belong in it. However, in practice, a disturbance of the natural environment will result in significant effects for only a few components of the system through direct influence, though changes in these components will in turn trigger some interactions so that other components may also be indirectly affected. Marine ecosystems are very complex, and we only partially understand how they function and the interactions between the various components. In practical management, it is therefore important to understand what are essential interactions and result in significant effects.

In an ecosystem approach to the management of the maritime areas, we need to look at natural fluctuations and the various disturbances of the environment in context and to understand key cause and effect links in the ecosystem to be able to identify essential ecological interactions. Such interactions are often cross-sectoral responsibilities for the management authorities. In Norway, it has not been normal practice to assess ecological interactions across sectors. The pressures (fishing, hunting and pollutants) and indicators that have been discussed here do, however, offer a basis for generating some hypotheses on cause and effect links, where natural conditions, management measures and other disturbances to the environment act across the traditional fields of sectoral responsibility. Issues which face us with overall, ecosystem-based management are, for example, how decisions by fishery management regarding fishing or fishing embargoes work alongside those made by nature management concerning the hunting or protection of species at other trophic levels, and how pollutants that belong under the sphere of responsibility of the pollution control authority act on an ecosystem exposed to natural fluctuations and already affected by decisions made in the fishery and nature management sectors? Based on capelin as a key species for ecology, a description of the situation and some examples of such hypotheses are given below.

Hypothesis 1: Fishing of capelin has a direct effect on the carrying capacity of the Barents Sea for species at a higher trophic level and we must assume that the carrying capacity is both lower and more unstable now than before the start of the capelin fishery. [The capelin is a bottleneck in the food web because it is one of very few species of pelagic shoal fish that converts the zooplankton production into fish biomass. Consequently, capelin (and other pelagic, plankton-eating fish) will constitute an important component of the carrying capacity of the area for species at a higher trophic level.]

Hypothesis 2: The carrying capacity of the area and fluctuations in it will manifest themselves in density-dependent, population-regulating effects for species whose population size is close to the carrying capacity level. [Several species which eat pelagic shoal fish in the Barents Sea have previously been exploited. They are now protected (for instance, large whales) or are exploited at a level which has no significant effect on the population size (for instance, several species of seabirds, the harp seal and to some extent the minke whale). It must be assumed that they have now recovered to population levels that are close to the present carrying capacity of the area. That is to say, the populations are limited by the carrying capacity and will not continue to increase unless the carrying capacity of the area increases.]

Hypothesis 3: Population regulation via the carrying capacity of the ecosystem (instead of through fishing or hunting) is, in itself, a process that will lead to increased concentration of pollutants in populations of arctic predators. [Several of the species in question at a high trophic level have life-history strategies which indicate that density-dependent, population-regulating effects will first manifest themselves in reduced reproduction before a reduction in the survival of adults will perhaps also be observed (for instance, in auks and marine mammals). This means that populations that are regulated by the carrying capacity of the area will achieve a higher average age than those which are growing or are being exploited (assuming that the exploitation concerns hunting of adults). Several of the fat-soluble pollutants that have high concentrations in arctic predators show an increase in concentration with increasing age. Hence, an increasing average age in a population will result in increased concentrations of pollutants in the population.]

Hypothesis 4: Starvation in seabirds and marine mammals as a consequence of the collapse in the capelin population may intensify the effects of pollutants and make individuals more susceptible to viruses or other pathogens which, in turn, may trigger epidemics. [In times of starvation, the predators (birds and particularly mammals) will mobilise energy that is stored as separate fat reserves. This also leads to fat-soluble pollutants that have lain inactive in fatty tissue being mobilised, placing the organism under additional stress through, for example, the deterioration of its immune system.]

The above hypotheses have not been documented, but are nevertheless likely. They show that resource management cannot be viewed in isolation from the ecosystem from which the resources are drawn, and there may also be clear links between the spheres of responsibility of the various sectors. Management decisions in one sector may intensify or reduce the effects of decisions in other sectors. The hypothetical examples above demonstrate that decisions in the fishery sector may have an effect on how pollutants behave in the ecosystem. However, it must be emphasised that effects of pollutants on the population level have not been clearly documented in the Norwegian Arctic, but studies performed on top predators like the polar bear and the glaucous gull demonstrate clear effects on their immune, hormone and enzyme systems.

3. Assessment in relation to national environmental targets

To what extent are the political environmental targets stated in the recent White Paper (St.meld. 24 (2000-01) ”The Government’s Environmental Policy and the State of the Environment” achieved?

Target 8.1

Utilisation of the resources in our near-arctic maritime areas must not lead to species or populations being endangered or made extinct.

The Institute of Marine Research continuously monitors most of the commercially exploited marine populations, and reference points have been defined for their protection and exploitation. Demands are in place regarding the sustainability of the fisheries, and the precautionary principle forms the basis of Norwegian fisheries management. No commercially exploited marine species are presently threatened by biological extinction in Norwegian Arctic waters as a consequence of their exploitation. *Target 8.1 therefore seems to have been fulfilled with regard to the fisheries sector.*

Some populations are nevertheless beyond safe biological limits in the sense that they are under the level considered justifiable to continue their exploitation at the same level. This is mainly because the quotas (which are often fixed in cooperation with other nations) have been fixed higher than recommended by ICES. For cod in particular, the forecasts, too, have now proved to have been too optimistic for some years. Owing to over-exploitation in the recent past, the catches of cod, Greenland halibut and Icelandic scallops are at a lower level than the long-term yield that could have been realised with optimal management.

Target 8.2

Populations of species now considered endangered or otherwise negatively affected by land use, harvesting and/or pollution must be preserved and, if possible, built up again.

In the Norwegian Arctic, there are a number of species which, because of small numbers or previous over-exploitation, must be regarded as endangered or negatively affected by harvesting and/or pollution. The ivory gull, glaucous gull and grey phalarope belong in this category. If the bowhead whales observed on the former whaling grounds off the north-west coast of Svalbard constitute a separate population, it must be regarded as being in extreme danger of becoming extinct because of its small size. Norwegian authorities have so far not taken responsibility for implementing measures to clarify the situation for these whales (see section 2.2.9).

The walrus is still found in only small numbers owing to over-exploitation in the past, although it is now showing some signs of a slow recovery. Several important walrus habitats are protected and landing has been banned on one important protected area, Moffen, since 1979. Nevertheless, no continuous monitoring is taking place that will give early warning if the positive trend is reversed.

The polar bear is a top predator which was over-exploited until it was protected in 1973. Because of its ecology, the polar bear is highly exposed to fat-soluble, bio-accumulated pollutants. The concentration of PCBs is at a level where endocrinal disturbances, a reduced immune defence system and reduced reproductive ability can be expected, as well as a lower life span in adults and higher mortality among cubs. A weakened immune system may trigger epidemics with dramatic and immediate consequences for the viability of the population. Climate changes which reduce the drift-ice habitat around the archipelagos in the Norwegian Arctic also threaten the continued existence of the species in these areas. Earlier population estimates are out of date or unreliable, but the Norwegian Polar Institute plans to begin a full survey in 2004. However, at present no monitoring is taking place that offers a basis for estimating the size of the population or its development, even though studies have given early warning of extreme stress from pollutants.

Past exploitation, pollutants, and not least the combination of these factors, have resulted in some populations which are now protected still being considered endangered, or in some cases, highly endangered. *Target 8.2 can therefore not be said to have been met with respect to several species.*

Target 8.3

An attempt must be made to maintain the extent of continuous wilderness areas in Svalbard. Special protection decisions must safeguard representative parts of the environment from significant encroachments or impacts by 2002. Important values in the marine environment around Svalbard must be safeguarded.

This cannot be answered on the basis of the information provided for this assessment. The target has probably not been reached in 2002, but the extension of the territorial limit to 12 nautical miles and a new conservation plan in 2003 will help to meet it.

The strategic objective under performance area 5 ”Chemicals that are hazardous to health and the environment” (more precise than in target 8.2): The discharge and use of chemicals that are hazardous to health and the environment must not result in damage to health or the ability of nature to produce and renew itself. The concentrations of the most hazardous chemicals in the environment must be brought down towards the background level for naturally occurring substances and to practically zero for man-made compounds.

This goal is far from being achieved and long-transported pollutants also prevent it from being solved nationally. The international effort being made through, among others, AMAP can give valuable input to important conventions (including the. Stockholm Convention) which have the aim of stopping the production and use of several organic pollutants.

4. Advice to management bodies regarding responses

The fishery management body has now come quite a long way with its monitoring of species that are, and in some cases are not, exploited. Reference points have been defined for protection and exploitation, and neutral advice on the catches that may be taken from stocks has been secured through international scientific organisations like ICES. However, measures should be put in place that more thoroughly ensure that scientific advice is followed up when quotas are fixed. Several of the stocks should be built up beyond the B_{pa} level, because this may be able to result in higher long-term yields.

Monitoring is not taking place today that will be able to provide early warning of risks to several species in the marine system near Svalbard that are central for ecology and/or important for environmental conservation policy. Measures must therefore be introduced to monitor both population trends and pollutants in non-commercial high-arctic species. This particularly applies to species that stand high in the food chain and are exposed to environmental pollutants. Examples are the glaucous gull and the polar bear, as well as the beluga whale, narwhal, walrus, ringed seal and bearded seal.

It is now possible to hunt ringed seals and bearded seals (the open season for ringed seals is 20 May to 21 March and for bearded seals 5 June to 25 April). However, no population monitoring or hunting statistics have been put in place for these species. In both national and international contexts, this is a form of management that seems far worse than the management of other species of marine mammals. Bringing the management of marine mammals in Svalbard in line with other marine mammal management in Norway should therefore receive high national priority.

For reasons explained earlier, the Norwegian Arctic functions as a ”slop sink” for long-transported environmental pollutants. Because of their persistence to breakdown (and the long half-life of some radioisotopes), the concentrations of these pollutants in the Arctic will be able to increase long after their discharge has ceased. Here we must reverse a well-used statement and “Think locally, but act globally”. Norway must make still greater efforts to achieve the introduction of global bans on the production and use of such pollutants. It is also important to halt deliberate discharges of radioactive isotopes that are carried by ocean currents to the Norwegian Arctic.

New chemical compounds now have to be approved before they are put on the market. Correspondingly, more extensive knowledge, assessments and, if necessary, “certification” of chemical compounds that are already in industrial production should be demanded, and measures should be taken against substances that have been in production and are still in circulation. This is important for Norway as a nation, not only as a measure to protect the arctic environment, but also because the harvesting and farming of marine biological resources is looked upon as an important growth area for national value creation. We are already in a situation where some products from marine production cannot be recommended for human consumption because of excessively high values of PCBs and heavy metals. It is therefore regrettable that Norway, too, is still emitting PCBs, for example when old double glazing in buildings is being replaced.

5. Advice about gaps in knowledge

- Good documentation is lacking regarding cause and effect relationships for biological effects on population levels of environmental pollutants that have documented effects on organs and organisms. This requires both more research and more monitoring.
- The nature management sector has significant gaps in knowledge linked to population development in a number of higher species. This concerns for example several species of gulls, coastal seals and whales near Svalbard, and the polar bear. Because of indications of decreases in their populations and their role as top predators that are highly exposed to fat-soluble pollutants, an investigation on, and a monitoring programme for, ivory gulls and glaucous gulls should be initiated. These, together with obtaining funding for monitoring polar bears, should have the highest priority for MOSJ.
- The fisheries sector has little knowledge about the structure and dynamics of the ecosystem, and the effects of fishing and hunting on the ecosystem. Knowledge is also lacking about the effects of harvesting on the medium trophic level while higher levels are not being exploited.

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RAPPORTSERIE 123

The environmental monitoring of Svalbard and Jan Mayen – MOSJ

Part 4: Assessment of the state of the environment: land

By Pål Prestrud


Photo: R. Aanes


Photo: K. Prestvold, SMS


Photo: E. Fuglei


Photo: G. W. - Gabrielsen

Contents

1 Background

This overall assessment is largely based on data and interpretations of individual MOSJ indicators presented on the MOSJ web site, http://miljø.npolar.no/mosj/start.htm. It contains data on the terrestrial species (reindeer, arctic fox, ptarmigan and geese) and cultural heritage sites that are covered by MOSJ, and pressures like traffic, hunting, trapping and shooting, pollution, refuse and introduced species. Scientific publications that supplement the data or introduce new results that are valuable for assessing long-term trends in the MOSJ terrestrial parameters or indicators have also been used. The assessment of climate as a pressure is based on the climate assessment undertaken simultaneously as part of the MOSJ project (see Part 2).

A preliminary version of this document was discussed at the assessment meeting held by MOSJ on 20-22 May 2003. After the meeting, several participants sent written comments and suggestions. These have largely been taken into account, but I alone am responsible for the views and assessments presented here. In some cases, I have been forced to make a choice because opinions have differed, or I disagreed with the comments and suggestions I received.

Many people have supplied data which form the background for this assessment. Information on, and links to, data reports and monitoring programmes can be found on the MOSJ web site. I am grateful to all who supplied data. Several people have also contributed suggestions and comment on texts belonging to the assessment. The following deserve special acknowledgement: Ole-Anders Braathen - NILU (pollution), Eva Fuglei - NPI (arctic foxes and ptarmigan), Åshild Pedersen (ptarmigan), Kristin Prestvold - Governor’s office (cultural heritage sites), Ingunn Tombre - NINA (geese), Geir Wing Gabrielsen - NPI (contamination), and Ronny Aanes - NPI (reindeer). In addition, Gunnar Sander (NPI) and Linn Bryhn Jakobsen (SFT) have made many useful comments and specific suggestions.

2 Status and features in the development

2.1 State

2.1.1 Svalbard reindeer (*Rangifer tarandus platyrhynchus*)

The herds in Adventdalen and Reindalen have been monitored each year since 1979, and the herd on the Brøggerhalvøya has been monitored after 15 reindeer were re-introduced there in 1978. Extensive research has also been done on the herds in Adventdalen and on the Brøggerhalvøya, to a lesser extent on the Reindalen herd, too. A number of scientific papers and reports on these herds have been published in the last few years. Systematic counts are also undertaken each year in the areas where hunting takes place, and these data are available from the Governor’s office. In addition, some sporadic registrations and counts have been made in other parts of Svalbard. An assessment of some of these data can be found on the MOSJ web site (Ronny Aanes 2002). The quantity of data and the knowledge available about the status of the monitored portions of the reindeer population in Svalbard can be characterised as good.

No clear trends over the last 20-25 years can be seen for the herds in Adventdalen (Tyler & Øritsland 1999, Aanes et al. 2003), Reindalen (Solberg et al. 2001), or the areas where hunting takes place. All these herds show great variations in size from one year to another. The herd that was introduced on the Brøggerhalvøya grew strongly until 1993, when there were approximately 375 individuals. It then collapsed and was reduced to around 75 in 1994 (Aanes et al. 2000, 2002). It has subsequently varied in size (R. Aanes, pers. comm.). Other registrations and counts show that reindeer have been continually roaming into new areas in recent years, and have established themselves between Isfjorden and Kongsfjorden, including Forlandet, and in southern Spitsbergen, for instance.

All the analyses of the long time series show that the reindeer herds vary in density (size) from one year to another, sometimes hugely, as a consequence of variations in both mortality and recruitment. By degrees, it has been well documented that density-dependence mechanisms combined with variations in the amount of snow and icing are important factors affecting the rate at which the herds grow (Aanes et al. 2000, 2002, 2003, Solberg et al. 2001). Other factors that may affect the herds, such as parasites, cannot be excluded either (Albon et al. 2002). Because the snow cover and icing of pastures will increase with the predicted rise in temperature and precipitation (see the MOSJ climate report), we may speculate on whether this will have negative effects on the herds in the long term. The effect of increased traffic as a pressure on the herds must be assessed in the light of a possible change in climate.

Conclusions

It seems fair to assume that the Svalbard reindeer population is viable at present. It has been continually spreading to new areas in the last 10-20 years. The population is probably larger now than it was 10-20 years ago, and numbers some 10,000 individuals. Considerable uncertainty is attached to this figure because no recent data exist from important parts of the range of the reindeer. Climate change may greatly affect the population.

2.1.2 Arctic fox (*Alopex lagopus*)

Arctic fox earths have been monitored in two parts of Svalbard. Hunting does not take place in one of these areas, Brøggerhalvøya and Kongsfjorden (ca. 221 km²), whereas it does in the other area, Sassen to Adventdalen (ca. 900 km²). Population density indices going back to 1978 are available for the Kongsfjorden area, but more systematic information on the sizes and numbers of litters in this area only exist since about 1993-94 (Fuglei et al. 2003). Just fewer than 10 earths with cubs have been recorded in this area. Data on the size and number of litters have been systematically collected from the Adventdalen-Sassen area in 1984-89 and 1997-2002 (Prestrud 1992, Prestrud & Eide unpublished), and 32 earths with cubs have been recorded there. Data also exist regarding the proportion of juvenile foxes among the fox bags taken on the western and northern coasts of Spitsbergen during the open seasons from 1982-83 to 1988-89 and 1996-97 to 2001-02 (Prestrud 1992, Prestrud & Eide unpublished).

There are no demonstrable trends in the parameters that have been measured in the two populations in Kongsfjorden and Adventdalen-Sassen over a period of approximately 20 years. The average size of litters varied between 4 and 6 from year to year, but the number of litters produced may vary, sometimes dramatically, from one year to the next, from 0 to 6 in the Kongsfjorden area (Fig. 1) and from 5 or 6 to 12 or 13 in the Adventdalen-Sassen area. There seems to be greater variability in the number of litters produced in the Kongsfjorden area than in Adventdalen-Sassen. For instance, only 2 litters were born in the Kongsfjorden area from 1996 to 1999, inclusive, whereas 29 litters were born in the Adventdalen-Sassen area in 1997-99, inclusive. The reduced reproduction in the Kongsfjorden area in this period coincides with a reduction in the density index after the winter of 1996 (Figure 1). This shows that the density of some sub-populations may vary extremely in certain periods. The reason for the difference between the two sub-populations is not known. The proportion of juveniles in the bags (see above) varied from 45% to 60% in different open seasons. This indicates that the Svalbard population is more stable than populations elsewhere in the Arctic where small rodents are present. There, the proportion of juveniles varies from approximately 10% to 90% from year to year. What causes these variations is not clear, but there are good indications that mortality in the reindeer population, which is greatly influenced by variations in the snow cover and icing due to variations in the climate, is of some importance.

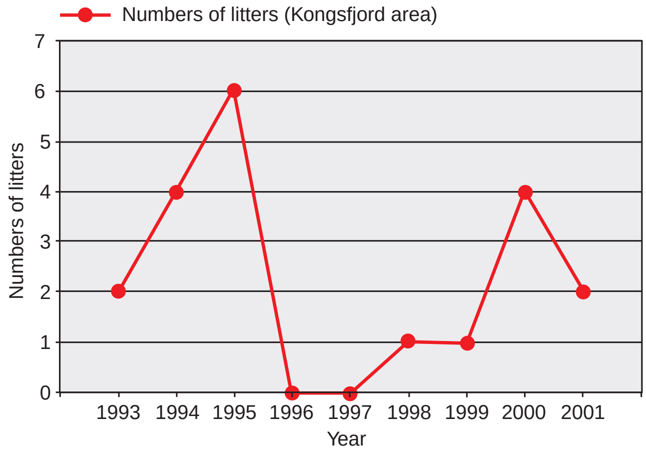

Figure 1
Variation in the number of arctic fox litters born in the Kongsfjorden area (Fuglei et al. 2003)

Data on litter size and the number of litters acquired from monitoring earths, and the proportion of juveniles in the bags, are primarily recruitment indices. Good estimates of the arctic fox population in Svalbard are lacking, and the population density indices are also inadequate. The data available for the trapping effort, the number of foxes trapped per 100 trap-days), do not suggest any trends in the population either (e.g. Figure 2).

Conclusion

There are no indications of long-term changes in the sub-populations of arctic foxes in Svalbard, and there is every reason to assume that they are viable. Variations in the availability of food, which, in some instances, is controlled by variations in climate, are an important factor affecting the sub-populations, and probably explain the great fluctuations in reproduction and recruitment from year to year.

2.1.3 Svalbard ptarmigan (*Lagopus muta hyperborea*)

The biology and ecology of the Svalbard ptarmigan have been little studied, and no long time series are available from the monitoring of the ptarmigan population in Svalbard. A pilot project began in 1999 to test ways of collecting data with a view to determining the size and development of the population and possible fluctuations in it. The project continued from 2000 and will conclude with an evaluation after the 2004 season. The data collected comprise counts of territorial males at approximately 80-100 permanent counting sites in Adventdalen and Sassendalen in April. Based on these 5 years of data and their statistical analysis, a monitoring programme will be designed which will involve the repeated recording of ptarmigan in April in selected valleys in the study area. An important aim is to work out indices to describe trends in the population. It is also planned to relate these data to the hunting statistics for Svalbard ptarmigan, to reveal possible relationships between the various monitoring parameters.

Hunting statistics, monitoring of territory-defending males (see the MOSJ web site) and a general impression of the population indicate that the population is viable. However, since no long time series from ptarmigan monitoring exist to provide a basis to draw any conclusions about trends, no reliable scientific basis is available to draw a definite conclusion.

2.1.4 Geese

Geese are listed as a MOSJ indicator, but the parameters which it is intended to measure have not yet been described. Three species breed in Svalbard, the barnacle goose (*Branta leucopsis*), the pink-footed goose (*Anser brachyrhynchus*) and the light-bellied brent goose (*Branta bernicla hrota*). Based on censuses undertaken in their wintering areas, good data exist for all these populations from at least the last 20 years with respect to variations in density and breeding success. All the populations winter along the coast from Denmark to Belgium, or on the north-west coast (Solway Firth) of the Irish Sea. Useful population estimates and estimates of the proportion of young birds in the populations (a measure of recruitment) can be obtained from these areas. Good estimates of the barnacle goose population exist from as far back as 1946. All the three populations of geese in Svalbard grew until 1997 (Madsen et al. 1998) (Figure 3), but there are indications that the populations of barnacle and pink-footed geese have ceased to rise in recent years (Madsen et al. 1999, I. Tombre, pers. comm.). The growth in the populations is probably chiefly due to improved survival, because the breeding success seems to have varied constantly from year to year throughout the period considered. There are probably two explanations for this, improved grazing conditions due to more intensive forms of agriculture, and

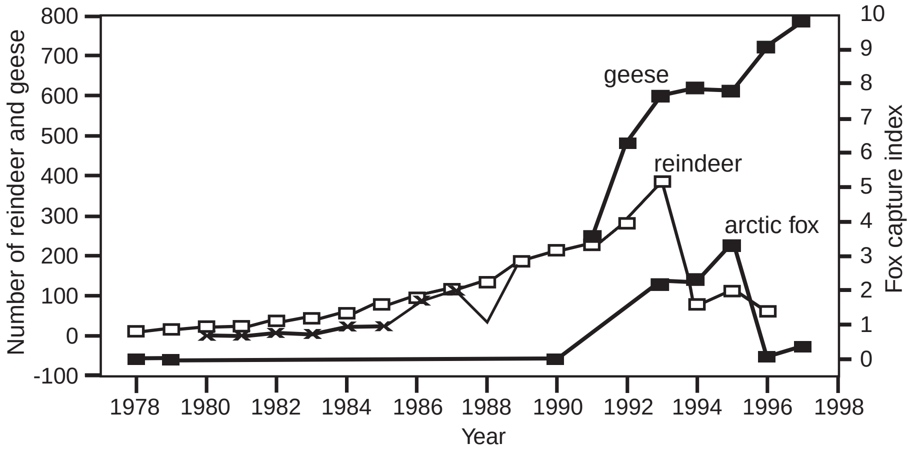

Figure 2
Changes in the trapping index, i.e. the number of arctic foxes taken per 100 trap-days, compared with changes in the populations of geese and reindeer in the Kongsfjorden area (Fuglei et al. 2003)

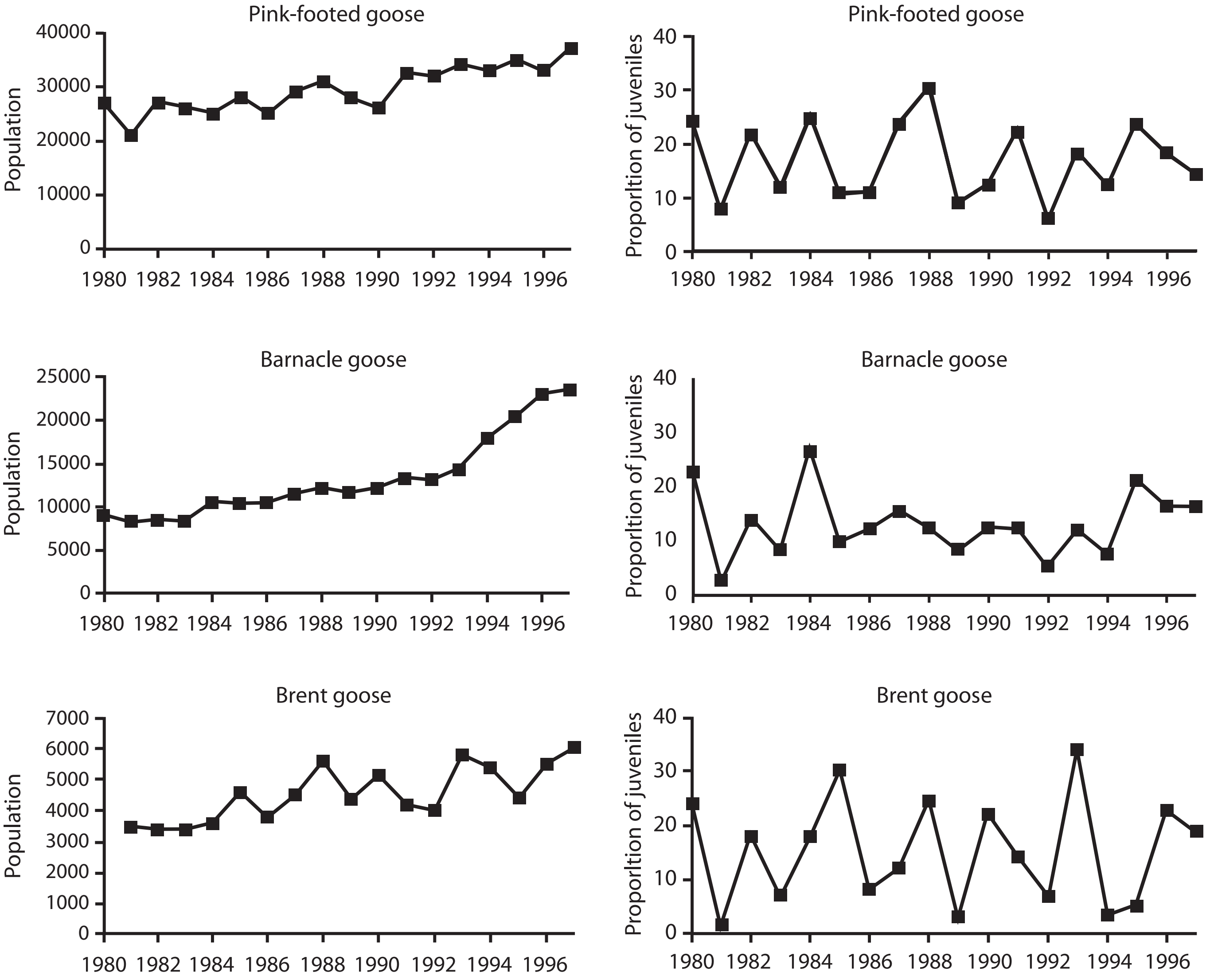

Figure 3
Trends in population size and breeding success since 1980 for the three species of geese breeding in Svalbard (Madsen et al. 1998)

the introduction of protection provisions in both Svalbard and the wintering areas. The populations have gradually become so large that conflicts have arisen with farmers in the wintering areas and on the migration routes. An international plan for the management of the populations has been drawn up by the countries affected.

The considerable annual variation in breeding success is first and foremost related to 1) variations in weather and snow cover at the breeding sites and ice conditions in the fjords, which affect the fitness of the chicks and their predation, and 2) variations in the fitness of the parents when breeding starts, which is largely influenced by the weather conditions in their wintering areas and during migration. The light-bellied brent geese breed in the harshest parts of Svalbard and are particularly exposed to bad weather and a late thaw. Both their breeding success and adult mortality vary extremely from year to year.

Conclusions

The Svalbard populations of barnacle geese and pink-footed geese are viable. The light-bellied brent goose population is very small compared to what it is believed to have been 50-100 years ago (some light-bellied brent geese also breed in Greenland), and it is uncertain whether it is viable. All three populations have increased in numbers since 1980, but recent counts suggest that the growth has flattened out in the case of the barnacle and pink-footed geese. An expected warmer and wetter climate may have both positive and negative repercussions, depending on whether the time of the thaw at the nesting sites changes and whether the growing season generally becomes shorter or longer in both the wintering and breeding areas. The conditions in the wintering areas may also be very important. The light-bellied brent goose population is perhaps most sensitive to climate change and increased traffic.

2.1.5 Vegetation

No data exist that are generated by MOSJ, and few publications are available regarding any changes in vegetation in Svalbard over time, except for a report produced for the Monitoring Programme for Terrestrial Ecosystems (Jacobsen 1994).

2.1.6 Cultural heritage sites

A great deal of mapping and description of cultural heritage sites has been carried out in Svalbard. Sites at Gravneset, Virgohavn, Hiorthamn, Smeerenburg, Fredheim and Sallyhamn were surveyed in detail and aerial photographed in 1997-99 as the onset of a monitoring programme. Information exists from these localities for each year since then. These data are being analysed and worked up, and will eventually enable changes to be traced over time. It has also been suggested that changes in the total

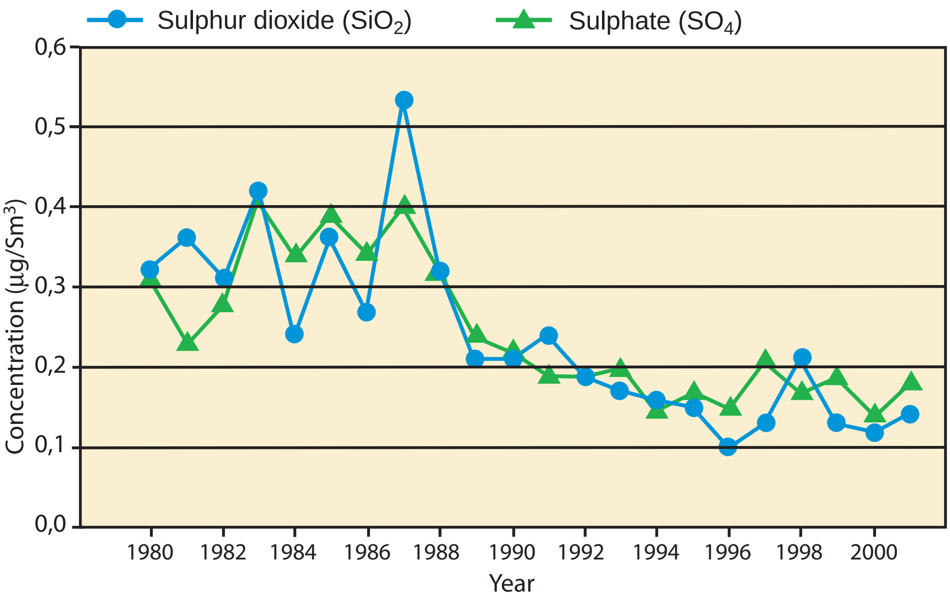

Figure 4
Concentrations of sulphur in the air at the Zeppelin Station at Ny-Ålesund (data from NILU)

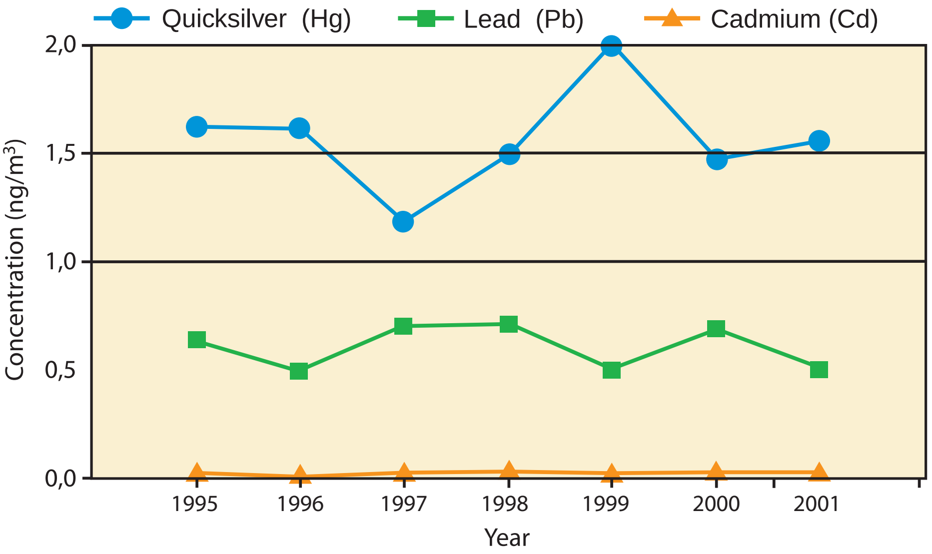

Figure 5
Heavy metals in the air at the Zeppelin Station at Ny-Ålesund (data from NILU)

number of recorded cultural heritage structures in Svalbard over time could be used as a parameter, but it is impossible to obtain information about trends in this parameter before the cultural heritage data base is updated and quality assured. It is believed that cultural heritage sites in Svalbard have so far been more affected by natural processes (waves, ice and wind) than human traffic.

2.2 Pollution

Little systematic monitoring of pollution in the Norwegian Arctic is taking place, except for measurements of air at the Zeppelin Station at Ny-Ålesund. Fortunately, some scientific publications and data collected in connection with research can be compiled into time series. The data presented here derive from such publications or data bases that have been made available, from the annual reports of the Norwegian Institute for Air Research (NILU) measurements made at the Zeppelin Station, or its web site, http://www.nilu.no/niluweb/services/zeppelin/ . The assessments are also based on two evaluations of the pollution situation in Svalbard made in association with MOSJ work in 2001.

2.2.1 Air pollution at Ny-Ålesund

NILU has demonstrated statistically significant mean reductions in the concentrations of sulphur dioxide and sulphate at Ny-Ålesund since 1980, amounting to -0.012 and -0.010 µg S $m^{-3} \cdot yr^{-1}$ (74% and 61%), respectively (Figure 4). This is a good reflection of the reduction in emissions in the rest of Europe. No corresponding statistically significant reductions in other components of acidification (mainly nitrogen compounds) have so far been found. In a report from 1993, the threshold for acidification was thought to have been exceeded in 5% of the ice-free parts of Svalbard (Lien et al. 1993). In view of the marked reduction in the past 10-12 years in the influx to Svalbard of substances producing acidification, it is likely that the threshold is now exceeded on less than 5% of the ice-free land area of the archipelago.

No trends in heavy metals in the air at Ny-Ålesund have been statistically analysed (Figure 5), but such data will be available in 2003. Apart from those of mercury, which is more easily dispersed because it is not bound to particles, the concentrations are approximately 50% below the level at the similar station at Lista in southernmost Norway. There are generally lower levels of heavy metals in Svalbard than close to the industrial sources, where most of the pollutants are deposited (AMAP 1997).

PCB: measurements from only the last 4 years are presented (Figure 6). Data exist from further back in time, but these are not presented because contamination problems have not been clarified. A statistical trend analysis cannot be performed yet because the time series is too short. However, the tendency is that levels

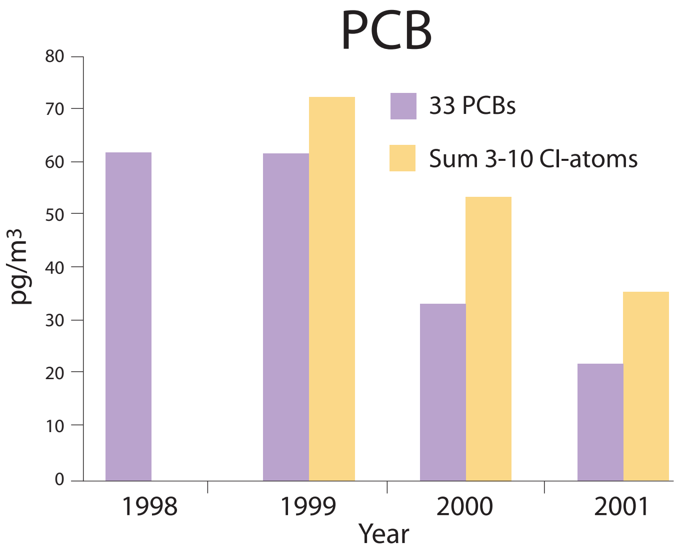

Figure 6
PCBs in air at the Zeppelin Station at Ny-Ålesund (data from NILU)

are decreasing, but the variation in the measurements is very high. DDT: measurements are only available for 10 years, but trend analyses are expected to be carried out on these data in 2003. The material available shows no obvious tendencies.

HCB: the time series from 1993 shows a clear tendency to decrease. The levels in 2001 were close to half what they were in 1994 and were the lowest measured in this period. Trend analyses are being performed in 2003.

HCH: the time series from 1993 shows a clear tendency to decrease. The levels in 2001 were close to half what they were in 1996 and were the lowest measured in this period. Trend analyses are being performed in 2003.

Chlordane: the time series from 1993 shows a clear tendency to decrease. Trend analyses are being performed in 2003.

Conclusion

The general tendency is that components of pollution measured in the air at Ny-Ålesund have decreased or remained unchanged in the last 5-10 years. Reservation has to be made because several time series are short and too little adequate research and too few statistical analyses have been performed on the data series. Moreover, some important components are not measured. However, the tendency corresponds well with that found elsewhere in the Arctic (AMAP 2002). The Norwegian Pollution Control Authority (SFT) has allocated funding for trend analyses for data on organic pollutants and heavy metals in the air, and these will be available during 2003[1]. Trend analyses were also presented for the AMAP report in 2002.

2.2.2 Contamination in arctic foxes

Measurements of PCB levels in arctic foxes were carried out in 1973-74 (Norheim 1978), 1983-84 (Wang-Andersen et al. 1993) and 1991-92 (Prestrud, unpublished). Table 1 shows the results.

The content of PCBs in Svalbard foxes was comparatively high and stable in the 1970s and 1980s. Measurements made in the 1990s suggest the levels are increasing, and concentrations in a few individuals were higher than in polar bears from Svalbard. However, it has to be taken into account that the most recently collected data have not been analysed in a scientific context, and only three point measurements exist, not a continuous series over a long period. Some figures from 1991-92 are extremely high and further investigations on a regular basis should be carried out to confirm or invalidate that the situation is as alarming as these data suggest.

The levels of mercury and other heavy metals are very low in arctic foxes, and probably have natural causes (Prestrud et al. 1994, Severinsen & Skåre 1997).

2.2.3 Contamination in Svalbard reindeer: organic pollutants and mercury

No long time series are available, but levels have been measured in samples collected in connection with the first phase of the AMAP (Arctic Monitoring and Assessment Programme) work in 1997 (Severinsen & Skåre 1997). The measurements show very low levels of contamination. No data or other indications show that mercury, lead or POPs constitute any problem for the reindeer in Svalbard.

2.2.4 Contamination in Svalbard ptarmigan: organic pollutants and mercury

No long time series exist for mercury, but screening was performed in connection with the preparation of the first AMAP report in 1997 (Severinsen & Skåre 1997). The mercury levels are low. No data or other indications show that mercury, lead or POPs constitute any problem for the ptarmigan population in Svalbard.

2.2.5 Overall assessment of pollution

The pollution in terrestrial biota in Svalbard is low and scarcely amounts to a pressure of special significance, with the possible exception of the arctic fox population. In the limnic environment, extremely high PCB values have been found in some arctic char in Ellasjøen, a lake on Bjørnøya, but these results have not been included in the MOSJ data. The transport of airborne pollutants to Svalbard seems to have dropped in recent years, but some reservation must be made since a number of relevant substances are not being measured. It is likely that less of the land area than previously (less than 5%) is exposed to acidification that exceeds the thresholds, because airborne transport of sulphur compounds has been substantially reduced in the past 15-20 years.

- Special watch must be kept on the mercury situation because: new knowledge about the transport of mercury to the Arctic and extensive deposition here in spring was presented by AMAP (AMAP 2002), and such transport has also been demonstrated by research carried out at Ny-Ålesund each year since 2000, mercury constitutes a problem in biota elsewhere in the Arctic, and relatively little is known about mercury in Svalbard biota.

The reasons for reduced levels of a number of contaminants in the air are probably that less coal containing sulphur is being used to

Table 1
PCB levels in livers and fat (µg/g fat weight and wet weight) of arctic foxes and polar bears in Svalbard. From Norheim (1978) (a), Wang-Andersen et al. (1993) (b), Severinsen & Skaare (1997) (c), Prestrud et al. unpublished (d) and Bernhoft et al. (1997) (e).

Year	**Liver (µg/g fat weight)**	**Fat (µg/g wet weight)**
Arctic fox 1973-4 (a)	12.4±14.2 (n=44)	10.3±11.7 (n=44)
Arctic fox 1983-4 (b)	9.7±9.9 (n=24)	8.3±11 (n=11)
Arctic fox 1992-3 (c)	20.5±31 (n=43)	46.9±38.0 (n=10)
Polar bear 1990-4 (d)	-	28.1 (n=20)

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[1] These will be published in autumn 2003 (see http://www.sft.no/nyheterdbafile10036,html)

generate power in European countries and, in part, Russia, nickel ore containing less sulphur is now being smelted on the Kola Peninsula, and the production and use of PCBs and persistent herbicides have been greatly reduced in the past 10-30 years in most countries that are sources of this kind of pollution in the Svalbard region.

A higher pollution load in the Russian Arctic is a consequence of the supply of pollutants via the large Russian rivers, together with airborne transport from various regions where these substances are still in use. It is also likely that both PCBs and DDT are still in use in Russia. Pollution from the Russian Arctic also reaches Svalbard.

2.3 Traffic

Traffic is clearly on the increase in Svalbard, in part rather rapidly. The following MOSJ parameters have risen strongly since 1995

- Overnight stays at premises offering accommodation in Longyearbyen have more than doubled since records began in 1995. A particularly strong increase has occurred since 1999, although there was a slight drop from 2001 to 2002.
- The number of disembarkation sites recorded as having been used by foreign cruise ships and coastal cruise vessels (sailing from Longyearbyen) has increased from 50 in 1996 to 126 in 2002 (see Figure 7 and the web page: MOSJ/Påvirkning/ferdsel/cruiseturisme). The number of people going ashore has doubled in this period. It is first and foremost the coastal traffic based on Longyearbyen which has increased. The overseas cruise traffic has changed only slightly in the past 10-15 years and accounts for approximately half of the passengers who land. However, these people only disembarked at 15 locations in 1996-2002, in addition to the permanently inhabited settlements.
- Petrol consumption in Longyearbyen was 70% higher in 2001-2002 than in 1995. Most of this rise results from an increase in the use of snowmobiles. Petrol consumption was almost stable, or perhaps dropped slightly, from 2001 to 2002.
- The number of registered snowmobiles increased by 400 from 1994 to 1998 when a new registration method was introduced. The increase of 175 from 2001 to 2002 is the largest number registered in a single year. It is not clear why this increase has not been reflected by higher petrol consumption.
- The above four parameters only give an indication of changes in the traffic. An attempt must be made to obtain better quantitative indicators for the variation in the development of traffic in Svalbard.

The number of helicopter hours flown in Svalbard has remained almost unchanged at just under 1000 hours a year since 1995. Likewise, the number of individual travellers (i.e. non-organised tourists) in areas where they are obliged to state their intent beforehand has also remained almost unchanged at around 500 a year since 1995.

The reason for the increase in traffic is the growth of organised tourism, which most probably results from a combination of more marketing, more knowledge about Svalbard as a tourist goal, more provision of facilities and better organisation. More research activity and more travelling on the part of local people are also contributory reasons. The statistics, however, offer little basis for distinguishing between these different groups.

In the course of a 10-15 year period, large parts of Svalbard have become more readily accessible than previously due to a substantial increase in the snowmobile traffic and, not least, the use of smaller vessels to take tourists (and scientists) round the entire archipelago. Lack of knowledge, in part concerning biological occurrences and impacts at the most visited places, makes it difficult to determine to what extent this increase has affected the natural environment. In general, increased traffic may give the following environmental problems:

1. Disturbance to animal life and damage to vegetation and soil
2. Noise and increase in refuse, which reduce the feeling of enjoyment for those wanting to experience unspoilt scenery and wilderness conditions
3. Damage to cultural heritage sites.

Many scientific studies have been performed on the impact of traffic on animal life, and a few have been carried out in Svalbard (on reindeer, arctic foxes, eider ducks and seabirds). Some of this information has been compiled with a view to assessing its effects on the animal life in Svalbard (Overrein 2002). It is difficult to draw general conclusions from these investigations because different species and populations have differing degrees of sensitivity to the effects of traffic and the sensitivity varies with the season. Where snowmobile traffic and traffic in general in summer have increased most (the central part of Nordenskiöld Land), there have apparently been no negative changes in the populations of reindeer, arctic foxes or geese (i.e. no statistically significant decline during the monitoring period). However, it is not known what the state of these populations would have been without traffic, or whether the traffic may have a negative effect if the populations find themselves in a crisis situation as a consequence of changes in other pressures. No knowledge whatsoever exists regarding possible changes in habitat use caused by disturbances. Such matters must be assessed in the light of the ambitious goals to maintain the wilderness character in Svalbard. Which effects are problematical can only be determined through assessments that judge values.

The present scale of traffic on the part of tourists will scarcely lead to significant damage to vegetation and soil, except where

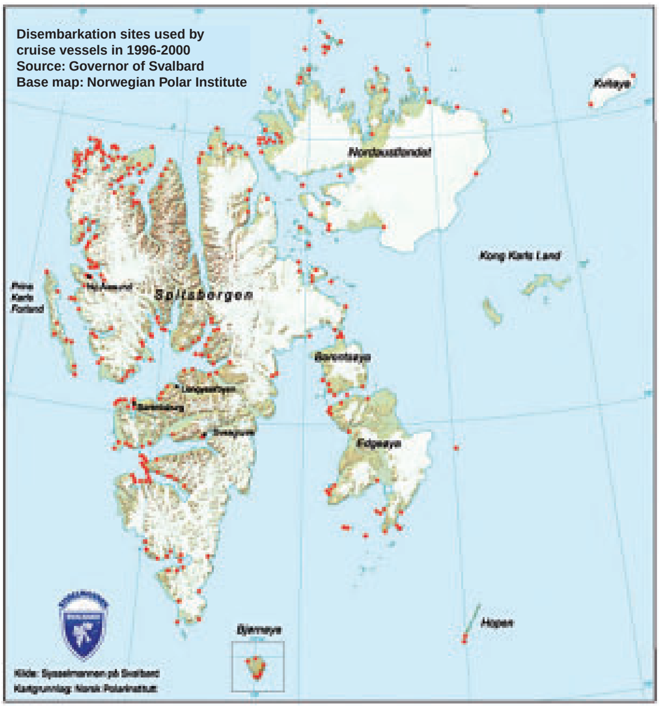

Figure 7
The number of disembarkation sites used by cruise vessels in Svalbard rose steeply from 1996 to 2002

cruise ships land large numbers of tourists in summer. However, it should be borne in mind that the monitoring programme is so far only capable of revealing changes in the vegetation cover near the cultural heritage sites that are being monitored by photographic documentation. There is also more cause for concern that the number of disembarkation sites is increasing than the number of tourists is growing.

Noise and the discarding of refuse, which impair the enjoyment people feel who want the countryside to be disturbed as little as possible, are among the most problematical aspects in connection with traffic in Svalbard. A great deal of motorised traffic in the terrain is not particularly compatible with what is normally associated with the wilderness concept. Little is known about which groups of users are affected, the scale of the problem and how the problem can be characterised.

Wear and tear at cultural heritage sites has been documented, but not quantified for the most visited localities. The use of new computer programs to analyse and compare digital photographs (of which there are series covering several years) should enable such information to be acquired (Vistad & Grytli 2003). There are also many instances of tourists and other visitors directly destroying or damaging cultural heritage structures, either wilfully or through ignorance. Independent of monitoring data, the Governor and the Directorate for Cultural Heritage should consider drawing up a prioritised list of localities or zones where restricted access should be introduced first, and another for where information and the means to gain enjoyment and satisfaction from the cultural history of the site should be provided without restrictions being imposed. There is every reason to believe that some cultural heritage sites are threatened as a consequence of the increased traffic, but natural erosion and the like will probably still continue to be a significant wear factor. Greater variability in climate and higher precipitation and temperature caused by human emissions of greenhouse gases may possibly accelerate the wear and tear and erosion of cultural heritage sites in Svalbard. The monitoring methods should be refined as much as possible to make them more cause-specific (help to distinguish between natural and anthropogenic pressures).

2.4 Hunting, trapping and shooting

Reindeer hunting is strictly regulated through quotas and is confined to just a few parts of Nordenskiöld Land. Moreover, the quotas have remained almost unchanged since hunting resumed in 1983. As the authorities have good control over both the herd and the numbers taken, it is unlikely that the bag will significantly affect this sub-population. Nevertheless, it is conceivable that some parts (particularly coastal areas) of the individual hunting countries have been harvested in a way that may have affected the herd, because too many animals may have been taken some years and the structure (age and sex composition) of the herd may have been affected.

The number of arctic foxes shot or trapped has also remained more or less unchanged in recent years, at around 100-120 a year in 1982-1989 and 1997-2002. In areas where shooting and trapping take place from Longyearbyen, the number taken some years has probably exceeded the figure for which recruitment should provide a basis. Immigration and extensive roaming from a surplus stock probably explain why this has not resulted in a reduced population density.

Hunting statistics for ptarmigan only exist from 1997 inclusive, and it is too early to say anything regarding trends in the numbers taken in this period. The number of ptarmigan shot has varied between 1200 and 1800 a year. This is doubtless far fewer than the population will tolerate.

The question of whether hunting, trapping and shooting affect a population is not always easy to answer. The degrees of the effect must be defined first. The numbers of reindeer and arctic foxes, perhaps also ptarmigan, present vary considerably from year to year. Vulnerability to pressure from hunting, trapping and shooting will, moreover, depend greatly upon the state of the population when it is being harvested.

2.5 Refuse on shores

The Governor's office has begun to monitor refuse on some shores in Svalbard, but records over several years still do not exist to provide a basis for assessing trends.

2.6 Introduced species

Little information exists about species that have been introduced to Svalbard, and very little work has been done on their distribution and numbers over time. Their potential for harmful effects is therefore difficult to assess. In general, it may be said that islands are specially at risk for harmful effects from introduced species. There is therefore every reason to follow the development carefully.

Several species of plants have been introduced to Svalbard. As far as is known, they are mainly confined to the vicinity of the settlements. Attempts have been made to release musk ox and two species of hares, but these populations died out many years ago. The sibling vole *Microtus epiroticus* has been established between Longyearbyen and Barentsburg for several decades, and probably reached Svalbard with hay imported as livestock fodder. The population has been studied for a decade or so and has proved to vary enormously from a few hundred individuals to around a hundred thousand. Once more, it is variations in precipitation and temperature in the winter that influence the population through icing and access to vegetation. No trends in the population have been traceable during this period. There has been speculation as to whether the species can adapt to the environmental conditions in Svalbard and gradually spread over large parts of the archipelago. If so, it will most probably have a great impact on the terrestrial ecosystems. However, there are no indications that this is taking place.

No information exists about the introduction of invertebrates. *E. multilocularis*, a tapeworm which has the sibling vole and arctic fox as its hosts, may have been introduced with the sibling vole.

It is possible to speculate on whether the great influx of visitors to Svalbard may also result in a greater chance of new species of vertebrates and plants being introduced. A clear link between the number of introduced species (invasion success) and the number of visitors and residents has been proved on sub-Antarctic islands (Chown et al. 1998). In combination with a changed climate, making it easier for new species to establish, this may also become a problem in Svalbard.

2.7 Overall assessment of pressures and the state of the environment

Human activities in the countryside, whether they concern travelling around or other physical disturbances to the environment, pollution, human-induced climate change or the taking of game, will always have some effect on the landscape or the species living there. The degree of impact that can be accepted is normative, and it is therefore the responsibility of political authorities to decide which changes are acceptable or to what extent one has to "play on the safe side". Ambitious targets have been set for the management of Svalbard as a wilderness area. In game management, for instance, the aim is to harvest populations in a way that will not affect their natural productivity and age and sex structure. Svalbard is intended to be one of the best-managed wilderness areas. The threshold values for changes which will prevent these targets being achieved are, at best, extremely vague.

However, a target has been set for cultural heritage sites, and this states that fewer than 0.1% of the individual structures will disappear each year. Even though it is difficult to measure such changes, the target is at least unequivocal and sends a clear signal about the ambition level. The point with monitoring is to reveal and halt the pressures before cultural heritage sites "disappear". Threshold values should therefore be more closely linked to the individual structure or group of structures. The present means of measuring the state of cultural heritage sites states proportional changes (for example in size, volume, or number of structures) from one investigation date to the next. Corresponding threshold values should also be set for other MOSJ indicators.

The flow to the terrestrial environment of the components of pollution that are measured in Svalbard is either being reduced or remains unchanged. Except perhaps as regards the arctic fox, it is reasonable to assume that the substances being measured have only minor negative effects on the terrestrial populations being investigated in the MOSJ programme. Mercury may be an exception. Pollution may locally affect the vegetation near settlements and mines, but this has little significance in a larger context. Based on the "precautionary principle" and the fact that no pollution is acceptable in wilderness, efforts obviously still need to be made to reduce the transport of pollution to the terrestrial environment of the archipelago. We must also not ignore the possibility that a change in climate may lead to increased airborne transport from the south, which may result in a new increase of pollution in Svalbard. It must also be borne in mind that the "new" pollutants being spread in the environment are scarcely being measured in Svalbard.

Temperature, precipitation and traffic are increasing in Svalbard. Even though it is known that such factors can have great biological importance, no changes have so far been proved. More precipitation in the form of snow, combined with a higher frequency of periods when temperatures are well above zero in winter, may give greater variability in the populations of reindeer and geese, perhaps also ptarmigan and arctic foxes. Consequently, sub-populations may experience crises more often, and these may become more far-reaching. In such situations, it is conceivable that disturbances deriving from increased traffic, hunting, trapping and shooting will be an extra load that triggers more permanent and far-reaching population changes.

The increased traffic, combined with a predicted rise in temperature and higher precipitation may expose the cultural heritage sites in Svalbard to increased wear and tear and erosion.

3 Assessment in relation to national environmental targets

Target 8.2

Populations of species now considered endangered or otherwise negatively affected by land use, harvesting and/or pollution must be preserved and, if possible, built up again.

With the possible exception of the light-bellied brent goose, none of the terrestrial species now covered by the MOSJ programme are directly endangered or strongly negatively affected by human activities today. Several of the species have previously been greatly decimated by excessive harvesting. There are insufficient data to assess the pressure on vegetation.

Target 8.3

An attempt must be made to maintain the extent of continuous wilderness areas in Svalbard. Special protection decisions must safeguard representative parts of the environment from significant encroachments or impacts by 2002. Important values in the marine environment around Svalbard must be safeguarded.

The implementation of the new protection plan will ensure that the extent of continuous wilderness areas in Svalbard is maintained. A continued increase in traffic at the same rate as we have seen so far may place this target under pressure.

Target 8.4

An attempt must be made to preserve a representative selection of cultural heritage sites in Svalbard and on Jan Mayen for scientific study and the enjoyment of future generations. The loss of cultural heritage structures as a consequence of human activity must not exceed an average of 0.1% a year.

A representative selection of cultural heritage sites has been preserved in Svalbard. Existing knowledge does not permit a conclusion that the target of 0.1% has been achieved.

Target 8.5

Transport and traffic in Svalbard must not result in significant or permanent damage to vegetation, or disturbance of animal life. Possibilities to enjoy the countryside undisturbed by motorised traffic must also be ensured in areas that are easily accessible from the settlements.

Traffic, particularly growing traffic as in Svalbard, will always have an effect on vegetation, the soil and some animals. However, no validation of significant or permanent ecological damage to the natural terrestrial environment has so far been presented. Knowledge is lacking in this field, because few studies have been performed. It is likely that visitor pressure will continue to rise, and it is uncertain whether traffic will lead to such damage being caused under given conditions. Traffic has resulted in wear and tear to vegetation at cultural heritage sites and has damaged them. Many people are of the opinion that opportunities to experience the countryside undisturbed by motorised traffic are reduced in Svalbard and that too few snowmobile-free zones have been designated to ensure such enjoyment near the settlements.

4 Advice to management bodies regarding responses

- A weakness with MOSJ is that no critical impact limits have been defined for the selected indicators. The management body must attempt to define which changes in the pressures and the populations are unacceptable. This will be important for the design of the MOSJ monitoring programmes.
- The increase in traffic (especially disembarking of passengers, but also snowmobiles) is troubling and the management body should follow this development particularly carefully and con tinuously assess what are acceptable levels and what actions must be implemented in various parts of Svalbard.

5 Advice about gaps in knowledge

- A systematic monitoring and research programme should be initiated urgently with the aim of demonstrating any changes in vegetation in Svalbard. One weakness of the MOSJ programme is that no such study exists. To make a rapid start, the possibility of using vegetation maps, satellite images, data from the fenced- in areas on the Brøggerhalvøya and in Adventdalen, the terrestrial monitoring plots in Kongsfjorden, and other material from the 1970s, 1980s and the beginning of the 1990s as reference material should be considered. It should also be feasible to make use of experience acquired from Abisko, Zackenberg and perhaps elsewhere to develop programmes for Svalbard. Botanists should also be brought into the ongoing analysis of changes on and around the cultural heritage sites – where the traffic is greatest.
- Programmes must start to measure the ”new” contaminants, like brominated flame retardants and toxaphenes. It goes without saying that the present programme of measurements taking place at the Zeppelin Station must continue.
- Levels of mercury in terrestrial animals must be measured regularly.
- Regular measurements must be made of pollutants in biota; the measurements of organic pollutants in arctic foxes must be specially intensified (a programme funded by the Research Council of Norway begins in 2003).
- Where adequate data exist, ”power analysis” should be performed to determine the quality of the entire monitoring programme. This will be able to reveal the extent of the changes that can be detected within a given period with its present scope. Such knowledge must be compared with a possible determination of critical effect limits to be able to adjust the scope and input of resources regarding the sub-programmes.
- More knowledge about the impact of traffic on the animal populations must be acquired. Provocation studies are insufficient. Acquiring knowledge on possible changes in habitat use, behaviour and physiology in the most affected areas must be given priority.
- The MOSJ programme should be pragmatic and use all the long time series that have been obtained through research if they can be conceived as having value for saying more about the development of the state of the environment in Svalbard. Example are the long time series for purple sandpipers and geese.
- It is not sufficient to just monitor the ptarmigan population by registering males that are defending territories. The possibility of acquiring data from shooting, such as the effort per bird shot and the proportion of chicks and juveniles in the bag should be looked into. Likewise, if possible, data should be gathered each year regarding the effort per arctic fox that is taken.
- New data on cultural heritage sites should be analysed and presented promptly, and work on the cultural heritage data base should be speeded up. Plant life and cultural heritage sites must be viewed in context. A relevant methodological approach (digital photographs) has been described by Vistad & Grytli (2003).
- New investigations of visitors to Svalbard should be initiated that describe both the kinds of visitors and their preferences for activities and environments in Svalbard. This will also be an important reference in relation to the ambitious aim that Svalbard will be one of the world’s best managed wilderness areas. What do visitors regard as ”wilderness” in the context of Svalbard, and what are possible threats to the wilderness experience? Are, for example, snowmobiles, cruise ships and small boats to be considered as threats, or merely ” neutral means of transport”?

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