CAFF
Conservation of Arctic Flora and Fauna

CIRCUMPOLAR BIODIVERSITY MONITORING PROGRAM

CAFF CBMP Report No. 19
December 2009

CIRCUMPOLAR MARINE BIODIVERSITY MONITORING PLAN

BACKGROUND PAPER

Acknowledgements

The Conservation of Arctic Flora and Fauna (CAFF) is a Working Group of the Arctic Council. The Circumpolar Biodiversity Monitoring Programme (CBMP) is the cornerstone program of CAFF.

CAFF Designated Agencies:

- Environment Canada, Ottawa, Canada
- Finnish Ministry of the Environment, Helsinki, Finland
- The Ministry of Domestic Affairs, Nature and Environment, Greenland
- Faroese Museum of Natural History, Tórshavn, Faroe Islands (Kingdom of Denmark)
- Icelandic Institute of Natural History, Reykjavik, Iceland
- Directorate for Nature Management, Trondheim, Norway
- Russian Federation Ministry of Natural Resources, Moscow, Russia
- Swedish Environmental Protection Agency, Stockholm, Sweden
- United States Department of the Interior, Fish and Wildlife Service, Anchorage, Alaska

CAFF Permanent Participant Organisations:

- Aleut International Association (AIA)
- Arctic Athabaskan Council (AAC)
- Gwich'in Council International (GCI)
- Inuit Circumpolar Conference - (ICC) Greenland, Alaska and Canada
- Russian Indigenous Peoples of the North (RAIPON)
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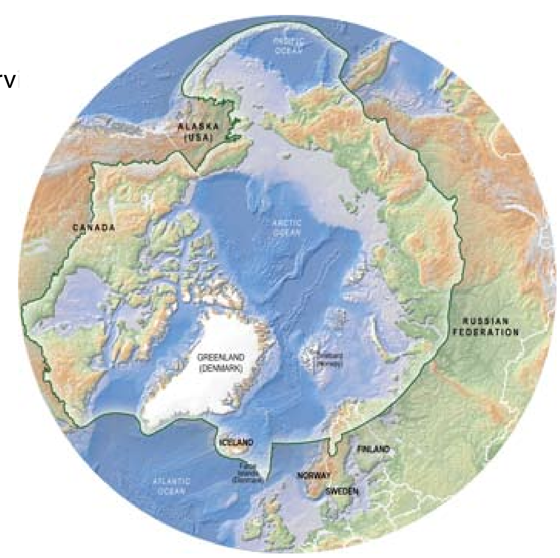

CAFF Designated Area

For more information please contact:
CAFF International Secretariat
Borgir, Nordurslod
600 Akureyri, Iceland
Phone: +354 462-3350
Fax: +354 462-3390
Email: caff@caff.is
Internet: http://www.caff.is

Editing: Mike Gill and Tom Barry
Design & layout: Tom Barry

Circumpolar Marine Biodiversity Monitoring Plan - background paper

A Supporting Publication to the
Circumpolar Biodiversity Monitoring Program
Framework Document

Conservation of Arctic Flora and Fauna

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1. Introduction

The Arctic hosts unique assemblages of organisms. The size and nature of Arctic ecosystems make them of critical importance to the biological, chemical and physical balance of the globe. Dramatic climate-related changes now underway are threatening the resiliency and sustainability of the Arctic's biodiversity and the overall balance of its ecosystems. Continued rapid change in the Arctic will have global repercussions affecting the planet's ecosystems and biodiversity as a whole. Maintaining the health of Arctic ecosystems is also of fundamental economic, cultural and spiritual importance to Arctic residents, many of whom maintain close ties to the sea.

Current Arctic biodiversity monitoring efforts are insufficient to provide an integrated picture of the status of and trends in key species, habitats, processes, and services. Better coordination of our existing monitoring networks is urgently needed to help improve our ability to detect important trends on a timely basis, attribute these trends to their underlying causes, and provide this information to decision makers to facilitate effective and timely responses.
In response to the challenges facing the Arctic and our current monitoring capacity, the Arctic Climate Impact Assessment recommended that long-term Arctic biodiversity monitoring be expanded and enhanced. The Arctic Council Conservation of Arctic Flora and Fauna Working Group's (CAFF) primary response to this recommendation has been the implementation of the Circumpolar Biodiversity Monitoring Program (CBMP).

The CBMP is working with scientists and local resource users from around the Arctic to harmonize and enhance long-term Arctic biodiversity monitoring efforts in order to facilitate more rapid detection, understanding, communication and response to significant trends and pressures.

The Arctic's size and complexity represents a significant challenge to detecting and attributing

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important biodiversity trends. This situation demands an integrated, pan-Arctic, ecosystem-based approach that not only identifies trends in biodiversity, but also the underlying causes. It is critical that this information be made widely available to those responsible for generating effective strategies for adapting to ongoing changes now taking place in the Arctic - a process that ultimately depends on rigorous, integrated, and efficient monitoring programs that have the power to detect change within a time frame of a few years to decades.

Towards this end, the CBMP is facilitating an integrated, ecosystem-based approach to monitoring through the development of five Expert Monitoring Groups representing major Arctic themes (Marine, Coastal, Freshwater, Terrestrial Vegetation & Terrestrial Fauna). Each group functions as a forum for scientists, community experts and managers to promote, share, and coordinate research and monitoring activities and utilize existing data to faciliate improved and cost-effective monitoring that has a greater ability to detect and understand significant trends in Arctic biodiversity.

1.1 Marine Expert Monitoring Group – Goals and Objectives

The Marine Expert Monitoring Group (Marine EMG)'s goal is to promote, facilitate, coordinate and harmonize marine biodiversity monitoring activities among circumpolar countries, and to improve ongoing communication amongst and between scientists, community experts, managers and disciplines both inside and outside the Arctic.

Specifically, the MEMG's objectives are:

- To develop a multi-disciplinary, integrated, pan-Arctic long-term marine biodiversity monitoring plan that:
  - Responds to identified science questions and user needs;
  - Identifies an essential set of indicators for marine ecosystems that are suited for measurement and implementation on a circumpolar level;
  - Makes use of existing monitoring capacity and information (both scientific, community-based and Traditional Knowledge);
  - Identifies key a-biotic parameters relevant to marine biodiversity that need ongoing monitoring;
  - Addresses current gaps in coverage (both elemental, spatial and temporal); and,
  - Identifies a core set of standardized protocols to be implemented across the Arctic.
- To facilitate implementation of the long-term monitoring plan.

This background paper represents the first step towards the development of a long-term, coordinated Arctic biodiversity monitoring plan. The purpose of this background paper is to facilitate the workshop process by identifying the key elements of the plan to be defined and agreed upon.

1.2 Timeline and Process

Co-led by Norway and the United States, and with members from Russia, Denmark/Greenland, Canada, Aleut International Association and Arctic Council Arctic Monitoring and Assessment Programme (AMAP), the Marine EMG is developing a multi-disciplinary, integrated, pan-Arctic long-term marine biodiversity monitoring plan based on the following schedule:

- November, 2008: Draft Background Paper completed
- December, 2008: Background Paper Peer Review conducted
- January, 2009: 1st Marine EMG Workshop
- June, 2009: Draft Integrated Monitoring Plan (IMP) completed
- October, 2009: 2nd Marine EMG Workshop
- December, 2009: Integrated Monitoring Plan completed
- January 2010: IMP implementation body convened

This background paper represents the first step towards the development of a long-term, coordinated Arctic biodiversity monitoring plan. The purpose of this background paper is to facilitate the workshop process by identifying the key elements of the plan to be defined and agreed upon.

1.3 Early decisions and program limitations

The process of developing a long-term, coordinated monitoring plan for Arctic marine biodiversity is ongoing, with this document signifying a milestone in its development. However, a number of events preceded the official formation of the Marine EMG and have framed the scope and focus for developing an integrated monitoring plan for Arctic marine biodiversity.

The development of the Marine EMG began in October 2006 at a CBMP Implementation Planning workshop in Anchorage. It was there that the concept of the Expert Monitoring Groups was created and work began on developing a concept for an integrated marine biodiversity monitoring plan. These concepts were further developed at another CBMP workshop in March 2008 in Washington, DC.

In addition, a number of significant decisions, influencing the focus and scope of an integrated monitoring plan for Arctic marine ecosystems, had been made during the initial development of the CBMP. These decisions highlighted a network of networks approach focusing on coordinating existing monitoring networks and capacity and identifying critical gaps (either geographic or thematic gaps) in observational coverage that could be filled if new resources became available. These decisions are captured in the CBMP's Framework Document and Five-Year Implementation Plan, both endorsed by the Arctic Council Senior Arctic Officials (SAO's) and Ministers.

CAFF is a multinational cooperative working group sustained by mostly in-kind resources. For a program with such limitations, there are certain elements that are essential if the program is to successfully be implemented and sustained. Some of these are summarised below.

1.3.1 Basis in existing monitoring

A carrying principle within the CBMP (a principle endorsed by the SAOs) is that the CBMP will interact first and foremost with existing monitoring activities, already active or planned and preferably circumpolar in scope. However, where appropriate (e.g., where no circumpolar network exists), the CBMP will also work with existing or planned regional, national or bilateral projects that could contribute to a circumpolar understanding of biodiversity trends. This approach reflects the CBMP's intention to develop plans that reflect existing monitoring capacity. If and when gap analyses identify new activities that are not addressed within existing projects, the CBMP will work to encourage the proper administrative/political jurisdictions to facilitate or fund the suggested new monitoring activity, or to seek funding from external sources.

Arctic science dates back well over 100 years as exemplified by the International Polar Year in 1882-1883. A wealth of data on various aspects of the Arctic marine system, including biological measurements, exists in various forms (e.g. scientific publications, gray literature (including industry studies), databases, photo libraries, field books, etc.), but is often not readily accessible. This data, in many instances, represents cost-effective opportunities for establishing retrospective, long-time series datasets. In addition, the Arctic contains a number of abandoned research sites and transects that could be re-sampled yielding extended time-series trend data.

In addition, Arctic indigenous residents have been observing and adapting to change for thousands of years. These observations (Traditional Ecological Knowledge) have been transferred from generation to generation and provide a historical perspective to Arctic change. While there is an opportunity, looking ahead, to coordinate our current monitoring approaches, there is an equal opportunity to 'rescue' existing information (both scientific and Traditional knowledge) to help us understand historical trends and put current trends in context.

1.3.2 Monitoring based on indicators

The CBMP has decided to use an indicator approach to monitoring and reporting. An indicator is defined here as an ecological entity for which the repetitive measurements may reveal the status and/or trend of the indicator itself or a larger part of the ecosystem. Indicators could therefore be species, communities and/or other biotic or abiotic elements or processes.

Early in the process, there was general agreement that the number of indicators should be restricted and, where possible, in line with the Convention on Biological Diversity's (CBD's) Headline Indicators (see Appendix 4). Ideally a small suite of robust indicators is better than a large suite of less robust ones. And, if not designed properly or interpreted incorrectly, a large number of indicators and parameters may give a false impression of precision and accuracy in status descriptions or predictions about future trends. In this regard, some indicators are more powerful than others and the development of the indicators will be hierarchical, where data permits, allowing the user to 'drill down' from broad scale indicators to specific regions, populations and/or time-series.

Sustaining long-term monitoring is challenging with a number of barriers to continually overcome. With this in mind, the CBMP and its Marine EMG has chosen to focus the scope and breadth of the monitoring plan on mostly existing monitoring capacity and a small suite of targeted indicators and parameters representing key trophic levels and critical ecological processes and fluxes. At the same time, it is anticipated that the planning process will identify critical gaps in marine biodiversity monitoring coverage that new resources, if found, could fill. It is believed that a simple monitoring plan will be more easily sustained and adopted. It would also be able to provide adequate monitoring coverage to allow for the detection of important trends in a reasonable time-frame, as well as identify emerging pressures.

At the same time it must be kept in mind that the inherent complexity of large ecosystems challenges our ability to detect biodiversity changes and identify links to anthropogenic impact by using a limited set of indicators. This represents the main challenge to the Marine EMG – developing a long-term marine biodiversity monitoring plan that is robust enough to detect trends over a time frame from a few years to decades, and simple and practical enough for large-scale adoption and long-term sustainability.

In summary, the resulting suite of indicators for monitoring marine biodiversity should include core indicators measuring biodiversity, indicators measuring general environmental data and indicators of anthropogenic impacts as described in 2.1.

2. Design and methodology

As stated in the CBMP 5-year Implementation Plan ch. IIIA "the CBMP plans to adopt an integrated ecosystem-based approach to monitoring in its program design, organization, and operation".

The final design and methodology of the program are to be discussed and finalized at the workshops.

2.1 Program design

In light of the aims and objectives listed in above, the monitoring program should be designed to:

- Identify changes in biodiversity within a reasonable timeframe (i.e. sufficient power to detect change).
- Identify possible links between biodiversity trends (losses) and anthropogenic stressors.
- Make the above information available in such a way that it can be used by managers and decision makers to develop strategies on how living resources in the Arctic may be used sustainably and on how northern residents can adapt to changing environmental conditions.

The CBMP 5-year Implementation Plan lists what the ecosystem-based approach to monitoring Arctic biodiversity implies:

- Keeping in mind the limitations described above it must be recognized that monitoring all elements of ecosystems - including species, habitats, ecosystem structure, processes, functions, and stressors to the ecosystems - is necessary to gain a meaningful picture of what is happening to biodiversity;
- A focus on trends, including recognition of the dynamic nature of Arctic ecosystems and the importance of identifying change that is outside the realm of natural variability;
- Recognition of the interplay between terrestrial, freshwater, and marine systems and the way it shapes Arctic ecology and the goods and services that Arctic biodiversity provides;
- Recognition of the dependence of Arctic biodiversity on conditions outside the Arctic;
- Recognition of humans and their cultural diversity as an integral component of many ecosystems; and
- Monitoring the interactions between people and biodiversity, such as sustainable use and the ability of biodiversity to provide essential goods.

One of the biggest challenges in designing an integrating marine biodiversity monitoring plan will be meeting the information needs that an ecosystem based approach demands within the constraints of a program that is both practical and sustainable. In order to achieve this, it is suggested that the MEMG identify a set of key biodiversity indices that will form the core of the monitoring plan. This core monitoring program would be the top priority for the CBMP and its efforts to encourage Arctic marine biodiversity monitoring. Regular reporting and archiving of core monitoring data could also become the primary and regular output of the programme. Recognizing that the CBMP will be dependent on other programs to actually carry out monitoring, this core program should be defined as specifically as possible with guidelines outlining, for example, the indicators to be measured, the methods to be used, the monitoring frequency and statistically quantified monitoring objectives. The core monitoring program would be based on existing/ongoing activities, but would also provide the guidance needed to enhance existing/ongoing activities that might not otherwise be designed to meet the requirements of the CBMP.


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While the core monitoring program should define a set of indicators that represent direct measures of biodiversity, it is suggested that a secondary set of indicators be identified that will be necessary for further interpretation of core monitoring data. These secondary indicators will be needed to describe, for example, changes in the environment that affect biodiversity. These could include indicators related to sea-ice, atmospheric conditions, physical and chemical oceanography, etc., that while not a direct measure of biodiversity have an impact on the ecosystem. These types of indicators may also be important for other environmental/oceanographic monitoring programs and are therefore likely being measured as part of other monitoring efforts. The CBMP could identify sources of this information and enter into agreements to share data with the responsible organizations. While the CBMP would not take on the responsibility for gathering data on secondary indicators, through these cooperative agreements it could exercise influence on other bodies to help better meet CBMP needs for this information.

Finally, the monitoring program will need to consider data on anthropogenic stressors that may be affecting biodiversity. As with the secondary indicators, monitoring indicators of anthropogenic stressors falls under the mandates of other programs (e.g. AMAP). Examples of such indicators might include levels and trends of pollutants, data on fisheries and marine mammal harvests, shipping frequency, and reported incidence of spills.

In order to maximize the availability of monitoring data on secondary indicators and indicators of anthropogenic stress, CBMP should cooperate with potential suppliers of this data and coordinate activities to optimize complimentary use of data. By cooperating with CBMP other programs will gain access to biodiversity data which will enhance the interpretation of their data. For example, AMAP will benefit from information about changing ecosystem structure and possible evidence of contaminant related effects. Industry will be benefit from the results when it comes to environmental assessment.

2.2 Indicator criteria

Monitoring should be focused on developing a set of "indices" or indicators within each ecosystem. This should be supplemented by assessments of changes in biodiversity and their underlying causes, carried out on a regular basis or when needed. These assessments will integrate the individual indicators with a variety of other data sources (for example research reports and indigenous knowledge).

The CBMP 5-year Implementation Plan lists criteria that the CBMP has been adopting when working on selection of indicators for Arctic biodiversity (see ch. IIIC). The list below is a blend of these criteria and criteria agreed on in the EMG discussions, in no intended order of priority.

The indicators should be chosen based on these criteria:

- Indicators should cover central elements in an ecosystem: both the physical aspects (for example extent of sea ice) and the biological components (such as abundance of key species and critical ecosystem processes).
- Indicators should therefore cover common species as well as those of public concern (e.g. red listed species) and importance to local communities.
- Indicators should include both lower and higher trophic levels.
- Indicators should be relatively simple to measure allowing for repeatable, accurate measurements.
- Indicators should be reflective of and be sensitive to ecosystem change, either through natural or anthropogenic drivers.
- Indicators should have scientific validity as well as relevance to, and resonance with, diverse audiences (e.g. local communities, decision makers, global public).
- Long data series (and the indicators derived from them) should be continued: the value of such datasets only increases over time

To enable the CBMP to contribute to the targets of the CBD the choice of indicators within the CBMP should be guided, where appropriate, by the indicators chosen by CBD (see Appendix 4).

2.3 Linkage to stressors

It will be necessary to include indicators of pressures from human activities in the monitoring program.

This is because humans are a natural part of Arctic ecosystems, but increasing pressures induced by human activities, such as fisheries, pollution from industry, introduction of invasive species, and climate gas emissions, are all contributing to severe changes in natural ecosystems in the Arctic and elsewhere.

A strong motivation of the program is to assess the effects of multiple pressures; thus, it is tempting to focus strictly on stressor-related indicators. An appropriate balance between indicators on biodiversity elements and stressor-related indicators must be developed to not only document change but to establish the causal relationships between changes in biodiversity and these pressures. As the knowledge base on causal relationships increases, refocusing of effort may be required, but an initial broad approach will be required until such relationships are better understood. This will require close cooperation with other agencies/ programmes that monitor indices of anthropogenic stressors and assess their impacts. To the greatest extent possible the CBMP should rely on these other organizations for the provision of synthesized data on stressors. Effective cooperation and coordination of monitoring activities should lead to overall enhanced assessment of impacts of marine biodiversity.

In summary, the resulting suite of indicators for monitoring marine biodiversity should include core indicators measuring biodiversity, indicators measuring general environmental data and indicators of anthropogenic impacts as described in 2.1.

2.4 Program organization

The inclusion of existing research and monitoring networks has been an essential part of the strategic planning of CBMP. Initially, the CBMP consisted of three networks: shorebirds, Rangifer, and The International Tundra Experiment (ITEX). CAFF has developed framework documents for all these networks .

The networks that will be identified as participants in an integrated marine biodiversity monitoring plan will need incentives to make their data available to CBMP. These incentives include being part of a larger network that allows access to other data and products that allows for a greater ability to identify and understand trends in specific Arctic regions. This can be achieved through competent, regular, and focused feedback to all the identified and included networks.

2.5 Standardization of methods

An evident part of running a monitoring program covering large areas and potentially incorporating many different monitoring activities and data sets is allocating adequate resources for standardization and meta-analysis of monitoring methods and procedures. Where standardization of methods proves difficult or impossible, emphasis must be laid on interpreting the indicators in ways that enable maximum pooling/comparison of data series (i.e. data cross-walking and intercomparability).

This work will be initiated at the workshops, but the continued successful monitoring effort will depend on a continuous effort to identify inconsistencies in monitoring methodology and the right instruments to enable harmonisation. Implementation of standardized monitoring protocols will depend upon identifying relatively inexpensive, repeatable protocols that can be implemented across the circumpolar region. It will also be dependent on the establishment of effective and efficient networks between the program coordinators and the executing monitoring agencies and/or persons.

2.6 Community-based monitoring

North America leads the Arctic in developing and employing community-based monitoring (CBM) approaches, thereby presenting the CBMP with an excellent opportunity to utilize and integrate these methods alongside science-based approaches. A number of programs are currently underway that employ community-based approaches to understand changes in Arctic biodiversity (e.g. Arctic Borderlands Ecological Knowledge Co-op and “Humans as Sensors” and “Citizen Science” in Bering Sea Sub-Network). There is an opportunity and need to expand upon and replicate these efforts around the Arctic to maximize the contributions of Arctic peoples to biodiversity monitoring. The CBMP’s Marine Expert Monitoring Group will draw from and identify both relevant scientific-based and community-based approaches to the monitoring of Arctic marine ecosystems. Each group will include and engage community, scientific, and Indigenous experts. They will not only work with existing research stations and monitoring networks to develop integrated, forward-looking monitoring programs, but also focus efforts on the retrieval and use of existing historical information, be it traditional knowledge or archived scientific data.

The Marine EMG is tasked, among other things, to develop a monitoring plan that would integrate data on large-scale changes in Arctic marine biodiversity with observations of local-scale changes that are being observed by local residents. The latter is of direct interest and concern to coastal communities. Designing such a monitoring plan will require sensitivity to policy questions as well as an appreciation of the opportunities for coastal communities to adapt and benefit from changes that are likely to occur in marine biodiversity. Indigenous peoples and other Arctic residents have out of necessity and interest been astute observers of marine and coastal conditions and their observations provide unique and long-term information that can also play an important role in identifying new research and monitoring indicators and questions.

On the other hand, the CBMP should be developing its strategy of cooperation with the understanding that there are different types of CBM activities that generate different types of data. Of equal importance is the source of data. The Arctic is home to many Indigenous peoples but also to other residents. Observations based on Indigenous knowledge would normally provide deeper insights but these data are more difficult to collect and process and therefore much more difficult to integrate with other types of data sets. The most common type of CBM is based on local knowledge of the residents. When these activities are conducted in Indigenous communities, i.e. the majority of residents are Indigenous, the participants who are the bearers of their Indigenous knowledge would automatically utilize it in their observations, both empirical and interpreting.

Currently, several terms are used to describe the knowledge of local residents: Traditional Knowledge (TK), Indigenous and Traditional Knowledge (ITK), Local and Traditional Knowledge (LTK), Traditional Ecological Knowledge (TEK), and Inuit Qaujimajatuqangit (IQ). The term that is used in the Arctic Council’s documents is Indigenous and Traditional Knowledge, which refers to the knowledge passed from generation to generation over hundreds of years and that may exhibit a sufficient difference with the Western Knowledge system in how the knowledge is acquired, transferred, utilized, and preserved. This term should be recommended for use by CBMP as it is an Arctic Council program. Local knowledge can be defined as any set of information or skills that any resident of a particular location could acquire.

In understanding CBM, the most important is to distinguish between different types of activities. There are no accepted standards and the following differentiation is compiled with an intention to help physical and natural scientists who are not well versed in the topic to better understand it.

1. Citizen science: monitoring is designed and implemented by scientists with the assistance of trained local residents volunteered or, more commonly, employed as research assistants. Methodology and data output follow the standards of conventional (Western) science. Some of the benefits of this type of monitoring are continuous collection of data in remote locations and engaging residents, especially young people, in science. There are many successful examples of such projects.
2. Local Stewardship: monitoring to document the state of the local environment to address various local issues is often initiated by the community but sometimes by the local or regional government; methodology and data output may not be consistent and the collected data may not be available for open distribution. A significant merit of this type of monitoring is fairly accurate spatial and temporal records of multiple indicators.
3. Humans as sensors: monitoring via surveying of local residents' perceptions of status and change of various phenomena is designed by scientists and conducted by researchers and/or trained local assistants. The data output is processed using sociological or ethnographic methods depending on the type of survey used. Some qualitative data, such as Elders stories, may be difficult to integrate with physical/natural science data but if taken in its entirety it could provide an additional depth to understanding the scientific question. In other words, one cannot extract a word from a story and try to make sense of it. However, more structured surveys can provide sufficient quantifiable data that can be easily integrated with other scientific data. This arguably

B. Olsen

is the only type of CBM that enables researchers to recreate data from past periods when no data were collected and there are gaps, as well as to better understand temporal changes without generating time series of observation. Similarly, "humans as sensors" research provides greater spatial information about many areas and about a greater variety of species and populations than accessible to conventional science.

Sites have been established in a number of Arctic communities to monitor marine mammal, fish and associated environmental variables, as appropriate, utilizing one or a combination of these approaches often in conjunction with conventional scientific methods. Community-based monitoring, especially in remote regions of the Arctic, often complements conventional scientific monitoring as it provides continuous observations at a local and more frequent scale, employing the capacity of local residents, who are in these regions year-round, observing change and holding knowledge passed down through generations. Indigenous and other Arctic peoples wish to impart their environmental understanding and observations to scientific discourse, not only because they have a great deal to offer, but also because this exchange represents an important step towards full participation in resource management activities. Developing partnerships with local residents, and committing to programs that advance their training, is now recognized as an integral (and in some jurisdictions required) part of any Arctic marine research program and is consistent with the goals and objectives of the Circumpolar Biodiversity Monitoring Program (see Henry Huntington. 2008. A Strategy for Facilitating and Promoting Community-Based Monitoring Approaches in Arctic Biodiversity Monitoring. CAFF CBMP Report No. 13, CAFF International Secretariat, Akureyri, Iceland).

Arctic community-based monitoring requires active participation of Indigenous groups and other Arctic residents, who work together to conduct research and monitoring. Such participation will also help to ensure that these initiatives address the priorities of Arctic communities. New community-based monitoring programs should respect the wishes of Arctic communities to be engaged early, and in all aspects of development and implementation of research and monitoring. Indigenous knowledge is sometimes considered "owned" by the knowledge holders and western science use needs to provide appropriate recognition and approval of each use.

It is envisioned that CBMP monitoring will build on existing relationships and Community-based monitoring locations, and expand to monitor additional key variables and new locations as the plan matures. In order to facilitate Arctic community engagement and discuss the most appropriate means of ensuring participation in community-based monitoring, the CBMP is establishing a Community-based Monitoring Guidance Group that will direct the promotion, expansion and development of community-based monitoring approaches and programs that serve to improve our ability to detect, understand and report on important trends in Arctic biodiversity.

2.7 Linkage to the Arctic Biodiversity Assessment

The CAFF Working Group of the Arctic Council is set out to produce a comprehensive, referenced and peer-reviewed report on status and trends of Arctic biodiversity to be published in two parts, one "Highlight Report" in 2010 and a fully referenced and peer-reviewed "Scientific Assessment" by 2013. . The timely implementation of an integrated Arctic marine biodiversity monitoring plan will make it possible for the outputs of this monitoring to be contributions to the 2013 scientific assessment.

3. Focal marine areas

The delineated focal areas for "Arctic Marine" systems are listed in this chapter but will be further described later in the document. The actual areas selected will not be open for discussion at the workshop, although small adjustments might be possible and necessary, due to ecological, administrative, or practical considerations overseen by the process leading up to the first workshop. For purposes of framework other relevant borders for Arctic marine areas as defined by the Arctic Council programs are briefly highlighted.

3.1 Methods for delineating Arctic areas

There are many ways to divide the Arctic marine area. Some delineations are purely based on ecosystem/ ecological characteristics while others are based solely on administrative criteria, or some combination of the two. The CBMP has decided to provide flexibility in monitoring area delineations to allow for the use and adoption

There are many ways to divide the Arctic marine area. Some delineations are purely based on ecosystem/ ecological characteristics while others are based solely on administrative criteria, or some combination of the two. The CBMP has decided to provide flexibility in monitoring area delineations to allow for the use and adoption of complete ecological units that are of most relevance to the system being monitored. When using ecological delineations, there are realm- and depth-based methods, as well as methods based on the degree of ice-cover. Effective monitoring of biodiversity requires that an ecosystem-based approach be used for choosing focal areas.

Each Working Group of the Arctic Council use slightly different area definitions, as shown in fig. 2.1, but none of these are purely based on ecological or biotic criteria.

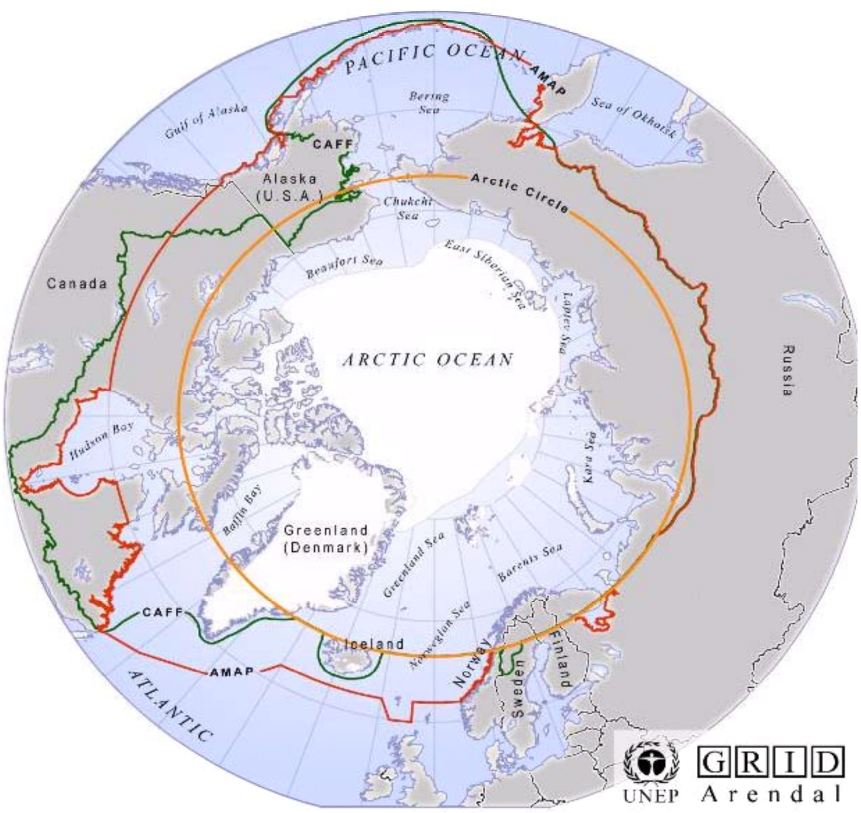

Fig. 3.1. Delineations of the CAFF and AMAP areas.

3.2 Criteria for priority

The MEMG has adopted a set of criteria for choosing focal areas that blends different sets of criteria suggested by MEMG members, and built upon the criteria developed at the CBMP Workshop in Anchorage November 29–30, 2006.

To be considered an Arctic marine focal area, significant parts of an area have to be at least seasonally ice covered or, alternatively, have been so in the recent past. Of note, most Arctic marine areas are experiencing or are expected to experience development pressures (e.g. oil and gas exploration and extraction, emerging commercial fisheries, potential pollution from ships, e.g. ballast water). These areas are also undergoing other changes, e.g. due to changes in climate variability and climate extremes (diminishing sea ice, changing freshwater inputs, water temperature and salinity).

Considering boundaries with coastal zones, Arctic Council definitions state that marine ecosystems exclude intertidal areas from 0-30 m depth. Shallower areas are included if they are relevant for the overall dynamics in marine areas.

All Arctic marine areas selected by the MEMG are either linked to Large Ocean Management Areas (LOMAs), Marine Protected Areas, National Wildlife Areas, Important Bird Areas, or other similar areas, and would benefit from supporting biodiversity monitoring data. These focal areas can link with the CBD's Ecologically and Biologically Significant Areas (EBSAs) and will preferably link with the Coastal and Freshwater EMG priorities, e.g. regions important for anadromous fishes.

The following criteria for focal marine areas are ordered by decreasing significance; none are mutually exclusive:

1. Marine ecosystems for which we have long and strong datasets and/or ongoing activities covering all trophic levels from phytoplankton and algae through zooplankton, benthic animals, pelagic fish, seabirds, marine mammals, as well as key supporting biogeochemical data. Areas for which reasonably good long-term data do not exist will not be included.
2. Biological hotspots (e.g. polynyas, marginal ice zones), since these physically dynamic areas are proven sources of important traditional foods, as well as significant habitat for many marine species:
   a) Marginal ice zone (MIZ), specifically the temporal and spatial variability of the MIZ during the spring bloom period.
   b) Polynyas should be included because they represent areas with relatively high productivity surrounded by low productivity areas.
3. Margins, boundaries and fronts - monitoring changes in their position that could lead to changes in biodiversity (e.g. ice edge, circulations, intruding Atlantic or Pacific Water altering vertical structure, river inputs)
4. Gateways (import and export biogeochemical properties, including biota and invasive species, with sea water)
5. Locations suitable for incorporating and/or developing community-based monitoring elements
6. Potential to conduct both sections (spatial coverage) and moorings (temporal, especially seasonal, coverage), using new technologies as they become available
7. Low productivity systems should be included because they may change profoundly as a consequence of anthropogenic impact, in particular climate change. Suggestions include the Central Arctic Basins.
8. Blocking domains (e.g. sills - affect migration of biota)

Mark Mallory

3.3 Marine focal area review

Focal areas are listed in the table below.

Marine Ecosystem	Areas included	Criteria Met	Comments
Atlantic Arctic gateway	Barents Sea incl. selected fjords west and east of Spitsbergen, Greenland Sea, Fram Strait	1,2,3,4,6	Good data from existing monitoring programs, no communities
Pacific Arctic Gateway	Chukchi-East Siberian Sea, Beaufort Sea, Northern Bering Sea	1,2,3,4,5,6,7	
West Greenland Arctic Gateway	Baffin Bay, Davis Strait, Labrador Sea, Lancaster Sound	1,2,4,5,6	Good data; gateway out of the Arctic; near several communities; contains the Northwater Polynya
Arctic Basin	Nearby North Pole region	1,2,5,6	Multidisciplinary data from the FSU "North Pole" drifting stations and recent PAICEX sea ice ecosystem data set
Hudson Bay Complex	Hudson Bay, Foxe Basin, Hudson Strait	1,2,3,5,6	Has some data from MERICA, GWAMM (others?); focal area of ArcticNet; experiencing rapid changes; close to several communities; may have development in future (fisheries)
Beaufort Sea – Amundsen Gulf – Viscount Melville – Queen Maud Gulf		1,2,5,6	Much data; shelf and ice edge important and changing; changing freshwater input; contains LOMA, EBSA and MPA; close to several communities

4. Brief description of ecosystems and pressures

4.1 The Arctic Pacific Gateway

4.1.1 Physical characteristics

The Bering Strait continental shelf complex (northern Bering Sea, Bering Strait and northward to the East Siberian, Chukchi and Beaufort Seas) is a major gateway from the perspective of ocean, ice, freshwater, nutrient fluxes, atmospheric fluxes of heat and moisture, as well as fluxes of biological organisms and organic carbon. Time-series measurements (1990-2004) from the Bering Strait indicate large annual variability transport (~0.4 to 1.2 Sv) and hence heat influx. Furthermore, Bering Strait provides ~40% of the total freshwater input to the Arctic Ocean giving it far-reaching implications for Arctic halocline formation, basin dynamics, and meridional overturning water on the Atlantic side of the Arctic.

The Pacific Arctic Region is experiencing the greatest seasonal retreat and thinning of sea ice in the Arctic, with 2007 having the highest minimal ice extent in the 35-year satellite data record and 2008 being the second greatest retreat in that record. Changes in sea ice formation and thickness influence albedo feedback, brine formation and halocline maintenance, so ice-ocean-atmospheric dynamics are extremely critical for regulating climatic conditions in the Arctic, and the whole Earth.

The shallow and dynamic Bering Strait region and adjacent seas are a key location to monitor ecosystem change. Apparent changes that are being observed in the oceanographic and ice system in this region could lead to dramatic impacts for higher-trophic level fauna, including benthic-feeding animals such as walrus, bearded seals, and gray whales, and pelagic-feeding bowhead and beluga whales that are of cultural and subsistence significance to Arctic Native peoples.

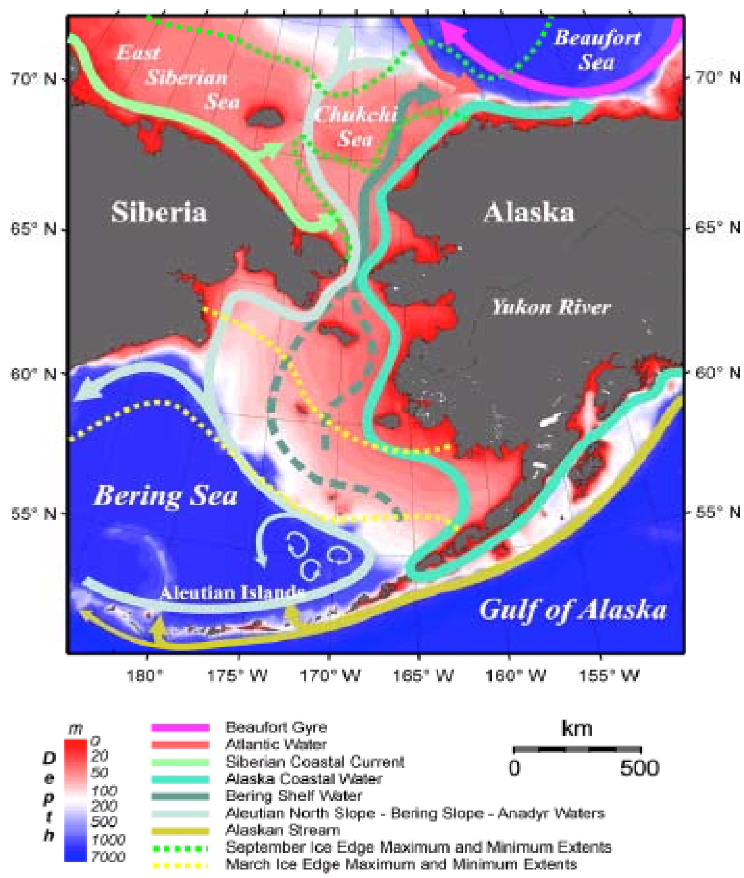

Figure 4.1 Illustration of the currents through the Bering Strait areas.

4.1.2 Biological characteristics

Large quantities of Pacific heat, nutrients, phytoplankton and zooplankton enter the region through the Bering Strait in a complicated mixture of water masses (i.e. Alaska Coastal, Bering Shelf, and Anadyr Water, Figure above), each with unique assemblages and quantities of plankton that are diluted by Coastal Arctic waters carried along by the East Siberian Current and water carried in from the deeper waters of the Canada Basin or Chukchi Plateau. Early in the season, the exact timing of the sea-ice breakup, the fate of the sympagic (=sea ice) community, and its match/mismatch to various components of the ecosystem can have profound impacts on this system and change the partitioning between benthic and pelagic productivity. For the most part, the high concentration of nutrients in Anadyr waters stimulate massive sea ice algal and phytoplankton blooms, that cannot be fully exploited by the zooplankton communities. Hence, much of this high production is exported unmodified to the benthos, resulting in impressively high biomass of benthic infauna and epifauna. These rich benthic communities then serve as feeding grounds (biological hot spots) for the bottom-feeding Pacific walrus, gray whales, and diving birds. The huge biomass of zooplankton imported to the Bering-Chukchi shelf in the flow of Anadyr Water accounts for the spectacular populations of seabirds, particularly planktivorous auklets, in the Bering Strait region, and undoubtedly supported resident bowhead whales prior to their decimation in the mid-1800s.

Both inter-annual and long-term variation in climate affects the relative transport of the different water masses through Bering Strait and hence the composition, distribution, standing stock, and production of sea ice communities, phyto- and zooplankton, and the tightness of benthic-pelagic coupling in the Chukchi Sea. There is significant concern that the Chukchi Sea may be undergoing an enhancement of energy utilization within its pelagic realm, with a consequent decline in the production made available to the benthic communities. Resulting changes in prey base are likely to have significant effects on population dynamics and survival of upper trophic level species.

4.1.3 Pressures

Heat and freshwater flow through Bering Strait has increased significantly in recent years. Visual and passive acoustic surveys suggest that gray whales are occupying the Chukchi and western Beaufort seas longer, potentially competing with bowhead whales for prey and interfering with subsistence hunting of the latter species. Sea ice decline means that tens of polar bears and, in 2007, tens of thousands of walrus now must haul-out on land resulting in increased mortalities and confrontations with Arctic residents. Furthermore, recent dramatic reductions in seasonal ice cover has opened this region to increased oil and gas exploration, exploratory fisheries and fosters the establishment of trans-Arctic shipping routes in the very realistic scenarios of a seasonally ice-free Arctic.

The Pacific Gateway also represents a pathway for pollutants into the Arctic from the Pacific, and has been shown to be the primary entry point of hexachlorocyclohexane (HCH) within seawater. The region also receives atmospheric deposits of persistent pollutants, including POPs and mercury, derived largely from Asia. The levels of POPs in predatory marine mammals and seabirds are found at levels of toxicological significance.

Carsten Egevang/ARC-PIC.COM

4.2 The Arctic Atlantic Gateway

4.2.1 Physical characteristics

Barents Sea

The Barents Sea is a shelf-sea covering an area of about 1.4 million km2. It is bounded by the coasts of Northern Norway and Northwestern Russia in the south, Novaja Zemlja archipelago in the east, Svalbard and Franz Josef Land in the north and the Norwegian Sea in the west (figure 3.1.2a). An average depth of the Sea is of about 230 meters, but there are several depressions with depths between 300-350 meters. Three main currents system flow into the Barents Sea that determine the main water masses: the Norwegian coastal current and the Murman coastal current, the Atlantic current and the Arctic currents system. The Atlantic water is warm and saline compared with the Arctic water masses, with the Polar front formed in the area of their interaction. The position of the Polar front is largely determined by bottom topography in the west and more influenced by prevailing weather and current conditions in the eastern part of the Barents Sea.

The Barents Sea is partially covered by ice. The area covered has declined during the last three decades, and recently, there has been four years when all sea ice has melted during the summer (2001, 2004, 2006 and 2007).

The Greenland Sea

The Greenland and Norwegian Sea is approximately 2.585.000 square km and is bounded by the Arctic Ocean, Svalbard, Norway, Faroe Islands, Iceland and Greenland. The continental shelf extends east from the Greenland coast and has a width of more than 300 km close to its northernmost part, becoming narrower further south. Off the shelf, waters reach depths of more than 3000 m.

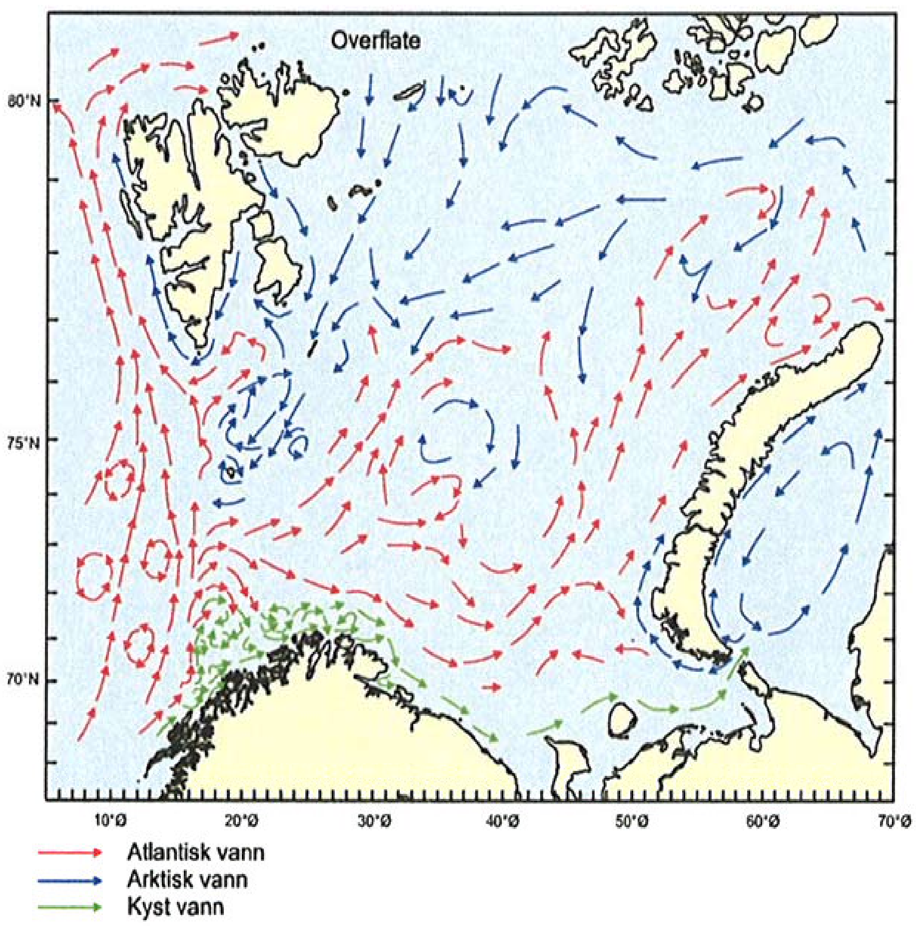

Figure 4.2.: The Barents Sea and the main current systems (red: Atlantic current, blue: Arctic current. Green: Norwegian coastal current)

A submarine mountain ridge extends across the North Atlantic from Greenland to Scotland, known as the Iceland-Scotland Ridge (IS-Ridge). It forms an efficient barrier between abyssal basins of the Arctic and the North-Atlantic. The water depth at the top of the ridge is commonly around 300-400 m, but it is transacted with deeper sills mainly between the Faroes and Shetlands, and to a lesser extent between Iceland and Greenland. Bottom water temperature in the Greenland and Norwegian Sea, north of the IS-Ridge, remains constant at -1°C from about 600 to 1200 m and down to the greatest depths of 5.600 m. However, because of the Norwegian Atlantic Curent, the surface water of the greater part of the Norwegian Sea is relatively warm northward from the Faroese Islands towards the northern coast of Norway. Closer to the top at the northern slope of the IS-Ridge, the bottom water temperature reaches 2° or 3°C; and slightly further to the southern side, the bottom water temperature may increases rather abruptly to about 5° or 8°C, sometimes within a distance of less than 20 km, for instance off the South-East coast of Iceland.

The Greenland and the Norwegian Sea is the Arctic Ocean's main outlet to the Atlantic. On the surface layers, the East Greenland Current transports cold and low salinity Polar Surface Water and sea ice during spring and summer. The deeper layers are crucial to the global seawater circulation, as the waters that have lost heat to the atmosphere change buoyancy, sink and contribute to the North Atlantic Deep Water.

Ice is present in the Greenland Sea year round in the form of icebergs, fast ice and drift ice. Icebergs are released by Greenlandic glaciers. The fast ice is stable and anchored to the coast, covering fjords and the outer coast. In some areas a stationary or semi-permanent shelf made up from fast ice is present year round. The drift ice consists of a mixture of multi-year and first-year ice floes of various sizes and densities that are transported southwards by the East Greenland Current. A shear zone with year round open cracks and leads may occur between the fast ice and the drift ice.

The largest polynyas of the Greenland Sea are the North East Water (NEW) off Kronprins Christian Land, the waters off Wollaston Forland and the mouth of the Scoresby Sound.

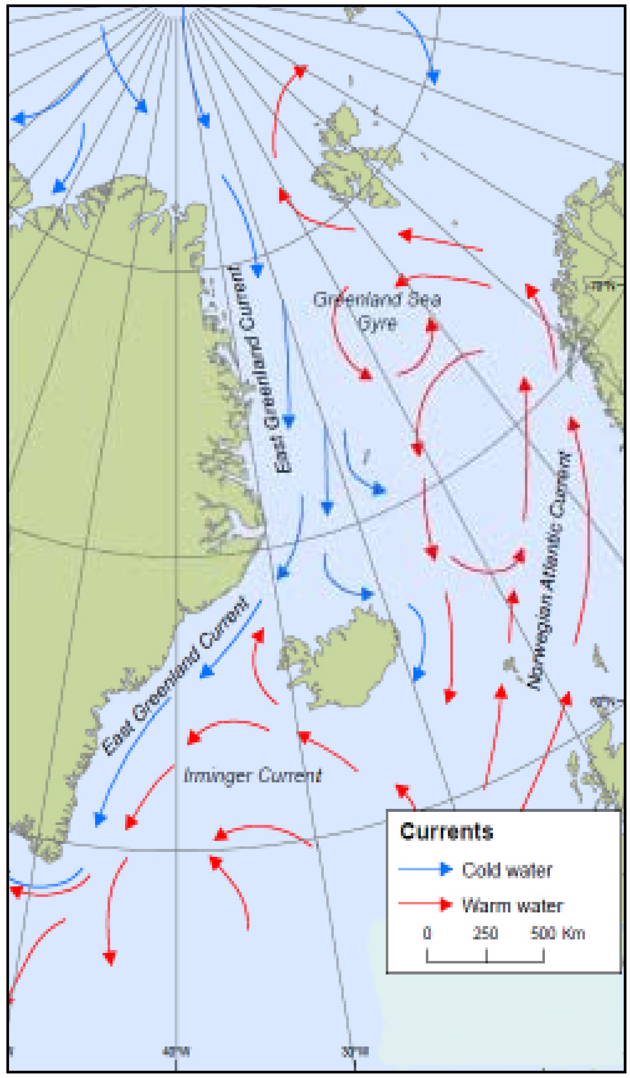

Figure 4.3 The Greenland Sea and its surface currents

4.2.2 Biological characteristics

Barents Sea

The Barents Sea is highly productive, particularly so at the polar front, the marginal ice zones and the edge of the continental shelf in the western Barents Sea. The biogeographic boundary between the Atlantic boreal and the Arctic biogeographic zones is located in the western part of the Barents Sea. The zooplankton community is dominated by Calanus species, with different species being important to the south and north of the Polar front (C. finmarchicus in the south and the more lipid rich C. glacialis in the north). The main planktivorous fish are capelin, herring and blue whiting, the latter is a boreal species that in recent years has been found in large numbers in the Barents Sea. Cod is the most important large predatory fish. Other important fish stocks are haddock and pollock. Greenland halibut, two species of redfish and coastal cod were once abundant, but are now severely overfished. Several species of whales and seals, a polar bear population of about 3000 individuals and several species of sea birds are also found in the Barents Sea. A considerable amount of the primary production is channelled through deep-water communities and benthos. Zoobenthos is a good indicator of climate changes and its structure and biomass vary under water temperature changes.

Greenland Sea

The key zooplankton species are copepods of the genus Calanus. Polar cod is very abundant, both pelagic and in association with the ice, and constitute a major food resource for seals, whales and seabirds. Other important fish species are Arctic cod, Greenland halibut and Arctic char. Capelin occurs in the south-eastern offshore waters.

Several species of seabirds are locally abundant in summer and spring, many breeding in colonies close to the polynyas. In spring and autumn, millions of seabirds migrate through the area on their passage from Svalbard and Russian breeding sites to Canadian wintering sites. The most numerous species are common eider, thick-billed murre, little auk and ivory gull.

Several species of cetaceans feed in the Greenland Sea during the periods with open water. Polar bear, walrus, ringed seal, bearded seal, narwhal and probably bowhead whale are found in the area throughout the year. There are globally important whelping grounds for harp seals and hooded seals.

The Iceland-Scotland Ridge marks a well known biogeographic boundaries between the benthic biota between of the Arctic and the North Atlantic Boreal Region. This boundary largely coincides with the transition between colder and warmer water masses which cover the sea floor. Characteristic species of the Arctic benthic fauna of the Norwegian and the Greenland Sea, reach their southern limit at the ISRidge, for example the molluscan species Yoldia limatula, Thracia myopsis, several Buccinum, Colus, and Boreotrophon, although the most high-arctic species like Portlandia arctica, Macoma loveni and Pandora glacialis do not reach it. Collaterally the IS-Ridge forms a connection between the European and the American shallow water faunas, with Iceland and the Faroes as “stepping stones”.

4.2.3 Pressures

Barents Sea

The main human driver in the Barents Sea is the fisheries. Despite overfishing, the cod stock remains large in Barents Sea. Overfishing is a persistent problem and probably hampers recovery of species like redfish and coastal cod.

If climate warming continues as predicted by IPCC, this will undoubtedly have large impacts on the Barents Sea ecosystem. In the long run, climate change may therefore become the main driver in the Barents Sea. An important question is whether fishing pressure reduces the resilience of populations to changes caused by climate fluctuation.

To date, there have been few large incidents related to ship traffic and oil and gas activities, and these activities should not be considered primary drivers at present. The risk of accidents in the future may however become considerable. In addition, oil and gas activities may affect the system indirectly through global warming caused by their products.

There is little pollution in the region, but persistent organic pollutants transported from outside the area through ocean and atmospheric currents do accumulate in the food chain. High concentrations are found in top predators such as polar bears and glaucous gulls, and may affect individuals and populations of such species.

Greenland Sea

Human uses of natural resources, such as fishing and mining, are limited to the southern parts. Subsistence hunting (marine mammals and seabirds) and artisanal fishing take place near Scoresbysund. Tourism is a growing industry.

Contaminants such as hydrocarbons and heavy metals are transported from other areas and have been documented in the food chain of the Greenland Sea (eg. in polar bears). There is an ongoing programme for oil exploration that can potentially develope into drilling and extraction, if suitable hydrocarbon deposits are found in the area.

4.3 Beaufort Sea – Amundsen Gulf – Viscount Melville – Queen Maud

4.3.1 Physical characteristics

This region is relatively shallow throughout, with an average depth considerably less than 200m, and has two particularly shallow areas, one being the Queen Maud Gulf and the other located at the boundary between Viscount Melville and Lancaster Sound.

Two different patterns of ice cover are present in this ecoregion. The northern part is characterized by the presence of pack ice, whereas the southern part has seasonal ice. Some data suggest that Viscount Melville Sound has a permanent ice cover, but the tracking of marine mammals in this area implies that there are enough gaps in the ice for them to breathe.

4.3.2 Biological characteristics

The most important biological feature in this ecoregion is the shallow water boundary between Viscount Melville Sound and Lancaster Sound, which is also associated with a permanent plug of ice in the Lancaster Sound west of Somerset Island. Combined, the shallow water and the ice plug create a boundary between western and eastern populations of belugas and possibly bowhead whales, and a western boundary to the narwhals from Lancaster Sound. This boundary area and its longitude to the south also correspond to a general boundary for seabirds and waterfowl, dividing populations (e.g. Common Eider (Somateria mollissima), King Eider (Somateria spectabilis), Thick-billed Murre (Uria lomvia) and Northern Fulmar (Fulmarus glacialis)) which in winter migrate to western and eastern

Fig. 4.4: Beaufort Sea – Amundsen Gulf – Viscount Melville – Queen Maud

areas. The northern edge of this ecoregion also represents a boundary for marine mammals and seabirds, as this is where permanent ice cover begins. Both bowhead whales (Balaena mysticetus) and beluga whales (Delphinapterus leucas) are found in the Beaufort Sea, and belugas migrate into the Amundsen Gulf and Viscount Melville. Overall, this region contains a mix of Pacific and true Arctic species.Please refer to www.atlas.gc.ca to locate the specific geographic places mentioned.

The southern part of this ecoregion can be considered a subregion based on freshwater influence and primary productivity. The Beaufort Sea is characterized by the presence of a polynya, which coincides with the Mackenzie River freshwater plume and the Beaufort gyre. Queen Maud Gulf also has a strong freshwater influence. High primary productivity in this region coincides with the Mackenzie River freshwater plume in the Beaufort Sea, extends into the Amundsen Gulf and partly into the Dolphin and Union Strait.

4.3.3 Pressures

Several anthropogenic pressures affect this marine area in the western Canadian Arctic and these may be delivered in a site-specific or an area-wide fashion. Moreover, these pressures may interact to result in cumulative effects on this ecosystem. Site-specific pressures and their context include items 1-3 below; area-wide pressures include items 4-6 below.

1) Hydrocarbon development and related infrastructure such as shipping have become an issue after a hiatus of approximately 20 years, with renewed interest in developing nearshore gas wells (and subsea pipelines) in the vicinity of the Mackenzie Shelf. Many ancillary activities causing ecosystem disturbance are anticipated to accompany increased exploration and development.

2) Nearshore subsistence harvests and fisheries for marine mammals, birds and fishes are of local concern. Overall, harvests are not large, are typically near to community locations, and are generally co-managed in a sustainable manner. At present, stocks of commercially viable species are not known to exist in the area but this may change.

3) General shipping consists mostly of annual resupply to remote communities. Increased ship traffic associated with ecotourism (e.g. ice-strengthened charter ships) is occurring through the area. While to date there have been no serious grounding incidents (despite poorly charted waters) nor appreciable hydrocarbon spills, these could become major future stressors. Development of land-based metal mines and other non-renewable resources in the central Arctic may ultimately drive development of deepwater port construction and increased shipping.

4) Climate change and increased climate variability is perhaps the most significant overall stressor for the area because it is or will result in significant follow-on effects directly and indirectly upon this ecosystem, e.g. shoreline erosion, permafrost degradation, increased precipitation and freshwater inputs to marine areas. Ecosystem restructuring is likely underway and will continue as climate change continues in the area.

5) Contaminants and other pollutants are delivered through wide-scale airborne or waterborne mechanisms and both of these are delivering persistent pollutants from more southerly areas. Land-based effects driven by climate change (e.g. permafrost degradation, slumping into freshwater systems) are likely delivering more nutrients and possibly more heavy metals to freshwater systems and into the marine environment via major north-flowing rivers.

6) Other potential stressors such as ultraviolet radiation increases may also be occurring; however, the significance of such is unknown at present for the marine system. Introduction of invasive species (e.g., via ballast water exchange or inadvertent transport) is considered to be a risk. Local development may increase pressures on local renewable resources.

4.4 The Arctic Basin

4.4.1 Physical characteristics

Geographically, the Arctic Basin is considered as a deep basin of the central part of the Arctic Ocean, surrounded by adjacent seas: Kara, Laptev, East-Siberian, Chukchi, Beaufort, and Lincoln Seas. It is customary the dividing of the Arctic Basin by Lomonosov Ridge onto two sub-basins: Eurasian and Amerasian ones.

The high latitudes consist in the presence of a polar day and polar night whose duration increases in the direction to the geographical pole. As the Arctic Ocean is not symmetric relative to the pole, the amount of the solar radiation (and the heat) coming on the underlying surface is different in the Arctic Basin and on its periphery. An important climatic feature of the average annual variation of the air temperature in the Arctic Basin consists in its slight fluctuations in the time period from December to March and in the absence of a distinct annual minimum. On the most of the Arctic Basin there are no time periods with a steady positive average daily temperature. However, the total duration of the time period with positive temperatures is sufficient to provide for annual melting of the snow cover and partially of the ice cover.

An important characteristic of the Arctic Basin consists in presence of the permanent ice remaining after summer ice melting. Seasonal ice is mostly formed on the ice-open area of the Arctic Seas during winter. The area of the sea-ice cover at the moment of its maximum development is formed by the areas of the Arctic Basin (4.47 mln. km²) and areas of the Lincoln, Beaufort, Chukchi, East Siberian, Laptev and Kara Seas (3.96 mln. km²) which makes the sum total of 8.43 million km². Because of the geographical position of epicontinental seas of the North Atlantic (Greenland, Norwegian, Barents, and White Seas), the Canadian Archipelago and the North Pacific (Okhotsk and Bering Seas), the seasonal sea ice formed at their areas are not participated in supporting of the sea-ice cover balance in the Arctic Ocean. According to the data of ice satellite observations in 1973-76 (NASA, 1987), the permanent ice occupied 70-80% of the Arctic Basin area and interannual variability of this area does not exceed 2% and the seasonal ice occupies 6-17% (pre-melting period of the middle 70th). During the period of active sea ice melting (last decade), the permanent ice area decreases to 6% in February 2008, but the seasonal ice area is recently increasing rapidly (Figure). Two general directions of ice drift are outlined: the Transpolar Drift from the western side of the Arctic Basin across the geographical pole and through the Fram Strait, and a clockwise Beaufort Gyre. Current drifting buys experiment (IABP) indicates very remarkable changes in direction and rates of ice drift in the Arctic Basin as well as the mooring experiment in the vicinity of the North Pole (NPEL) and time-series measurements during the IPY (PAICEX) show large variability transport of heat with warm Atlantic water to the ice.

Both sea ice and water of the upper Arctic Basin are recently under remarkable climate variations. Recently, it is very important to show: How will recent warming in the Arctic affect physical, chemical and biological properties of the low atmosphere-sea ice-upper ocean system? Do the recent remarkable shrinking and melting of permanent sea ice cover and warming and freshening of surface water in the Arctic Basin connect with globally processes in a whole scale of the Arctic Ocean? Still now, information about


Paul Nicklen

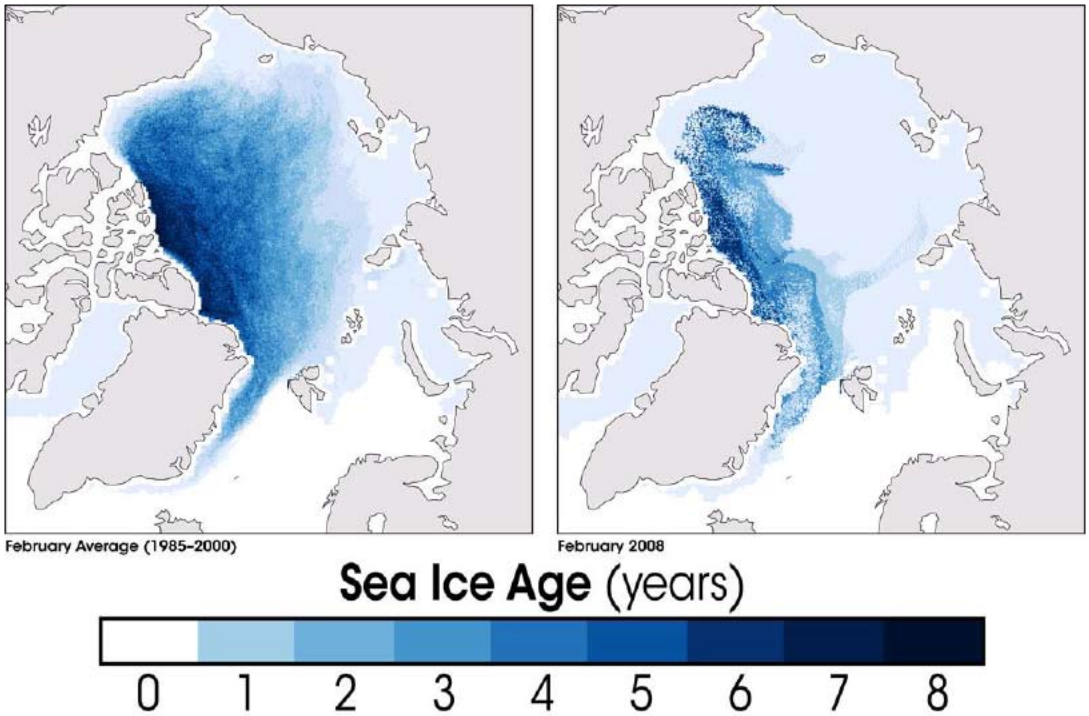

Figure 4.5 Arctic Sea ice age and extent in February 2008 (right) compared to the average for 1985-2000 (left). The area and thickness of sea ice that survives the summer has been declining over the past decade. Whereas perennial ice used to cover 50-60% of the Arctic, it covered less than 30% in 2008—down 10% from 2007. The ice that remains is also getting younger. In the mid- to late 1980s, over 20% of Arctic sea ice was at least six years old; in February 2008, just 6% ice was six years old or older. Source: http://nsidc.org/data/seaice_index/n_plot.html

these questions is still insufficient, however, the knowledge is very important for assessment of the Arctic sea-ice cover condition and modeling of climatic and ecological processes in the nearest future.

The North Pole region in the Arctic Basin is a key area to monitor both environmental and biological change. Long-term science and action plans need to be similar during research period as well as field observations need to be done with same sampling strategy, field and labs equipment, using same methods of measurements, scheduled samplings, fixation etc. Main priorities need to be focused on observations of snow, sea-ice cover and 0-1000-m water column dynamic, and included albedo measurements, CTD casts, hydrological samplings, and ecosystem studies.

4.4.2 Biological characteristics

Since F. Hansen's "Fram" expedition well known that the Arctic Basin is non-wilderness world but very miscellaneous by sea ice microorganisms, phyto- and zooplankton species, fishes and benthic fauna. In this permanent ice-covered Arctic Basin, the organic energy requirements for the high trophic level organisms are supported by sea-ice flora photosynthesis during short summer period. Phytoplankton production is negligible in comparison to the sea ice biota.

Under conditions of a stable climate, permanent sea ice represents an integral stable ecological system with a constant species composition of the flora and fauna. The system stability persists due to average equilibrium thickness supported by summer ice thawing from above and winter compensation ice growth from below. This property, which can be referred to as sea ice cover homeostasis, the ability to retain its average equilibrium thickness, is of great ecological significance. In geographical scale of the Arctic Ocean, the balanced relationship between regions of multiyear ice production and output from the basin, from one hand, and mechanisms maintaining a constant species composition of ice organisms within the vertical crystalline structure, from another one, determines the stability of the permanent sea ice ecosystem in the Arctic Basin.

Observations carried out over the last decade revealed appreciable changes in the qualitative and quantitative composition of the sea ice biota in the Arctic Basin compared to the composition in the middle 1970s. For example, the total list of ice algae identified for that period comprises more than 200 species and an order of magnitude less in last decade. The prevalence of sea diatoms was a significant feature of sea ice biota in the 1970s, and their domination greatly decreased in the past decade. The sea ice fauna composition has also changed. Such mass representatives of protozoans and invertebrates as foraminifers, tintinninids, mites, nematodes, turbellarians, rotifers, copepods, and amphipods inhabiting the ice mass in the 1970s were rarely encountered in the last decade.

Recent reduction of sea ice extent and decreasing of ice thickness is not a fact of the complete disappearance of sea ice cover in the Arctic Ocean. In fact, a reduction of multiyear ice surface leads to increasing of ice-free areas where seasonal ice is formed in winter. Now, in the Arctic Basin it observes the intensive process in reconstruction of sea-ice cover from domination of multiyear ice onto domination of seasonal ice. If this dynamic will be continued the Arctic Basin will be similar to the Southern Ocean where seasonal ice is a dominant component reaching more 80% of its surface (NASA 1983), by another words, in time marine Arctic is getting more features of marine Antarctic.

4.4.3 Pressures

Melting of sea ice has remarkable increased in last decade. It suggests changes in composition, structure and function of the sea ice and the upper ocean ecosystems. Field observations in the Arctic Basin during the SHEBA experiment 1997-1998, "Arctic-2000" expedition, ICEX-2003 ice camp expedition, North Pole-32, 33, 34 ice drifting stations in 2003-2006, the number of ice-breaker cruises at "Polar Stern", "Healy", "Oden" as well as observations conducted during the IPY 2007-2008 have revealed many facts of changes on different environmental and biological levels. Such evolution may result in reorganization of the whole lower trophic structure of the ocean and, probably, may affect the ecology and dynamic of marine ecosystems, and fishes, birds, and mammals included.

In spite that the central part of the Arctic Basin is not a region for fishery, oil and gas exploration, nevertheless, this region has played and will play in future very important role in redistribution of pollutants due to ice drift and/or currents between coastal and shelf areas and the Arctic Basin peripheries far from sources of pollution.

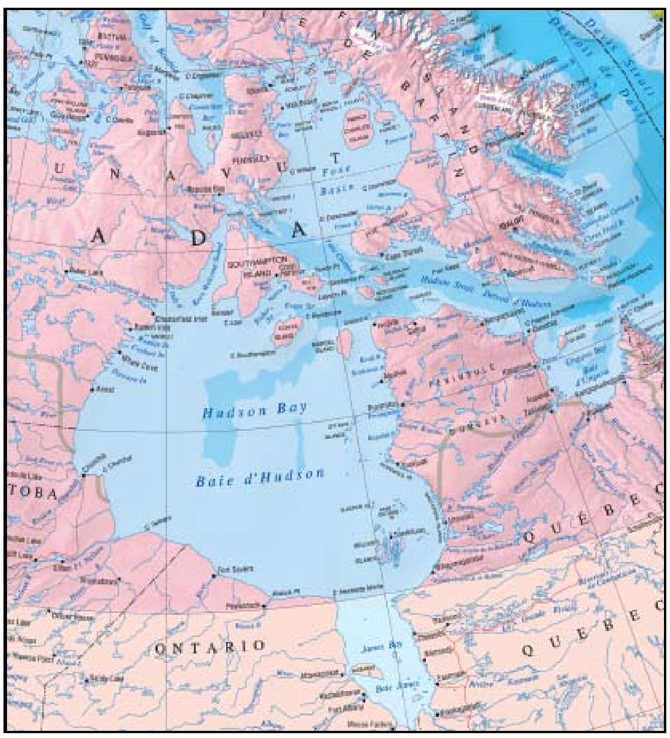

Figure 4.6 : Hudson Bay Complex

4.5 Hudson Bay Complex

4.5.1 Physical characteristics

This system is initially characterized by degree of enclosure, with the mouth of Hudson Strait as its eastern boundary and the Fury and Hecla Strait as its western boundary. Depth is approximately 200m for Hudson Bay and Foxe Basin, with greater depth in Foxe Channel and Hudson Strait. Water flow unites the various parts of this ecoregion. Tides are an important physical oceanographic feature, which control mixing in the whole complex. Another strong influence comes from the large input of freshwater from Quebec, with the plume starting in James Bay and following the Quebec coast to the north, all the way to the tip of Labrador. Because of this freshwater influence, stratification in Hudson Bay is from north to south and west to east. Ice cover in this system is seasonal, with the presence of two polynyas, one in northwestern Hudson Bay and another in north western Foxe Basin. Foxe Basin and Hudson Bay are characterized by cyclonic circulation systems.

4.5.2 Biological characteristics

One biological property shared throughout the system is high primary productivity, which is only found to be low in the center of Hudson Bay. This high productivity is partly the result of strong tidal mixing. There is also a change in Pandalus species at the mouth of Hudson Strait; P. montagui in the Strait, P. borealis outside.

Although this system is treated as a single ecoregion, it contains several ecological subdivisions. In terms of species distribution, there is a southern distribution limit for Arctic specialist waterfowl species, at the mouth of Foxe Basin. There are generally no seabirds in central Hudson Bay and Foxe Basin due to the absence of breeding cliffs, but they are present in Hudson Strait. These seabirds, mostly thick-billed murres, feed primarily on capelin (Mallotus villosus), sand lance (Ammodytes spp.) and benthic organisms. For marine mammals, bowhead whales are found primarily in Hudson Strait and Foxe Basin, whereas narwhals are found near Southampton Island, and beluga whales in Hudson Bay and Ungava Bay. Rosewellton Strait to the west of Southampton Island was historically an area of high bowhead harvests. Walrus (Odobemus rosmarus) are found in Foxe Basin and on the Coats and Mansel Islands, whereas Harbour seals (Phoca vitulina) are found from the northern shore of Hudson Strait and south into Hudson and Ungava Bays. Shrimp (Pandalus spp.) and Greenland halibut (Reinhardtius hippoglossoides) occur in the Hudson Strait and Ungava Bay. On the basis of these distributions, three subregions could be defined: Hudson Strait, Hudson and James Bays, Foxe Basin. The area surrounding Southampton Island might be considered a fourth subregion.

4.5.3 Pressures

The main human drivers in Hudson Bay have been created by (past) commercial whaling and indirectly by global warming. The bowhead whale population that used the greater Hudson Bay region as a calving area was decimated to unsustainable levels around 1915. The bowhead population has partly recovered leaving the ecosystem to respond to the initial removal of considerable living biomass responsible for consuming huge quantities of zooplankton and the current revival of consumption of the basal trophic level. Ecosystem ramifications are unknown.

There is continued loss of sea ice extent, thickness, and duration within the Hudson Bay region due to global warming. Understood ramifications include decreasing fitness of polar bears and seals and the displacement of Arctic cod as the primary forage fish to recent invasive species: sandlance and capelin. Another invasive species, the killer whale (Orcinus orca) arrived into the region around 1950 because of the loss of sea ice in Hudson Strait and the growing population of orca predators is thought to be creating considerable predation pressure on marine mammals such as bowhead, beluga, and narwhal whales.

With the loss of sea ice, the port of Churchill may become a significantly greater marine traffic destination. Greater ship traffic and oil and gas activities are considered likely and therefore the risk of accidents in the future may be considerable.

4.6 Baffin Bay – Davis Strait – Lancaster Sound

4.6.1 Physical characteristics

There is a very well defined shelf line off north eastern Baffin Island, separating the shallow inshore from the deep (>1000m) offshore. Lancaster Sound is characterized by depths typical of the continental shelf.

Davis Strait is characterized by the presence of seasonal ice, with the duration of the ice cover being longer on the inshore than offshore regions. The inshore area of Davis Strait is also strongly influenced by tides and the input of freshwater. The southern boundary of Davis Strait is associated with the northern limit of a warm deepwater mass; the boundary was drawn from north of Cumberland Sound (Cape Dyer) to Greenland. This ecoregion includes a polynya (the Northwater Polynya), which starts at the mouth of Lancaster Sound and goes north to Cape Dunsterville on the eastern shore of Ellesmere Island.

4.6.2 Biological characteristics

Primary productivity is relatively high in Lancaster Sound, Prince Regent Inlet, and

at the entrance of Admiralty Inlet, all along the northern and eastern coasts of Baffin Island, and becomes substantially lower as you move offshore. The southern boundary identified by bottom water temperature also corresponds to limits in the distribution of marine mammal and of large colonies of Northern fulmars and black-legged Kittiwakes (Rissa tridactyla). Shrimp (Pandalus borealis) and Greenland halibut occur in the southern portion of this ecoregion, and may be found further north, but there is no available fishery data. Turbot are produced in the offshore regions and then move inshore towards

Baffin Island, demonstrating the connectivity within the ecoregion. It also represents part of the wintering area of narwhals. Seabirds, belugas, and narwhals

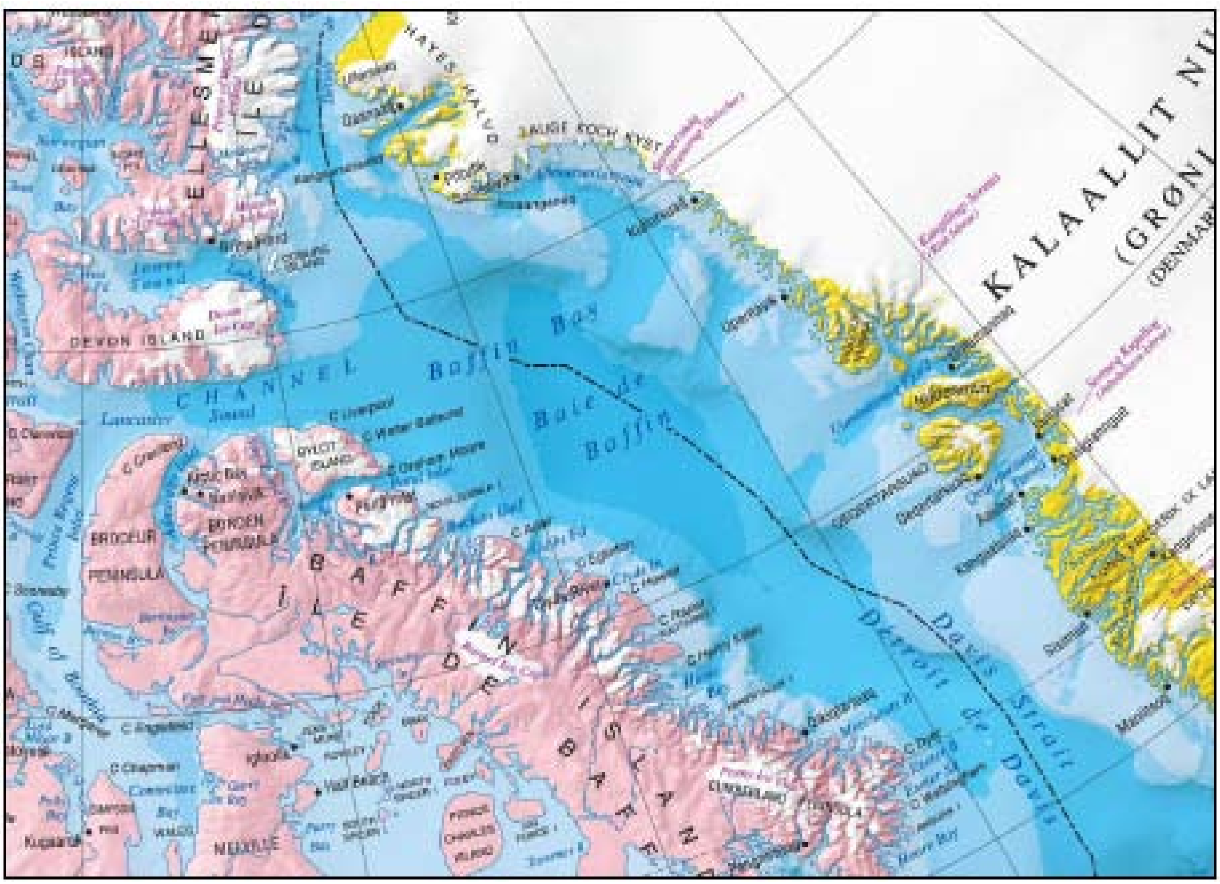

Fig. 4.7: Baffin Bay – Davis Strait – Lancaster Sound

are present throughout Lancaster Sound and their distribution ends at the shallow water/ice plug boundary with the Viscount Melville region. Marine mammals (belugas, narwhals) and seabirds migrate seasonally from Lancaster Sound to the eastern coast of Baffin Island. Seals are found into the southeastern part of the Arctic Archipelago and their distribution determines the boundary between Lancaster Sound and the Arctic Archipelago ecoregions in this area.

4.6.3 Pressures

The distribution of marine fauna could be affected by climate change, including the expansion of ranges northward, and introduction of species. The loss of sea ice associated with climate change may increase shipping in the Arctic and related activities could have unfavourable environmental impacts. These include releases of substances through emissions to air or discharges to water; accidental releases of oil or hazardous cargo; disturbances to wildlife through sound or sight; collisions with whales or birds attracted to lighted ships; and the introduction of invasive alien species in ballast water and cargo, as well as via hull fouling. Unfavourable environmental effects are also associated with shipping infrastructure such as dredging shipping lanes and port developments.

Hydrocarbon development and related infrastructure also poses a threat to Arctic ecosystems as discussed in previous sections. Seismic activity, construction of artificial islands and ice roads in shallower areas, dredging, shipping, and over-wintering of heavy equipment all are anticipated as this activity increases in degree and scope. The nature and consequences of activities in deeper water on the shelf break to the Arctic Basin remain unknown at present. The ever-present threat of an oil spill under ice is an unknown risk.

Emerging commercial fisheries for turbot and shrimp have the potential to affect the abundance of these species; there are also risks related to bycatch associated with this activity. Trawling and deep sea gillnets may affect deep water corals.

United States Fish and Wildlife Service

5 Expert Workshops

Broad expertise (both scientific and community-based) on various aspects of Arctic marine ecosystems must be brought together to design a monitoring plan that will effectively:

1. Identify trends in biodiversity
2. Identify possible links to anthropogenic activities/ causes of these trends

Two workshops will be held to: design an integrated Arctic marine biodiversity monitoring plan: identify the networks to be involved; and produce an implementation plan.

5.1 First Workshop (Tromsø)

The first workshop will focus on developing the integrated monitoring framework for Arctic marine biodiversity. This would include identifying what to monitor (indicators), when (over what time period and how often) and where (geographic locations associated with selected focal marine ecosystems). The first workshop will focus on identifying what monitoring is required within the focal marine ecosystems described in chapter 4. Work to date by the Marine Expert Monitoring Group has determined that, based on a number of criteria, these are the highest priority focal marine ecosystems for the Arctic marine biodiversity monitoring plan. It is not the intention to revisit the choice of focal marine ecosystems during the workshop.

To design the biodiversity monitoring plan, it will be necessary to address the following overarching questions:

- How should the monitoring plan be designed to be able to detect trends in marine biodiversity in the Arctic and to identify links between such trends and anthropogenic activities or impacts?
- What criteria should be used to choose common and standardized indicators (parameters) and monitoring sites?
- What existing and ongoing monitoring activities/ programs can be used to build the integrated monitoring plan?
- These discussions should produce an outline of the monitoring plan. At the same time, we can already anticipate some of the changes in biodiversity that might occur in Arctic marine environments. The workshop will therefore continue with the following questions:
- Of the biodiversity trends we might expect in Arctic marine environments, which ones will the monitoring plan likely be able to detect?
- Which trends will the plan likely be unable to detect?
- This will provide the background for the last two questions:
- What are the major gaps in current monitoring?
- What new and existing data and/or projects could be developed to fill these gaps?

5.2 Second Workshop (Washington)

The second workshop is intended to produce a draft Integrated Monitoring Plan for marine biodiversity. This monitoring plan is one of several that together will contribute to the Circumpolar Biodiversity Monitoring Program[2].

The following questions should tentatively be the main issues for the second workshop:

- What organizations and networks are responsible for the monitoring found relevant during the first workshop, and which organizations are the main users of the monitoring information?
- What organizational structure (e.g. network, or network of networks) will be necessary to organise the relevant monitoring programs and activities to form and implement an integrated Arctic marine biodiversity monitoring plan?
- What resources will be required to develop and implement the monitoring plan, recognizing that some elements may be dependent on the continuation of programs that are the responsibility of single countries?
- What critical gaps remain, and what approaches should be considered to fill these?

[2] Biodiversity monitoring plans are also being developed for coastal, freshwater, terrestrial vegetation and terrestrial fauna ecosystems.

6. Data management

A key objective of the Circumpolar Biodiversity Monitoring Program (CBMP) is to create a publicly accessible, efficient, and transparent platform to house information on the status of and trends in Arctic biodiversity. This objective will be instrumental in achieving the Program's mandate to report on trends in a timely and compelling manner so as to enable effective policy responses.

Data sources, formats, and subjects range widely across the Arctic marine biodiversity research and monitoring community. The challenge is to access and manage the immense, widely distributed, and diverse amount of Arctic marine biodiversity data from the multitude of contributors, levels and formats. A related challenge is effectively correlating biodiversity data with physical, chemical and other data in order to better understand the possible causes driving biodiversity trends at various scales (regional to global).

Meeting these challenges will significantly improve policy and management decisions through improved access to current, accurate and integrated information on biodiversity trends and their underlying causes at multiple scales.

6.1 Purpose of data management

Efficient data management is fundamental to the success of the CBMP. It provides the means to connect individual partner networks and indicator development efforts to an integrated whole that can be communicated effectively to a range of audiences and stakeholders. Executed correctly, data management can fulfill the following functions for the CBMP:

- Quality assurance – ensures that the source datasets and indicator development methodologies are optimal and that data integrity is maintained throughout processing steps.
- Consistency across indicators and networks – encourages the use of common standards and consistent reference frames and base datasets.
- Efficiency – reduces duplicate efforts through sharing metadata, methodologies and experiences.
- Sustainability – ensures archiving capability and ongoing indicator production throughout the CBMP.
- Enhanced communications – produces (and distributes) information products through integrated Internet services, making indicator methodologies accessible and providing metadata on source datasets.
- Improved linkages – ensures complementarity between various networks and partnerships and with other related international initiatives, such as the CBD Clearing-House Mechanism, other indicator processes (national, regional and global), multinational environmental agreements (MEAs), and global assessment processes (such as Global Environment Outlook and the Millennium Ecosystem Assessment).
- Enhanced credibility –provides transparency and certainty with respect to methodologies, datasets, and processes.

The implementation of the Marine Biodiversity Monitoring Plan will rely on the participation of many partners on multiple levels. An efficient and user-friendly metadata and data management system will enable this collaboration to occur. It will provide unique opportunities for monitoring networks to exchange data, draw comparisons between similar data sets, and correlate biodiversity data with the physical and chemical data derived from other networks external to the CBMP.

A roadmap for data management (CBMP Data Management Strategy) has been developed to guide the management and access of metadata and data amongst and between the CBMP networks.

6.2 Key elements of CBMP data management

6.2.1 The web-based portal as a data interface

Modern management toolkits and new computational techniques are required to address the data management challenges posed by a complex global initiative such as the CBMP. A state-of-the-art web-based and geo-referenced digital toolkit is envisioned for the management of CBMP data in order to ensure optimum data quality and quantity.

Web-based portals provide a convenient data search, discovery, entry and compilation point and enable worldwide access to data. The web-based portal will serve several purposes for the CBMP. First, it will provide geo-referenced access to data from within partner networks and a common platform with multiple entry points for data access, integration, harmonization and delivery. Second, it will enable a wide range of user groups to analyze trends, synthesize data, and produce reports with relative ease.

The CBMP is developing a web-based data portal (using Seabird productivity data as the pilot) that will act as a common entry point for a broad spectrum of users, including the Marine EMG and its associated partners. The portal will be compatible with ongoing initiatives such as the Global Biodiversity Information Facility (GBIF), CBD and International Polar Year (IPY) and will allow limited and controlled access to many decentralized and distributed databases.

6.2.2 Metadatabase

The CBMP is developing a metadatabase that will track current monitoring programs and the data they collect. The relevant Arctic marine biodiversity monitoring programs identified by the Marine Expert Monitoring Group will be input into this metadatabase. The searchable metadatabase will be housed online for easy access and updated periodically.

6.2.3 Data and metadata standards

In order for the various networks involved in implementing the Marine Biodiversity Monitoring Plan to collaborate, input and share data and metadata, common data and metadata standards need to be chosen.

The CBMP has chosen the Federal Geographic Data Committee (FGDC) standard to ensure compatibility with the Global Earth Observation System of Systems (GEOSS) program. Data standards are more complex in nature as different data standards are needed for spatial and non-spatial data. The resulting implementation plan will have to include identification of the data standards to be used.

Appendix 1 Inventory of existing monitoring capacity by nation

The program lists on the following pages are inventory lists of existing monitoring capacity in the Arctic nations as reported by the MEMG members. The submitted information has in some cases been simplified and transferred from one format to the present tabular format. This procedure might have caused errors and/ or inaccuracies. The original inventory lists will be available at the workshop and upon request. Acronym explanations can be found in the original lists.

Canada – marine monitoring programs

Program title	Objectives	Specific species and/or ecosystems included	Geographic coverage	Time coverage	Contact person/project leader
Pan-arctic tagging of beluga (IPY)		Beluga whale *Delphinapterus leucas*	Hudson Bay waters surrounding Nunavik	2007-2009	Mike Hammill, Department of Fisheries and Oceans
C30: Canada's Three Oceans (IPY)		Prokaryotes, pico-, nano- and phytoplankton, benthos, marine birds and mammals	From Vancouver Island to Nova Scotia	2007-2009	Eddy Carmack, Department of Fisheries and Ocean
Climate variability and change effects on Chars in the Arctic	Examine linkages between climate change and mercury bioaccumulation	Arctic char and related fishes of the genus *Salvelinus*	Nunavut, Nunavik, Nunatsiavut and the Northwest Territories	2007-2008	James Reist, Department of Fisheries and Oceans
Effects of global warming on polar bears, seals and whales (IPY, ArcticNet)	Movement of the marine mammals from telemetry; tissue samples	Polar bear and other marine mammals	Hudson Bay	2007-2009 (program initiated in 2003)	Steven Ferguson, Department of Fisheries and Oceans/University of Manitoba
The circumpolar flaw lead (CFL) system study (IPY, ArcticNet, NSERC)		Mesozooplankton, fish larvae, marine mammals, epibenthic assemblages	The Amundsen Gulf and the Southern Beaufort Sea	2007-2011	David Barber, University of Manitoba
Determining the diet of the Greenland Shark in a changing Arctic (IPY)		predation of Greenland shark on marine mammals during winter ice cover and summer open water periods	Nunavut	2007-2008	Aaron Fisk, University of Windsor
How seabirds can help detect ecosystem change in the Arctic (IPY)		Seabirds (murres, fulmars, gannets, storm-petrels)	Nunavut and Newfoundland	2007-2008	William Montevecchi, Memorial University
Polar ecosystems in transition: An inter-disciplinary investigation into the impacts of climate change on polar bears (IPY)	Examine foraging ecology in four populations and whether trends of chemical pollutants in one population has changed with increasing temperatures	Polar bear	Nunavut, Manitoba, Nunavik and Nunatsiavut	2007-2008	Elisabeth Peacock, Government of Nunavut
The Hudson Bay Complex Observatory (IPY)	Studies of abundance, productivity and biodiversity	Plankton and benthos	Hudson Bay, Hudson Strait, Foxe Basin and Ungava Bay	2007-2008	Michel Starr, department of Fisheries and Oceans

Canada – marine monitoring programs

Program title	Objectives	Specific species and/or ecosystems included	Geographic coverage	Time coverage	Contact person/project leader
Impact of climate change on Arctic benthos (ArcticNet)	Studies of biodiversity and secondary productivity	Demersal fish, macrobenthic and meiobenthic communities	Arctic Ocean	2008-2011	Philippe Archambault, Department of Fisheries and Oceans / Institut Maurice-Lamontagne
Arctic Marine Mammals and Northerners Adaptations (ArcticNet)		Walrus, bearded, ringed seal, narwhal, beluga, bowhead, killer whales, polar bears.	entire Canadian Arctic	2008-2011	Steven Ferguson, Department of Fisheries and Oceans / University of Manitoba
Effects of climate change on the Canadian Arctic wildlife (ArcticNet)		Tundra wildlife and marine birds	Eastern Arctic and Hudson Bay (6 main sites)	2008-2011	Dominique Berteaux, Université du Québec à Rimouski
Long-term observatories in Canadian Arctic waters (ArcticNet)	Long-term observations of marine mammal vocalizations	Marine mammals	Hudson bay, Baffin Bay, Beaufort Sea and the Eastern Arctic Ocean	2008-2011	Yves Gratton, INRS-ETE
Marine Biological Hotspots: Ecosystem Services and Susceptibility (ArcticNet)	Studies of abundance and biodiversity	Microalgae, phytoplankton, zooplankton, fish bacteria, Archaea and picoeukaryotes	Arctic Ocean	2008-2011	Jean-Eric Tremblay/ Michel Gosselin, Université Laval/ Université du Québec à Rimouski
Multi-Species Tracking of Aquatic Animals in the Canadian Arctic (ArcticNet/OTN)	Studies of movement and behavior	Marine animals	Arctic Ocean	2008-2011	Terry Dick, University of Manitoba
Cumberland Sound ecosystem and invasive species (OTN - Strategic Network Grant)		Beluga, narwhal, Greenland halibut, capelin, Greenland shark	Cumberland Sound	2009-2012	Aaron Fisk, University of Windsor and Steven Ferguson, Department of Fisheries and Oceans / University of Manitoba
Polar Research Observatories for Biodiversity and the Environment (PROBE) (NSERC/IPY)	Multi-taxon genetic biodiversity survey	Multiple taxa	Polar regions	2007-2008	Paul Hebert, University of Guelph

Canada – marine monitoring programs

Program title	Objectives	Specific species and/or ecosystems included	Geographic coverage	Time coverage	Contact person/project leader
Microbial biodiversity of High Arctic ecosystems: Canadian partnership in the International Polar Year Program MERGE (NSERC/IPY)	Studies of abundance, biogeography, biodiversity, identity and environmental genetics	Microbes; eukaryotes, bacteria and archaea.	Kuujjuarapik, Bylot Island, Axel Heiberg Island, Ward Hunt Island, Ellesmere Island and Resolute	2007-2008	Warwick Vincent, Université Laval
Vertebrate molecular ecology and conservation biology (NSERC)	Studies of DNA profiles of vertebrate populations	Vertebrates (e.g. polar bear)	M'Clintock Channel and the Gulf of Boothia	2007-2008	Peter Boag, Queen's University
Orcas of the Canadian Arctic (OCA) - Arctic killer whale research (NWMB)				2006-2012	Steven Ferguson, Department of Fisheries and Oceans / Freshwater Institute
Bowhead whale calving demography (NWMB).	Provide population vital rate statistics from Foxe Basin calving site	Bowhead whale	Foxe Basin	2007-2012	Steven Ferguson and Jeff Higdon, Department of Fisheries and Oceans / Freshwater Institute
Polar bears and climate change: habitat use and trophic interactions		Polar bear		2007	Andrew Derocher, University of Alberta
Hudson Bay ringed seal movements and demography, satellite tagging of ringed seals and bearded seals and comparison with polar bear satellite telemetry results (DFO)		Ringed seals, bearded seals, polar bear	Hudson Bay		Steven Ferguson, Sebastian Luque, Lilly Peacock, Department of Fisheries and Oceans / Freshwater Institute
Phylogenetic and functional diversity of an arctic microbial community (NSERC)				2007-2008	Keith Egger, University of Northern British Columbia
Arctic parasitology (NSERC)				2007-2008	Mark Forbes, Carleton University

Canada – marine monitoring programs

Program title	**Objectives**	**Specific species and/or ecosystems included**	**Geographic coverage**	**Time coverage**	**Contact person/project leader**
Evolutionary ecology and biodiversity of Arctic fishes (NSERC)				2007-2008	Jeffrey Hutchings, Dalhousie University
Variabilité de la production primaire dans la baie d`Hudson et le haut Arctique canadien (NSERC)	Studies of the water column		Hudson Bay complex, Beaufort Sea	2007-2008	Michel Gosselin, Université du Québec à Rimouski
Ecology of polar bears in changing climate (NSERC)		Polar bear		2008-2009	Andrew Derocher, University of Alberta
Ecology of peripheral fish populations at their northern extremes (NSERC)		Fish		2008-2009	Jeffrey Hutchings, Dalhousie University
Rare Biosphere of the Deep Arctic Ocean (NSERC/ICOMM)	Studies of total biodiversity of bacteria and archaea in the deep Arctic Ocean.	Bacteria and archae	Canada Basin, Labrador Sea, Beaufort Sea, Nansen Basin	2007	Connie Lovejoy, Université Laval
Mackenzie Shelf Ecosystem Study (Northern Coastal Marine Studies Program)	Integrated ecosystem study	Phytoplankton, zooplankton, ichthyoplankton, fish, and benthos	Beaufort Sea, Mackenzie Delta	2003-2009	Don Cobb and Steve Blasco, Department of Fisheries and Oceans/ Natural Resources Canada
Winter Ecology of the Beaufort Sea Survey (WEBSS) (PERD)			Beaufort Sea		Patricia Ramal, Department of Fisheries and Oceans
Effects of oil and gas development on juvenile burbot and burbot reproduction (PERD)		Burbot *Lota lota*			Pete Cott, Department of Fisheries and Oceans
Behaviour and movements of ringed seals and bowhead whales in SE Beaufort Sea (PERD)		Ringed seal and bowhead whale	SE Beaufort Sea		Lois Harwood, Department of Fisheries and Oceans

Canada – marine monitoring programs

Program title	**Objectives**	**Specific species and/or ecosystems included**	**Geographic coverage**	**Time coverage**	**Contact person/project leader**
Yukon North Slope nearshore fish ecosystem study (PERD)					Jim Johnson, Department of Fisheries and Oceans
Ecosystem Modeling Project: Carbon Studies in Beaufort Sea (PERD)			Beaufort Sea		Patricia Ramal, Department of Fisheries and Oceans
A comprehensive study on chronic toxicity of production water on immune responses and feeding behaviour of cod (Gadus morhua) (PERD)		Cod *Gadus morhua*			Dounia Hamoutene, Depart-ment of Fisheries and Oceans
Chronic effects of production waters on the reproductive health and productivity of fish: assessment of the potential effects of selected species of socioeconomic importance or identified as species at risk (PERD)					Jerry Payne, Department of Fisheries and Oceans
Seismic effects on invertebrates (PERD)					Ken Lee, Department of Fisheries and Oceans
Core monitoring - ringed seals (NCP)	Ecotoxicological studies (heavy metals and organic environmental pollutants)		Spatial patterns in Arctic Canada	2004 - ongoing (also much data 1991-2004)	Derek Muir, Environment Canada
Core monitoring – beluga (NCP)	Ecotoxicological studies (heavy metals and organic environmental pollutants)		Spatial patterns in Arctic Canada	2004 - ongoing (also much data 1991-2004)	Gary Stern/Gregg Tomy, Department of Fisheries and Oceans
Core monitoring – narwhal (NCP)	Ecotoxicological studies (heavy metals and organic environmental pollutants)		Spatial patterns in Arctic Canada	2004 - ongoing (also much data 199/2004	Gary Stern/Gregg Tomy, Department of Fisheries and Oceans

Canada – marine monitoring programs

Program title	Objectives	Specific species and/or ecosystems included	Geographic coverage	Time coverage	Contact person/project leader
Core monitoring – walrus (NCP)	Ecotoxicological studies (heavy metals and organic environmental pollutants)		Spatial patterns in Arctic Canada	2004 - ongoing (also much data 1991-2004)	Gary Stern/Gregg Tomy, Department of Fisheries and Oceans
Core monitoring - seabirds (thick-billed murre and northern fulmar) (NCP)	Ecotoxicological studies (heavy metals and organic environmental pollutants)		Prince Leopold Island and Coats Island (temporal trends)	2004 - ongoing (also much data 1991-2004)	Birgit Braune, Environment Canada
Core monitoring - sea-run Arctic char (NCP)	Ecotoxicological studies (heavy metals and organic environmental pollutants)		Spatial patterns in Arctic Canada	2004 - ongoing (also much data 1991-2004)	Marlene Evans/Derek Muir, Environment Canada
Core monitoring - polar bear (NCP)	Ecotoxicological studies (heavy metals and organic environmental pollutants)		Spatial patterns in Arctic Canada	2004 - ongoing (also much data 1991-2004)	Rob Letcher, Environment Canada
BEMP (NOGAP)	Studies of effects of petroleum activity on marine wildlife	Whales, seals, polar bears, seabirds, and fish	Beaufort Sea and region	1983-1987	INAC and EC
BREAM - (an initiative that combine and coordinate the efforts of BEMP and MEMP) (NOGAP)			Beaufort region and Mackenzie Valley/Delta area	1990-1994	INAC and EC
MERICA-Nord: Monitoring and Research in the Hudson Bay Complex (N-CAARE, PERD)	Studies of abundance and biomass	Phytoplankton, zooplankton, benthos and larval fish	Hudson Bay Complex (Hudson Bay, Hudson Strait and Foxe Basin	2003-2005	Michel Harvey, Institute Maurice-Lamontagne of DFO
Climate Variability / Change and Marine Ecosystem Resources in Hudson Bay (ArcticNet)	Studies of primary production and zooplankton	Phytoplankton and zooplankton	Hudson Bay	2004-2008	Michel Gosselin, Université du Québec à Rimouski

Canada – marine monitoring programs

Program title	Objectives	Specific species and/or ecosystems included	Geographic coverage	Time coverage	Contact person/project leader
Nunatsiavut Nuluak: Baseline inventory and comparative assessment of three Northern Labrador Fjord-based marine ecosystems (ArcticNet)	Baseline inventory and comparative assessment of three northern Labrador fiord-based marine ecosystems		Anaktalak Bay, Saglek Bay and Nachvak fiord	2004-2008	Ken Reimer, Marina Biasutti, Royal Military College of Canada / Nunatsiavut Department of Lands and Natural Resources
Marine Productivity & Sustained Exploitation of Emerging Fisheries (ArcticNet)	Studies of biological productivity, fisheries resources and marine mammal populations of the coastal Canadian High Arctic	Plankton, fish and marine mammals	North Water, Central Archipelago, Mackenzie Shelf	2004-2008	Jean-Eric Tremblay, Université Laval
Ice-Atmosphere Interactions and Biological Linkages (CASES-NSERC)		Ice algae biomass; phytoplankton at different water depths; sampling of zooplankton and larval fish	Cape Bathurst, Amundsen Gulf	2002-2006	D. Barber, University of Manitoba
Light, nutrients, primary and export production in ice-free waters (CASES-NSERC)	Studies of phytoplankton; abundance, standing stock and production	Phytoplankton	Lake Mackenzie & Cape Bathurst	2001-2006	S. Demers, Université du Québec à Rimouski
Microbial communities and heterotrophy (CASES-NSERC)	Studies of rates of microbial heterotrophy; microheterotrophs; microzooplankton and picoplankton; protist identification and counts	Plankton	At the polynya and delta sites; freshwater-saltwater transition of the Mackenzie River	2002-2006	Warwick Vincent, Université Laval
Pelagic food web: Structure, Function & Contaminants (CASES-NSERC)	Food web studies	Mesozooplankton (copepods, appendicularians and macrozooplankton predators) and fish larvae	Mackenzie Shelf	2002-2006	D. Deibel, Memorial University Newfound-land

Canada – marine monitoring programs

Program title	Objectives	Specific species and/or ecosystems included	Geographic coverage	Time coverage	Contact person/project leader
Benthic processes and carbon cycling (CASES-NSERC)	Studies of amount, quality, and species composition of phytodetrital deposition over an entire productivity season on an Arctic continental shelf	Benthos macro- and megafauna	the stamukhi zone for ice scour, the Mackenzie Lake, and across the shelf to the slope, including the polynya area	2002-2006	A. Aitken, University of Saskatchewan
Optics, nutrients, primary and export production (NOW-NSERC)	Studies of primary production	Phytoplankton and ice algae	North Water Polynya	1997-2001	N. Price, McGill University
Microbial-Metazoan Trophic Coupling (NOW-NSERC)	Studies of phytoplankton and planktonic predators	Phytoplankton, microbes, protistan and metazoan grazers	North Water Polynya	1997-2001	R. Rivkin, Memorial University
Plankton-Vertebrate Trophic Coupling (NOW-NSERC)	Trophic studies	Phytoplankton, copepods, macrozooplankton, Arctic cod	North Water Polynya	1997-2001	L. Fortier, Université Laval
Carbon Flow, Contaminants, and Trophic Structure (NOW-NSERC)	Trophic studies	Birds and ringed seals	North Water Polynya	1997-2001	Ian Stirling, Canadian Wildlife Service (DOE)
Impact of UV-B on biological productivity (NOW-NSERC)	Studies of effects of UV-B radiation on a marine food web	Algae, microheterotrophs, copepods and fish	North Water Polynya	1997-2001	S. Demers, Université du Québec à Rimouski

Greenland – marine monitoring programs

Program title	**Objectives**	**Specific species and/or ecosystems included**	**Geographic coverage**	**Time coverage**	**Contact person/project leader**
Aerial surveys for marine mammals	To provide management advice for harvested species	Large whales, narwhal and beluga, walrus (plan to include polar bears)	West and East Greenland (East Greenland to a lesser extent)	Standardised in 2005- (approx. every 5 years). Plus older time series for some species	Mads Peter Heide-Jørgensen, Fernando Ugarte, Greenland Institute of Natural Resources (GINR)
Seabird Monitoring	Monitoring of breeding seabird populations	Primarily *Uria aalge*, *Rissa tridactyla* and *Somateria molissima*	West Greenland	1998- (annual or less). Opportunistic surveys in the past	Flemming Merkel, Aili Labansen, GINR
Monitoring of shrimp and fish stocks in West Greenland	Resource monitoring of commercially important populations and non commercial species, West Greenland	Several fish species and shrimp	West Greenland	1988- (annual)	Helle Siegstad, GNIR
Monitoring of shrimp and fish stocks in East Greenland	Resource monitoring of commercially important populations and non commercial species, East Greenland	Several fish species and shrimp	East Greenland	2007- (annual) Plus older time series	Helle Siegstad, GNIR
Monitoring of Greenland Halibut in East Greenland	Resource monitoring	Primarily Greenland Halibut	East Greenland	1998- (annual, not 2001)	Kaj Sünksen, GINR
Monitoring of offshore stock of Greenland Halibut West Greenland	Resource monitoring	Primarily Greenland Halibut	West Greenland	1997- (annual)	Kaj Sünksen, GINR
Monitoring of inshore stock of Greenland Halibut West Greenland	Resource monitoring	Greenland Halibut	Uummannaq and Ilulissat area, West Greenland	1993- (annual)	Bjarne Lyberth, GINR
Monitoring of inshore stock of snow crab	Resource monitoring	Snow crab (*Chionoecetes opilio*)	West Greenland (two areas)	1997- (annual)	AnnDorte Burmeister, GINR
Monitoring of offshore stock of snow crab	Resource monitoring	Snow crab (*Chionoecetes opilio*)	West Greenland	S: 1999- N-P: 2001- (annual)	AnnDorte Burmeister, GINR

Greenland – marine monitoring programs

Program title	**Objectives**	**Specific species and/or ecosystems included**	**Geographic coverage**	**Time coverage**	**Contact person/project leader**
Monitoring of inshore stock of cod	Resource monitoring	Cod (*Gadus morhua*)	West Greenland (two areas)	1982- (annual)	Holger Hovgaard, GINR
Sampling from the commercial fisheries	Biological samples from the commercial fisheries	Primarily shrimp (*Pandalus borealis*) and Greenland halibut (*Reinhardtius hippoglossoides*)	West and East Greenland	1993- (annual)	Bjarne Lyberth, GINR
Sampling from salmon fisheries	Biological samples from salmon fisheries	Atlantic salmon	West Greenland	1969- (annual)	Rasmus Nygaard, GINR
Hydro-monitoring West-Greenland	Monitoring of physical parameters. 71 positions	Salinity and temperature (CTD)	Coast off West Greenland	1950- (annual)	Helle Siegstad, GNIR
Marine Basic (MB) Nuuk	Monitoring of marine environment at one position of the Nuuk fjord	Physical and chemical parameters, phyto- and zooplankton composition.	Nuuk, (West Greenland)	2005- (monthly)	Søren Rysgaard, GNIR
MB Nuuk	Monitoring of marine environment. Annual transect of the Nuuk fjord	Physical and chemical parameters, phyto- and zooplankton composition and fish.	Nuuk, (West Greenland)	2007- (annual)	Søren Rysgaard, GNIR
MB Nuuk	Presence an movement of whales	Humpback whale	Nuuk, (West Greenland)	2006- (annual)	Søren Rysgaard, GNIR
MB Nuuk	Monitoring of several breeding sea bird in the Nuuk fjord system	*Uria lomvia, Uria aalge, Cepphus grylle, Alca torda, Fratercula arctica, Somateria molissima, Sterna paradisaea, Rissa tridactyla and several Larus species*	Nuuk, (West Greenland)	2006-	Søren Rysgaard, GNIR
MB Zackenberg	Monitoring of marine environment	Physical and chemical parameters, phyto- and zooplankton, benthos and macro algae.	Young Sound, Northeast Greenland	2003- (annual)	Søren Rysgaard, GNIR
MB Zackenberg	Monitoring of fish and pinnipeds	Fish, walrus and seals	Young Sound, Northeast Greenland	2003- (annual)	Søren Rysgaard, GNIR

Norway – marine monitoring programs

Norway – marine monitoring programs

Program title	Objectives	Specific species and/or ecosystems included	Geographic coverage	Time coverage	Contact person/project leader
Monitoring Program for The Barents Sea	Program established to follow up The Management Plan for The Barents Sea	Phytoplankton, zooplankton, benthos, fish, marine mammals, sea birds, sea ice, temperature, contaminants in sediments and biota	Norwegian part of The Barents Sea (Norwegian sector/Western part)		Knut Sunnanaa, Institute of Marine Research, Norway
Seabird Population Program/SEAPOP – includes several projects specified in the list (see below)	Monitoring of breeding and wintering seabird populations	See interlinked programmes and projects below	Norwegian coast from Lofoten and Northward, and the sea area around Svalbard (74-81° N and 8-34° E inc. the Bear Island)	2005-	Brit Veie-Rosvoll, Morten Ekker (DN) Tycho Anker-Nilssen (NINA), Hallvard Strøm (NPI)
Monitoring Program for Svalbard and Jan Mayen (MOSJ) – includes several projects specified in the list (see below) There are more elements in MOSJ than shown below	Monitoring	See interlinked projects below	Svalbard Archipelago (74-81° N and 8-34° E) and Jan Mayen		Birgit Njåstad, NPI
National Monitoring of the Marine Environment and Living Resources	Monitoring of sea environment with special focus on sustainable fisheries management	Physical and chemical parameters, zooplankton, phytoplankton, fish eggs and larvae, several fish species, prawn, lobster, benthic ecosystems	Barents Sea (Norwegian sector /Western part) and Norwegian Sea		Lead: Norwegian Institute of Marine Research (IMR)
Integrated Mapping Programme for the Norwegian Seas and Coastal Areas (MAREANO)	Map the seabed	Bathymetry, geology, biology and contaminants	Seabed in Norwegian waters (Barents Sea)	2005-2010	Ole Jørgen Lønne and Lene Buhl-Mortensen (IMR), Trond Skyseth (SK), Terje Thorsnes (NGU)

Norway – marine monitoring programs

Program title	Objectives	Specific species and/or ecosystems included	Geographic coverage	Time coverage	Contact person/project leader
Marine Environment – Physical And Chemical Parameters	Routine monitoring of marine climate and contaminant components in the water column	Temperature, salinity, and nutrient	Transects in Norwegian marine areas incl. Svalbard. Regional coverage in the Barents Sea, Norwegian Sea and Northern Sea - Skagerak	Some data are very old	IMR
Operative Buoys	Monitoring of åhysical parameters, waves and traffic	Temperature, salinity, currents, waves, water level	Norne, Ekofisk, Ormen Lange, Karmøy, Jomfruland, Vardø and Barents Sea		Staoilhydro, Phillips, OCEANOR, Fobox, Petergaz and the Directorate for Coastal Affairs
Kongsfjorden – Fram Strait	Zooplankton		Kongsfjorden (Spitsbergen 79^{o} N and 12,5^{o} E) – Fram Strait		NPI, INIS, NFH, IOPAS
Zooplankton monitoring	Acquire data for estimation of biomass and lower trophical level production	All zooplankton species	Defined transects in Norwegian marine areas and in Svalbard. Regional coverage in the Barents Sea, Norwegian Sea and Northern Sea - Skagerak	1980-	IMR
Phytoplankton monitoring	Acquire data for estimation of biomass and lower trophical level production	Phytoplankton and chlorophyll a	Defined transects in Norwegian marine areas and in Svalbard. Regional coverage in the Barents Sea, Norwegian Sea and Northern Sea – Skagerak.	1980-	IMR, UiT/NFH

Norway – marine monitoring programs

Program title	Objectives	Specific species and/or ecosystems included	Geographic coverage	Time coverage	Contact person/project leader
Geléplankton monitoring	Acquire data for estimation of biomass and lower trophical level production	Density, and species/groups	Defined transects in Norwegian marine areas and in Svalbard. Regional coverage in the Barents Sea, Norwegian Sea and Northern Sea - Skagerak	1980-	IMR
Fish Eggs and Larvae monitoring	Estimation of recruitment of commercial fish species	Fish eggs and larvae	North Sea, Norwegian Sea, Barents Sea		IMR
Resource Monitoring of Commercially Important Populations and Non-commercial Species	Monitoring of abundance and composition of commercially important populations. Includes about 40 stocks	Greenland halibut, Monkfish, Brisling, Sea sand eel, Whiting, Haddock, Saithe, Flatfish, Herring, Blue Whiting, Halibut, Capelin, European hake, Mackerel, Spur-Dog, Turbot, Arctic cod, Witch, Horse Mackerel, Cod, Redfish, and cephalopod	Barents Sea, Norwegian Sea, Northern Sea/Skagerak		IMR
Mapping of Ice Habitats	Species diversity, ecological studies in sea-ice	Sampling of algae, ice-fauna, ice thickness and kind, and snow depth	Barents Sea East of Svalbard and North to the Shelf edge of the Polar Sea		UiT/NFH, UNIS, NPI
Benthos/shellfish monitoring	Resource monitoring and species composition	Shrimps, *Paralithodes camtschaticus*, Iceland scallop	Barents Sea		IMR
Benthos Ecosystem in the Barents Sea	Monitoring of benthos condition and study its ecological influence	Habitat distribution, macro-fauna, hyper-benthos, by-catch	Barents Sea		IMR
Benthos Fauna in the Barents Sea	Time development of benthos communities	Species composition	Storfjorden (Svalbard) and the Bear Island groove		Akvaplan-niva

Norway – marine monitoring programs

Program title	Objectives	Specific species and/or ecosystems included	Geographic coverage	Time coverage	Contact person/project leader
Sub-littoral Rocky Bottom in Svalbard and Bear Island	Monitor development in time of natural sub-littoral rocky bottom communities in the Arctic	Rock sessile organisms, recruitment and growth, photographing, video	Kongsfjorden and Smeerenburgfjorden in Svalbard, and Bear Island		Akvaplan-niva
Mapping of Corals, Sponge etc. in the Barents Sea and Norwegian Sea	Mapping of vulnerable coral and sponge habitats in the Barents Sea, methodology	Detailed bathymetry, habitat mapping and mega-fauna	Barents Sea, Norwegian Sea		IMR
Mapping and Monitoring of Corals	Mapping and monitoring of corals in Norwegian seas	Corals and associated fauna	Barents Sea, Norwegian Sea		IMR
Rocky bottom research along the coasts of Northern Norway, Svalbard and Jan Mayen	Mapping and state monitoring	Benthic ecosystems	Along the coasts of Northern Norway, Svalbard and Jan Mayen		Bjørn Gulliksen, University of Tromsø
Offshore monitoring of the Norwegian petroleum activities	Monitoring of pollutants and species diversity in sediments in the vicinity of offshore installations. Monitoring of uptake and effects of pollutants in mussels and fish	Sea bed fauna/biodiversity/ecosystems. Fish and caged blue mussels in water column	The whole Norwegian shelf where there is oil and gas activities		Anne Mari Vik Green, SFT
The Sea Mammal Research Program	Population registration and monitoring, parts included in MOSJ	Whales (mainly Balaenoptera acutorostrata, but also others), Pagophilus groenlandicus, Cystophora cristata, Phoca vitulina, Phoca hispida, Halichoerus grypus, Odobaenus rosmarus	Whales: North Sea, Norwegian Sea and Barents Sea (Norwegian sector /Western part). Ringed seal: Greenland Sea (Northern part from 76^{o} N should be relevant), Norwegian coast, and Spitsbergen Walrus: Svalbard		IMR, NPI

Norway – marine monitoring programs

Program title	Objectives	Specific species and/or ecosystems included	Geographic coverage	Time coverage	Contact person/project leader
Population ecology of Polar bear in the Svalbard area	MOSJ	Ursus maritimus	Svalbard (74-81^{o} N and 8-34^{o} E)	1967-	Magnus Andersen, NPI
Polar bear population in the Barents Sea	Longterm monitoring of population size by aerial line transect surveys, MOSJ	Ursus maritimus	Barents Sea, Svalbard, Frantz Josef Land, Novaja Zemla (72-81^{o} N and 8-72^{o} E)	2004-	Jon Aars, NPI and Russian cooperation
Monitoring of seabird populations in Bear Island	Population trend monitoring of the two largest seabird species in the Barents Sea and the marine ecosystem these species belong	Uria aalge, Rissa tridactyla, Fulmarus glacialis, Stercorarius skua, Alle alle, Larus hyperboreus	Bear Island (74-75^{o} N and 18-20^{o} E)	1986-	Hallvard Strøm, NPI
Svalbard seabird monitoring program	Monitoring of trends, demographic parameters and diet of some seabird species in Svalbard	Uria aalge, Uria lomvia, Alle alle, Fulmarus glacialis, Somateria mollissima, Rissa tridactyla, Stercorarius skua, Larus hyperboreus	Svalbard (74-81^{o} N and 8-34^{o} E)	1988-	Hallvard Strøm Harald Steen, NPI
Population development and ecology of Seabirds in Hornøya, Eastern Finnmark	NNMP	Rissa tridactyla, Uria aalge, Uria lomvia, Fratercula arctica, Phalacrocorax aristotelis	Hornøya Island (is situated at the mainland about 71^{o} N and 30^{o} E, but the breeding populations migrates and feeds in southern part of the Barents Sea)	1980-	Rob Barrett, University of Tromsø
Population development of Seabirds in Southern Varanger, Eastern Finnmark	Breeding population monitoring	Rissa tridactyla, Phalacrocorax carbo, P. aristotelis, Uria aalge, Alca torda	Southern Varanger archipelago (is situated at the mainland about 71^{o} N and 30^{o} E, but the breeding populations migrates and feeds in southern part of the Barents Sea)	1966-	Rob Barrett, University of Tromsø

Norway – marine monitoring programs

Program title	Objectives	Specific species and/or ecosystems included	Geographic coverage	Time coverage	Contact person/project leader
Ivory gull (MOSJ)	Breeding colony monitoring and blood sampling/contamination	Pagophila eburnea	Svalbard Archipelago and Frantz Josef Land (76-81° N and 8-72° E)	2007-	Hallvard Strøm, NPI (Russian side: Maria Gavrilo AARI)
Long-term variations in arctic soft-bottom benthos I	Benthic community composition	Benthic ecosystems	Open Barents Sea (72-76° N and 8-34° E)	1920's-	Akvaplan-niva
Long-term variations in arctic soft-bottom benthos II	Benthic community composition	Benthic ecosystems	Svalbard fjords (76-80° N and 8-24° E)	1980-	Akvaplan-niva
Monitoring of sedimentary environments in Isfjorden, Svalbard	POPs levels in sediments and benthic organisms	Benthic ecosystems	Selected fjords in the Isfjorden complex, Svalbard (78-79° N and 13-18° E)	1992- (approx 5 year interval)	Akvaplan-niva (+ others) contracted by Sysselmannen Svalbard
Ships of opportunity and remote sensing	Oil in sediment contamination	Benthic and pelagic ecosystems (mostly algae)	Along the coastal sailing transect of the Norwegian "Hurtigruten" up to Kirkenes, Finnmark and from 2007 the sailing transect from Tromsø to Longyearbyen (about 72-78° N and 12-18° E)		Dominique Durand, NIVA

Russia – marine monitoring programs

Program title	Objectives	Specific species and/or ecosystems included	Geographic coverage	Time coverage	Contact person/project leader
RFBR Project: Multifunctional analysis of the sea ice and surface water ecosystem dynamic in the Central Arctic Basin	Census of marine life within sea ice-surface water	Sea ice biota, phytoplankton, zooplankton, and fish	Beaufort Gyre and Transarctic ice drift	2008-2010	Igor A. Melnikov Shirshov Institute of Oceanology, RAS
Hydromet/RAS project: PanArctic Ice Camp Expedition (PAICEX)	Monitoring of the sea ice and surface water ecosystems		Mezopolygon nearby the North Pole	2005-2012	Igor A. Melnikov Shirshov Institute of Oceanology, RAS
Hydromet/RAS project: PanArctic Ice Camp Expedition (PAICEX)	CTD measurements		Mezopolygon nearby the North Pole	2005-2012	Sergey V. Pisarev Shirshov Institute of Oceanology, RAS
Hydromet/RAS project: PanArctic Ice Camp Expedition (PAICEX)	Monitoring of the sea ice biota and phytoplankton	Species composition and biomass	Mezopolygon nearby the North Pole	2005-2012	Rinat M. Gogorev Botanical Institute, RAS
Hydromet/RAS Project: PanArctic Ice Camp Expedition	Monitoring of the sea ice fauna and zooplankton	Species composition and biomass	Mezopolygon nearby the North Pole	2005-2012	Tatyana Semenova, Alex N. Timonin, Shirshov Institute of Oceanology, RAS
RAS World Ocean program	Monitoring of the sea ice biota and phytoplankton	Species composition and biomass	White sea, Kandalaksha Bay, Moscow State University Biological Station	1996-recent	Ludmila S. Zhitina Moscow State University
Benthic surveys	Macrozoobenthos/magazoobenthos	Abundance and biomass	Chukchi sea	Sampling frequency: In 1935-1938, 1988, 1989, 1995, 2004-2006	Nina Denisenko, Zoological institute of the RAS
Benthic surveys	Macrozoobenthos/magazoobenthos	Grab quantitative samples	Pechora Sea (south-eastern part of the Barents Sea	Sampling frequency: In 1927, 1958, 1968, 1992, 1993	Zoological institute of Russian academy of sciences (ZIN),

Russia – marine monitoring programs

Program title	Objectives	Specific species and/or ecosystems included	Geographic coverage	Time coverage	Contact person/project leader
Macrozoobenthos study by scientific programs of research institutes	Macrozoobenthos/magazoobenthos	Abundance and biomass	Kola transect 33º30' E Barents Sea	Sampling frequency: Periodically (1936, 1948, 1956, 1968, 1984, 1995, 1997, 2001)	Zoological institute of Russian academy of sciences (ZIN), MMBI
Academician and applied institutes	Monitoring of zooplankton	Plankton net sampling	Pechora Sea (south-eastern part of the Barents Sea	From time to time in frames of scientific programs	MMBI, PINRO
Hydro-monitoring Barents Sea program	Nansen bottles time-series		Stations and sections in the Barents Sea	Monthly samplings, Complete at the end of 1980s	MMBI/Hydromet
Monitoring of stock of Atlantic cod; Sampling from the commercial fisheries	Trawls surveys		Stations in the fishery areas	Annual samplings	PINRO, VNIRO
Sampling from salmon fisheries	Various size measurements and tissue sampling from salmon fisheries		Coastal fisheries, Southern part of the Barents sea	Annual samplings	PINRO
Marine birds (ongoing program)	Estimation of abundance in colonies and its dynamic		Southern and south-eastern parts Barents Sea	Annual samplings	MMBI, AARI
Barents Sea, White Sea Mammals (ongoing program)	Estimation of abundance		Barents Sea, White Sea	Annual samplings	MMBI, SevPINRO
White Sea zooplankton program	Net zooplankton sampling	Taxonomy, abundance and biomass	Stations in Chupa Bay of the White Sea	Decadal (3 times in month) during 50 years	Zoological Institute of RAS
Monitoring of littoral macrozoobenthos	Frame sampling		Polygon in Chupa Bay of the White Sea	Seasonal	Zoological Institute of RAS

USA – marine monitoring programs

Program title	Objectives	Specific species and/or ecosystems included	Geographic coverage	Time coverage	Contact person/project leader
Orbital remote sensing of the Arctic (NASA)	Studies of sea ice extent, ice motion, age/thickness deformation, ice mass balance of ice sheets, shift in ocean currents, geostrophic flow, sea surface temperature, ice surface temperature, primary productivity via ocean color	Remote sensing, primarily abiotic, but also primary production	Pan-Arctic	1978- (daily)	Seelye Martin, NASA
RUSALCA – Russian-American Long-term Census of the Arctic (NOAA)	Observation of oceanographic and climatic parameters, and studies of biodiversity through censuses.	Phytoplankton, zooplankton, benthos and fish	Bering Strait, Chukchi Sea, Wrangel Island north to Makharov Basin and onto the Chukchi Plateau	2004-	Kathleen Crane, Arctic Research program, CPO, NOAA
Hidden Ocean (NOAA)	Census of Marine Life, From Ice to seafloor, Physical and Chemical Oceanographic measurements, T, S, P, nutrients, productivity, Contaminants		Canada Basin, Chukchi Plateau, Northwind Ridge	2002, 2005	Rolf Gradinger, UAF and Jeremy Potter, Ocean Exploration, NOAA
Various surveys in the Bering and Chukchi Seas (NOAA)	Surveys of 250 fish and 42 marine mammal stocks, 27 commercially important fish and crab stocks	Crab, fish and marine mammals	Bering and Chukchi Seas	Annual to biennial	NOAA Alaska Fisheries Science Center
BASIS (NOAA)	Gridded fisheries oceanography, CTD, NPZ, catches from epipelagic (0-20 m) trawls.	Fish	Bering Sea, Eastern Chukchi Sea, Arctic Ocean	Biennial (if possible)	Mike Siegler, AFSC, NOAA
Beaufort Sea Marine Fish Survey (NOAA)	Gridded fisheries oceanography, CTD, NPZ, catches from epipelagic (0-20 m) trawls.	Fish	US Beaufort Sea	2008?	NOAA, UA, UW and MMS

USA – marine monitoring programs

Program title	Objectives	Specific species and/or ecosystems included	Geographic coverage	Time coverage	Contact person/project leader
FOCI (NOAA)	Measurements from oceanographic-biophysical moorings and acoustic observations of marine mammal calls and underwater ambient noise		Eastern Bering Sea middle shelf	2004-	Phyllis Stabeno, NOAA
NABOS (NOAA)	Measurements from oceanographic moorings, CTD and ice buoy deployments moorings		Russian Shelf Break to deep Arctic Ocean	2002-	Igor Polyakov, IARC, University of Alaska, Fairbanks
BEST and BSIERP (NSF/NPRB)	Comprehensive oceanographic, ecological and climatic study		The eastern Bering Sea Shelf	2007-2012	William Wiseman, NSF, Ray Sambrotto, Lamont-Doherty Earth Observatory, Phyllis Stabeno, NOAA, Lee Cooper, Univ. of Maryland, Carin Asjian, WHOI
AOOS – Alaskan Ocean Observing System (NOPP/Ocean.US)	Observation/measurements of oceanographic and climatic parameters		Bering Sea, Eastern Chukchi Sea, Arctic Ocean ++	2003-?	Molly McCammon, AOOS, Anchorage, AK
ArcOD - Arctic Ocean Biodiversity (CoML)	Studies of diversity in each of the major three realms: sea ice, water column and sea floor, including fish, mammals and birds	Fish, mammals and birds	Pan-Arctic	2004-2010	Rolf Gradinger, Russ Hopcroft and Bodil Bluhm, University of Alaska, Fairbanks
Natural Geography in Shore Areas (NaGISA)	Studies of diversity of benthic fauna form top of intertidal to ~30m depth	Benthic fauna	Global nearshore	2004-2010	Katrin Iken and Brenda Konar, University of Alaska, Fairbanks

AMAP – marine monitoring programs

Program title	Objectives	Specific species and/or ecosystems included	Geographic coverage	Time coverage	Contact person/project leader
North Pole expeditions (Russia), ongoing	Monitoring contaminant levels in various abiotic media	Measurement of standard hydrochemical indicators in seawater and sediments as well as broad suite of contaminants	Central Arctic Basin		Yuri S. Tsaturov (AMAP HOD for Russia)
Spitzbergen expeditions (Russia), ongoing	Ecological impact assessment related to historic mining activity	Analysis of sea ice, seawater, seawater suspended matter and bottom sediments for broad range of contaminants	Grønfjord and Isfjord Bays		Yuri S. Tsaturov (AMAP HOD for Russia)
Environmental Monitoring at Zackenberg, MarineBasic (Denmark), ongoing	Long term monitoring of physical, chemical and biological parameters in Young sound Greenland	Broad suite of parameters in sea-ice, sea-water, and biota including phyto/zooplankton, benthos, fish (Arctic Char), and marine mammals (seal and walrus)	Young sound		Søren Rysgaard (Greenland Institute for Natural Resources)
Denmark					
Screening of "new" contaminants in the marine environment of Greenland and the Faroe Islands (Denmark), (2002-2003)	Investigation of novel contaminants in marine biota including fluorinated and brominated compounds, and synthetic musks	Pilot whale and fulmars from the Faroe Islands as well as marine sediments, shorthorn sculpins,ringed seals, minke whales from West Greenland and shorthorn sculpins, ringed seals and polar bears from East Greenland.	East and West Greenland, Faroe Islands		Rune Dietz (NERI, KNE for AMAP POP Expert Group)
Effects of POPs in Polar Bears in the Greenland Sea. (Denmark), 1999-	Investigation of contaminant related effects in polar bears	Polar bears	East Greenland and Svalbard		Rune Dietz (NERI)

AMAP – marine monitoring programs

Program title	Objectives	Specific species and/or ecosystems included	Geographic coverage	Time coverage	Contact person/project leader
Epidemiological assessment of the linking between contaminant load, lifestyle factors, effect markers and health effects in Greenland (Denmark), ongoing	permanent monitoring system in Greenland for surveillance of contaminant load on humans and the health effects of the load	Humans. Involves study of dietary exposure to contaminants through consumption of marine foods.	Greenland		University of Aarhus, Department of Environmental and Occupational Medicine
Fate of mercury in the Arctic (FOMA, Denmark), - 2004	Study of mercury transport including entry to the marine environment	Marine food web (benthic/pelagic), polar bear, birds of prey (peregrine falcon, white tailed eagle)	East/West Greenland, Svalbard, Disko bay (food web)		Henrik Skov (NERI)
Effects of marine pollution on child development on the Faroe Islands, Phase III (Denmark), - 2003, ongoing?	Measure exposure to contaminants and relate to possible effects, e.g. immune function	Children exposed to contaminants through consumption of marine foods	Faroe Islands		Faeroe Islands Hospital Services
Pilot study of POP-effects in pilot whales at Faeroe Islands, 2003 - ?	effects on the Pilot whale, response on selected POP bio-markers	Pilot whales	Faroe Islands		Heilsufrødiliga Starvsstova
Carbon uptake in the Greenland Sea, 2003 - ?	determine the marine carbon uptake in the Greenland Sea	Primary production	Greenland Sea		Research Centre Risø
Effect of POPs in Sledge Dog and Polar Bear (POESI), Denmark, 2003-2009	Investigate toxic effects of POPs in upper trophic level marine mammals	Polar bear	East Greenland, Svalbard and Kara Sea		Rune Dietz (NERI)
Greenland tissue and databank http://www.dmu.dk/International/Arctic/Pollutants/Databank	Facilitate international scientific work	Broad spectrum	Greenland		NERI,

AMAP – marine monitoring programs

Program title	Objectives	Specific species and/or ecosystems included	Geographic coverage	Time coverage	Contact person/project leader
Greenland Marine Contaminant Monitoring, Denmark, ongoing since early/mid 1980s	Contaminant levels and trends	Ringed seal, polar bear, walrus sculpin, guilemot	Avanersuaq, Ittoqqortoormiit, Qeqartarsuaq,		Rune Dietz (NERI)
Iceland					
Contaminants monitoring	Contaminant levels and trends	Blue mussels, cod, Seaweed (Ascophyllum nodosum)	Numerous locations around Iceland		
Norway					
Contaminant monitoring in seawater and sediments, ongoing	Contaminant levels and trends	Seawater and sediments	Barents Sea, Norwegian Sea: Haltenbanken, Lofoten, North Sea with Skagerrak and Kattegat		
Contaminant monitoring in marine biota around Svalbard, ongoing	Contaminant levels and trends	Polar bear, Glaucous gull, Brünnich's guillemot, Ringed seal, Harp seal, Hooded seal, Beluga, Minke whale, Walrus, Common eider, Black guillemot, Kittiwake, Common guillemot	Svalbard area, the Barents Sea		Geir Gabrielsen, Norwegian Polar Institute
Contaminant monitoring of marine biota near the Norwegian coast	Contaminant levels and trends	Blue mussel, cod, flatfish, flounder, plaice, lemon sole	Various locations on the Norwegian Coast		
Contaminant dynamics in marine food webs	Contaminant processes	Food web, from phytoplankton/ice algae to marine mammals	Fram Strait, Barents Sea		Geir Gabrielsen, Norwegian Polar Institute
Effect of climate on biological population parameters	Population dynamics	Recruitment, growth, migration, distribution of fish (cod, herring, capelin, haddock); Production, distribution of plankton; Species composition/ community analysis (bottom benthic fauna, fish)	Barents Sea, Norwegian Sea		

AMAP – marine monitoring programs

Program title	Objectives	Specific species and/or ecosystems included	Geographic coverage	Time coverage	Contact person/project leader
Spatial and temporal trends in marine abiotic environment	Climate change related impacts on the marine environment	T, S in sea water	Standard sections in the Nordic and Barents Sea; Standard stations along the Norwegian coast		
Effects of contaminants on polar bear and glaucous gull, study completed	Biochemical, physiological, immune and population effects of POPs	Polar bear and glaucous gull	Svalbard		Geir Gabrielsen, Norwegian Polar Institute
United States					
Investigation of Heavy Metal and Organochlorine Concentrations in Polar Bears (Ursus maritimus) Tissues collected in Alaska	Contaminant levels and trends	Polar bear	Beaufort, Chukchi, and Bering seas.		Todd O'Hara, University of Alaska Fairbanks
Alaska Marine Mammal Tissue Archival Project (AMMTAP) and Seabird Tissue Archival and Monitoring Project (STAMP)	Wildlife monitoring and specimen banking	N. fur seal, ringed sea., bearded seal, harbour seal, spotted seal stellar sea lion, walrus, beluga, bowhead, polar bear, seabird eggs.	Beaufort, Chukchi, Bering seas, and gulf of Alaska		Paul Becker, National Biomonitoring Specimen Bank, NOAA
Alaska Native Cord Blood Monitoring Program	Levels and trends of human dietary contaminant exposure	Yupik Eskimo, Inupiat Eskimo	Bering and Beaufort seas		James Berner, Alaska Native Tribal Health Consortium
Canada					
Temporal trends of contaminants in marine biota (annual)	Levels and trends in marine biota	Seabird eggs (thick-billed murre, northern fulmar), anadromous char, beluga, ringed seal	Beaufort sea, central archipelago, Hudson Bay/Davis Strait, Lancaster Sound, Baffin Bay, Labrador Sea		Jason Stow, Northern Contaminants Program

AMAP – marine monitoring programs

Program title	**Objectives**	**Specific species and/or ecosystems included**	**Geographic coverage**	**Time coverage**	**Contact person/project leader**
Temporal trends of contaminants in marine biota (5yr)	Levels and trends in marine biota	Seabirds and seabird eggs (thick-billed murre, northern fulmar, black guillemot, glaucous gull, black-legged kittiwake), walrus, narwhal, polar bear	Beaufort sea, central archipelago, Hudson Bay/Davis Strait, Lancaster Sound, Baffin Bay, Labrador Sea		Jason Stow, Northern Contaminants Program
AMAP CANADA – CONT'D					
Studies of contaminant pathways and processes in Arctic Marine ecosystems (periodic)	Contaminant pathways and processes	Benthic, pelagic and under-ice food-webs	Beaufort sea, Baffin Bay, Labrador Sea, Hudson Bay/ Davis Strait, Lancaster Sound		Jason Stow, Northern Contaminants Program
Levels and trends of contaminants in human blood, including the Inuit Health Study (approx 5yr)	Contaminant levels/dietary exposure in humans	Contaminant levels in adult and maternal blood coupled with dietary exposure assessment. Exposure is largely associated with consumption of traditional marine diet	All Inuit and Inuvialuit communities in the Canadian Arctic		James Edwards, Northern Contaminants Program
Nunavik Cohort Study	Epidemiological study of contaminant related effects on infants and children in Nunavik	A broad range of endpoints are measured in relation to exposure to marine derived contaminants.	Inuit communities of Nunavik (Northern Quebec, Hudson Bay/Davis Strait)		James Edwards, Northern Contaminants Program

Appendix 2 Related processes – learning experiences

Below you will find an overview bringing to attention related processes and/or process elements. These processes will be briefly described (1-2 paragraphs), and elements of potential value to a CBMP Marine Monitoring Program will be emphasized.

Weblinks are embedded within the project titles (Ctrl-click to follow link):

Management plan for the Barents Sea

This management plan was launched 2005 and is based on an ecosystem approach. One part of the plan is establishment of an extensive monitoring program that covers several of the major elements of the Barents Sea ecosystem (see chapter 7 for details). Data on human activities are also assembled. Reports on the state of the ecosystem are published annually.

Ecosystem Studies of of Sub-Arctic Seas (ESSAS)

The goal of the ESSAS Program is to compare, quantify and predict the impact of climate variability and global change on the productivity and sustainability of Sub-Arctic marine ecosystems.

Barents Sea Impact Study (BASIS)

The Barents Sea Impact Study (BASIS) is a Global Change research project developed under the auspices of the International Arctic Science Committee (IASC). After a planning phase of five years (1992-1996), a research proposal was submitted in 1997 to the IV Framework Environment and Climate Programme of the European Commission. This proposal was accepted and did received funding for an initial period of two years (1998-1999). The study was finished in 1999, but leaves behind useful data.

Bering Sea Impact Study (BESIS)

This study of the consequences of climate change for Alaska and the Bering Sea region was completed in 1999. This was a research project, but the study might cover some monitoring data.

NOW (International North Water Polynya Study)

This is a research network that brings together Canadian and foreign expertise in Arctic oceanography to study and model the climatic and oceanographic mechanisms of formation of the North Water Polynya, the biological production taking place within and around its ice boundaries, and the fate of this production in the ocean.

MOSJ (Monitoring program for Svalbard and Jan Mayen)

This monitoring program has been established to assess whether the goals are achieved for Norwegian environmental monitoring of Svalbard and Jan Mayen. The monitoring program covers climate, elements of marine and terrestrial biota and human activities. It overlaps partly the monitoring program of the Barents Sea management plan.

CAFF/AMAP Coordinated Monitoring Effort (CME)

The aims of CME are to:

- Form a more complete picture of the overall state of Arctic ecosystems, and their extent of structural integrity, resiliency, and sustainability
- Identify and/or quantify stressor affecting sustainability of Arctic ecosystems, and therefore the Arctic's living resources
- Seek efficiencies of operation as directed by the Senior Arctic Officials (SAO´s)

Objectives:

- As far as possible take advantage of approaches already accepted by the Arctic Council (e.g., integrated ecosystem-based approach, large marine ecosystems) bring the existing data of the two monitoring programs together where possible for analyses.

- To achieve a more cost efficient collection and storage of data, and a better use of the data collected in assessments and research.
- Identify areas of commonality (species and/or sites and/or ecosystems), where data from the two programs already exist within national monitoring programs and analyze how the data overlap, where the linkages are, what the data is signifying, and where the gaps lay.

- Based on the gap analysis, initiate projects to fill these gaps.
- Establish better linkages between the findings of this coordinated monitoring program with those of other programs, within and outside the Arctic, in order to broaden the scope of understanding of the potential impacts of Arctic and global change.
- Communicate the findings of this coordinated monitoring effort in published reports and maps, for use by policy-makers, environmental managers, indigenous people's organizations, international organizations, and the general public.

ArcticNet studies

There are several pertinent projects being funded through ArcticNet (e.g. Marine biological hotspots: ecosystem services and susceptibility to climate change).

Sustained Arctic Observing Network (SAON)

SAON has been formed to develop a set of recommendations on how to achieve long-term Arctic-wide observing activities that provide free access to high-quality data on a number of central physical, biological and social elements in the Arctic.

BEST (Bering Ecosystem Study)

The 2004 BEST Science Plan outlines a multi-year research initiative to improve understanding of the effects of climate variability, at multiple temporal and spatial scales, on eastern Bering Sea marine ecosystems. Social scientists have developed a parallel science plan, **Sustaining the Bering Ecosystem**, which outlines a community-based research program focused on the residents of Bering Sea communities and their need to understand how climate variability will affect their future. These two plans have been integrated into an **implementation plan** for a single program that will study the ecosystem as a whole, including the social implications of climate change and the roles of people in the system.

This research program outlines a multi-year research initiative to improve understanding of the effects of climate variability, at multiple temporal and spatial scales, on eastern Bering Sea marine ecosystems. Social scientists have developed a parallel science plan, "Sustaining the Bering Ecosystem", which outlines a community-based research program focused on the residents of Bering Sea communities and their need to understand how climate variability will affect their future. These two plans have been integrated into an implementation plan for a single program that will study the ecosystem as a whole, including the social implications of climate change and the roles of people in the system.

NPRB-BSIERP (North Pacific Research Board/ Bering Sea Integrated Ecosystem Research Program)

Climate models predict warming in the Bering Sea region over the next 30 years. On the southeastern shelf of the Bering Sea, this projected warming will profoundly alter ecosystem structure by changing pathways of energy flow and the spatial distribution and species composition of fish, seabird and marine mammal communities, thereby affecting commercial and subsistence fisheries. Building from that conceptual framework, the BSIERP study focuses on a series of explicit, testable hypotheses.

Russian-American Long-term Census of the Arctic (RUSALCA)

RUSALCA implements long-term monitoring of physical, chemical and biological components in the Chukchi Sea encompassing Russian and US territory. A set of moorings monitors physical characteristics across Bering Strait and on the shelf at high data collection frequency (annual) and biological sampling every 4-5 years.

Pacific Arctic Group (PAG)

The Pacific Arctic Group is a forum for collaboration and coordination with a focus on fostering information transfer and field planning amongst individuals, institutions and countries working in the region of the Pacific Arctic. Membersip includes representatives from China, Korea, Japan, Russia, Canada and the USA. The Pacific Arctic Region is loosely defined as the areas lying between Russia and the United Statesd (Bering Strait) and extends northward including the Beaufort Gyre and Arctic Ocean and south including the Bering Sea. Of the many themes covered by PAG, themes 4 and 5 are of particular interest to CBMP:

Theme 4: Identify and monitor ecosystem and biological indicators and chemical tracers (e.g., ice, water column, benthic, higher trophic organisms, isotopes and trace gases) of climate change in the Pacific Arctic.

Theme 5: Investigate sea ice thermodynamics including sea ice thickness, extent, and its interactions with ocean and atmospheric forcing in the Pacific Arctic region. Investigate sea ice dynamics such as sea ice drift, interactions between different ice packs.

Alaska Ocean Observatory System (AOOS)
The Alaska Ocean Observing System's mission is to improve the ability to rapidly detect changes in marine ecosystems and living resources, and predict future changes and their consequences for the public good. When fully developed, AOOS will:

- Serve as the Alaska regional node for a national network of observing systems;
- Systematically deliver both real-time information and long-term trends about Alaska's ocean conditions and marine life;
- Provide to the public Internet access to cost-free data and information on coastal conditions; and
- Supply tailored products to meet the needs of mariners, scientists, industry, resource managers, educators, and other users of marine resources.

Alaska Department of Fish and Game
The Alaska Department of Fish and Game's mission statement is "To protect, maintain, and improve the fish, game, and aquatic plant resources of the state, and manage their use and development in the best interest of the economy and the well-being of the people of the state, consistent with the sustained yield principle."

Core Services:
- Provide opportunity to utilize fish and wildlife resources;
- Ensure sustainability and harvestable surplus of fish and wildlife resources;
- Provide information to all customers;
- Involve the public in management of fish and wildlife resources; and
- Protect the state's sovereignty to manage fish and wildlife resources.

Goals:
- Optimize economic benefits from fish and wildlife resources.
- Optimize public participation in fish and wildlife pursuits.
- Increase public knowledge and confidence that wild populations of fish and wildlife are responsibly managed.
-

North Slope Borough, Department of Wildlife Management
The Department of Wildlife Management facilitates sustainable harvests, and monitors populations of fish and wildlife species through research, leadership, and advocacy from local to international levels. As the North Slope Borough's budget declines, the department will focus on diversifying funding and concentrating on subsistence species of the highest interest to the North Slope residents.

Circumpolar Monitoring Strategies for ringed seals and beluga whales
Background documents have been developed as result of an initiative taken by the US Marine Mammal Commission. The documents have been finalised and can be downloaded from the CBMP website **(http://www.cbmp.is).**

Arctic ROOS
This is an observing system that has been established by a group of 14 member institutions from nine European countries working actively with ocean observation and modeling systems for the Arctic Ocean and adjacent seas. One of the goals of Arctic ROOS is to contribute to the legacy of IPY, maintaining cost-effective and useful observing systems after the end of IPY.

Molecular Microbial Biodiversity of Arctic Seas (MMBOAS)
This project on microbial biodiversity has been taking place over the past six years using ships of opportunity.

Bering Sea Sub-Network
International Community-Based Environmental Observation Alliance for Arctic Observing Network (BSSN) is a project involving six local indigenous communities in the Bering Sea region, three in Russia and three in Alaska, to monitor and share the environmental changes they observe. Changes could include the shift of southern species north, distribution and abundance of fish and other temperature-

sensitive species, changes in ice patterns, and weather observations. Relevant as community-based monitoring.

Census of Marine Life - ArcOD (Arctic Ocean Diversity) or **http://www.arcodiv.org**

The CoML is a 10-year international collaborative effort involving researchers from more than 80 nations. ArcOD is a CoML project aimed at making an inventory of biodiversity in the Arctic sea ice, water column and sea floor from the shallow shelves to the deep basins using a three-step approach: compilation of existing data, taxonomic identification of existing samples, and new collections focusing on taxonomic and regional gaps. A second CoML project, NaGISA, assesses biodiversity in nearshore areas (<20 m) on a global scale including the Arctic, using a set of standardized sampling protocols. While neashore regions are generally not a focus of the CBMP, they may be included in some areas. All CoML projects make their data publicly available through the OBIS database.

OBIS

OBIS (Ocean Biogeographic Information System) is a fully georeferenced species presence and distribution database established by the Census of Marine Life program. It is an evolving strategic alliance of people and organizations sharing a vision to make marine biogeographic data, from all over the world, freely available over the World Wide Web. It is not a project or program, and is not limited to data from CoML-related projects. Any organization, consortium, project or individual may contribute to OBIS.

CBIRD

CBIRD is a seabird expert group under CAFF. These experts cooperate in planning, design and reporting of arctic seabird monitoring, CBIRD will be the relevant "organization" to serve data on seabird indicators into CBMP.

IUCN Polar Bear Specialist Group (PBSG)

The Polar Bear Specialist Group is the international expert group on polar bears, serving under auspices of the IUCN Species Survival Commission. The group meets regularly, every 4th year at present, and discusses status and knowledge gaps regarding management and the future survival of polar bears. The group has been collaborating with the CBMP for a while, and will be the relevant body to decide on what polar bear monitoring activities can be implemented within CBMP.

AKMap (Alaska Department of Environmental Conservation)

The Alaska Department of Environmental Conservation's policy is "To conserve, improve, and protect its natural resources and environment and control water, land, and air pollution, in order to enhance the health, safety, and welfare of the people of the state and their overall economic and social well being".

Its primary services are to:

- Provide policy direction for the department, and relentless coordination of investment and service delivery,
- Ensure that public concerns are fully considered in department decisions and actions,
- Establish department objectives and assures performance,
- Serve as spokesperson for the Governor on environmental matters,
- Serve as judge for administrative appeals,
- Adopt all department regulations.

US Interagency Agreements (BWASP, COMIDA, BOWFEST)

U.S. Inter-agency agreements have been established between the Minerals Management Service (MMS), Department of Interior (DOI) and the National Marine Mammal Laboratory (NMML), Alaska Fisheries Science Center (AFSC), National Marine Fisheries Service (NMFS), National Oceanographic and Atmospheric Administration (NOAA), Department of Commerce (DOC). The intent of these agreements is to conduct surveys of bowhead whales (Balaena mysticetus) and other marine mammals in the Alaskan Arctic.

The following projects are included in these agreements:

BWASP: The intent of the Bowhead Whale Aerial Survey Project (BWASP) is to conduct surveys of bowhead whales (Balaena mysticetus) during their fall migration through the western Beaufort Sea. In 2008 these surveys were extended across the northeast Chukchi Sea to document marine mammal distribution for most of the period from mid-June to mid-November. More>

COMIDA: The goal of the Chukchi Offshore Monitoring in Drilling Area (COMIDA) study is to augment scientific knowledge about the distribution and abundance of marine mammals in the Chukchi Sea Planning Area (CSPA). Results of COMIDA research will facilitate mitigation related to oil and gas development.

BOWFEST: The Bowhead Whale Feeding Ecology Study (BOWFEST) is a multiyear MMS-funded study started in 2007 that focuses on late summer oceanography and prey densities relative to whale distribution over continental shelf waters within 100 miles north and east of Point Barrow, Alaska. Increased understanding of bowhead behavior and distribution is needed to minimize potential impacts from petroleum development activities.

NABOS (Nansen and Amundsen Basins Observational System)

The major objectives of this project are the following:

- To quantify the structure and variability of the circulation in the upper, intermediate, and lower layers of the Eurasian and Canadian Basins;
- To evaluate mechanisms by which the Atlantic Water is transformed on its pathway along the slope of the Eurasian and Canadian Basins;
- To evaluate the impact of heat transport from the Atlantic Water on ice;
- To investigate the strength and variability of the Fram Strait and the Barents Sea branches of the Atlantic Water;
- To estimate the rate of exchange between the arctic shelves and the interior in order to clarify mechanisms of the arctic halocline formation;
- To evaluate the storage and variability of heat and fresh water, particularly within the halocline of the Canada Basin;
- To quantify Pacific water transport, variability, and water-mass transformation mechanisms from the Chukchi Sea shelf toward the Eurasian Basin.

Shelf-Basin Interaction (SBI) (completed)

U.S. funded research aimed at understanding how the Arctic Ocean margins (from the shore to the basin) function within the arctic system as a whole.

Study of Environmental Arctic Change (SEARCH)

SEARCH is a U.S. interagency effort to understand the nature, extent, and future development of the system-scale change presently seen in the Arctic. These changes are occurring across terrestrial, oceanic, atmospheric and human systems, including:

- Increased air temperatures over most of the Arctic;
- Changing ocean circulation and rising coastal sea level;
- Reduced sea ice cover; and
- Thawing permafrost.

The core aim of SEARCH is to understand the recent and ongoing complex of interrelated pan-arctic changes. These changes are affecting ecosystems, living resources, and the human population, and are impacting local and global economic activities.

Currently nearly 70 projects are funded as SEARCH activities by U.S. agencies. Many more SEARCH-related projects are supported through other programs.

Other relevant processes not described in detail:

- Beaufort Gyre (Canada/US)
- C3O
- CASES (completed)
- CCAMLR
- Circumpolar Flaw Lead-Canada (CFL)
- COMAAR
- European Marine Strategy
- LME/PAME LME
- National Monitoring of the Marine Environment and Living Resources
- OSPAR/JMP
- Second International Conference on Arctic Research Planning (ICARP II)

Appendix 3 Marine Expert Monitoring Group – members and associates

Norway (co-lead)	US (co-lead)
Norway (co-lead) Co-lead/Member: Reidar Hindrum, Senior Adviser Directorate for Nature Management, International Division, N-7485 Trondheim Associates: Dr. Ingrid Bysveen, Senior Adviser Directorate for Nature Management, Marine Division, N-7485 Trondheim Dag Vongraven, Senior Adviser Norwegian Polar Institute, Environmental Management Office, Polar Environmental Centre, N-9296 Tromsø Dr. Per Arneberg, Senior Adviser Norwegian Polar Institute, Environmental Management Office, Polar Environmental Centre, N-9296 Tromsø Mrs. Julia Tchernova, Secrerary Norwegian Polar Institute, Environmental Management Office, Polar Environmental Centre, N-9296 Tromsø	**US (co-lead)** Co-lead/Member: Kathleen Crane, PhD, Mission Coordinator Arctic Research Program, NOAA Climate Program Office, 1100 Wayne Ave., Suite 1202 Silver Spring, MD 20910-3282 Associates: Dr. Sue E. Moore NOAA/Fisheries, Office of Science and Technology , 7600 Sand Point Way, NE, Seattle, WA 98115-6349 Dr. Russ Hopcroft Institute of Marine Science, 120 O'Neill P.O. Box 757220 University of Alaska Fairbanks, Fairbanks, AK 99775-7220 Katrin Iken, PhD Institute of Marine Science, University of Alaska Fairbanks Fairbanks, 227 O'Neill, P.O. Box 757220 AK 99775-7220 USA
Russia Member: Igor A. Melnikov, PhD, Senior Scientist P.P. Shirshov Institute of Oceanology, RAS Moscow, Russia Phone: +7 (495) 124 20 18 Cell: +7 916 604 3131 Email: migor39@yandex.ru Associates: Boris I. Sirenko, PhD, Head of Laboratory Russian Academy of Science Zoological Institute Marine Research Laboratory Nina V. Denisenko, PhD, Senior Scientist Russian Academy of Science Zoological Institute Marine Research Laboratory Olga S. Liubina, PhD, Head of Division Russian Academy of Science, Murmansk Marine Biological Institute, Benthos Division,	**Canada** Member: Jill Watkins, Ph.D., Senior Scientific Advisor Ocean Sciences - Canadian Hydrographic Service, Oceanography and Climate Branch, Science Sector, Fisheries and Oceans Canada, 615 Booth Street, Ottawa, ON K1A 0E6, CANADA Associate: Dr. Jim D. Reist Research Scientist, Arctic Fish Ecology and Assessment Research Section, Fisheries and Oceans Canada 501 University Crescent Winnipeg, Manitoba, Canada, R3T 2N6

<table>
<tr><td>Greenland

<u>Member:</u>
Fernando Ugarte, Head of Department
Greenland Institute of Natural Resources
Department of Birds and Mammals
Box 570, 3900 Nuuk, Greenland

<u>Associate:</u>
Aili Labansen
Greenland Institute of Natural Resources
Department of Birds and Mammals
Box 570, 3900 Nuuk, Greenland</td><td>Iceland

<u>Member:</u>
Dr. Gudmundur Gudmundsson, Head of Collection and Systematics Department & Curator of Marine Invertebrates, Icelandic Institute and Museum of Natural History,
Po Box 5320, Hlemmur 3, 112 Reykjavik, Iceland</td></tr>
<tr><td>CBMP

<u>Chair:</u>
Mike Gill, Chair,
Circumpolar Biodiversity Monitoring Program
91780 Alaska Highway,
Whitehorse, Yukon, Canada
Y1A 5B7</td><td>AMAP

<u>Member:</u>
Jason Stow, Environmental Scientist
Northern Contaminants Program,
Department of Indian Affairs and Northern Development,
456 Dominion St. Winnipeg MB, R3G 2M9</td></tr>
<tr><td>Aleut International Association

<u>Member:</u>
Victoria Gofman, Executive Director
Aleut International Association
333 West 4th Avenue, Ste 301, Anchorage, Alaska, US 99501

<u>Associate:</u>
Andrea Grant-Friedman, Ph.D.
Data Manager, Bering Sea Sub-Network
Aleut International Association
333 W. 4th Avenue, Suite 301
Anchorage, AK 99501 USA</td><td>PAME

<u>Member:</u>
Soffia Gudmundsdottir
Borgum, Nordurslod
PAME Working Group
Akureyri
Iceland
pame@pame.is</td></tr>
</table>

Appendix 4 CBD Headline Indicators

Sustainable use	• Area of forest, agricultural and aquaculture ecosystems under sustainable management • Proportion of products derived from sustainable sources • Ecological footprint and related concepts
Threats to biodiversity	• Nitrogen deposition • Trends in invasive alien species
Ecosystem integrity and ecosystem goods and services	• Marine Trophic Index • Water quality of freshwater ecosystems • Trophic integrity of other ecosystems • Connectivity / fragmentation of ecosystems • Incidence of human-induced ecosystem failure • Health and well-being of communities who depend directly on local ecosystem goods and services • Biodiversity for food and medicine
Status of traditional knowledge, innovations and Practices	• Status and trends of linguistic diversity and numbers of speakers of indigenous languages • Other indicator of the status of indigenous and traditional knowledge
Status of access and benefit-sharing	• Indicator of access and benefit-sharing
Status of resource transfers	• Official development assistance provided in support of the Convention • Indicator of technology transfer