2. November 2013

**Report of 2nd Scientific Meeting on Arctic Fish Stocks, Tromsø 28-31 October 2013**

## 1. Introduction

Fisheries science experts from the five Arctic Coastal States, representatives of international science organizations and the ICC met in Tromsø, Norway, on October 28-31, 2013, to respond to terms of reference (TORs) drafted following consultations among their respective governments in Washington D.C., USA (April 29-May1, 2013). This second scientific meeting followed a previous workshop in Anchorage, June 2011 and continues the mandate from the coastal states in regards to the Arctic Ocean in Oslo (June 2010). The Terms of Reference and related questions and attendees for the Tromsø meeting are provided in Appendices 1 and 2.

The Arctic Ocean (Figure 1) is surrounded by the landmass of the USA, Canada, Denmark/Greenland, Norway and Russia. While the Arctic Ocean earlier was ice-covered for most of the year, global warming has brought reduced ice cover and raised discussions about the prospects for utilization of natural resources including fisheries in the central portion of the Arctic Ocean, i.e. the high seas beyond national jurisdiction. Currently, commercial exploitation of natural resources, including fisheries, only takes place in waters under national jurisdiction in the marginal seas surrounding the Arctic Ocean (e.g. the Bering and the Barents seas) and the sea areas surrounding Greenland. In the Beaufort, Kara, Laptev, East Siberian and Chukchi seas subsistence fisheries (e.g. chars, whitefishes) occur close to the coast, depending upon ice conditions.

The Arctic Ocean is characterized by a deep (>2000 m), mostly high seas central area (2,8 million km2) surrounded by shallow (most <200 m) shelf areas, most of which are within the jurisdictions of the coastal states (Figure 2). For this highly spatially and temporally variable system, the knowledge base and monitoring activities differ among the shelf seas (Appendix 3, country summaries of activities). For the deep Arctic Ocean very little information exists with respect to fishes and their supporting ecosystems. Information to date indicates systemic changes are well underway (changes in sea ice, nutrients, pH, etc.).

## 2. Response to Terms of Reference

The responses address three themes: the establishment of baselines for measurement of change, the evaluation of relevant scientific meetings, and future meetings.

*ToR 1. Establish baseline conditions and define information needs for to monitoring changes in baseline conditions which might influence patterns of distribution and abundance of finfish in the Arctic Ocean. This is viewed as a high-priority requirement.*

Response:
"Baseline conditions" is a problematic concept because change is the only constant

for both shelf seas and the Arctic Ocean. However, large-scale and coordinated monitoring is required as soon as possible to capture temporal and spatial variability. The starting point should include knowledge of the biodiversity at all trophic levels as well as species and oceanographic characteristics.

*a. Briefly review current programs for monitoring critical environmental parameters and patterns of distribution and abundance of plankton, fish, invertebrate and marine mammals in the Arctic.*

In the marginal seas where all the large fisheries take place, annual surveys are conducted (Figure 2). Most of these include physical and biological oceanographic sampling as well as information regarding fishes and fisheries. In addition, satellite coverage provides some essential physical environmental variables. Locations of observing programs are in the North Atlantic approaches to the Arctic Ocean including Fram Strait and the Norwegian, Barents and Kara seas, and in the North Pacific approaches to the Arctic Ocean, the northern Bering Sea, Chukchi Sea, East Siberian and Beaufort seas. These observations are critical to document changes, for example, range extensions of fish species to the north.

Some shelf areas have been surveyed for fisheries resources recently, others not (e.g. the Laptev Sea and East Siberian seas). To maintain consistency, new surveys on Russian shelves and enhanced surveys in other areas, for example the Beaufort Sea, could follow protocols currently used in the Barents and Kara seas. In addition, we recommend that existing surveys be extended to include the continental slope regions where practical as these, together with the shelves, are primary areas where new species are expected to be found. Similar surveys should be planned and conducted for accessible areas of the deep Arctic Ocean.

In addition to field surveys, there are important synthesis activities in place. For example, the International Council for the Exploration of the Sea (ICES) reviews and integrates information on Atlantic shelf seas to provide scientific advice to member countries and regional organizations. There are also other bodies compiling and storing information, such as the marine expert network of the Circumpolar Biodiversity Monitoring Programme. Other initiatives include: an international database on walrus, bowhead, and polar bears developed by Russia and the U.S.; metadata synthesis activities (Polar Data Catalogue, Synthesis Of Arctic Research); the marine fish section of the Arctic Report card; and the North Atlantic Marine Mammal Commission (NAMMCO) integration of international data.

*b. Evaluate survey design and sampling protocols and develop recommendations to ensure methodological, temporal and spatial consistency.*

We recommend consistency with past practices in sampling within geographic sectors where long-term time series exist; internal consistency is more important than comparability across regions. When possible, physical and chemical oceanographic sampling should be standardized across all regions. Plankton, benthos and fish sampling gear differ across and within regions. One way to address these differences is to report changes within regions as standardized anomalies and compare trends across regions. A workshop (see below) should be held to evaluate methods of comparing similarities and differences among sampling methods and gear types.

Other information gaps to be filled include: fish life history such as spawning, migration, maturity, and growth; stock structure; trophic (predator-prey) relationships; and taxonomy. Such data are useful to predict and understand potential shifts in ranges of fish onto shelf seas and the deep Arctic Ocean, and to document changes in the underlying ecosystem. These data are also essential for fisheries management.

> *c. Discuss and, as appropriate evaluate, the survey design and sampling protocols of a survey program for the central Arctic Ocean to monitor the distribution and abundance of finfish and shellfish stocks of potential commercial importance.*

Polar/Arctic cods (*Boreogadus saida* and *Arctogadus glacialis*) perform essential functions in Arctic marine ecosystems. Acoustic surveys imply relatively high abundances in the Beaufort Sea and Barents seas. To fully understand their importance in the Arctic ecosystems, acoustic surveys should be carried out in order to estimate abundance and biomass around the deep Arctic Ocean, from the shelf to at least 1500m depth in the basin. In addition, we recommend evaluating the environmental conditions (oceanography) and trophic ecology (e.g. prey base, predators) of polar cods along the slope and in the open ocean.

Biological knowledge of the high seas areas in the Arctic Ocean is limited. Therefore, we recommend exploratory trawl surveys on the slope and shallower parts of the central basin of the Arctic Ocean: the Chukchi Plateau, the Russian end of the Mendeleev Ridge (East Siberian Sea), and the Lomonosov Ridge (northern Laptev Sea). Demersal fish or shellfish are not expected to expand into the deep basin of the Arctic Ocean. It is uncertain how commercial and non-commercial species will respond to reduced ice cover and other changes. Therefore we also recommend that each country extend existing research surveys for fish and shellfish from adjacent shelves towards the Arctic Ocean. Other survey options in deeper waters include remote video and photography.

Studies to understand nutrient availability and primary and secondary productivity in the Arctic Ocean (especially over the shelf break and slope) are needed to determine if there is sufficient present and projected future production to support commercially viable fish populations. It will also be important to understand the timing and variability of primary production in relation to zooplankton demand. In addition to ship-based operations, satellite and airborne data are useful for identifying newly accessible areas and locations of high biological activity.

An initial joint international Arctic Basin oceanographic and fish survey (including acoustics) is recommended, using ice-capable vessels with trawl capability or the combination of an icebreaker and a fishing vessel. The results from initial surveys will advise potential future fish and ecosystems monitoring efforts for the Arctic Ocean. Additional future surveys are required to understand effects of climate and sea ice variability on fishes in the Arctic Ocean in the longer term.

Previously unsurveyed shelf and Arctic basin areas between existing annual fisheries surveys on the shelves and the deep Arctic Ocean should also be surveyed periodically to document movement (i.e. distributional shifts) of fish. Sampling

programs are also required to track biological contents of Atlantic water as it moves into the Arctic basin. For example, monitoring the movement of species in the St Anna Trough connecting the Kara Sea shelf to the deep Arctic Ocean would be important. To widen the geographic scope for monitoring, we need to develop and establish linkages between proxy measures and fish production that can be measured from ice breakers. These could include zooplankton, icthyoplankton and physical characteristics such as temperature.

*ToR 2. Evaluate the outcome of relevant recent scientific meetings, such as the ICES/PICES (North Pacific Marine Science Organization) workshop in St. Petersburg in May 2013, and discuss strategies to communicate outcomes regarding implications of climate change on management of living marine resources in the Arctic context*

Results from the ICES/PICES Workshop on Global Assessment of the Implications of Climate Change on the Spatial Distribution of Fish and Fisheries (WKSICCME-spatial) were reported to the meeting. The workshop was held 22-24 May 2013 in St. Petersburg, Russia, to discuss climate-driven changes in the spatial distribution of living marine resources. The workshop was organized by the PICES\ICES Strategic Initiative (Section) on Climate Change Impacts on Marine Ecosystems and was attended by 67 scientists from 13 countries as well as representatives from ICES, PICES and the FAO. The workshop was held to foster the development and testing of analytical methods for detecting changes in distribution, assessing the skill of different modelling approaches, and quantifying uncertainty in projected climate-driven changes. Other important questions addressed were: How do we best design a global database of marine observations and what are the strategies used to assess vulnerability (of resources and those that depend upon them) to shifts in distribution? The workshop was organized around six theme sessions: (1) Analytical methods for detecting changes in spatial distribution, (2) Skill assessment and model inter-comparison, (3) Quantifying uncertainty, (4) Design specification for database of observations of distribution of living marine resources, (5) Vulnerability assessment, and (6) Communicating outcomes to inform decisions regarding management of living marine resources under changing climate. Recommendations from the ICES/PICES WKSICCME-Spatial will improve methods used to assess regional and latitudinal differences in the vulnerability of species or species groups to climate change-induced shifts in ocean conditions.
http://www.pices.int/publications/other/WKSSICME_spatial_Report_24June.pdf
http://www.ices.dk/community/groups/Pages/WKSICCME-Spatial.aspx

The strategic initiative/section of SICCME addresses shifts in finfish distribution in space and time that are likely impacts of climate change in the Arctic. Thus, the group welcomed the initiative by ICES and PICES and acknowledged the scientific advancements made in the related fields of biological and ecosystem modelling. The group took notice in particular of the relevance to the Arctic of the approaches of the workshop regarding data-poor situations and the associated uncertainties as well as the regional downscaling approaches recommended by the workshop. In addition, the group noted the value of communicating results of scientific research in ways accessible to the public identified in the workshop. The group also took notice of the envisaged roadmap of SICCME for the coming years and encouraged the initiative to consider Arctic in its work.

*ToR 3. Consider meetings and other fora for future scientific cooperation*

The Tromsø workshop identified assessing the distribution and abundance of Polar Cod in the central Arctic basin as a high priority. A planned workshop at the 2014 ESSAS Annual Science Meeting in Copenhagen (April 7-9, 2014) aims to synthesize current information on the stock structure, distribution and biology of Polar Cod throughout the Arctic, and to identify potential climate change effects on their distribution and dynamics. We encourage the workshop to include discussions of the structure and design of a future monitoring program for Polar Cod

We recommend a follow-on Arctic fisheries science workshop(s) be held to address key scientific issues. Topics to consider include the following: 1) modeling of potential changes in the spatial distribution of fish stocks and their planktonic prey in Arctic marine ecosystems. Because types of observations, gears and methods for sampling plankton and fish differ across regions and novel sampling methods may be needed, 2) discussion of such methods and the different types of data available, priorities for data collection and the similarities and differences among sampling methods and gear types currently used in different regions to develop appropriate methods of comparison; 3) discussion of monitoring programs from ships of opportunity and the incorporation of local and traditional ecological knowledge to detect changes in Arctic marine ecosystems.

To take advantage of ships of opportunity, we point to the international Distributed Biological Observatory (DBO) that has been established in the North Pacific. The DBO is envisioned as a *change detection array* along a latitudinal gradient extending from the northern Bering Sea to Barrow (http://www.arctic.noaa.gov/dbo/index.html). DBO sampling is focused on transects centered on locations of high productivity, biodiversity and rates of biological change. Sampling at the DBO includes CTDs (with and without rosettes), phytoplankton and zooplankton nets, mud grabs and trawls. A similar set of locations could be established in the North Atlantic. In some areas of the North Atlantic (e.g., the Norwegian and Barents seas) sufficient monitoring is currently taking place to create a "virtual DBO." These DBOs would be sampled on an opportunistic basis in conjunction with ongoing activities to maximize sampling at key locations that are currently undersampled. The DBO concept can be envisioned as an early indicator of substantive change beyond natural variability. Once such change is detected, more comprehensive sampling could occur to better document and understand causation and consequences. The DBO concept could also be extended further to Arctic shelf areas and the central Arctic Ocean. We recommend a workshop to discuss the location and design of such monitoring sites.

**Figure 1: Map of the Arctic Ocean**

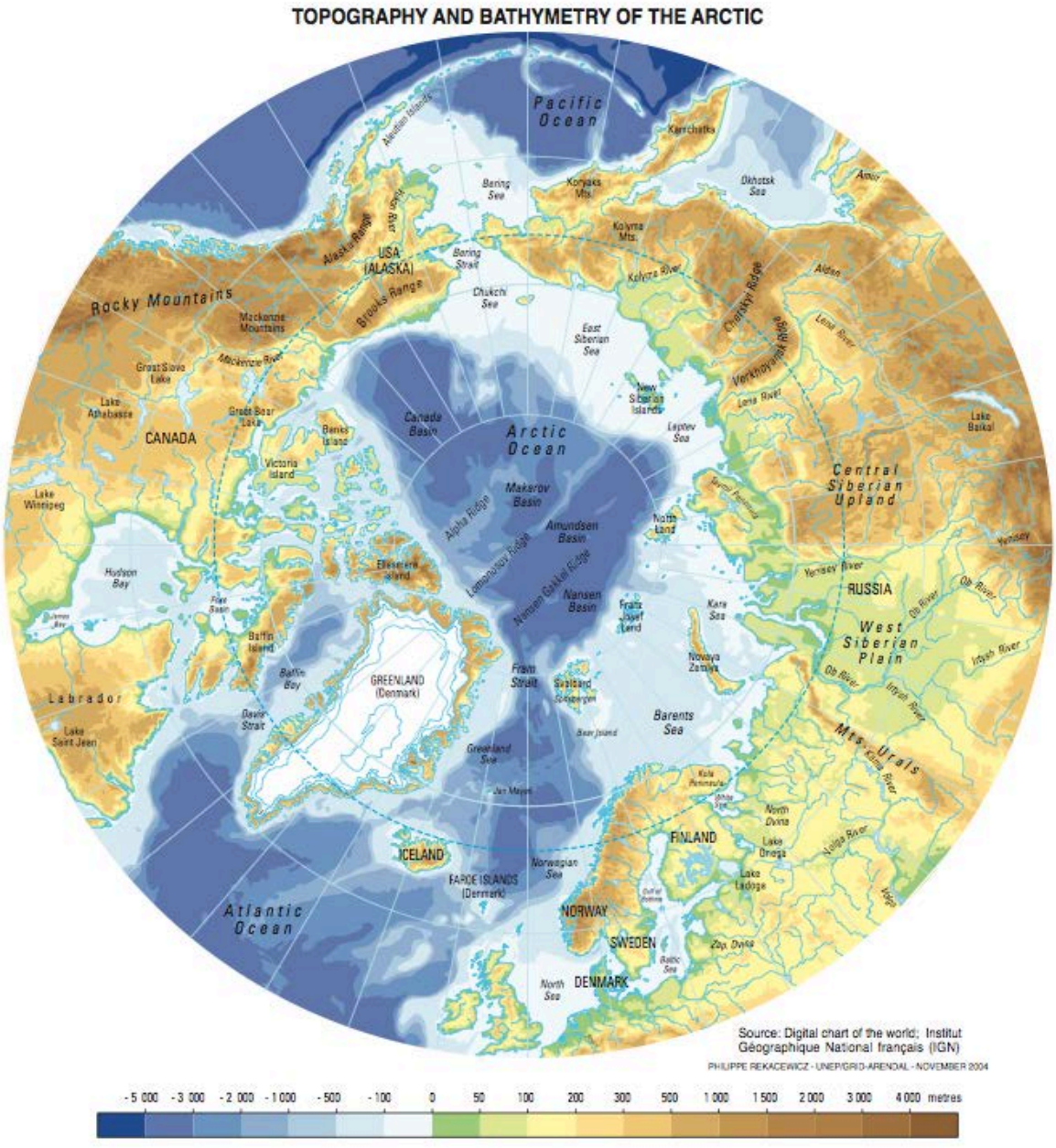
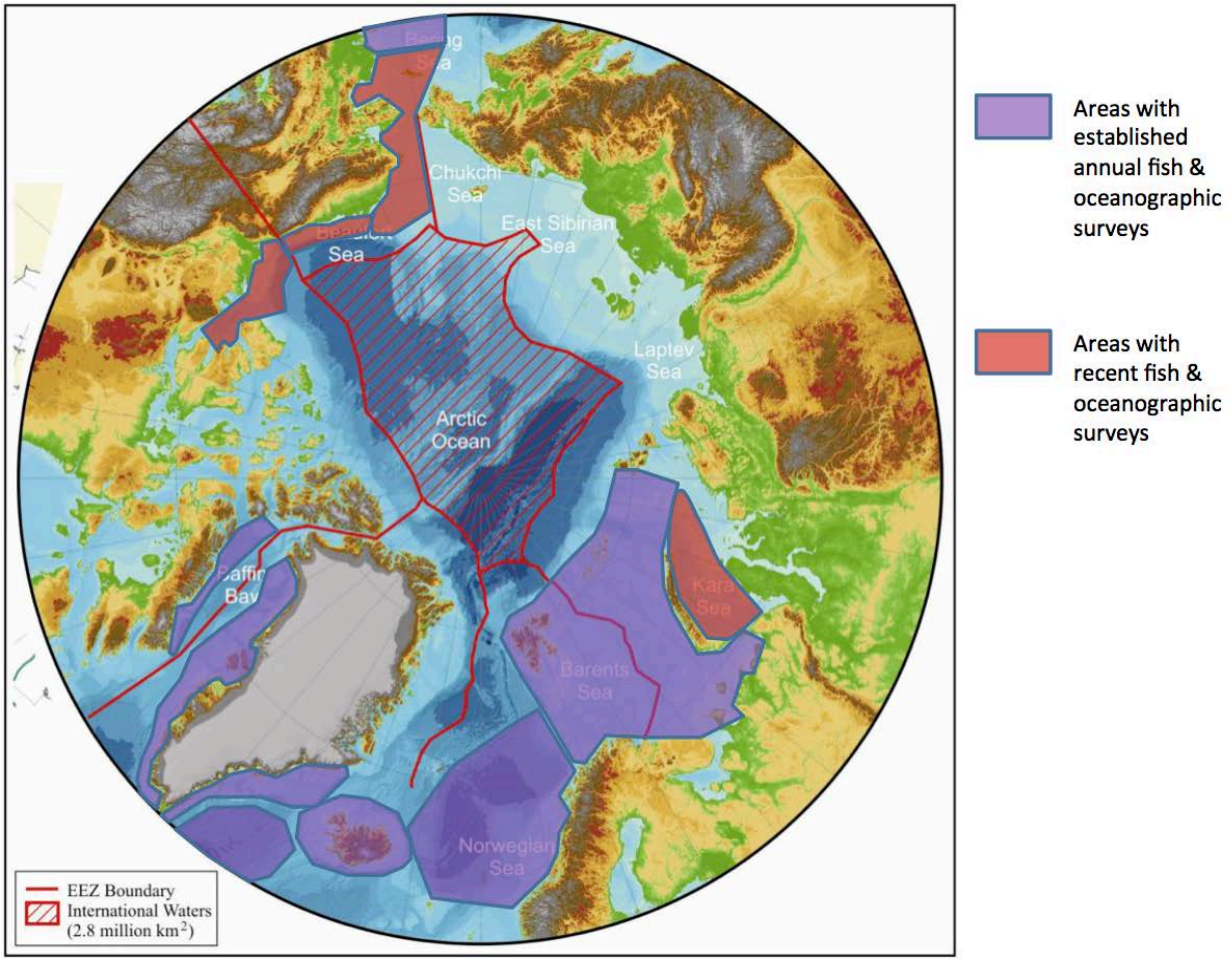


**Figure 2: Map showing areas under and beyond national jurisdiction and the** regions that are surveyed at least annually for assessing fish and oceanographic conditions and fish resources (purple polygons) and areas that have only been surveyed in recent years (red polygons).



## Appendix 1: Terms of reference for the meeting

### Terms of Reference for Second Meeting of Scientific Experts on Fish Stocks in the Arctic Ocean, Tromsø, Norway October, 2013

Following discussions at the meeting in Oslo 22 June 2010, where senior officials of the coastal States stressed the need for further scientific research on fish stocks and their ecosystems in the Arctic Ocean, a Meeting of Scientific Experts on Fish Stocks in the Arctic Ocean was held in Anchorage 15-17 June, 2011. At a meeting including scientists, managers, and policymakers convened in Washington, D.C. on 29 April- 1 May 2013 it was agreed that the Institute of Marine Research, Norway should host a second scientific workshop in Tromsø, Norway in late October 2013.

The Anchorage workshop addressed current information on fish stocks, reviewed ongoing and planned scientific activities, identified current information gaps and options to address them, and set priorities in regard to identified research requirements. The workshop also discussed opportunities and impediments to further cooperation. Though commercial fishing in the central Arctic Ocean was not imminent then or at the present, there remains a need for further scientific research on the state and nature of living marine resources and their ecosystems. There is also a need to increase our understanding of the impact of climate change on Arctic ecosystems in general.

The 2013 meeting of senior officials of the central Arctic Ocean coastal states in Washington D.C. determined that the chief objective of a second workshop of scientific experts will be to examine the data and monitoring requirements for providing answers to questions about the status of Arctic living marine resources with particular focus on the central Arctic Ocean region. A series of questions pertaining to any possible movement of fish stocks of commercial interest into the high seas in the Central Arctic Ocean were developed to assist the discussion (see appendix 1).

The purpose of these supplementary Terms of Reference, supplementing the Terms of Reference agreed before the 2011 Anchorage meeting, is to describe the issues which the scientific experts are requested to consider in a second workshop. With the need for continuity in mind, the October 2013 workshop will follow up on the Anchorage workshop by revisiting the issues raised at the first workshop, with special emphasis on further discussion of the research priorities. In particular, the workshop will address this priority item from the Anchorage meeting:

1. Establish baseline conditions and define information needs for to monitoring changes in baseline conditions which might influence patterns of distribution and abundance of finfish in the Arctic Ocean. This is viewed as a high-priority requirement.

    a. Briefly review current programs for monitoring critical environmental parameters and patterns of distribution and abundance of plankton, fish, invertebrate and marine mammals in the Arctic.

b. Evaluate survey design and sampling protocols and develop recommendations to ensure methodological, temporal and spatial consistency.

c. Discuss and, as appropriate evaluate, the survey design and sampling protocols of a survey program for the central Arctic Ocean to monitor the distribution and abundance of finfish and shellfish stocks of potential commercial importance.

2. Evaluate the outcome of relevant recent scientific meetings, such as the ICES/PICES workshop in St. Petersburg in May 2013, and discuss strategies to communicate outcomes regarding implications of climate change on management of living marine resources in the Arctic context.

3. Consider meetings and other fora for future scientific cooperation.

This workshop will constitute an initial, necessary step for science to be able to respond to the overarching questions regarding the likelihood and significance of commercial fish and shellfish stocks moving into the Central Arctic Ocean. Subsequent workshops will address other priority issues, including questions relating to modeling of ecosystem properties.

Participants at the workshop will include fishery and ecosystem scientists from the coastal states of the central Arctic Ocean, as well as others with relevant scientific expertise who are associated with the International Council for the Exploration of the Sea (ICES), the North Pacific Marine Science Organization (PICES), and other similar organizations. When deciding on participation to the workshop, the governments of the Arctic coastal states should consider including, as appropriate, local and indigenous perspectives.

The scientific experts will report back to their respective Governments, who will decide on further steps to be taken.

**Appendix. Thematic Questions Relevant to the Workshop**

• What fishes exist in the Central Arctic Ocean and what is their role in the structure, function, resistance and resilience of the Arctic marine ecosystems and their biota?

- What fishes are present in the marginal shelf areas within the waters under national jurisdictions of the respective Arctic countries and which of these may colonize, move, or become straddling stocks between such waters and the high seas?
- What fishes present in the waters under the jurisdiction of the Arctic countries are currently straddling stocks and what reliance do these have on processes, habitats or elements within the high seas of the Central Arctic Ocean?
- What biological conditions must exist in the Central Arctic Ocean to underpin and support commercial exploitation and do these now exist?
- What information and monitoring data exist to inform decision-making regarding sustainable, potential fisheries in the Central Arctic Ocean?
- What gaps exist in this information base? What is required in the short, medium and long term in order to develop the information particularly from

the perspective of establishing early warnings of negative effects of potential commercial fishing on Arctic ecosystems, critical habitats therein, or at risk sensitive biota?

- What individual and joint projects should be initiated by the Arctic coastal states in which geographical areas and over what time frame, in order to develop the information needed and monitor the changing state of the Central Arctic Ocean, and develop understanding of the changing ecosystem therein?

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## Appendix 3. Country reports and contributions from international organizations

### Canadian Overview Summary (Reist, Li & Kristmanson)

*Canadian Strategic Research Relevant to the Arctic Ocean*

This research focuses upon three themes as follows.

1) Beaufort Sea: Initial surveys were conducted for offshore fishes, their habitats and ecological relationships in the southern Canadian Beaufort Sea (40-1500m depths) in 2012 and 2013. Species newly known for the area have increased overall diversity to about 70 fish species. Deeper offshore and northern shelf areas along the northwestern margin of the Arctic Archipelago remain unsurveyed, in part due to persistent pack ice present near to shore.

2) Synthesis Activities: Existing information regarding Arctic marine fishes in Canada is being synthesized through development of a Guide to Arctic Marine Fishes of Canada (publication in 2014) and mapping of distributions of species through point occurrences. Diversity knowledge and occurrence maps provide the basis for assessing rearrangements of species distributions in the context of climate change. Canadian experts have also been involved in the Arctic Biodiversity Assessment (Fishes, Marine Ecosystems chapters) and in the ongoing marine monitoring component of CAFFs Circumpolar Biodiversity Monitoring Programme.

3) Oceanographic activities in the southern Canada Basin, Beaufort Sea & Amundsen Gulf: These include radionuclide tracer measurements in the Arctic Ocean since the first historical studies conducted from ice stations in the 1970s and early 1980s. The main purposes are (a) to establish time scales for water circulation in the Arctic Ocean, (b) determine pathways and fluxes for carbon transport, and (c) assess the importance of contaminant transport through the Arctic Ocean. Recent investigations have focused on measurements of artificial radionuclides ($^{129}$I, $^{137}$Cs) derived from nuclear fuel reprocessing plants in Europe which have been used to determine transit times and mixing rates for Atlantic-origin, surface and intermediate waters in the Arctic Ocean. Other ongoing investigations include measurements of $^{230}$Th and $^{231}$Pa to determine intermediate and deep ocean ventilation rates and $^{234}$Th and Ra isotopes to estimate off-shelf carbon transport in the Beaufort Sea. The time series nature of some of these investigations (e.g. the transient tracer, $^{129}$I has been tracked on an almost annual basis since the early 1990s in the Canada Basin) provides a monitoring aspect to some of these programs. Since 2003, annual icebreaker surveys have monitored summer oceanographic and biogeochemical conditions in the Canada Basin including the Beaufort Sea. This Joint Ocean Ice Study (JOIS) is an ongoing multinational collaboration involving the Joint Western Arctic Climate Study (JWACS), the Beaufort Gyre Exploration Project (BGEP), including the 2007 Canadian International Polar Year (IPY) program Canada's Three Oceans (C3O). This multi-year record of observations has identified changes in the community structure of the microbial community that are linked to the physical-chemical environment of the upper water column overlying the deep Central Arctic Ocean. For Amundsen Gulf, the oceanography, biogeochemistry, and microbial diversity has been studied annually since 2006 by a consortium of Canadian universities (ArcticNet) under programs such as Canadian Arctic Shelf Exchange Survey (CASES), Circumpolar Flaw Lead (CFL), and International Polar Year Canada's Three Oceans (C3O).

*Additional Canadian Arctic Initiatives*

Stock Assessment Activities: Research to support management of coastal anadromous fishes is ongoing throughout the area; a coastal monitoring program has also been implemented in the Beaufort Sea area; surveys of offshore and inshore waters for marine fishes in Baffin Bay and Davis Strait have been annually conducted for the last several years; and, surveys for shrimp in Hudson Strait are ongoing. A multi-species aerial survey of marine mammals in the eastern Canadian Arctic occurred in 2013.

Oceanographic Activity: Waters of the Canadian Arctic Archipelago, Baffin Bay/Davis Strait and the Labrador Shelf 'downstream' of the Arctic Ocean are monitored for changes and effects of Arctic warming. a) In the Canadian Arctic Archipelago (Barrow Strait), since 1998 an instrumented mooring array monitors volume, heat and freshwater transports to establish magnitudes, seasonal and inter-annual variability in Arctic-to- Atlantic Ocean fluxes, and to explore linkages with the climate system (ASOF (Arctic/sub-Arctic Ocean Fluxes) component). The Barrow Strait hydrographic line is also identified by the Global Ocean Ship-Based Hydrographic Investigations Program (GO-SHIP) as an important hydrographic section for monitoring of chemical, biological and physical properties as part of a sustained global climate observing network. A strong instrument development component has provided specialized tools for measurement challenges that are unique to the Arctic, including a capability to make near surface measurements under ice with the development of a moored under-ice profiler, *Icycler*. The array has evolved towards a more integrated ecosystem monitoring tool with new techniques and instruments for remote monitoring of phytoplankton and zooplankton populations. Besides the new capabilities for year round monitoring of biota, ice thickness instrumentation and moored water samplers have been added to provide time series of ice transport and chemical properties. Annual surveys to measure nutrient ratios, alkalinity, oxygen isotopes and carbon have been maintained across Barrow Strait since 1998. The combination of moored physical, chemical and biological measurements provides insight into the interactions between biota and the ice and ocean environment in the Canadian Arctic Archipelago (CAA), and extended monitoring will provide data to assess climate-related impacts to the physical and chemical environments then to biological productivity and behaviour. b) Transports through Davis Strait have been measured with an instrumented array since 2004. Monitoring of Arctic transports into the Atlantic captures the outflow of all 3 northern passages through the CAA. Canadian participation in both the Barrow Strait and Davis Strait monitoring arrays provides the opportunity to look at linkages between measurements at the 2 locations over seasonal and inter-annual time scales. It also allows for the assessment of the Barrow Strait proportion of the transports and their variability relative to the total through the entire CAA. Annual surveys to measure nutrient ratios, alkalinity oxygen isotopes and carbon have been maintained across Davis Strait since 2005. A survey across Nares Strait is completed opportunistically. These lines are important contributions to international efforts for monitoring water chemistry properties to address CO2 sequestration and ocean acidification issues. c) The Atlantic Zone Off-shelf Monitoring Program (AZOMP) of has conducted spring oceanographic, biogeochemical, and plankton surveys of the Labrador Sea annually since 1994, from the Labrador Shelf through the central Labrador Basin, to the Greenland Shelf along the World Ocean Circulation Experiment (WOCE) AR7W transect.

**Greenland Research Activities in the Arctic Ocean**
The northernmost part of Greenland that border up to the Arctic Ocean is covered by ice year round and no significant fishing or hunting activities has been conducted. Therefore very limited research activities on monitoring distribution and abundance of plankton, fish, invertebrate and marine mammals has taking place. Models show that the northernmost part of Greenland (EEZ) and the adjacent area in the Arctic Ocean will be the last ice free area.

Long term extensive monitoring program is conducted in the more southernmost part of west- and east Greenland to monitoring the fish and shellfish resources. Change in the ecosystem has been documented including appearance of mackerel, increase in cod and decrease in shrimp. Greenland aims to increase observations on the east Greenland coast to monitor ecological changes.

Arctic Science Partnership (Greenland-Canadian-Danish research collaboration) future plans include research activities on the Arctic Ocean drift in 2015 and in Lincoln Sea in 2017 on ecosystem function.

**Norway and Russia**
The oceanic current systems in the northern waters of the north east Atlantic is strongly influenced by the topography of the Norwegian Sea basin, the continental shelf slopes, the bathymetry of the shelf bottom in the Barents Sea and the trough's from the Barents Sea to the Arctic Ocean. Although indices of oceanographic parameters, e.g. temperature, are taken from southern areas of the Barents Sea they reflect large scale changes taking place all the way north to the shelf slope leading into the Arctic Ocean. Many fish species, e.g. Atlantic cod, show large fluctuations related to changes in indices of temperature and there has been shown that counter clockwise geographical movement is associated with warming. The upwelling in the Nordic Seas is the most productive waters in the system and this production is transported with inflowing Atlantic water into the Barents Sea and further north into the northern slope areas. The extensive survey coverage in the Barents Sea and adjacent waters conducted mostly as joint surveys between Russia and Norway aim at monitoring the total extent of distribution of important commercial species in the area, i.e. Atlantic cod, capelin, haddock, shrimp and polar cod. The link between temperature signal and stock size, e.g. spawning stock of Atlantic cod, is not maintained in the very warm periods and this may be associated with the lack of winter ice in these periods, leading to an expansion of cod distribution and a corresponding larger potential for increase in stock size. There is reported settlement of young Atlantic cod on the shelf north of Svalbard and this is associated with upwelling of Atlantic water along the slop in the same areas.

Several surveys are conducted under annual agreement of the Joint Russian Norwegian Fisheries Commission. The four principal joint annual surveys in the Barents and Norwegian Seas and adjacent waters are as follows:

- The Joint Russian-Norwegian winter survey for demersal fish which started in 1981 and takes place in February and March. This survey covers the southern, ice-free part of the Barents Sea.
- A demersal survey is carried out by Russia in November-December. This survey provides information essential for assessment of the main demersal fish stocks.
- The annual joint Russian – Norwegian ecosystem survey which first took place in 2003. This survey covers ice free areas in the Barents Sea (from the southern coastal areas to approximately 81oN), in August – September during the minimum sea ice extent. This ecosystem survey was designed by combining of several historic surveys, including the acoustic survey for pelagic fish, the international 0-group survey, a shrimp survey, and a Greenland halibut (*Reinhardtius hippoglossoides*) survey, dating back to the early 1960s. The survey now includes monitoring and observation of hydrography, pollution, plankton, benthos, pelagic and demersal fish, marine mammals and seabirds.
- The annual Norwegian Sea survey which has been carried out every May since 1995. This survey is organized by the ICES Working Group on Northeast Atlantic Pelagic Ecosystem Surveys (WGNAPES, formerly PGNAPES), and is a joint international survey with participation from Russia, Norway, Iceland and the Faroe Islands. Data are collect data on hydrography, plankton and pelagic fish annually, and in some years seabirds and marine mammals are also monitored.

All data collected during these surveys are available in joint data bases, and serve as the basis for common fisheries management in the Barents Sea and adjacent waters, and for ICES assessments and advice. The data are also available to the Joint Norway-Russia Environment Commission.

The extensive monitoring in the Barents and Norwegian seas has provided good baseline information on species distributions and the state of the ecosystems.

**Norway**

Norway has funded two strategic projects (2014-2018) relevant for the Arctic Ocean. One of them has focus on trophic interactions in the Barents Sea and for providing steps towards an Integrated Ecosystem Assessment (TIBIA). The overall objective is to improve the understanding of the trophic interactions, food web structure and function, and energy flow in the Barents Sea ecosystem. The project will be based on data from the joint Russian and Norwegian Barents Sea Ecosystem survey. The other one has focus on the Arctic Ocean ecosystem with an overall objective to develop a knowledgebase on the state and variability of the present and future Arctic Ocean ecosystem, and to explore potential options for providing ecosystem-based advice in a changing climate context. Study area is mainly the waters under Norwegian jurisdiction in the Arctic Ocean, but the survey may be extended into international waters. The approach is extension of the Barents Sea Ecosystem northwards to cover the ice free areas of the Arctic Ocean in combination with a baseline study going also into the ice covered regions in 2016-2017.

**Russian Research Activities in the Arctic**

The intensity of the Russian fishery science research activity in the Arctic region varies depending on the fisheries significance of region.

Russia continues own investigations in the Barents Sea for the oceanography, plankton, benthos, pelagic and demersal fish, marine mammals and seabird with view to the ecosystem studies and stocks/fishery regulation. Most of the data has published and available for others especially for the straddling and high migrated stocks. Most data are included to joint Russian-Norwegian results of the studies of the Barents Sea and adjacent waters. Some times investigations for fish are presents in the Kara Sea (southern and western parts) and the Laptev Sea during national special surveys or as extended part of the traditional (inl. joint) surveys. Where its possible the surveys were extended norwards up to 83 N. However, last years of marine mammals airborne investigations are significantly decreased. Future years assumed the continuation of above mentioned trends.

For the central part of Russian Arctic (Laptev Sea and East-Siberian Sea) fishery research activity is very low because ice cover the sea almost throughout year and the commercial fishery is very poor. The main fishery and research activities were developed and continue in the coastal area.

The eastern part of the Russian Arctic is available for the fishery research only last some years. However, the south-eastern of the Chukchi Sea is available for a long time and investigations for fish, mammals, plankton and oceanography are presents. Russia plan to extend integrated trawl-acoustic, oceanographic, and plankton surveys that conducted once every two to three years. The next one is scheduled for 2014 (depending on funding) and will cover the southern Chukchi and East-Siberian Seas.

**US delegation report**

Paleontological records, scientific observations and traditional knowledge suggest that the Arctic is trending towards a state not seen before. The region is rapidly warming and continued changes in sea ice, ocean chemistry, and marine ecosystems structure and function are unfolding. Loss of sea ice is opening up regions of the Arctic basin for potential commercial interests. Within the US EEZ, an Arctic Fishery Management Plan is in place that closes Arctic waters north of Bering Strait and within the US EEZ to fishing. To understand the impacts of loss of sea ice on Arctic ecosystems and concerns about impacts of oil and gas development and increased shipping traffic in the Arctic has led to the development of research activities in the Chukchi Sea and Beaufort Sea. Much of the focus has been on collecting information on the bio/physical oceanographic conditions and fish community structure in pelagic, benthic, and nearshore environments using standard survey grids and collection gear. Collaborative research with international scientists also continues to occur in the Chukchi Sea (RUSALCA) and regions of "biological hotspots" have been identified and a monitoring program within these regions has been initiated (DBO – Distributed Biological Observatory).

Survey results for fish and shellfish communities suggest that the pelagic community is dominated by Arctic cod, saffron cod, herring, capelin, Pacific salmon and jellyfish. Age 0 Arctic cod are distributed along shelf waters within the Chukchi Sea and older fish are found off the shelf in slope waters of the Beaufort Sea; Pacific salmon,

mainly juvenile pink and chum salmon can be found in large numbers with coastal and shelf waters of the Chukchi Sea; jellyfish biomass can be high in surface waters along the Chukchi Sea shelf. A comparison of standardized survey results conducted in the eastern Bering Sea and Chukchi Sea found that diversity of fishes is intermediate between the Bering Sea and high Arctic. The benthic community is dominated by invertebrates (seastars, sea urchins, brittle stars etc.). Snow crab are also highly abundant within the shelf waters of the Chukchi Sea and slope waters of the Beaufort Sea. Survey results suggest that snow crab found in the Chukchi Sea are small, with very few reaching commercial size; whereas, larger snow crab are found along the Beaufort Shelf. Data from some of these research efforts can be found on the Alaska Ocean Observing System (AOOS).

US research surveys in the Chukchi Sea and Beaufort Sea 2008 to present.

- Beaufort Sea
    - A survey of the benthic and pelagic communities of the western Beaufort Sea during 2008.
    - Beaufish - A broad scale (145$^{o}$ W to 155$^{o}$ W) survey collected fishes across ~200 nmi of the Alaskan Beaufort Sea shelf in 2011-2013.
- Chukchi Sea
    - SHELFZ (Shelf Habitat and EcoLogy of Fish and Zooplankton): A survey of benthic and pelagic communities from onshore-nearshore-offshore of the Chukchi Sea during 2013.
    - Arctic Eis (Arctic Ecosystem Integrated Survey): A fish (pelagic and benthic fish communities) and oceanographic survey from 60N to 72N was conducted during 2012 and 2013.
    - ACES (Arctic Coastal Ecosystem Survey): A survey of coastal fish communities near Point Barrow was conducted during 2012 and 2013.
    - CSESP (Chukchi Sea Environmental Studies Plan): A fish and oceanographic survey within the oil and gas lease sale region was conducted annually
    - RUSALCA (Russia and America Longterm Census of the Arctic): A joint Russia and US survey on fish and oceanographic metrics has been conducted annually. .
    - DBO (Distributed Biological Observatory): A monitoring project to serve as a “change detection array” for identification of and consistent monitoring of biophysical changes in the region.

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Traditional Knowledge (Inuit)

The health of the Arctic ecosystem is vital to our well-being and way of life. This way of life has been shaped by at least the last 10K years and has provided us with a base of knowledge to build upon and adjust as the environment changes. For this reason, it is important to remember that we hold vital knowledge and information needed to understand the changes that are occurring. In part, this knowledge tells us of the importance of interconnecting environments. That nothing occurs in isolation. This means that we have to look at the entire food web to understand the consequences of our decisions and the changes that are occurring. Here we will talk

about fish, but cannot forget that in the same conversation we must consider phyto and zooplankton, marine mammals, oceanographic features, and more. We have to base these conversations on more than what surveys have been conducted and what species were identified.

With this understanding, the Inuit have practiced a form of Ecosystem Based Management for centuries. It is important that research also takes this approach. That research includes both traditional knowledge and science, recognizing that the two complement each other, and that Inuit are part of setting the research agenda.

Remember: this environment is the basis of our existence. Inuit reliance on the ecosystem and understanding of the interconnections between trophic levels has given us a strong understanding of this environment; for example, our strong knowledge of benthic species and connection to walrus, and this connection to ice. All of this is also a reminder that we, Inuit, live in this environment, in this ecosystem connected to the high Arctic.

Side points: with all of these points is the importance of extending research beyond economically important species;

1. Connectivity among habitats must be considered at all times (within this synergistic and cumulative effects must be considered).
2. Global processes affect local populations
3. Productive capacity must consider ecosystem services, not just provisioning of fishes, but the entire ecosystem.
4. Foster a greater understanding of biodiversity
5. Multi-scale (spatial and temporal) analyses are needed to identify dominant patterns of connections and disconnections to inform decision makers.

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Species of interest:

Polar cod (*Boreogadus saida*)
saffron cod (*eleginus gracilus*)
Pacific herring (*clupea pallasi*)
capelin (*mallotus villosus*)
snow crab (*chionoecetes opilio*)
pink salmon (*onchorhynchus gorbuscha*)
chum salmon (*O.keta*)
Chinook salmon (*O. tshawytscha*).

**International organizations and programs**

**International Arctic Science Committee (IASC)** (Reigstad, Ingvaldsen)
The International Arctic Science Committee (IASC) is a meeting place for scientists from 21 nations, organized in 5 working groups. The members are national delegates are preferably active researchers. The Arctic Ocean Science board was merged with IASC in 2009, and functions as the marine working group. The idea is that the nations represented inform each other on ongoing or planned national and international

activities, and new cooperative initiatives may be supported through endorsement, or small money support for workshop or meetings. IASC also facilitate cross-disciplinary initiatives that involve two or more of the five working groups; marine, terrestrial, cryosphere, social and human, and atmosphere. The annual Arctic Science Summit Week hosts several arctic related meetings, and aims to be a place where Arctic activities also outside the IASC framework can be discussed, initiated and coordinated. Initiatives on activities from the Arctic fish community would be welcome in IASC and the marine working group.

**International Council for the Exploration of the Sea (ICES)** (Kellerman)
ICES is a network of more than 1600 marine scientists from more than 230 research institutes in 20 member countries and beyond. Eight of its member countries are Arctic Council members. ICES is a meeting place for marine scientists and coordinates and promotes marine research around the North Atlantic. This includes adjacent seas such as the Baltic Sea and North Seas as well as the Arctic Ocean. ICES is a meeting point for producing bottom-up science which complements top-down driven research to meet requests in response to societal needs. ICES work produces knowledge about the marine ecosystems which is also developed into unbiased, non-political advice on fisheries, ecosystems and the environment. Our advice is used by the 20 member countries, which fund and support ICES, to help them manage the North Atlantic Ocean and adjacent seas.

ICES core activities are focused through more than 120 expert groups, a science (SCICOM) and an advisory committee (ACOM), science symposia, and an Annual Science Conference. ICES holds one of the largest databases in the world on marine ecosystems. ICES is ready to expand its activities into the Arctic Ocean science arena:

- To take responsibility for key areas for climate and ocean change: e.g., Reykjanes Ridge and the Siberian shelf are within ICES geography

- A retreating multi-year sea ice opens shelf areas for fisheries: management and conservation issues requiring input from science and advice

- A warming Arctic Ocean drives major changes in marine ecosystems for which ICES has advisory responsibility.

ICES thrives to provide foundations and enable more informed decision-making related to adaptation action in a rapidly changing Arctic by

- Help creating a framework for ecosystem overviews and integrated assessments of ecosystem changes,

- in there, consider the expansion of distribution and migration ranges of commercial fish species,

- introduce IEA as a management tool for regulating human activities and for protecting the quality of living of the Arctic populations

Several ICES Expert Groups produce science on and knowledge about Arctic ecosystems. The Working Group on Oceanic Hydrography (WGOH) produces the ICES annual report on ocean climate (IROC), the Zooplankton Ecology Group (WGZE) produces a biannual status report for the North Atlantic. Other Expert Groups coordinate ecosystem surveys in the North Atlantic, including the Norwegian and Barents Seas (WGNEACS, WGIPS). The ICES Arctic Fisheries Working Group (AFWG) provides annual advice on fisheries management since 1959 on Arctic fish stocks in subareas I, II, Harp and Hooded Seals (with WGHARP), as well as on northern shrimp (*Pandalus*). In addition, the group provides ecosystem overviews for these areas.

The new ICES Science Plan as part of the ICES Strategic Plan, to be released early in 2014, foresees integrated ecosystem monitoring and assessment as core facilitators towards an improved, integrated understanding of ecosystems.

**Ecosystem Studies of Sub-Arctic Seas (ESSAS)** (Drinkwater)
The international Ecosystem Studies of Sub-Arctic Seas (ESSAS) program, which began in 2005, aims to compare, quantify and predict the impact of climate variability and global change on the productivity and sustainability of subarctic marine ecosystems. The comparative approach is used to gain insights into what is fundamental and what is unique in particular ecosystems that cannot be gained by studying individual ecosystems by themselves. In 2011, ESSAS extended its formal interest into the Arctic, primarily in terms of examining the exchanges between the Arctic and the Sub-Arctic and their influences on the physical, chemical, and biological impacts in both regions by forming an ESSAS Arctic-Subarctic Interactions Working Group (ASIWG). During the past two years, the WG has held several workshops, theme sessions and meetings, especially on the role of advection on Arctic and Subarctic ecosystems. This includes comparisons between the Atlantic and Pacific sectors of the Arctic, e.g. between the Chukchi and Barents seas, and between the Arctic and Antarctic and how they might be modified under future climate change. Future meetings in 2014 include workshops on comparative studies of Arctic cod (*Boreogadus saida*), analyses of the responses of humans to major changes in fish resources, and paleo studies on how changes in marine resources have influenced the establishment of human settlements and fluctuations in their population levels over centuries to millennia. Theme sessions within ICES and PICES in 2014 will be held on the fate of biological material exchanged between the Arctic and subarctic.

**European Polar Board (EPB) (**Harald Loeng)
The mission of the European Polar Board is to:

- Identify future scientific areas and strategic priorities of polar science within Europe
- Coordinate scientific agenda setting and represent it in European Policy Formulation
- Represent European Polar Research in the global context
- Develop or support concepts for joint use of polar infrastructure

Related to this workshop it was underlined that the EPB also focuses on natural resources in the Arctic Ocean. Baseline documentation of polar marine environments and ecosystems is needed to effectively manage natural resources.

Recognizing the potential and importance of polar marine resources, Europe must take on the challenges for sustainable management and use of living resources, alongside environmentally-sensitive extraction of mineral and hydrocarbon resources. This requires increased multi-national and multi-sectorial collaboration and investment. The aim should be to establish a comprehensive and sustained system for marine observation and data-exchange.

The EPB raise a number of significant questions for understanding polar marine resources. These include:

- How will polar marine ecosystems respond to a broader seasonal range of environmental temperatures?

- What will be the consequences of rapid ocean acidification for polar ecosystems?

- How will increased coastal erosion affect Arctic marine ecosystems?

- What are the bio-geographical consequences of climate change for polar organisms and how will this impact the viability of existing commercial fisheries and bio-prospecting opportunities?

- What are the implications for Arctic marine ecosystems of increased shipping and the associated land-based supporting physical infrastructure around the Arctic Ocean?

In addition, information was provided on Arctic Council working groups such as the Conservation of Arctic Flora and Fauna (CAFF) and the Arctic Monitoring and Assessment Program (AMAP). These working groups are mainly concerned with assessments and monitoring such as the Circumpolar Biodiversity Monitoring Program (CBMP) under CAFF.