Report of a Meeting of Scientific Experts on Fish Stocks in the Arctic Ocean

Anchorage, Alaska, June 15-17, 2011

1 INTRODUCTION

Scientific experts from the five Arctic Coastal States—Canada, Greenland, Norway, Russia and the United States-- met in Anchorage, Alaska, on June 15-17, 2011, to respond to terms of reference (TORs) drafted following consultations among their respective governments in Olso, Norway, on June 22, 2010. The TORs are provided as Appendix 1 and a list of participants is provided as Appendix 2. Each section of this report responds to a specific TOR.

For the purposes of this workshop, the focal points for discussion were fish, invertebrate and marine mammal stocks, the ecosystems which support them, and the effects of climate variability and change. Sustainability of existing subsistence harvests and commercial fisheries, particularly those in coastal areas and sub-arctic seas, and how it may be affected by climate change, was the underlying priority. The information needs required to support appropriate decisions regarding potential future development of fisheries in the central Arctic Ocean were also considered.

2 CURRENT INFORMATION AND DATA ON FISH STOCKS, THEIR ECOSYSTEMS AND PATTERNS OF MIGRATION (TOR 1)

2.1 Summary of current information and data on fish stocks and ecosystems

Physical factors characterize Arctic marine ecosystems. These include a very high proportion of shallow continental shelves, dramatic seasonal change, low temperature, extensive permanent and seasonal ice cover, and a large supply of freshwater from rivers and melting ice. The oceanography of these systems is influenced by weak flow of Pacific water through the Bering Strait and vigorous flow of Atlantic water through the Fram Strait. Ice breakup currently occurs in June or July and re-forms in September or October. In summer, water stratifies in response to temperature and salinity, forming a vertically layered water column. Primary production is influenced by the timing of ice breakup and stratification, resulting in a short production season.

The Intergovernmental Panel on Climate Change 4th Assessment Report (IPCC AR4) and the Arctic Climate Impact Assessment (ACIA) document potential climate change impacts on Arctic ecosystems. Close examination of climate change impacts on sea ice based on the IPCC AR4 scenarios suggest that the Arctic may be ice free in summer by 2030 or 2040. However, due to the declination of the earth, conditions will remain cold and ice-covered in winter. As the Arctic Ocean warms, less old, thick ice, will be present. Furthermore, ice break up may occur earlier, and the duration of open water may last longer, resulting in an extended growing season. Thus, ecosystem productivity

pathways may ultimately switch from the present ice-dominated light-limited benthically coupled systems to increased open-water dominated nutrient-limited planktonic production. Climate change will likely change the seasonal magnitude of the Atlantic inflow into the Arctic; however, the magnitude and timing of these changes are uncertain. Projections suggest that the pH of the Arctic Ocean will drop (ocean acidification) and this may create added stress to organisms with calcareous shells over time. At present, however, the spatial impact of ocean acidification and the vulnerability of species to shifts in pH are uncertain.

Marine biota that seasonally or permanently inhabit the Arctic have specialized survival strategies to accommodate the challenging environment of this area. Survival strategies include:

- Matching the timing of spawning, hatching, and mating to maximize the emergence of young in seasons when prey or hospitable conditions are available.

- Conducting seasonal movements for spawning and feeding to maximize the probability of encounter with suitable prey, and/or to avoid inhospitable conditions.

- Habitat partitioning to promote co-existence of competing species and predator avoidance.

- Physiological features, such as blood antifreeze (e.g., polar cod (*Boreogadus saida*), and Alaska plaice (*Pleuronectes quadrituberculatus*) to survive in cold conditions, or high growth potential (e.g., herring (*Clupea pallasi*), capelin (*Mallotus villosus*), and polar cod *(Boreogadus saida)*) to survive in short growing seasons.

The possible pathways by which climate variability may affect ecological processes are many and vary across a broad range of temporal and spatial scales. Climate variability affects fish and invertebrates directly through physiology, including metabolic and reproductive processes, and indirectly as a result of changes in their biological environment (predators, prey, and species interactions) and abiotic environment (physical and chemical conditions, habitat type and structure). Furthermore, ecological responses to climatic variation may be immediate or lagged, linear or nonlinear, and may result from interactions between climate and other sources of variability.

To prepare for change, it is critical that the scientific community develops a sufficient understanding of the biophysical processes governing the region to assess the ecosystem impacts of climate change, and to consider the implications of anthropogenic stress resulting from human use of natural resources under a changing climate. Further research is required to improve understanding of: the processes determining the variability in the ocean circulation, positions of oceanic fronts, species sensitivity to climate change, match/mismatch between predators and prey, indirect and non-linear effect on biological processes, and competitive interactions which may occur if new species are introduced into the ecosystem. For example, many Arctic species have relatively narrow habitat and niche requirements. Their likely response to increases in competition from more opportunistic species in a warmer Arctic is unclear.

Large-scale commercial fisheries for fish and invertebrates exist in the southern shelf seas (e.g., the Bering Sea, Barents Sea, Baffin Bay and along the coast of east and west Greenland). Some of the species currently targeted by these fisheries have been

observed in the Arctic Ocean. Within the Arctic, current information on distribution and abundance of concentrations of these species, uncertainty in the ecosystem effects of fishing, and the technical and logistical challenges of conducting fishing operations in remote regions all suggest that commercial fisheries are not likely to emerge in the Arctic in the short term. While it is possible to identify commercial species that may colonize the shelf seas of the Arctic Ocean, current understanding of the ecosystem is insufficient to predict when or if colonization will occur, nor its effects.

Circumpolar aboriginal communities conduct commercial and subsistence fisheries for anadromous fish (e.g., Arctic char (*Salvelinus alpinus*), Dolly Varden (*Salvelinus malma*), and whitefishes (*Coregonus* spp.)) and marine mammals. Typically these fisheries have relatively small economic value but are important for the economic viability and social health of the communities. Climate change may affect fish and marine mammal habitat (spawning/birthing, migration and feeding), impacting the productivity of the stocks and the health of the communities. Traditional and local knowledge of the Indigenous Peoples represents an important knowledge base suitable for evaluating present integrity and future changes of Arctic ecosystems.

3 ONGOING AND PLANNED SCIENTIFIC ACTIVITIES (TOR 2)

The information provided in this section was provided by workshop participants as an initial step in cataloguing ongoing and planned activities. The participants agreed that this information is not comprehensive and that it would take significant effort to develop a comprehensive database but that this should be undertaken. The US agreed to take the lead in this activity.

3.1 Ongoing scientific activities of Russia and Norway

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 81^{o}N), 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. It has also provided opportunities for a large number of projects which have investigated species and community responses to changes in ocean climate over the years. These projects comprise both empirical and modeling studies. Coupled biophysical, zooplankton and fish models, and a more comprehensive ecosystem model (Atlantis), are currently being developed and will be significant tools for studying climate change effects in the Barents and Norwegian Sea ecosystems, as well as potential shifts in the distributions of various species into the Arctic Ocean.

In recent years, a warmer ocean climate has expanded the ice-free areas in the Barents and Norwegian seas. This is a challenge to the survey design, requiring coverage of larger areas within the limited survey time available. In relation to potential changes in the Arctic Ocean, survey coverage of the newly ice-free, northern areas is of high importance.

In addition to joint cruises, both countries also conduct separate investigations.

3.2 Research Activities of Canada and Greenland

The area between Canada and Greenland composed of the Baffin Bay, the northern part of the Davis Strait and the Hudson Strait is surveyed in the late fall (September/October) by Canada and Greenland in their respective exclusive economic zones at depths ranging from 400 to 1500 meters. Some of the important fishing grounds are surveyed annually while other areas, like the northern part of the Baffin Bay, are alternately covered through the years. The bottom trawl surveys all use the same research vessel and methods thereby allowing direct comparisons of concentrations of various fishable stocks such as grenadiers (*Macrourus berglax*) and redfish (*Sebastes mentella* and *S. marinus*). At present the most important groundfish species surveyed is Greenland halibut (*Reinhardtius hippoglossoides*) which supports a commercial fishery reviewed annually by the Northwest Atlantic Fishery Organization (NAFO).

In the southern part of the area there is a fishery for Northern Shrimp (*Pandalus montagui* and *P. borealis*) only on shallower grounds. This area is on the Greenlandic side and is surveyed in June, July and August from 60°N in the south (Cape Farewell) to 72°N in the north at depths ranging from 50 to 600 meters. Later in the year in September/ October, the Canadian side is surveyed in the same manner. The target species of these surveys is Northern Shrimp, however information on biomass and

abundance of fish species such as grenadiers and redfish species are also important for the assessment.

The collection and evaluation of information on several trans-boundary marine mammal stocks in this area such as narwhal, beluga, bowhead whale and walrus are also coordinated between the two countries.

Additionally, Greenland operates two similar surveys in August/ September at the east coast of Greenland covering the area from 60° N to 67°N at depths from 50- 600 meters and 400-1500 meters.

3.3 U.S. Research Activities in the Arctic

Fish and crab surveys of the Chukchi and Beaufort Seas have been infrequent. A survey of the eastern Chukchi Sea shelf was completed in 1976 (between Bering Strait and Point Hope) and 1990/1991 (between Point Hope and Point Barrow) for demersal fish. A survey of the Chukchi Sea was completed in 2007 for surface fish. A survey of the Beaufort Sea was completed in 2008 for demersal fish. These surveys were completed using standard gear, which allows comparison of results among areas including the Beaufort, Chukchi and Bering seas. In addition, surveys using small trawls (plumb staff beam and otter) have been conducted in small areas related to oil and gas exploration and development, both during the 1970s and again in recent years, funded by the oil and gas industry and US Government. The United States and Russia also have collaborated in the RUSALCA program, which used the same small-scale gear during the mid-2000's to sample transects spanning the western and eastern Chukchi Sea shelves.

A survey of the eastern Chukchi Sea shelf is planned by the US for 2012 for oceanography, plankton, demersal and pelagic fish. In addition, some biological research on genetics and energy density of two abundant forage species in the Chukchi Sea (capelin (*Mallotus villosus*) and Arctic cod (*Boreogadus saida*)). All survey operations will follow standard protocols so that results are comparable between regions (e.g., Bering Sea vs. Chukchi Sea). Abundance measurements for snow crab (*Chionoecetes spp*.), Arctic cod, capelin, sculpins (Scorpaeniformes), eelpouts (Zoarcidae**),** and Pacific salmon (*Oncorhynchus* spp.) species are expected to result.

The U.S. conducts considerable research and survey work in the eastern Bering Sea, and much of this work takes place north of the Arctic Circle. However, the primary focus of this workshop (on the Pacific side) was on waters to the north of the Bering Strait (the Chukchi and Beaufort Seas) so details of Bering Sea activities are not provided in this report.

3.4 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. For the Barents Sea, about a hundred scientific research expeditions with tens of thousands of trawl and oceanographic stations are executed every year. Resources of cod, haddock, Greenland turbot, king crab, capelin, Polar cod and other fish are studied to estimate

their stock conditions, abundance dynamics trends, and ground the fishery efforts and management recommendations. Ecosystem studies cover the Barents Sea and adjacent Kara Sea areas, and sometimes the Laptev Sea. The ecosystem surveys now include oceanography, plankton, benthos, pelagic and demersal fish, marine mammals and seabirds. Extensive monitoring in the Barents Sea and adjacent areas is also conducted by observers on commercial fishery vessels. It has provided comprehensive baseline information for fishery forecasts and ecosystem dynamics studies. From the eastern part of the Russian Arctic, integrated trawl-acoustic, oceanographic, and planktonic surveys are conducted once every two to three years. The next one is scheduled for August – October of 2011 or 2012 (depending on funding) and will cover the southern Chukchi and East-Siberian Seas. According to previous studies, fish biomass consists mainly of Polar cod, juvenile capelin, and herring to a lesser degree. Snow crab predominated in the benthic community. Total biomass density increased in direction towards the south-eastern Chukchi Sea, influenced by the inflow of Bering Sea water. Frequent penetration of Steller sea lions into the Arctic area has been observed since the beginning of the 21st century.

3.5 Ongoing and planned research activities – Canadian Eastern Arctic and Archipelago

In addition to the Canada-Greenland studies, stock assessments of coastal fisheries and research on factors affecting distribution and abundance of Arctic char, Greenland halibut, Greenland shark (*Somniosus microcephalus*) and marine mammals (beluga, narwhal, killer whale and seals) will be ongoing. New research on the migratory patterns of these species will be undertaken as part of the Ocean Tracking Network program.

3.6 Ongoing and planned research activities in the Canadian western Arctic – Alaskan Beaufort Sea

3.6.1 Coastal Fishes/Ecosystems (migratory or similar ecosystems in nearshore areas between Canada-Alaska):

- Dolly Varden - genetic stock structure (populations and mixed coastal groups) with (US and Canada); Canadian research also includes assessment of populations and freshwater habitats.

- Coastal fish community – seasonal migratory study being completed; monitoring of indigenous fishery on coast and nearshore ecosystem structure/function studies underway (Yukon North Slope).

- Mackenzie Shelf studies – integration of studies conducted 2003-2009 across the ecosystem underway with publication anticipated in 2012 (Northern Marine Coastal Studies).

- Studies of marine mammals – sampling of harvested beluga ongoing in Canada.

- Recovery in High Arctic kelp community (US funded).

- Beaufort Sea marine fish monitoring survey in central Beaufort Sea (US funded).

- Epifaunal communities in the central Beaufort Sea (US Funded).

3.6.2 Offshore Beaufort Sea:

- Oceanographic, benthic, lower trophic level (plankton), and Arctic cod (hydroacoustics) studies underway and/or completed by the ArcticNet consortium (U. Laval, Quebec).

- Oceanographic sampling (CTD casts) from ships of opportunity (mostly Canadian Coast Guard icebreakers).
- Bowhead feeding variability in the western Alaskan Beaufort Sea (US Funded).

- Monitoring distribution of Arctic whales (US funded).

3.7 Planned Research in Canadian Beaufort Sea (links to Alaskan work noted if relevant)

3.7.1 Ongoing coastal research:

- Coastal fishes and fish communities – continuing as described above; hopefully with expansion of monitoring to additional coastal locations near to Beaufort Sea communities.

- Harvest sampling of marine mammals.

3.7.2 Offshore Beaufort Sea:

- Research on deeper water fish community structure – outer shelf to slope (150-1000m) planned as part of Beaufort Regional Environmental Assessment in relation to oil and gas development.

- ArcticNet activities as noted above continuing for at least next two years.

- Preliminary genetics research on Arctic cod being conducted with planned extension to include Alaskan samples (and possibly additional pan-Arctic samples) (linked to a US study).

3.7.3 Research Gaps

- Outer shelf/slope fish communities and habitat utilization studies.

- Canada Basin/Arctic Ocean ecosystem studies (lower trophic levels, nutrients/productivity) and higher trophic level sampling for diversity, habitat

associations, population and related studies of macrobenthos, fishes and marine mammals/birds.

4 CURRENT INFORMATION GAPS AND OPTIONS TO ADDRESS GAPS (TOR 3)

- Baseline information regarding physical, chemical and biological conditions is lacking for many parts of the Arctic. Baseline information is essential to provide a foundation for evaluating change, and to provide initial conditions for modeling.

- Understanding how climate change will impact the oceanography of the Arctic is lacking. Research should include projections that take into account factors such as ocean circulation, temperature, ice loss, acidification, and freshwater input.

- Questions regarding the extent to which climate change may impact primary productivity and whether any such changes might result in restructuring of the Arctic marine ecosystems should be addressed.

- While much is known about the conditions that would be necessary to establish self-sustaining fish and crab populations in the Arctic and the surrounding shelf seas, further research on this topic is necessary and should focus on the following questions:

    - Will these conditions be achieved and if so, when and for what species?

    - If successful colonization occurs, will it alter Arctic marine ecosystems?

5 PRIORITIES IN REGARD TO IDENTIFIED RESEARCH REQUIREMENTS (TOR 4)

- Develop and improve monitoring of plankton and fish, invertebrate and marine mammal distributions and abundance and associated environmental factors (physical and biological). This is viewed as a high-priority requirement which includes the need to establish baseline information and to monitor for changes in baseline conditions.

- Improve understanding of vital rates as they relate to population productivity of key species, e.g., fecundity, growth, birth rate, mortality rates. This type of basic information is essential to understanding resilience to change and ability to colonize new regions. Results of this work would also support essential modeling and forecasting analyses.

- Improve understanding of life stage and habitat linkages of key fish and invertebrate species, in order to predict potential colonization routes and areas.

- Develop predictions of potential changes in fish production based on ecological models that consider current understanding of likely changes in Arctic primary and secondary productivity.

- Study ecosystem processes to support improved modeling of fish, invertebrates, and marine mammal productivity and distribution.

- Refine models and perform scenario modeling of ecosystem responses to climatic change for Arctic marine ecosystems.

6 OPPORTUNITIES FOR AND IMPEDIMENTS TO CLOSER COOPERATION (TOR 5)

6.1 Opportunities

Even though there is much useful information available regarding climate change and other changes in the Arctic marine ecosystems, participants identified substantive gaps in information and understanding of the processes involved. There was consensus that the changes necessary to support sustainable populations of commercially important fish stocks in the international zone of the Arctic Ocean will occur slowly, if at all. There was also consensus that some changes in these ecosystems are already taking place and there is an immediate need for additional monitoring and modeling to better characterize baseline conditions and support improved understanding of processes and possible future conditions of the ecosystems. This work is considered high priority because change is already occurring and improved scientific understanding is essential to address concerns about the impacts of anthropogenic activities which are expected to increase. Thus, we now have an opportunity to build on the foundation of work that has already been accomplished, and to marshal the resources necessary to carry out more comprehensive and better-integrated monitoring and research.

The following specific activities were identified as elements of a strategy to meet these needs:

- Implementation of formal programs for exchange of scientific experts among coastal States. Such exchanges could include short-term visits for workshops and technology transfer, and longer-term arrangements such as post-doctoral research and training. These programs would also facilitate participation in research cruises and cruise planning.

- A workshop to design and facilitate development of pan-Arctic baseline ecosystem surveys. This workshop should be held before the end of 2012, with follow-up meetings for planning and coordinating surveys. These meetings should also address data management and dissemination needs.

- One or more workshops, also to be held by the end of 2012, to address the modeling and forecasting priorities identified in section 5.

Participants emphasized the importance of encouraging and coordinating government and academic research on Arctic marine ecosystems. They noted the success of the International Polar Year in this regard and suggested that this concept be developed to support multi-year research programs in the Arctic.

6.2 Impediments

- Platforms for conducting research in the Arctic are inadequate and insufficient. Research vessels suitable for this type of work are expensive to build and operate and this is a limiting factor. Furthermore, technologies for monitoring and collecting measurements in the harsh conditions of the Arctic are often inadequate.

- The infrastructure to coordinate pan-Arctic marine ecosystem research has yet to be established. In this regard, possibilities include leveraging the capabilities of existing organizations.

- Funding levels for this work are insufficient. Furthermore, a common funding mechanism which would allow governments to share the costs of multi-lateral research projects and programs is lacking.

7 CLOSING COMMENTS

Participants agreed that it would be beneficial to schedule future meetings to develop a coordinated research plan, and to coordinate and report on Arctic research. In particular, they agreed on the importance of moving forward to take advantage of the opportunities identified in section 6.1 as soon as possible. Inclusion of scientists from countries outside the Arctic coastal states would greatly enhance our collective ability to address these priorities and would also likely bring additional resources to support research and monitoring needs. Therefore, we encourage broader international participation in this endeavor.