Experts' Workshop on Sea Ice-Associated Biodiversity

Conservation of Arctic Flora and Fauna
Working Group of the Arctic Council

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Prepared for
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1 INTRODUCTION

Paul Kluckner, Regional Director General, Environment Canada, opened the workshop by acknowledging that the Arctic is experiencing a time of rapid change. If trends continue, the northernmost part of Environment Canada's mandate will be significantly impacted. . He also noted the added responsibility for Canada since several models indicate that, in extreme warming scenarios, the islands in the Canadian Archipelago may become the last refuge for much of the biodiversity that is the subject of this workshop. The Canadian Government is taking note of this unprecedented change, and is working to preserve northern biodiversity.

Kluckner acknowledged that the changes of concern are circumpolar, and include increases in human activity in the north as the sea ice recedes. At a recent conference on shipping there was discussion about security and safety – the safety of our people and our borders but also the safety of the environment in the face of increased industrial activity. This activity can bring economic benefits for the people of the north but the risks must be taken into account.

Circumpolar countries have different legal systems that can be used to achieve common outcomes if programs are planned in a cohesive manner with an understanding of common objectives.

This CAFF initiative has great potential, Kluckner concluded, to help establish ecosystem objectives and a better understanding of risks associated with changes in Arctic sea ice.

Workshop Chair, Garry Donaldson, Canadian Wildlife Service, welcomed participants and emphasized the importance of taking into account all aspects of biodiversity through an inclusive approach that welcomes many partners.

He introduced the three workshop objectives:

1. Outline past trends and the current situation for sea ice-associated biodiversity and project what might happen in the future.
2. Consider issues facing sea ice-associated biodiversity and what actions might be required to adapt to or mitigate the effects of reduced availability of Arctic sea ice.
3. Outline a technical report on the effects of sea ice loss on ice-associated biodiversity and determine next steps.

Donaldson explained the goal of producing a technical report with relevant and practical recommendations that will be implemented. It will provide tools for government, NGOs and others interested in sea ice-associated biodiversity in the Arctic.

Facilitator Julie Gardner[1] invited other participants to introduce themselves. Some 25 delegates attended from Canada, the US, Denmark/Greenland and Russia. They brought to the workshop a broad range of expertise, including phytoplankton, zooplankton, benthic ecology, marine mammals, fisheries, sea birds and marine conservation policy and legislation.

This report on the workshop synthesizes ideas brought forward in presentations and discussions into five sections: Project context, Overview of Arctic sea ice trends and issues, Current and future state of sea ice associated biodiversity, Issues facing sea ice-associated biodiversity and actions to address them, and the Technical report.

[1] Dovetail Consulting Group, Vancouver BC, Canada

2 PROJECT CONTEXT

The progenitor of this CAFF initiative is the Project on the Status and Conservation Issues of Arctic Sea-Ice-associated Biodiversity. Presentations explained this connection and expanded on where this workshop specifically fits in to the Arctic Biodiversity Assessment (www.caff.is/aba) project. Workshop participants presented summaries of three other related initiatives[2], and reviewed a number of relevant monitoring programs. Discussion stressed the need for linkages between the various initiatives to maximize efficiency.

2.1 Project on the Status and Conservation Issues of Arctic Sea-Ice-associated Biodiversity

Trish Hayes from Environment Canada introduced the place of CAFF within the Arctic Council. She explained that the Arctic Council includes representatives from eight Arctic countries, six indigenous people's organizations, observers from non-Arctic countries and international organizations. The Council has six working groups each with a different thematic focus and CAFF (www.caff.is) is the Arctic Councils biodiversity working group...

The mandate of CAFF is "to address the conservation of Arctic biodiversity, and to communicate the findings to the governments and residents of the Arctic, helping to promote practices which ensure the sustainability of the Arctic's living resources; and to monitor, assess, report on and protect biodiversity in the Circumpolar Arctic." CAFF supports initiatives in six areas:

- Promoting and facilitating science
- Assessment
- Monitoring
- Communication and outreach
- Global linkages
- Conservation strategies
- Developing Scientific, conservation and Policy and recommendations

This CAFF-sponsored workshop flows from earlier work for the Arctic Biodiversity Assessment (ABA)... Janet Hohn, of the US Fish and Wildlife Service, went on to describe the ABA. A significant product of the first phase of the project was the *Arctic Biodiversity Trends 2010* report, released last May www.Arcticbiodiversity.is). The report studied 22 indicators for trends of change; sea ice-associated biodiversity is one such indicator. The commonality of habitat for threatened species, with multi-year sea ice declines affecting mega-fauna, came to be seen as an emerging issue, central to the ABA, and sea ice-associated biodiversity was identified as a research need.

The ABA has three phases and this workshop is in response to the key finding from the Arctic Biodiversity Trends 2010 report which noted that unique Arctic habitats for flora and fauna, including sea ice have been disappearing over recent decades and that some species of importance to Arctic people or species of global significance are declining. Phase 2 of the ABA entails a full science assessment, and Phase 3 will focus on presentation of an overview and recommendations scheduled to be delivered at the Arctic Council ministerial meeting in 2013.

[2] (1) The Circumpolar Biodiversity Monitoring Programme (CBMP); (2) Snow Water Ice Permafost Assessment (SWIPA); Rapid assessment of CircumArctic Ecosystem Resilience (RACER).

The ABA is led by the USA, Finland and Denmark/ Greenland Canada and Sweden, so almost all the Arctic countries are involved. Permanent Participants also play a key role in developing and guiding the development of the ABA.

The project leads for the sea ice-associated biodiversity initiative are the US and Canada. This initiative starts with this workshop, which builds on other work (described below). The aim is to produce a draft report as guided by this workshop, and to schedule a second sea ice-associated biodiversity workshop this fall, with a final report to be released towards the end of 2011.

The *Arctic Biodiversity Trends 2010* report states that “Sea ice represents a unique ecosystem in the Arctic, providing habitat to specialized ice-associated species that include microorganisms, fish, birds, and marine mammals.” Examples include Ice Algae, Arctic Cod, Ivory Gull, Polar Bear, Walrus and Ringed Seal. Examples of conservation issues identified in the report include: ongoing decline of multi-year sea ice habitat; possible mismatches with life histories of ice-associated species if timing of life function shifts; species shifting northward and their replacement by more generalist species; and increased competition at higher trophic levels and species competing for decreased habitat.

2.2 Snow, Water, Ice and Permafrost in the Arctic (SWIPA)

Tony Gaston of Environment Canada reported on Chapter 3 of the SWIPA report, which focused on the biodiversity around the edge of the sea ice – i.e. one-year ice.

Key findings of Chapter 3 included:

1. Multi-year ice is decreasing, while first-year ice, which is very important to biodiversity, is increasing.
2. The open water period is increasing and this has consequences for flora and fauna. This also means a shift from ecosystems limited by the availability of light, to ecosystems limited by the availability of nutrients.
3. The Consequences of these changes in energy flow are not known.
4. The timing of ice retreat will affect the availability of sea ice-associated organisms, especially plankton and fish that are important to marine mammals and birds.
5. Changes in first-year sea ice are affecting the distribution of Seals, and what the Seals do as the ice changes is important.
6. There is potential for increased predation from Killer Whales as there is more open water. This will affect all marine mammals, with undetermined consequences.
7. Extinction of some Arctic endemic species is almost inevitable if this trend continues and northward range extensions of southern species can also be expected.
8. Not all productivity will decrease, but the changes will affect some of the higher trophic levels that depend on larger copepods. The larger, lipid-rich, Arctic copepods are decreasing, with important consequences to species like Bowhead Whales. As an example of the changes occurring, data in Northern Hudson Bay shows that when the sea ice is principally breaking up later in the summer, the length of daylight is already declining, and there is then a concentrated bloom of phytoplankton. In 2010, there was an earlier break-up so there was a much longer period of light availability. This factor will be important as a driver of change.

SWIPA’s broad approach is to describe the physical changes in sea ice and project future changes; look at feedbacks (as the ice decreases, how it feeds back into the physical system to induce further changes); address ecosystem changes, of which biodiversity is one component; and assess what this mean for humans.

2.3 Rapid Assessment of CircumArctic Ecosystem Resilience (RACER)

Peter Ewins, from the Arctic Program, WWF-Canada, reviewed the RACER initiative. RACER addresses the question of how ecosystems might respond to the rapid rate of climate change, especially in the context of resilience/vulnerability of key components of system function. The pace of change in the Arctic is twice the global average, and there is uncertainty regarding what it means for changes in Arctic sea ice and the resultant effects on sea-ice associated biodiversity.

RACER does not focus on a single species but rather works on the drivers that come together in ways that allow species to flourish. The objective is to identify, map and raise awareness about areas and features that are readily identifiable, that are considered significant to building future ecological resilience and that are likely to persist in the face of change.

The Arctic was divided into 27 marine eco-regions and is comprised of four key analytical steps:

1. Characterize key features and areas today in the marine eco-regions;
2. Work out how to assess vulnerability to climate change;
3. Explore questions about the persistence of key features into the future; and
4. Final assessment of social-ecological system resilience.

Key terms include:

- Processes: key functional components of a system
- Drivers: key variables responsible for functioning of a process.
- Features: areas in which drivers are regularly aligned to support significant biological production.
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Information is collected on geophysical features, biodiversity and ecosystem services. Then the emphasis moves to marine productivity and drivers. Algorithms derived from SeaWiFSsatellite imaging provide indices of production. For the Beaufort ecosystem case study, trends over the last twelve years in marine productivity were examined, providing an interesting spatial perspective.

- Step 1 involves identifying key features using a combination of remote sensing satellite images and detailed studies to map key features.
- Step 2 determines how vulnerable an ecosystem is. 17 key variables have been identified and three were singled out as being of particular importance and for which data are available on a global scale i.e., relative trends for salinity, sea surface temperature and sea-ice..
- Step 3 explores resilience.
- In step 4, linkages are made e.g.to system resilience, and issues such as the importance of access to country food (i.e., where species will persist and be accessible to harvesters).

- To continue this example, the approach is organized around the taxonomic group from which species can be harvested and determines whether it will be benthic-dominated or pelagic. There will likely still be annual ice, so communities will be able to access protein-rich country food. Food security is expected to be a key focus of the report and those involved will look to input from experts in writing that section.

2.4 Circumpolar Biodiversity Monitoring Program (CBMP)

Tom Barry, Executive Secretary of CAFF, summarized the CAFFs CBMP which is an international network of scientists and local resource users working together to enhance Arctic biodiversity monitoring to improve detection, understanding and reporting of important trends in biodiversity so as to facilitate more informed and timely management decisions. The CBMP has over 60 global partners, 33 of which are Arctic biodiversity monitoring networks operating and linked to the CBMP. Many of these networks have received substantial support from the International Polar Year. The last two years have been an active and productive time for the CBMP. It has accomplished many important tasks and embarked upon a number of exciting projects which will be of critical importance in enhancing our understanding of the status and trends of Arctic Biodiversity. The CBMP is now in Year 3 of its five year implementation.

The current challenges facing effective monitoring of Arctic biodiversity monitoring were noted i.e. lack of coordination and long-term commitment to sustainable funding levels for efficient, long-term programs. Other challenges include how to incorporate traditional ecological knowledge (TEK) and address limited involvement of local people. Lack of a circumpolar perspective, transcending national perspectives, results in incomplete and irregular coverage, and a limited ability to observe change and identify the mechanisms driving change. This in turn limits the ability to inform decision making.

The CBMP takes an ecosystem-based management approach, operating as a network of networks coordinating existing species, habitat and site-based networks. A series of Expert Monitoring Groups are being activated, each dealing with one of the Arctic's major systems (Marine, Coastal, Freshwater, Terrestrial). These will serve as an umbrella mechanism for coordinating existing biodiversity monitoring activity in the Arctic. Each Expert Monitoring Group is tasked with developing long-term integrated monitoring plans.
The plan is to take a pan-Arctic view so as to extract trends on a circumpolar scale, with ecosystem monitoring plans and species-specific monitoring frameworks.

A range of Arctic marine activities are already underway and efforts are being made to focus on what is monitored, when and how. Examples include an analysis of marine protected areas and the Arctic Species Trends Index marine analysis, which pulls together over 1,000 data sets spanning 1974 2008. The Circumpolar seabird analysis and the marine component of the Arctic Biodiversity Assessment are also ongoing. CAFF is working with the Arctic Councils Arctic Monitoring and Assessment Program (AMAP) working group on a project to identify marine sensitive areas in the Arctic.

It was noted that capacity issues are a barrier to more involvement from indigenous communities, and that having people with "boots on the ice" is critical to getting accurate information.

2.5 Other monitoring programs/activities

Information on various monitoring programs was presented so as to ensure linkages between these activities and the sea-ice associated biodiversity project. Jill Watkins, provided an overview of CAFFs CBMP Arctic marine biodiversity monitoring plan and explained that the objective of the marine monitoring plan is to establish trends and link them to drivers, e.g. climate change and pollution. The marine monitoring plan will establish baseline indicators across the trophic spectrum so that, over time, changes and trends can be calculated. Eventually, the intention is to link these changes to anthropogenic stressors like shipping, harvesting, and use that information to inform decision-makers. There

Implementation of the plan is just starting and there is potential for close linkages with this sea ice initiative. The Marine Plan is essentially an ongoing monitoring plan (as opposed to a snapshot) based on existing data and information. It does not involve creating new data, although this would be a welcome by-product.

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Given the objectives of the Marine Plan, monitoring needs that emerge from the sea-ice associated biodiversity workshop discussions may complement the CBMPs marine plan. That said it is not necessary for this group to generate a full-blown suite of monitoring activities but rather to identify possible monitoring activities in order to see where the interests and activities of the two initiatives intersect.

Workshop participants also mentioned the following connections related to monitoring:

- The AMAP working group deals with contaminants and CAFF works very closely with them.
- CAFF through the CBMPcooperates with NOAA
- The CBMP is I the biodiversity component of SAON (Sustainable Arctic Observing and is closely involved in developing SAON.
- Annual Arctic reporting uses sea ice is an indicator.
- In the Canadian Arctic, national parks are established and have their own monitoring programs. It is important to keep in mind what roles they can play and what recommendations can be made to them. In this respect it was noted that CAFF is in the process of finalising a protected areas monitoring framework for the Arctic.

2.6 Importance of linkages

With the project scheduled for completion in late 2011, it is important that linkages between this project and associated initiatives, particularly monitoring, are sufficiently strong. Care needs to be taken to incorporate the work of other programs, like SWIPA, and add to it. There are many connections between the authors of the SWIPA report and the technical report flowing from this workshop and this will ensure that these two initiatives are coordinated

Attention also needs to be given to insure alignment with other ongoing efforts and activities. However given the importance of the issue priority must be placed upon completing the project on time and insuring a dynamic flow, with action-oriented linkages and solutions.

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A key challenge is to ensure that these initiatives become sustainable. Another is to find ways to shorten the response time between the point when information is first available and the point when it is brought forward to inform policymakers.

3 OVERVIEW OF ARCTIC SEA ICE TRENDS AND ISSUES

To set the scene for the discussions to follow, three speakers shared their research on aspects of trophic relationships in connection with changes in Arctic sea ice. Discussions filled in more information about trophic relationships involving a range of species. A fourth speaker, Gabriel Nirlungayuk, focused on human aspects of Arctic sea ice trends and issues.

3.1 Impact of ice-cover decrease on Arctic marine secondary production – mid-trophic relationships

Dominique Robert of Québec – Océan summarized the results of studies on mid-trophic relationships, with particular attention paid to the role of Arctic Cod. He pointed out that the Arctic Ocean is characterized by highly-seasonal solar irradiance, low temperatures and sea ice, so there is relatively low diversity, and a few key species like Arctic Cod represent the main energy channel linking primary production to mega-fauna.

There are two distinct cycles of primary production for the coastal Arctic: the production of ice microalgae represents less than 20% of total production under the sea ice, and phytoplankton production represents more than 80%. (Discussion acknowledged that these averages vary by area, depending on the sea ice cover, and ratios can even be reversed in some areas.)

Ice microalgae are mostly diatoms, which grow in the ice and at the ice/water interface in spring. Earlier breakup of sea ice will constrain ice algae growth to the months of low light availability, so they will be reduced or will disappear in some places. Earlier ice break up also means an earlier phytoplankton bloom. Currently, with the reduced period of growth, there is intense build-up of production. The question arises as to whether nutrient renewal in the surface layer will permit larger production when there is an extended period of light for growth.

Older studies showed a strong link between the open water period in terms of months and annual pelagic primary production, at the expense of a previously-rich benthic production. Primary production is expected to increase with a longer ice-free season, due to increased light and nutrient renewal, though it remains unclear to what extent. On a global scale, a relationship was determined by Iverson in 1990. With ecosystems in the Atlantic, for example, the relationship between fish and squid and total phytoplankton production shows a linear relationship, while that relationship is less clear in the Arctic. Therefore we cannot expect emerging Arctic stocks to replace devastated southern stocks.

A paper by Bill Li et al. related to zooplankton and fish biodiversity demonstrated that in the Canada Basin from 2004 to 2008 temperature generally increased, salinity generally decreased (melt of sea ice) and nanophytoplankton cells decreased, to the benefit of even smaller, pico-phytoplankton cells. Smaller phytoplankton cells are expected to replace the large diatoms that currently dominate the spring bloom and this can be expected to change zooplankton production and diversity as well.

Arctic Cod is the main delimiting fish species in the Arctic Ocean. Echo-sounding, which shows spawning aggregations under the sea ice, showed major spawning aggregations in early

February and then again just before the ice breakup. This indicates that pack ice is important to spawning (i.e. to protect eggs and larvae).

A study of prey during the early larval stage, when good survival is critical to recruitment, found *Calanus spp. N* comprised about half of the Arctic Cod diet. The study also examined whether they selected for this species or whether it was simply due to abundance. The analysis showed very strong positive selectivity for *Calanus nobleii*, but negative selectivity for the smaller prey species, so the prey species that are becoming abundant are not important to larval Cod.

In Baffin Bay, hatch dates for Arctic Cod in 2005-2006 are at least a month earlier than they were in 1998. In the Laptev Sea, there was earlier spawning in recent years, consistent with early opening of the Laptev Sea ice cover. Early spawning can represent an advantage for Arctic Cod, as it permits them to achieve a larger size before their first winter. But without ice, the larvae will likely be subject to more predation pressure.

It is uncertain whether Arctic Cod will be displaced by more generalist species like Capelin, which produce very small larvae. If smaller copepods take over, it might benefit them, and in the long term, Capelin may out-compete Arctic Cod in some areas. In northern Hudson Bay, for example, the prey brought to thick-billed Murre chicks used to be mostly Arctic Cod, but it has shifted to Capelin with sea ice reduction.

Looking forward, in the short term (to mid-century) increased primary and perhaps secondary production from a longer ice-free season is expected, with a reduction in ice algae and loss of much of the sympagic ecosystem. There may be displacement of large nano-phtyoplankton by pico-phytoplankton in the spring bloom and a shift from larger herbivorous copepods (*Calanus spp*) by smaller omnivorous and generalist species. Arctic Cod recruitment might fail due to increase predation on larvae, a decline of preferred *Calanus* prey species during the larval stage, and competition from boreal generalists such as Capelin. The shift in dominance of some key zooplankton taxa will affect biodiversity at higher trophic levels.

Discussion explored spatial differences such as those between the shelf and the open ocean. Multiyear ice used to dominate the open ocean, and now it is new ice, and thinner. In the deep ocean, phytoplanktons have been taking over. There is little known on the deep basins.

At the southern edge of the sea ice shifts are also being observed, as in southern Hudson Bay where there is a shift to capelin and sand lance. Predators may be surviving on other species. Possibly related observations include larger Arctic char and changes in bird diets. Major changes with birds have been followed in subsequent years by a shift from Arctic Cod, when the condition of chicks started improving again as they learned to catch the new prey. In Hudson Bay the change was in the mid-1990s, so now is an opportune time to study the southeast Beaufort Sea.

3.2 Seabirds and ice in the Arctic – an example of higher trophic relationships

David Boertmann from the Danish National Environmental Research Institute summarized work on Arctic sea birds that he had undertaken with his colleague Jerome Fort. Sea birds are top predators and indicators of marine ecosystems and have a pivotal role in the marine food web, with some 100 million birds in Baffin Bay (in the autumn) alone. They also play a very important role as vectors of carbon to marine ecosystems.

There has been a strong decrease in both the extent and period of sea ice around Greenland.

Data on Greenland seabird species do not show a strong association with summer or winter sea ice for most species, except for the Ivory Gull (crucial in both summer and winter) and Little Auk (important in summer).

The Ivory Gull is a threatened high-Arctic sea-ice specialist, with summer and breeding distribution within the limits of summer sea ice. Breeding sites are located on cliffs, ice floes, gravel banks, small islands and coastal plains in northern Greenland. Tracking studies show that Ivory Gulls find food exclusively in areas of sea ice in summer, within 230 k of their nests. They explore huge areas covered in sea ice in summer. Seasonal migration patterns of banded Ivory Gulls around the Arctic Circle and southern Greenland in winter show the common factor is sea ice. The northeast Greenland population is stable but populations in southern Greenland and Canada are decreasing. Svalbard and Russian population trends are unknown. Threats include contaminants (bio-magnification of contaminants), reduction of sea ice habitat, and hunting. Conservation status is “near threatened” globally, “vulnerable” for Greenland and Norway and a species of “special concern” in Canada.

The Little Auk is the most abundant seabird species in the northern Atlantic. Tracking studies show post-breeding areas off the sea ice, and a winter area off Newfoundland. Many of these areas are along the ice edge and they use the areas outside of the ice cover.

Major summer prey species include *Calanus hyperboreus a*nd the smaller *Calanus glacialis*. The birds travel up to 130 km to reach the edge of the sea ice to find food. The feeding ecology in winter is unknown. A study will examine the degree of association with sea ice and the extent to which the birds rely on sea ice by looking for evidence of biomarker IP25 (which is exclusively produced by ice-associated diatoms).

Population trends are generally unknown, but some southern colonies have been abandoned. Threats include hunting, industrial activity (e.g. oil spills, which is an issue with the opening of oil exploration and drilling), and increases in water temperatures. Conservation status is rated as “least concern” in most areas, except Greenland where a major colony disappeared some years ago. But it is difficult to monitor smaller trends or to detect change unless entire colonies disappear.

In discussions it was pointed out that the Ivory Gull is proposed to be listed as “endangered” in Canada. The distribution of colonies has changed radically and there appears to be a retreat. Most southern colonies of Baffin and Devon islands have disappeared and most of the populations are now on Ellesmere. This is consistent with the abandonment of southern Greenland colonies and a northward movement there over the last 30 years. Discussion also touched on the Arctic tern. This bird flies from Alaska to the AntArctic Peninsula and is a good indicator. It spends four months one way, and eight months the other way. It breeds near ice in open water and its main food is krill, though as a food generalist, it takes what food is available.

3.3 Other species and trophic relationships

In discussions various other points were made about trophic relationships:

- It was suggested that in the case of the shift from Arctic Cod to capelin, size and energy density are important. Gaston noted that the birds they are studying are bringing in 1- to 2-year old Arctic Cod (pre-spawning) that are 10-15 cm in length. The birds have the full range of lengths available and they are selecting the ones that suit them. Seals presumably can take a range of sizes as they do not have to carry the food to chicks.

What will affect them more are the schooling characteristics of fish. It has affected the prey search patterns of murres, which experienced a delay in re-establishing success due to the time required to learn new patterns.

- In connection with schooling patterns it was suggested that predators such as Narwhals and other marine mammals may switch to fish with different schooling behaviours. How to get energy most efficiently is the primary issue for predators.
- Regarding patterns for Seals, in open water they are still pre-spawning fish. They would not have as high lipid content as later in the season. A question was raised as to whether Ring Seals adjust foraging depth in April and May. Larger marine mammals store reserves and can coast over periods going without food, while birds lack the body mass to do that.
- Discussion addressed whether species will need as much energy as they move into warmer water: Seals and birds are homeotherms, needing the same energy irrespective of temperature, whereas fish will fluctuate their energetic requirements with water temperature. When colder, with less energy, their growth rates will slow, so there is less production, which could result in impacts at higher trophic levels. Regarding impacts on Polar Bears, since bears are well adapted to conserving heat in the Arctic, a major net benefit would not be expected.
- It was pointed out that sea ice dynamics and consequences for biodiversity should not overshadow another major change that affects ecosystems: vast inflows of fresh water into deep ocean basins. These are thicker, colder layers of freshwater that move around as a water mass for years. They are exiting the Canadian archipelago and gyring out into the Pacific. Therefore caution is needed in attribution of cause: Is it because the sea ice is gone or is it a combination of cryospheric changes, of which sea ice is just one aspect?
- The salinity of upper layers of water is connected to sea ice. In summer a thin freshwater layer is associated with sea ice. There are also algae for brackish water that were not previously observed in the Arctic.

3.4 Looking back on sea ice-associated biodiversity

A criticism of the ABA was that it failed to take into account the distant past. The workshop Steering Committee felt it would be worth briefly considering the historical ecology of the Arctic, and how far back participants feel this initiative should go. Participants were invited to reflect on what sea-ice biodiversity was like in the past, including what can be learned from Indigenous knowledge. Comments included the following.

- Discussion of the past depends on timescales. The timeframe used for baseline comparison depends on what the objective or question is. Significant differences in timescales for baselines would stem from what portion or attribute of ecosystem is the focus (e.g. Bowheads vs. copepods). This is scoping and scaling is critical, especially if the product is to be used for forward casting.
- It is appropriate to look far enough back to see time periods when conditions were similar to what we expect in the future.
- When looking back, it is important to keep in mind that there are three levels of biodiversity: genetic, population and ecosystem.

- When considering climate change and ice conditions making connections to anthropogenic impacts is complicated. There are different layers of consideration and the task is multi-faceted.
- The baseline is shifting so fast that SWIPA is using data from the 2002-04 period.
- An important factor related to informing action is rates of change. Are the rates of change discernible in a population? There is much more work involved in annual updates of population biology than in integrating satellite and sea ice information. Therefore it is important to carefully consider the nature of the problem and the question being asked.
- Variability needs to be distinguished from change. Variability is not interesting if it is natural, but if it is human-driven it can become a challenge.
- The technical report should include text on the history of sea ice i.e.: how old is the Arctic sea ice ecosystem from a biological point of view; how has ice thickness fluctuated; what is the history of ice free areas? Then consider the reasons for the changes – are they anthropogenic or not?
- Anthropogenic influences date from the 1700s, so focus should be placed upon variations since the 1700s, and on the variations currently observed. It is not necessary to look at millennia scale changes to consider the past. (e.g. a recent paper discusses the period in which sea ice appeared 47 million years ago. There was a different set of species at that time that have since disappeared.)
- Conservation managers need practical outcomes. There will be increased human activity the Arctic and managers and policymakers need to know what changes are projected and how to insure sustainability.
- Information from researchers is important – key circumpolar indicators can provide a snapshot of what is changing in real time.

3.5 Inuit Qaujimajatuqangit and sea ice

Gabriel Nirlungayuk spoke about the role of local knowledge in areas where sea ice is integral to people's way of life. He emphasized that sea ice is very important to Nunavut communities. He introduced some important Inuit terms to the workshop:

- The term "Inuit Qaujimajatuqangit" (IQ) translates as "that which is long known by Inuit." This represents the past, present and future knowledge, experience and values of Inuit society.
- "Avatimik Kamattiarniq" means that people are stewards of the environment and must treat all of nature holistically and with respect, because humans, wildlife and habitat are inter-connected. Inuit invented hunting techniques to survive in a hostile environment. Study of animals occurred throughout the cycle of life.

Inuit have occupied the Canadian Arctic for over 10,000 years. They use sea ice for transportation and harvesting. Vast knowledge of currents/tides, conditions, animal movements, etc. was learned and passed on through generations. The Inuit have different names that identify distinct forms of ice, including clear ice, ice that forms from snow, presser ridge, and small multiyear ice, broken ice off glaciers, new ice and tide line ice. Multiyear ice is very important for seal pupping, seal haul-outs and for cooling the sea. Annual ice is very productive, and important for seal breathing holes and for human and Polar Bear hunting.

The Inuit have been observing many changes, including seasons setting later, mild fall temperatures (later ice formation), freezing rain in winter, and lakes drying up in summer. The floe edge – where solid ice meets the water – changes every year and is getting closer to the land. The ice is also thinner (eroding from the bottom). Cracks of four to five feet in depth used to be observed, and now only two-feet-deep cracks are being observed. On land, permafrost melt has caused some landslides and even split one community.

As climate changes, new species are arriving (e.g. robins and grizzly bears). This is not all negative: there are more Belugas and Narwhals, and more Bowhead Whales. Despite concerns, global Polar Bear populations are currently at record levels. Caribou and Musk oxen are thriving in Nunavut.

The climate is changing and cannot be ignored (e.g. accidents from people falling through the ice are increasing). People are the biggest contributors to climate change. The discovery of resources is also attracting industry which presents new challenges (e.g. icebreakers and daily shipping to extract iron ore on Baffin Island, and uranium mining).

Discussion focused on the place of humans in the ecosystem and their ability to adapt. Studies have sought to document historical knowledge, what people are seeing and how people are trying to adapt to changes. In Alaska, the decrease in ice is leading to increased coastal erosion, forcing communities to relocate, and raising difficult issues (e.g. relocating a community's cemetery). At a RACER workshop in October 2010, Greenland Inuit commented that they had adapted to many things in the past and that they welcomed the opportunity to catch more fish and to grow cabbages and potatoes.

Chapter 4 of the SWIPA report addresses human benefits and consequences related to changes in sea ice and there is an overarching, integrated chapter that covers all human factors.

4 CURRENT AND FUTURE STATE OF SEA ICE ASSOCIATED BIODIVERSITY

The first objective of interactive group discussions was to outline past trends and the current situation for sea ice-associated biodiversity and project what might happen in the future (including direct effects of sea-ice loss on marine species and indirect effects on terrestrial species). The results of these group discussions, along with plenary discussions of the groups' results, are summarized here under four themes:

1. Quantifying the ability of people and wildlife to adapt to an ice-free/ice-reduced scenario
2. Impacts of disappearance of sea ice on genetic diversity, Beyond sea ice
3. Implications for terrestrial ecosystems
4. Changes to the species mix as a result of sea ice change.

4.1 Quantifying the ability of people and wildlife to adapt to an ice-free/ice-reduced scenario

The potential for some communities and wildlife to adapt is high; four main considerations are pivotal for those with lower adaptation potential:

1. *Scenarios:* Cumulative effects of multiple stressors raise more complex questions than adapting to single stressors. Moreover, adaptation differs between generalists and

specialists. The critical life history stages for species, in relation to habitat parameters, inform how critical the association is (e.g. ice obligated vs. ice associated).

2. *Spatial scale of stressors or habitat and the question of extirpation vs. shifts:* For example, the range of polar species at the southern end of their range (e.g. Arctic Cod, ice-associated diatoms) will recede along with the ice.
3. *Temporal scale:* The rate of change may affect the ability to adapt. This ties in to the concept of plasticity.
4. *Plasticity:* Most animals have alternate life history strategies, and, when presented with a challenge, will do something else (e.g. Arctic char choosing not to go to sea). Yet at a certain scale there may not be alternatives – it is a matter of ice obligation: If a species is going to lose habitat, does it have an alternate habitat? For species such as Walrus or Polar Bears, there may not be any such options. In the case of birds, some return to natal colonies but others are nomadic. Sea bird colonies that depend upon a specific habitat may not adapt as easily as another animal that is not as site-dependent. In general terms, an outline of which species will take advantage of changing conditions and which species will take longer to take advantage of changes is apparent. For example, Razorbills have shown more tendencies to move with changing conditions than other types of Auks. There are also possibilities for humans to adapt but there may be limitations related to cultural traditions. For example, you can hunt Minke Whales, but that may not be supported, locally or internationally, by cultural restrictions.

4.2 Impacts of disappearance of sea ice on genetic diversity

The overarching conclusion was that any time an ecological niche changes, alterations to genetic variation are to be expected, via species mixing or being introduced into areas where they did not previously exist. Genetics is the heart of conservation, but the question is how can it direct conservation: should the emphasis be on conserving genetic diversity or the number of individuals? There is also a human component: cultures have evolved to adapt to their environment, so when that changes, it can affect their health.

The main impacts and related themes discussed were:

- Traditional Arctic species may disappear with a reduction in sea ice. Their spatial distribution will change and direct and indirect competition between species may be affected. The future relationship between new species moving in and traditional species is uncertain.
- Numbers of some species will increase; e.g. there was one species of sea ice dinoflagellates and now there are 40.
- Species mixing will occur (a factor most relevant to animals on or close to the surface). There are many Atlantic or Pacific species that have been divided since the Pleistocene. As the Northwest Passage opens up, introgression will occur. With species moving towards each other genetic diversity will eventually decrease, however it is not clear how widespread this will be. One factor will be ongoing ecological barriers between some populations. Populations may interbreed or not, in which case there may be different species (e.g. Pacific and Atlantic herring). There will be more interchange between populations of Atlantic and Pacific Whales and Walruses; e.g. Bowhead whale from the Chukchi Sea are in the Beaufort Sea.
- Ice algae will disappear, affecting species that depend on it. This may affect the water column due to harmful algae development. (Some discussion qualified this statement in

connection with the ratio of annual to multi-year sea ice. The potential effect of storms bringing nutrients from deep waters in the fall that could freeze in the ice was mentioned.)

- Loss of sea ice in the summer will affect the adaptation of micro-algae. Different systems (no multiyear sea ice) and the different sub-state of sea ice (“Strategy of waiting”) need to be taken into account.
- There have been few genetic studies in the Arctic, and existing knowledge is not uniform e.g., we know a lot about Polar Bears but little on micro-biota. We lack empirical data upon which to base actions.
- On a global scale, how do Arctic lineages compare with others in terms of their age? The link is the human component: human health, food security and culture.

4.3 Beyond sea ice – implications for terrestrial ecosystems

Impacts related to terrestrial ecosystems were discussed in four categories.

Climate impacts:

Reduced ice conditions in neighbouring land areas (e.g. Greenland – increased summer precipitation) might have implications for biological aspects (e.g. winter feeding for Musk oxen, which might in turn have human impacts). Increased summer rain means increased river flow and consequently impacts on fish.

Physical impacts:

A physical impact would be coastal erosion.

Biological impacts:

Reduced or changed ice cover could have numerous biological impacts. These include:

- impacts on vegetation, affecting feeding areas for Musk ox, for example;
- a possible switch from primarily benthic to primarily pelagic production, which might affect anadromous fish stocks;
- impacts on Walrus haul outs;
- impacts on distribution of species like birds and Polar Bears (e.g. the issue of hybridization and the issue of carbon transfer with large sea bird colonies);
- impacts on shore birds, like mergansers;
- isolation of island populations that use sea ice to migrate, and changing population dynamics;
- loss of permafrost and lake habitat for lake fish;
- Impacts on land-based predators like Arctic Fox as seabirds disappear.

Human impacts:

These include increased hazards to humans from Polar Bears (more inland encounters). River fisheries could be impacted. With increased accessibility for shipping and industrial activity there will be a need for terrestrial bases, which will have impacts on ecosystems. Other issues include potential loss of tourism due to industrial effects and impacts on subsistence harvests.

4.4 Changes to the species mix as a result of sea ice change

Questions addressed under this theme included:

- What new species are likely to establish as a result of a reduction in sea ice?
- What are the positive and negative effects of changes to the species mix on other wildlife and people?
- What may happen to newcomer species that may take advantage of sea ice disappearance?

Global biodiversity is declining. Within this pattern, part of what characterizes the Arctic is the unique, charismatic mega-fauna that may be affected by loss of biodiversity. There are also species that may take advantage of the changes to extend their range. While Arctic Cod and large copepods are diminishing, there are increases in other species. Not all species will be equal in the changing relationships. In terms of incoming species, some will probably not be significant, while the arrival of Killer Whales for example will have a dramatic impact on marine mammal communities.

Some species currently play a pivotal role in Arctic ecology. Understanding the characteristics of those species that make them pivotal would make it easier to predict what the changes will be. For example, not much is known about Arctic Cod even though there has been much research on that species. They are a major organism for transferring lower-level production to higher-level consumers.

Some species have experienced significance range expansion. Salmon are extending their range to the Arctic, along with Herring and Pollock. Higher mammals like Grizzly Bears and Grey Whales have been sighted in the western Arctic. Humpback and Minke Whales are pushing into eastern areas. At the smaller scale, birds like the Razorbill, Black-backed Gull, White Tailed Eagle and Raven are also advancing.

Other changes include emergence of new, smaller copepods such as *Calanus pacificus* in the west and *C finnmarcaicus* in the east. This has an effect on the trophic food web. The bottom level of the food web pyramid is invisible but very important (algae and phytoplankton).

The trend that is most emphasized is the introduction of southern species into northern communities. However there are increasing arguments for diminished productivity within benthic communities. For example, in some areas, the abundance of small anthropods is growing but biomass as a whole is diminishing, so food for grey Whales is decreasing. Thus, we need to take into account biomass as well as the abundance numbers for each species.

Within species mixing and range extensions, there is also the opportunity for unwelcome invasive species. Some invasive species are brought by humans but others come on their own. Humans have been assisting the introduction of harmful/toxic microalgae and have introduced species through ship ballast. Invasive Snow Crab and King Crab are on the rise. The smaller the invasive species, the more difficult it is to deal with. In some cases species may successfully fill ecological niches and be adopted for future development. Accordingly, it is often impossible to determine whether an invasive species will result in a positive or negative effect.

Other themes related to humans include changes to human population sizes and distributions. In some parts of the Arctic, human populations have changed greatly over the last 50 years or so. The arrival of people resulted in important changes, and humans are important predators. At the same time, humans are increasingly threatened by Polar Bears, and they compete with hunters for Seals. Workshop participants recognized that there are differing views on some of these issues.

5 ISSUES FACING SEA ICE-ASSOCIATED BIODIVERSITY AND ACTIONS TO ADDRESS THEM

The second objective addressed at the workshop was to consider issues facing sea ice-associated biodiversity and what actions might be required to adapt to or mitigate the effects of reduced availability of Arctic sea ice. The results of these discussions, along with related plenary discussions, are summarized here in four categories.

5.1 Issue themes and categories

Urgent issues facing sea-ice associated biodiversity were identified. These included impacts on human communities and culture as well as biophysical issues. They converged on the following primary themes:

- Social, biological, and physical aspects
- Biological hotspots, i.e., where and what is most sensitive
- Increased industrialization and resource development
- Climatic and biophysical variation, e.g., ocean and atmospheric coupling
- Need for more research

It was noted that the lack of understanding of what is happening makes prediction difficult. Thus care must be taken with projections, as there is a risk of over-reliance on modelling and compensation for variations needs to be taken into account. At the same time, there is a large literature on outcomes, with only minor differences regarding variability in space and time (i.e., within two decades, there will be significant loss of sea ice throughout the Arctic Archipelago). The workshop considered:

- What are the important changes that are occurring?
- What are the consequences of these changes?

This perspective lead to four types of changes:

- Loss of multi-year ice (this began as “loss in the total extent of ice”)
- Changes in extent of seasonal ice
- Shifting timing and distribution of ice
- Changes in density and concentration (quality) of ice

It was noted that the two ways of organizing ideas outlined above could be expressed in a table with types of changes in ice across the top and issues regarding biological and human impacts grouped below those headings. This would make it convenient to address issues that come up in different areas, e.g., both seasonal and multi-year.

For the purpose of the workshop, ensuing discussions were organized by the four types of changes in ice. For each type, workshop participants discussed biophysical consequences, social-cultural and economic consequences, as relevant (and according to the expertise available in the discussion group). Then attention was turned to the actions required to adapt to or mitigate the effects of change in the ice. Participants reflected on the following three types of actions, with less emphasis on monitoring to avoid overlap with the monitoring project under the CBMP Marine Plan:

- Related information gaps that require targeted research

- Methods for monitoring sea-ice associated biodiversity
- Conservation actions required to mitigate impacts (broadly, from research to biodiversity monitoring plans)

5.2 Loss of multi-year ice

5.2.1 Issues

The discussion focused on multiyear ice and distinguishing this from seasonal ice. There will always be ice and there will always be seasonal ice but the primary concern is multi-year ice.

Physical/hydrological changes related to loss of multi-year ice

A number of physical changes will have consequences for biodiversity:

- The average age of the existing ice is 20 years. The ice accumulates over years; some survives the summer and contributes to multi-year ice. Over time, the mean age is falling, and will probably go down to about five years. A lowering of the average age of the ice leads to changes in the spatial distribution of the ice (as it changes, shrinks, and moves).
- There will be increased fragmentation.
- There is potential for the reconnection of the Atlantic and Pacific Oceans.
- The loss of multi-year ice will contribute to a shift in the climate system in the northern hemisphere.
- Less multi-year ice means less total area of the sea will be covered by ice, so more water will be exposed. This will create a larger surface area for CO^2 to get absorbed into water and will lead to increased acidification of the ocean.

Impacts on species, habitat and ecosystems

- At the southern edge, there is an increase in areas without ice. Organisms that depend on permanent ice may go extinct. Species that live with seasonal ice may move in.
- Fragmentation of ice cover may lead to difficulty in species finding places to breed.
- There are some places that Polar Bears can no longer gain access to. At the same time, other species, like Grizzly Bears, are expanding their areas.
- Where populations have been separated, ice receding could allow interbreeding and spread diseases that were formerly isolated.
- There is also loss of unique habitat and species that depend on them. For example, there were once six meltwater ponds on Ellesmere Island and now there is only one. Icewater dams are also melting. Changes are occurring in polynyas with consequences for habitat.

Safety and security

- People in the high Arctic depend on ice to travel to resources such as Caribou and Muskox. As the ice thins, hunting becomes more dangerous, and this is happening in many traditional hunting areas. Thus, ice disappearing has impacts on safety and food security.

Changes to industry

- Less ice will decrease impediments to shipping, and the increased potential for industries has many implications.
- As new industries arrive in the north, there could be an influx of people, which could lead to the creation of new communities.
- Expansion of industry will have positive economic impacts (e.g. increased employment) as well as negative impacts (e.g. on fisheries or tourism).
- There could be regional variation in impacts, e.g. fisheries could be negatively impacted in some areas and positively impacted in others. There can also be mixed impacts within a single industry in a single region.

Impacts on fisheries

- Impacts on fisheries may be complex within regions. For example, the Barents Sea marginal ice zone is retreating northward and eastward. The fish are following the ice zone retreat, fishermen are following the fish, and so far the fisheries have not collapsed. However, the prediction is that the marginal ice zone will recede into the area between Norway and Russia, so fisheries will cut then across international boundaries.
- Increased productivity for fisheries at international boundaries could lead to conflict.
- There is unlikely to be a major surge in productivity of fisheries, as happened in Peru.
- Above the ice, it is relatively easy to observe processes and understand regional differences and local issues, as compared to going below water.
- Local people are finding that as the fishing industry expands humans are beginning to fish the same species that other species rely on. For example, Beluga and Narwhal rely on Turbot, and now there will be a Turbot fishery.

5.2.2 Actions

Addressing impacts on species, habitat and ecosystems

- Ensure all unique habitats are identified. Work with local authorities to prevent loss of unique habitat. Use those that have already been lost as examples to illustrate key messages.
- Undertake genetics and other research to determine if, when, and where re-connection of species is happening, and if it is posing a problem. Conservation actions would depend on the nature and extent of the problem.
- Seek improved satellite coverage of selected areas to monitor changes in polynyas, especially those where current research is identifying the greatest impacts of increased wind on distribution of species.
- Increase research and monitoring of ocean acidification. Identify and monitor changes in current (and future) areas of sensitive habitat for species, e.g., less for Polar Bears, more for Seals.

Addressing safety and security

- Identify key areas that require improved monitoring of ice conditions.
- Increase community education and outreach to raise awareness and prevent accidents.
- Research the extent and nature of contamination of wildlife resources and people by industry in the north and elsewhere, which affects food security.

- Improve consistency of monitoring activities.
- Conduct outreach and education through community health centres (which could also engage in monitoring activities).

Integrated assessment and planning for expansion of industrial activities

- Identify sensitive areas and develop inventories.
- Learn what industrial activities are planned, and where;
- Determine potential and cumulative impacts and compare these with areas where ice loss has already happened and impacts are being observed.
- Integrate ecosystem assessments and planning.
- Develop policies and regulations around oil spills (impacts and responses), oil and gas development, shipping and tourism activities, and mineral extraction.
- Identify current and potential hot spots to forecast problems arising from current activities.
- Plan future industrial activity.

Research on fisheries

- Research may be needed to identify changes in migration and breeding patterns due to loss of multi-year ice that effect changes in fisheries.

5.3 Changes in extent of seasonal sea ice

5.3.1 Issues

Seasonal changes and phytoplankton

- There will be reduced ice in summers but increased seasonal ice from fall to spring. It will fall into a similar cycle as at temperate latitudes. The expansion of open water in the summer (along with loss of multi-year ice) will lead to phytoplankton blooms (both primary and secondary production).

Redistribution of species

- There will be changes in distribution of ice-obligate species at the southern end of the seasonal ice.

Changing harvesting opportunities

- The consequences of seasonal ice changes for hunters will vary with people's ability to access resources.

Increase in UV radiation

- UV radiation will increase in the summer, with greater penetration and irradiance on the water surface. This will have mostly negative impacts on species.

Coastal erosion

- With decreasing ice (multi-year ice or seasonal), there is increasing fetch and therefore stronger wind action on the shoreline, increasing coastal erosion.

5.3.2 Actions

Adaptations related to wildlife harvesting

- If the Polar Bear population gets too large, there may be many less healthy bears competing for the same food supplies. A two-pronged approach would start at the community level by recognizing systems of traditional management based on what people know. However, in some parts of the north, that is not sufficient, so there must be a regulatory backstop in place to support wildlife populations and ensure community access.

Research on migratory species (Caribou, Seabirds)

- Species such as Caribou may be unable to follow migratory routes because of open water barriers. Research is required on the cumulative effects of the movements of migratory species across areas. Linkages with large ocean management area (LOMA) planning may be worth exploring to support this research.

Research on UV irradiation

- Consolidate existing knowledge, identify research gaps, and determine where to go from there.

Mitigating coastal erosion

- Monitor coastal erosion, strive to anticipate future impacts, and work with communities to plan mitigation.
- Communities could be monitored to determine if there is a need to move a community or take other actions to help the community adapt.

Large Ocean Management Areas

- To manage ecosystems/seascapes create LOMAs, which can help address issues within defined areas. Bring together communities, NGOs and governments to develop action plans specific to those areas.
- Connect adjacent areas to address issues of common concern (e.g. drift ice). For example even though a LOMA is a non-regulatory body, it could make recommendations about where, how much, and how often to allow ocean vessel traffic onto resource sites, from the perspective of habitat management.

5.4 Shifting timing and distribution of ice

From a biodiversity perspective, the loss of multi-year sea ice may be less important than the shifting timing and chronology of Arctic sea ice, particularly in the first part of the year in annual ice. There is total ice and seasonal ice, and between those there is timing. The seasons are lengthening, with consequences that do not relate to total disappearance of sea ice.

5.4.1 Issues

Issues related to shifting timing and distribution of sea ice includes:

- There will be distributional changes in the location of first-year ice – the area it covers as it moves north.
- Shifting timing could have impacts on migratory species.
- There will be increased access for sub-polar temperate species.
- Uncertain freeze-up times could lead to ice entrapment of species; e.g. there are more cases of ice entrapment of Whales because of the lowered predictability of ice formation in fall.

5.4.2 Actions

Actions related to impacts on migratory species

- Knowing about the impacts on migratory animals could suggest research directions. A possible action would be changing the timing of shipping so as not to interfere with the movements and breeding of migratory species.

Relevance of life history to adaptation

- Changes in ice might interfere with ("mismatch") species' ability to time critical life events with other ecosystem events. A species' ability to reproduce is determined by when they do what. For example, once a bird lays eggs, or an embryo is implanted in a marine mammal, the timing of everything else is fixed. Much depends on the degree to which an organism determines events in its life history. If its life events are genetically determined, adaptation will be slow and possibly unsuccessful. In contrast, if events are behaviourally determined, the organism may be able to adapt with changing processes instead of through evolution. In general, the mismatch is likely to be more significant for organisms that are higher in the food chain – phytoplankton will be less vulnerable than Seals. The number of species for which this information is available small, so discussion focused research gaps rather than actions, though the possibility of translocation of species to make impacts less severe was touched on.

Research on distribution of biological diversity

- Knowledge of how biological diversity is distributed in the Arctic is insufficient. Distribution of vertebrates is relatively well known, although less so in the central Arctic Ocean. The distribution of invertebrates is not very well known, especially at the lower tropic levels. This leads to difficulty in assessing where the main biological diversity lies. Areas with high diversity will be the areas of greatest concern.

- When looking at the scale of the Arctic basin and its biodiversity, the microbiota is important. The larger animals are less relevant in the basin than they are on the shelves. The areas of most fundamental importance lie at the lower trophic levels.

Research on winter processes

- A large gap in knowledge is about winter processes. As spring comes earlier, there is a need to know what ice season activities will be most affected as opposed to non-ice season activities.

Other research gaps

- Which species will be more affected—those that are highly productive species or those that are less productive?
- There is a lack of information about predator-prey interactions, and other interactions. Interactions are important and yet difficult to study. Knowing more about them might increase understanding of how communities are going to respond.
- Genetic diversity will be affected as previously separated groups begin interbreeding. How genetic diversity develops may be important in determining how well species adapt to environmental changes.
- Change from larger to smaller cell phytoplankton will have reverberating consequences throughout the food chain. Some of this is already being observed, but the long-term consequences are not yet known.
- There is a particular need for more research in the central Arctic Ocean.

5.5 Changes in density and concentration (quality) of ice

The density or concentration (distinct from thickness) of ice is changing. The following changes in the type and characteristics of ice were noted:

- Changes in density, thickness, and composition of ice will impact habitat.
- Increased fetch results in rubble ice as opposed to land-fast ice and this can restrict species access to other species. For example, Polar Bears (and humans) may find their ability to hunt Seals restricted by rubble ice.
- Pressure ridges will still be created by the interaction between land-fast ice and currents, but there will be shrinkage in size.
- More pieces of ice will be released through the archipelago, making shipping more dangerous.

Changes related to snow and ices were also discussed. Less snow will accumulate on open ice, because increased wind will blow more snow onto the ocean. Thus, even though there will be more snow, there could be less depth of snow on the ice, possibly impacting, for example, the ring seal population. More snow on the ocean will introduce more fresh water into the ocean water.

The actions generated by the group of workshop participants that focused on changes in sea ice density and concentration were of a cross-cutting nature and are included in the following section.

5.6 Other issues and actions

Suggestions from workshop participants that do not fit easily within the above four areas, or cut across them, are listed here.

5.6.1 Conservation areas and zoning

- Climate scenarios and stressors should be addressed via a network of SMAs, marine protected areas, and a zoned approach to identifying key resilient features and areas. This requires development and implementation of an international, systems-based, strategic-planning approach.
- Improved understanding of multi-year and annual iceshifts should be pursued by establishing firm baseline data and modelling of downscaled climate change scenarios (re trophic-level changes) to project future key areas for research and protection.
- To maximize the impact of Arctic research, areas have to be set aside from development.
- It is widely known that ice persists the longest in the high Arctic. Science is showing that this is a special area and a major hot spot.

5.6.2 A circumpolar monitoring network, and investment in research and monitoring

- All assessments to date have highlighted the decline of monitoring across the board, which indicates that these issues are not being taken seriously. Documentation is needed to illustrate the problems, and a broad overview is lacking. These factors point to the need to establish and resource a network of bio-physical monitoring sites across the circumpolar north that supports a combination of monitoring and research activities, with an emphasis on community engagement.
- Creating a network of monitoring stations does not have to mean new infrastructure. In Alaska, a new cooperative conservation and monitoring program was recently opened. It is a multi-agency partnership that is deciding on priorities and research. Its scope covers everything north of the Brooks Range and extends into Canada.
- Unless the new initiative is significantly different, the response will be “we’ve already got it.” (And even if the proposed system is necessary, more could be done with what we have now.) The potential overlap with, and role of existing initiatives should be considered :
    - To address the input of contaminants from continental sources, consider encouraging AMAP to expand the network of monitoring stations in the circumpolar area.
    - The CBMPs marine monitoring plan was based on existing data collections and determining which locations might be best for contributing information on the Arctic. It is not intending to set up a new network or seek funding.
    - CAFF is useful in promoting further investment by the government in Arctic research.
    - US researchers are setting up DBOs at a few stations where people have been sampling in the same locations for a long time.
    - Another gap related to monitoring on-the-ground biodiversity is an adjusted Seaways. By using remote sensing as a proxy for biodiversity, much of the monitoring work is already done, although it would need to be ground-checked.
- The best chance of having significant funding sustained may be to move out of the biodiversity box and into an ecosystem environment monitoring network. The network could then be used for many phenomena besides biodiversity, which need to be tied together to create a better chance of making sense. An ecosystem approach can be inclusive of all the trophic levels.

5.6.3 *Improving understanding and use of Indigenous and local knowledge*

- In Nunavut, there is a gulf between scientific and traditional knowledge—a sandpaper effect between people who are doing good research and people who live there. Ways need to be found to involve more of the people who live there in research and science.
- There is much support from northerners for science working on Arctic species but there are questions about the methods. The methods that have evolved for gathering information on wildlife tend to be intrusive and there is a lack of explanation about what needs to be done. Sometimes it seems that scientists are just playing with the animals.
- Other issues include:
    - Biologists take information from the region and local people are not informed of the results.
    - Is knowledge individually owned or is it collective? For example, a hunter may have learned from different people how to dress an animal, but then they take what they like and add to their method, making it their own. Who does that knowledge belong to?
    - Scientists want to access traditional knowledge for free, yet scientists are not asked to work for free.
    - Often scientists use traditional and local knowledge in their publications, which are then owned by the researcher or university, so the people who were the source of the knowledge need permission to use the publications.
    - There are ethics around how traditional knowledge is interpreted. Elders may not have PhDs, but in some cases their knowledge may be better because it goes back thousands of years.
    - Arctic research is often being done by professors and university students when it could be done by local people.
- Momentum is building in Nunavut involve local people in designing and implementing surveys and drawing conclusions. Forums should be held to meet with local people and discuss research findings, without politicians or decision makers present, to help people get involved.
- Community and local knowledge should not be ignored in contrast with “traditional knowledge.” Local experience of climate change impacts is not traditional, but it is on-the-ground, local knowledge and is important.

Local involvement in monitoring

- Workshop participants emphasized the need for greater efforts to get local communities involved in monitoring. Much information could be recorded on a more ongoing (longer term, less seasonal) basis than what many current studies offer.
- Community-based monitoring can be less costly, yet there can still be major expenses such as helicopter time. Government funding is limited, so efficiencies have to be sought. The Bering Sea network has been very successful in attracting funding for community based work.
- One example of including traditional knowledge and involving more northern residents in monitoring is monitoring for land birds through a program that is essentially citizen science – volunteers contribute to a database. This could be done in communities throughout the Arctic.
- A Nunavut version of a community-based monitoring program in which local people can be involved throughout the year is needed. Perhaps local people could be paid to

contribute information that is organized, used systematically, and properly integrated with the overall plan.

- Hunters are embracing technology, for example, by using computer animations for harvesting applications in their own language. This demonstrates their capacity to use scientific monitoring tools. They can go hunting, gather information, and then input that into the system. In some cases, hunters are doing seal tagging without scientists helping. They do the tagging, take biopsies, analyze biopsy samples, and do it more economically than scientists can.

5.6.4 Attention to lower trophic levels

- Stemming from the ways people value different types of biodiversity, upper trophic levels receive more attention than lower trophic levels even though lower levels are integral to the ecosystem. Biodiversity should be documented at the lower trophic levels.

- Non-profit groups tend to address issues at the upper trophic levels, so concerted effort is needed to interest NGOs and the public in the micro-biota at the lower trophic levels.
- There is a need for political awareness and the will to take action on all the issues, not just the popular ones.
- Primary production should be monitored in the deep basin.

5.6.5 Need for coordination

- There is a shortage of expertise worldwide, especially regarding the lower trophic levels. There is a lack of capacity in physical stations but also a lack of scientists passing knowledge along to the next generation. There needs to be better communication among people who are doing this work, beyond publishing papers.
- Information that emerges from research has to get to the right people to ensure that it informs actions. For example, there is a lack of planning around the creation of parks in Russia. A lot of this kind of information can feed into where parks are planned.
- Protection of any ecosystem is all the more difficult if the ecosystem is mobile and/or is in international waters.
- Issues of concern are large scale, encompassing many countries, and the whole of the issues is greater than the sum of its parts: changes to Arctic ice will affect countries throughout the world, not just Arctic nations.
- In Canada, the US, and Russia, existing organizations can (and in some cases do) react fairly quickly. There is an opportunity to enhance those inter-jurisdictional activities and abilities.
- Fisheries and Oceans Canada documented how international research helps the department do its research. It is about selling the value of the science from an applied perspective. That may suggest an avenue to demonstrating how research throughout the trophic levels contributes to priorities.
- Ideally, international, systems-based strategic planning/sea ice scenarios would be generated that address climate change scenarios and cumulative stressors via a network of special management areas or marine protected areas and a zoned approach, with attention to key resilient features/areas.

6 THE TECHNICAL REPORT

The CAFF Steering Committee drafted an outline of the technical report that participants reviewed and accepted. The outline was revised subsequent to the meeting to reflect participant comments and is included later in this section, along with an approach to assembling the report, responsibilities and a timeline. Workshop participants generated overall priorities for the report and listed some key messages, also included below.

6.1 Priorities for the report

Workshop participants had a number of suggestions for ensuring the report has impact. Their comments are clustered into eight categories below.

Get people's attention

- Keep in mind that there is "monitoring report fatigue" and make sure we are contributing something new. Shape the message to make people pay attention until they get it – to break out of the mould of using science to preach to scientists.
- Topics that might catch people's attention include:
  - Movement of key fisheries into other jurisdictions;
  - The vulnerability of lifestyles;
  - The "warm Arctic, cold continent" effect;
  - relation of loss of sea ice and sea level rise to global cryospheric change (millions of people will be affected by sea level rise by 2100);
  - The area or species with the greatest vulnerability, species going extinct, ecosystems at high risk of extinction.
  - The concept of Security (services food security) should be a key selling point for the report.
  - The mega-fauna need to be emphasized - Bowhead, Narwhale and Polar Bear so as to attract attention. To consider what happens to species highly adapted to sea ice ecosystem – will these go extinct etc.
  - Conversely we need to find a way to ensure that the lower trophic levels are not neglected and whose importance can be easily communicated. To consider human valuation of biodiversity and the tendency to over emphasise higher trophic levels.
  - The concept of uncertainty should run throughout the report. That is, given the changes taking place and the rate of these changes there is no going back.
  - A key issue to be highlighted is the transition between ice types i.e. what does this mean and what can be done about it. What can be done to address this situation and what are the plausible actions that could be taken.
  - To emphasise throughout the report the human dimension, how they are an integral component of the ecosystem and what impact the changes will have on humans both regionally and globally. For example, one impact can perhaps be seen in the concurrent decline of biodiversity and cultural diversity and the loss of verbally transmitted cultural knowledge. What is the capacity to adapt to and respond to these changes?

- The uniqueness of this ecosystem and the species it contains. The loss of critical habitat and alteration of key processes.
- The rate of loss being experienced and the consequent issues of new species expansion i.e. invasive species.
- Changes in extent and rate of development (natural resource exploitation, minerals, fisheries, population changes (influx of people and communities, shipping etc), increased access to resources and the resulting impacts.
- To highlight the global effects and linkages that changes to Arctic sea-ice-associated biodiversity have both regionally and globally.
- The lack of information and Arctic-wide integrated datasets and monitoring.
- The lack of political will and the need to engage decision makers.
- Methods for ecosystem conservation especially with regards to international waters and mobile ecosystems and lack of implementation of ecosystem based management plans. The role of hotspots – marine sensitive areas and their identification.
    -
- With an ecosystem focus, the recommendations could be about how governments could protect the whole instead of just place- or species-based issues.

Use different versions for different audiences

- Determine who the audience is and speak to their level of knowledge. Decision makers may not see things in terms of scientific headings, so translate science into terms that mean something to the intended audience.
- The project will produce three products:
    - The technical report will address people with more scientific background. It will provide the factual underpinnings for the recommendations.
    - A second report will contain policy recommendations for decision makers and provide background in lay terms.
    - A third product will consist of communications tools for public consumption, directed at individuals, teachers, school children, etc., with suggestions as to what individuals can do.

Document impacts to leverage action

- In issue areas where little can be done, it is appropriate to discuss ways to mitigate the damage. At the same time, those examples can be used in political arena as leverage to illustrate the larger, long-term implications of loss of loss of habitat.
- There is a multiplicity of layers from which to suggest policy development or changes.
- When stories about Polar Bears and sea ice decline are expressed as barometers of the unpleasant and costly global changes we are facing in the future, insurance companies take notice. This adds impact to policy recommendations. So even where there is little we can do directly, we can use the information as examples to help effect policy changes that will prevent similar problems in the future.

Influence policy

- After considering trends, changes, impacts and urgent issues, the attempts of workshop participants to identify actions often resulted in a conclusion that “little can be done” to mitigate or adapt to impacts. This highlighted the need for action at a broader, policy scale to address the human causes of climate change.
- In order to address the conservation of Arctic biodiversity the threats must be addressed and that is difficult, based on the current evidence. Monitoring alone does not address the threats, especially when there is evidence of runaway change and an out-dated approach is still being taken. The report has to be the engine that will develop a more focussed assessment in a shorter time-span so that we can get information to ministers and more focussed policy recommendations.
- The shortest distance between science and policy is an assessment. Assessments have an after- or during- process of policy development. Politicians have to be convinced that is a clear and present danger. A problem in the past has been the duration of time between the start and delivery of an assessment, development of considerations for policy, etc. The important factor is not so much the enunciation of issues but about the timing and speed of delivery.
- Most countries have two mechanisms for enacting policy: protection of species and protection of places. These are the vehicles through which things happen.
- Politicians want to see actions delivered through their own endorsed procedures, so ensure that their people are involved. Yet this is a challenge in the Arctic, because there are not many people working on this region. By comparison, NASA recently allocated $560 million to work on the Pacific Ocean – a budget of this size would go far in the Arctic.
- CAFF’s Arctic biodiversity assessments are already starting to influence policy in the member countries of the Arctic Council. This work will directly influence what we do in such forums.

Include human aspects

- Take care to ensure that biodiversity includes humans. Pictures of the food chain tend to be missing people at the top.
- Keep returning to the people connection – both local people and their ability to access mega-fauna (and the differing opinions connected with such issues) – in order for this report to make a worthy difference.
- This is not only about conservation but also responsible, sustainable use of sea ice-associated biodiversity. Sustainable use is part of conservation.

Be clear about scale, scope, and limits of knowledge

- Consider spatial as well as temporal scales, considering about how far back in time to go. Take care not to overemphasize the past rather than the future – the real value-added will be in looking forward and making recommendations.
- Explain that this is about areas that have been changed and what we do about them, as well as the areas that remain.
- Allow that there will be more to say about changes in seasonal sea ice than multi-year ice, because we know more and there is more biodiversity.

- Be careful with predictions. When people in the north hear about models projecting Polar Bear extinction 50 years from now, they become sceptical. The projections section of the report must be very science based.
- Make sure that the report reflects the gaps in our knowledge about biodiversity.

Provide definitions and explain key concepts

- Define “sea-ice associated ecosystem.”
- Establish the difference between sea-ice-dependent and sea-ice-associated species at the outset so as to provide the science underpinnings to ensure that possible consequences, such as key species extinctions, make sense.
- Provide context about ice – the types of ice (multi-year and annual), the impacts of each on marine birds or mammals, the connections of the ice to the land and the ice caps, and the different types of ice habitat. This is complicated, yet essential to predicting the future of ice-associated species and helping people understand the causes of the changes.
- Include throughout the report the perspective that, as multiyear ice decreases, seasonal ice will increase.

Choose a focus: species to ecosystems

- One perspective was to profile mega-fauna because it gets people interested. Focusing on mega-fauna could also help to explain the uniqueness of sea ice associated-biodiversity – a leftover from the ice age. Assess the uniqueness of this fauna relative to other biogeographic regions.
- Another perspective was that the ecosystem approach may be a “harder sell” but people have to understand that mega-fauna only survive through dependence on a whole ecosystem. The same is true for the microscopic layer on the base of the sea ice. Over 200 species of diatoms live inside the sea ice. People are attracted to bigger species, but this level of biodiversity is incomparable.

6.2 Key messages

Workshop participants pointed out the importance of avoiding a litany of key messages and crafting instead a few hard-hitting ones. The key messages could be stated in a preamble, before the introduction, and the material that follows should support them. Following are the top-of-mind ideas for key messages from the workshop.

- Global connections to climate change, i.e., what all of this means to people inside and outside of the Arctic (as SWIPA dealt with chemical and ecospheric processes, and higher order changes in terms of human systems) Loss of polar ice caps will affect global climate.
- The ice will always be there but there will be loss or severe degradation of multi-year ice, and we don’t know what that means or if it can be replaced by seasonal ice.
- Humans are part of biodiversity.
- Changes predicted in an Arctic with a longer ice-free season
- Ecosystem
- Uniqueness of sea-ice habitat
- Rapid loss of species, habitats, and ecosystems

- Cumulative effects of multiple stressors
- No going back – unidirectional timeline
- Impact on culture
- Adaptation and capacity to adapt
- Altered services required to address decreased food security, etc.
- Growth in some areas, such as new species coming in
- Conservation efforts and remediation
- Proximate versus ultimate causation

6.3 Draft outline for the report

NOTE: the following outline should be considered as a record of what was presented at the workshop recognizing that this outline will be updated based on comments received.]

Draft outline - *50 pages total*

- *for a technical report on the effects of sea-ice loss on biodiversity in the Arctic*

1. **Key messages** - *1 page*

2. **Introduction** – *3 pages*
   - Why is sea-ice associated biodiversity important and how is it unique?
   - Why do changes to sea-ice associated biodiversity matter?
   - What are the consequences of changes in sea-ice for sea-ice associated biodiversity and what are the potential solutions?
   - Who and what do these changes in biodiversity affect?
   - What are the regional/global impacts of these changes?
   - Goals and objectives of this report

3. **Context** – *2 pages*
   - Where did this project originate i.e. in the key findings of the Arctic Biodiversity Trends 2010 report
   - The role of this project and what new perspective it brings
   - Outline how the report links to and builds upon the results/methods from: the ABA, SWIPA, CBMP, RACER and other ongoing projects which are addressing the identification of marine sensitive areas in the Arctic i.e. AMSA(II)c and IUCN etc
   - The scope of the project i.e. spatial and temporal
   - Project structure and timeline
   - Ecosystem based approach

4. **Arctic sea-ice associated biodiversity introduction -** 2 pages
   - *the physical nature of Arctic sea ice capturing the extent, distribution, timing and structure of seasonal and multi-year ice*

     Sections summarizing the status and trends, vulnerabilities and major impacts on sea-ice-associated biodiversity

4.1 Status, trends and vulnerabilities for biota related to changes in extent of multi-year sea ice, – *5 pages*

- General current use of multi-year ice by biodiversity
- Impacts of changes in multi-year ice on biodiversity:
    - reduction in extent
    - change in distribution
    - change in timing
    - change in structure
    - change in human activity and corresponding effects on biota

4.2 Status, trends and vulnerabilities for biota related to changes in seasonal ice – 12 pages

- General current use of seasonal ice by biodiversity
- impacts of changes in seasonal ice on biodiversity:
    - change in extent/proportion
    - change in geographic distribution
    - change in timing
    - change in human activity and corresponding effects on biota

5. **Human dimension** – *10 pages*

   Suggested themes:

   - Human dimension e.g. restriction on movements and travel leading to increased reliance on boats and machinery
   - Food security and the potential effects
   - incorporation of local knowledge and science
   - Impact of changes to communities as changes in ice makes Arctic more accessible to economic development.

6. **Future projections for changes to sea-ice-associated biodiversity** – *10 pages*
   - longer time scale than will be considered in section 4

7. **Conservation and scientific recommendations** – *5 pages*

8. **References**
   -

9. **Suggested box texts:**
   - A text outlining the uniqueness of vertebrate fauna
   - A text linking the Arctic and the AntArctic e.g. Arctic terns, migrating marine mammals
   - A text providing a contrast between an indigenous perspective and a traditional Scientific approach e.g. on Polar Bears perhaps using a regional perspective
   - A text providing an overview of ice and the key physical aspects/changes

- A text using defining what is meant by the term biodiversity
- A box text(s) on specific marine mammals
- What happens to highly adapted sea-ice associated species - are these the first to go, which ones are they etc
- Methods for ecosystem protection especially with regards to international waters and mobile ecosystems.
- How to bridge the gap between science and traditional knowledge. Involving knowledge keepers and community members in information gathering and conservation processes.
- The effects of changes in sea-ice-associated biodiversity on terrestrial ecosystems

6.4 Report assembly

Donaldson discussed the report's assembly as an introduction to asking workshop participants which aspects of the report they would like to contribute to. He noted that he would serve as the report's managing editor, gathering contributions from people and pulling them into the document, with help from Tom Barry. The process will be as transparent as possible, with frequent updates, possibly using a web-based networking tool. What the group is working toward at this point is not the final product but it will feed into the document to be produced by the end of August and discussed in Russia. Recommendations will be developed after that. The time-frame is short, so efficiency is important.

Gardner asked participants to consider two questions: What can you write (on what topic and for what section of the outline)? And who else can you suggest we call on to write a section? Participants were assured that, given that each has expertise in a particular geographic part of the Arctic; contributions do not necessarily need to be circumpolar in scope. Furthermore, several people who could not attend the workshop have expressed interest in this project and asked to be kept informed of developments – they too can be approached to contribute.

6.5 Timeline for report production

The goal is for the draft report to be finished in August in time to be presented at the workshop in Russia in September. It will be produced on a tight timeline, with publication and release happening in April 2012.

The five phases of the project timeline are as follows:

Phase 1: Detailed outline to be completed by the end of May, 2011.

Phase 2: Draft technical report to be completed by the end of August, 2011.

Phase 3: Present the draft report at workshop in Russia in September and use input to develop conservation and scientific recommendations by the end of September, 2011.

Phase 4: Three months for review from October to December, 2011. Ideally this will include a scientific review by key people who were not involved in the process, a national review, and an internal review.

Phase 5: Incorporate changes and develop policy recommendations and summary by March 2012, so the report can be released at the IPY conference in Montreal in April, 2012.

Two points raised by workshop participants emphasized the tight timeline: the time required to pull together local and traditional knowledge for the human dimension, and the time that review processes usually take. CAFF management will do their best to make all processes efficient, drawing on membership of the CAFF board to streamline communications.

7 CLOSE

Melnikov expressed gratitude, on the verge of his retirement, for the invitation to participate in the workshop and the warm reception. Many others around the table echoed the sentiment that the workshop had been a very good experience and they look forward to continuing the work.

Gardner lauded the group for their interest, energy and commitment to the work, to the extent that the workshop objectives were fulfilled with time to spare.

Steering Committee members were unanimous in their appreciation for the hard work of the participants at the workshop and are looking forward to working with them as well as others who could not be in attendance in the months to come.

8 APPENDIX 1: LIST OF PARTICIPANTS

Surname	first name(s)	Organization
Barry	Tom	Conservation of Arctic Flora and Fauna (CAFF)
Dickson	Cindy	Arctic Athabascan Council (AAC)
Ewins	Peter	World Wildlife Fund – Arctic
Alidina	Hussein	World Wildlife Fund – Arctic
Ferguson	Stephen	Fisheries and Oceans Canada
Tomascik	Tomas	Parks Canada
Nirlungayuk	Gabriel	Nunavut Tunggavik Inc
Richardson	Evan	Environment Canada
Poulin	Michel	Canadian Museum of Nature
Reist	Jim	Department of Fisheries and Oceans
Boertmann	David	Danish National Environmental Research Institute -
Belikov	Stanislav	All-Russian Research Institute for Nature Protection
Mordvintsev	Ilya	A.N. Severtsov Institute of the Ecology and Evolution, Russian Academy of Sciences
Tomascik	Tomas	Parks Canada
Melnikov	Igor	Shirshov Institute of Oceanology
Hohn	Janet	US Fish and Wildlife Service
Majewski	Andy	Department of Fisheries and Oceans
Fortier	Jerome	Danish National Environmental Research Institute -
Hayes	Trish	Environment Canada
Dominique	Robert	Québec-Océan
Watkins	Jill	Fisheries and Oceans Canada
Donaldson	Gary	Environment Canada
Gaston	Tony	Environment Canada
Smith	Duane	Inuit Circumpolar Council (ICC)
Thompson	Amy	Gwich'in Council International
Carpenter	Larry	Wildlife Management Advisory Council (NWT)
Gorman	Kristen B.	Association of Early Polar Career Scientists (APECS)
Staples	Lindsay	Wildlife Management Advisory Council (North Slope)
Hardy	Sarah	Association of Early Polar Career Scientists (APECS)

9 APPENDIX 2: RESPONSIBILITIES FOR WRITING SECTIONS OF THE REPORT

[NOTE: this section reflects offers made to write sections by participants who where present at the workshop. In some cases, suggestions were made on others who might be able to contribute – these should not be misconstrued as commitments on their part.]

Texts	Coordinators	Contributors	Suggested authors
Key messages	Jill watkins (?)	Steering Committee	
Introduction	Gary		
Context	Gary/Tony Gaston (see comment)		
Arctic sea-ice associated biodiversity	Gary / Kristen Gorman	Igor Melnikov (see comment)	George Hunt / Rolf Gradinger /Christine Michelle
Biological impacts of projected reduction in extent of multi-year sea ice	Gary / Kristen Gorman	Igor Melnikov (see comment)	George Hunt / Rolf Gradinger /Christine Michelle
Marine mammals		Stanislav Belikov /David Boertmann/Stephen Ferguson / Igor Melnikov/Evan Richardson	Kit Kovacs / Kristin Laidre
Seabirds		Kristen Gorman /David Boertmann/Jerome Fortier/Tony Gaston	Maria Gavrilo
Fish		Kristen Gorman /Robert Dominique/Andy Majewski	Brenda Cohner (?) / Brenda Noracross (?) / /Christine Michelle
Plankton		Robert Dominique	Russ Hopcroft / Michelle Gossian / Connie Lovejoy /Jean Eric?
Benthos		Kristen Gorman /Sarah Harding	Phil Rochebreaux (?)
Algae		Michel Poulin	
Genetics	Sarah Harding (?)	Sarah Harding	Phil Rochebreaux (?)

Biological impacts of early changes to extent of seasonal ice	Gary / Kristen Gorman	Igor Melnikov (see comment)	George Hunt / Rolf Gradinger /Christine Michelle
Marine mammals		Stanislav Belikov /David Boertmann/Stephen Ferguson / Igor Melnikov/Evan Richardson	Kit Kovacs / Kristin Laidre
Seabirds		Kristen Gorman /David Boertmann/Jerome Fortier/Tony Gaston	Maria Gavrilo
Fish		Kristen Gorman /Robert Dominique/Andy Majewski	Brenda Cohner (?) / Brenda Noracross (?) / /Christine Michelle
Plankton		Robert Dominique	Russ Hopcroft / Michelle Gossian / Connie Lovejoy /Jean Eric?
Benthos		Kristen Gorman /Sarah Harding	Phil Rochebreaux (?)
Algae		Michel Poulin	
Genetics	Sarah Harding (?)	Sarah Harding	Phil Rochebreaux (?)
Biological impacts of eventual reduction in extent of seasonal ice	Gary / Kristen Gorman	Igor Melnikov (see comment)	George Hunt / Rolf Gradinger /Christine Michelle
Marine mammals		Stanislav Belikov /David Boertmann/Stephen Ferguson / Igor Melnikov/Evan Richardson	Kit Kovacs / Kristin Laidre
Seabirds		Kristen Gorman /David Boertmann/Jerome Fortier/Tony Gaston	Maria Gavrilo
Fish		Kristen Gorman /Robert Dominique/Andy Majewski	Brenda Cohner (?) / Brenda Noracross (?) / /Christine Michelle
Plankton		Robert Dominique	Russ Hopcroft / Michelle Gossian / Connie Lovejoy /Jean Eric?
Benthos		Kristen Gorman /Sarah Harding	Phil Rochebreaux (?)
Algae		Michel Poulin	

Genetics	Sarah Harding (?)	Sarah Harding	Phil Rochebreaux (?)
Human considerations	Tom (? I could perhps coordinate this section)	Gabriel Nirlungayuk / Larry Carpenter	Victoria Gofman / Harry Brower / Lene Kielsen /Shari Garhead
Future projections for changes to sea-ice-associated biodiversity	Peter Ewins (?)	Jerome Fortier	Martin Sommerkorn / Bruno Travle (? Mgill University) /Stephanie firman (Columbia University)
Conservation and scientific recommendations	Jill watkins (?)	Steering Committee	
Box texts			
A text outlining the uniqueness of vertebrate fauna	Tony Gaston		
A text linking the Arctic and the Antarctic e.g. Arctic terns, migrating marine mammals	Kristen Gorman		Carsten Egevang
A text providing a contrast between an indigenous perspective and a traditional Scientific approach e.g. on polar bears perhaps using a regional perspective	Gabriel Nirlungayuk		
A text providing an overview of ice and the key physical aspects/changes	□	□	
A text using defining what is meant by the term biodiversity			
A box text(s) on specific marine mammals			
What happens to highly adapted sea-ice associated species - are these the first to go, which ones are they etc			

How to bridge the gap between science and traditional knowledge. Involving knowledge keepers and community members in information gathering and conservation processes.			Mike Gill
Methods for ecosystem protection especially with regards to international waters and mobile ecosystems.			
The effects of changes in sea-ice-associated biodiversity on terrestrial ecosystems			