Arctic sea ice associated biodiversity:

importance and challenges[1]

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Current Status

- Arctic sea ice has decreased rapidly and substantially in extent and thickness in the past 30 years[2]. Sea ice is being lost at a faster rate than projected by even the most pessimistic of climate change scenarios.
- Biodiversity is experiencing a variety of impacts as the sea ice changes. It is not clear exactly what will happen as sea ice continues to disappear.
- The ongoing trend of declining sea ice is likely to lead to changes in the sea-ice ecosystem shifting toward a open water, sub-Arctic ecosystem[3] over a larger area[4,5].
- Species' responses to shrinking sea ice will depend upon their ability to adapt, their natural history, and the scale of environmental changes which may take place.

Issues

- Arctic species are likely to face competition for food and habitat from sub-Arctic species, which are experiencing a range expansions due to increased phytoplankton

1 This document is summarised from recent CAFF publications on Arctic sea ice associated biodiversity

2 National Snow and Ice Data Center (NSIDC). http://nsidc. org [Accessed 12 January 2010].

3 Grebmeier, J.M., Overland, J.E., Moore, S.E., Farley, E.V., Carmack, E.C., Cooper, L.W., Frey, K.E., Helle, J.H., McLaughlin, F.A., and McNutt, S.L. (2006). A major ecosystem shift in the northern Bering Sea. *Science*. 311:1461–1464.

4 Moline, M.A. (2008). High Latitude Changes in Ice Dynamics and Their Impact on Polar Marine Ecosystems. *Ann. NY. Acad. Sci.* 1134(1).

5 Bluhm, B.A. and Gradinger, R. (2008). Regional variability in food availability for Arctic marine mammals. *Ecol. Appl.* 18(Suppl): S77–S96.

and zooplankton productivity associated with food generation[6] [7] [8].

- Bottom feeding marine species may experience less food availability, leading to impacts throughout the food chain.
- Species may face difficulties adapting to the timing of breeding, feeding, migration, and other life strategies associated with sea ice.
- Key species of cultural and economic importance may be negatively affected.
- Changes in Arctic biodiversity have global repercussions and changes are creating both challenges and opportunities for Arctic peoples.

Considerations

- Comprehensive understanding of the sea-ice ecosystem does not yet exist and baseline data regarding population and trends of ice-associated species is limited due to the difficulty in surveying in such an extreme and remote environment.

CAFF´s Recommendations

- CAFF has begun work on the Arctic Sea Ice Associated Biodiversity project to:
    - provide a summary of the current status and trends of ice-associated biodiversity, including direct effects on marine species and indirect effects on terrestrial species,
    - describe the expected reaction of biota to less sea ice,
    - reflect on the implications for northern peoples, and
    - recommend actions that might mitigate these changes.

6 Moline, M.A. (2008). High Latitude Changes in Ice Dynamics and Their Impact on Polar Marine Ecosystems. *Ann. NY. Acad. Sci.* 1134(1).

7 Gradinger, R. (1995). Climate change and biological oceanography of the Arctic Ocean. *Philos. T. Roy. Soc. A.* 352:277–286.

8 Smetacek, V. and Nicol, S. (2005). Polar ecosystems in a changing world. *Nature*. 437: 362–368.

Next Steps

- Sea Ice Associated Biodiversity project will build upon the recently released Snow, Water, Ice and Permafrost in the Arctic report which focused on Climate Change and the Arctic Cryosphere.
- Contribute to the Arctic Councils Arctic Biodiversity Assessment
- Assist the Marine Expert Monitroing Group understand and interpret changes in Arctic sea ice associated biodiversity.

Introduction

Unique Arctic habitats for flora and fauna, including sea ice have been disappearing over recent decades[9]

The loss of Arctic sea ice threatens biodiversity across an entire biome and beyond[10]

Arctic sea ice is the basis for a unique ecosystem in the Arctic, providing a habitat to specialized ice-associated species that include microorganisms, fish, birds, and marine mammals. Some species depend on sea ice for essential life functions while others associate with sea ice for a specific reason, but also occur in other habitats. Each of these species depends and associates with sea ice for different reasons that are unique to their individual biological needs. Ice algae form the base of the food web (Figure 1) is a good example. Some algae stay attached to the bottom of the ice, some fall into the water column, and some fall to the bottom of the sea, and in so doing provide food for species that feed at different depths. Protists (single-celled organisms) and zooplankton eat the algae which are then eaten by, for instance, Arctic cod[11] and sea birds, which in turn act as the major link to other

9 A key finding from "Arctic Biodiversity Trends 2010: selected indicators of change"

10 *Global Biodiversity Outlook 3*, Convention on Biological Diversity (CBD) 2010

11 Lønne, O.J. and Gulliksen, B. (1991). On the distribution of sympagic macro-fauna in the seasonally ice covered Barents Sea. *Polar Biol.* 11:457-469.

fish and birds, seals, and whales[12]. Polar bears prey upon seals from the ice and walrus forage on clams from drifting pack ice.

What changes are taking place to Arctic sea ice?

In the past 100 years, average Arctic temperatures have increased at almost twice the average global rate[13]. Arctic sea ice has changed in recent years, decreasing substantially in extent and thickness, with thin first-year ice replacing thicker multi-year ice[14]. Over the past thirty years, seasonal minimal sea ice extent in the Arctic has decreased by 45,000 km^2 per year[15]. Sea ice is being lost at a faster rate than projected by even the most pessimistic of climate change scenarios, such as those reported by the Intergovernmental Panel on Climate Change (IPCC - www.ipcc.ch) and a nearly ice-free Arctic Ocean in late summer is likely within this century and possibly before mid-century[16].

What are the effects on sea ice associated biodiversity?

The recently released Arctic Biodiversity Trends 2010 report (www.arcticbiodiversity.is)[17] by the Conservation of Arctic Flora and Fauna (CAFF – www.caff.is) working group of the Arctic Council (www.arctic-council.org) found that unique Arctic habitats for flora and fauna, including sea ice have been disappearing over recent decades. Many Arctic species are found in association with sea ice and can therefore be expected to be significantly affected by the projected reduction in sea ice availability. Early warning signs of losses in the sea-ice

12 Bradstreet, M.S.M. and Cross, W.E. (1982). Trophic relationships at high Arctic ice edges. *Arctic*. 35:1-12.

13 Intergovernmental Panel on Climate Change (IPCC). (2007). Summary for Policymakers. In: Climate Change 2007: The Physical Science Basis. Contribution of Working Group I to the *Fourth Assessment Report of the Intergovernmental Panel on Climate Change*. Solomon, S., D. Qin, M. Manning,Z. Chen, M. Marquis, K.B. Averyt, M. Tignor and H.L. Miller (eds.)

14 National Snow and Ice Data Center (NSIDC). http://nsidc. org [Accessed 12 January 2010].

15 Post, E *et al*. (2009). Ecological dynamics across the Arctic associated with recent climate change. *Science*. 325 (5946):1355–1358.

16 Wang, M. and Overland, J. 2009. A sea ice free summer Arctic within 30 years? *Geophys. Res. Lett*. 36:L07502.

17 Arctic-biodiversity-trends 2010:selected indicators of change, *Conservation of Arctic Flora and Fauna*, Biodiversity Working Group of the Arctic Council.

food web include declines in populations of some species associated with sea ice, such as ivory gulls and polar bears. The response of individual ice-associated species to changes in sea ice will depend upon their ability to adapt, their natural history, and the scale of environmental changes which may take place. While sea ice associated biodiversity is experiencing a variety of impacts as the sea ice changes, it is not clear exactly what will happen as the summer sea ice continues to disappear.

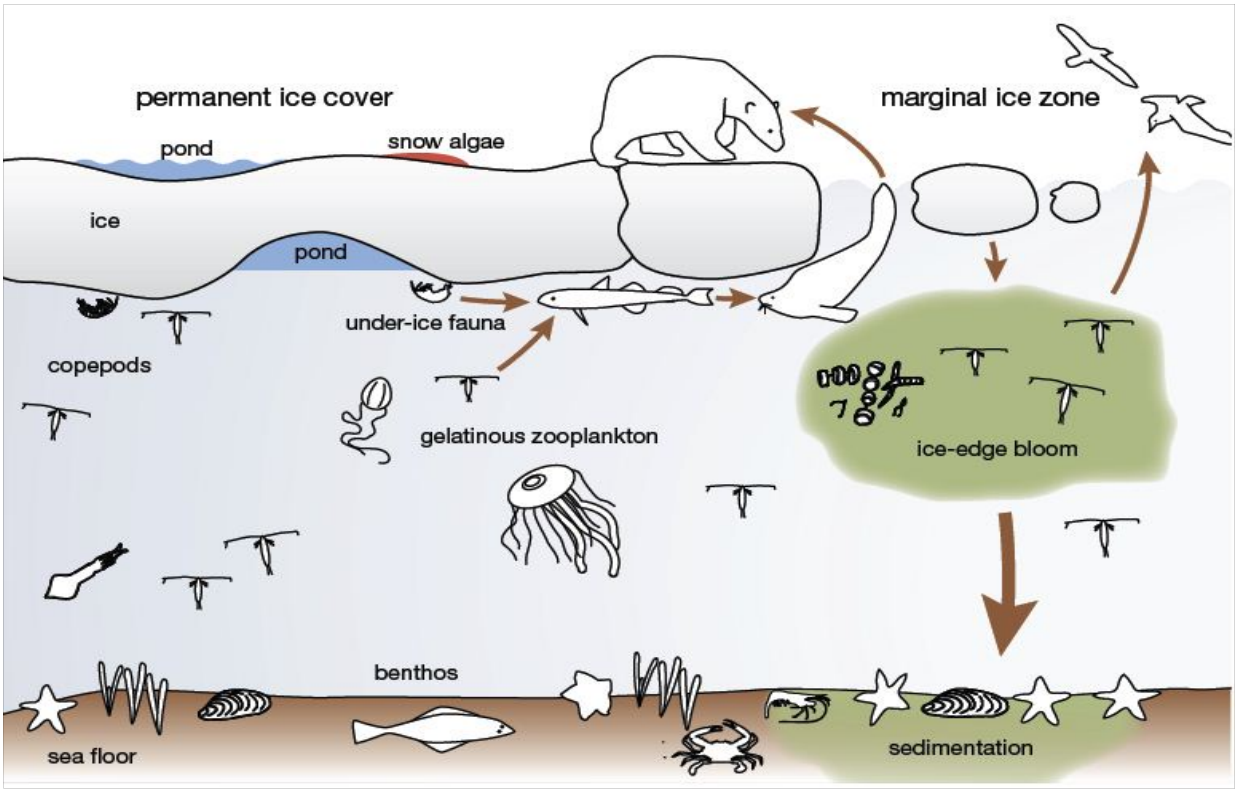

Figure 1: Schematic representation of the Arctic marine ecosystem and its interactions[18]

What are the concerns for the future?

The ongoing trend of declining sea ice is likely to lead to changes in the sea-ice ecosystem shifting toward a pelagic, sub-Arctic ecosystem[19] over a larger area[20,21]. Phytoplankton and

18 Gradinger, R., Hopcroft, R.R. and Bluhm, B. (2004). Arctic Census of Marine Life (Arc-CoML) Program Proposal. University of Fairbanks. Fairbanks, Alaska. 35 pp.

19 Grebmeier, J.M., Overland, J.E., Moore, S.E., Farley, E.V., Carmack, E.C., Cooper, L.W., Frey, K.E., Helle, J.H., McLaughlin, F.A., and McNutt, S.L. (2006). A major ecosystem shift in the northern Bering Sea. *Science*. 311:1461–1464.

zooplankton productivity is predicted to increase, with sub-Arctic species expanding their range and competing with existing Arctic species[22] [23] [24]. The increased production in open water will increase the prey concentrations for bowhead whales[25].

However, with less ice, there may be less ice algae that falls to the bottom, leaving less food for bottom-feeding marine species. Marine mammal species that are capable of using both pelagic and benthic prey may be less affected by the expected changes in the food web structure[26]. There may be mismatches with the life histories of ice associated organisms if the timing of life functions shifts due to reduction of sea ice[27]. If one or more of the links between increased light penetration, higher production by ice algae, increased activity and breeding of zooplankton grazers and predators, and production and feeding of larval and juvenile Arctic cod fail, then effects may flow through the sea-ice ecosystem on to top predators, such as ringed seals and birds and possibly polar bears[28].

It is unclear how the reduction in sea ice is affecting Arctic cod. It is likely that a generalist species will replace Arctic cod as the main forage fish as sea ice decreases[29]. According to

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20 Moline, M.A. (2008). High Latitude Changes in Ice Dynamics and Their Impact on Polar Marine Ecosystems. *Ann. NY. Acad. Sci.* 1134(1).

21 Bluhm, B.A. and Gradinger, R. (2008). Regional variability in food availability for Arctic marine mammals. *Ecol. Appl.* 18(Suppl): S77–S96.

22 Moline, M.A. (2008). High Latitude Changes in Ice Dynamics and Their Impact on Polar Marine Ecosystems. *Ann. NY. Acad. Sci.* 1134(1).

23 Gradinger, R. (1995). Climate change and biological oceanography of the Arctic Ocean. *Philos. T. Roy. Soc. A.* 352:277–286.

24 Smetacek, V. and Nicol, S. (2005). Polar ecosystems in a changing world. *Nature*. 437: 362–368.

25 Bluhm, B.A. and Gradinger, R. (2008). Regional variability in food availability for Arctic marine mammals. *Ecol. Appl.* 18(Suppl): S77–S96.

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28 Moline, M.A. (2008). High Latitude Changes in Ice Dynamics and Their Impact on Polar Marine Ecosystems. *Ann. NY. Acad. Sci.* 1134(1).

29 Bouchard, C. and Fortier, L. (2008). Effects of polynyas on the hatching season, early growth and survival of polar cod Boreogadus saida in the Laptev Sea. *Mar. Ecol. Prog. Ser.* 355:247-256.

modeling, with warming temperatures and a retreat of the ice edge of 5 km per year, Arctic cod may be extirpated from most of its range in 30 years[30]. Arctic marine mammal ranges are generally expected to shift northward to inhabit areas within their preferred metabolic temperature tolerances because conditions at the southern limits of their previous distribution will no longer meet their ecological needs[31]. Sea birds may initially benefit from reductions in sea ice as it renders their prey base more accessible; however, as that prey base changes in extent and species composition, their ability to adapt is uncertain. In addition, the northward extension of more southerly ranging seabird species may result in greater competition for resources. Interannual changes in the onset and severity of seasonal sea ice may also affect the length of feeding seasons, timing of migrations, fecundity, and survivorship of marine mammal species[32]. Marine mammals will likely compete with one another on some level despite their different specializations[33]. If the climate continues to warm, a continued reduction in sea ice will follow and likely result in the northward expansion of some presently sub-Arctic species, with potential for increases in disease, predation, and competition for food[34] [35].

30 Cheung, W.W.L., Lam, V.W.Y., and Pauly, D. (2008). Dynamic Bioclimate Envelope Model to Preduct Climate-Inducted Changes in Distribution of Marine Fishes and Invertebrates. In: W.W.L.Cheung, V.W.Y. Lam, and D. Pauly (eds.) *Modelling Present and Climate-shifted Distribution of Marine Fishes and Invertebrates*. Fisheries Centre Research Report 16(3):5-50.

31 Laidre, K.L., Stirling, I., Lowry, L.F., Wiig, .., Heide- J.rgensen, M.P. and Ferguson, S.H., (2008). Quantifying the sensitivity of Arctic marine mammals to climate-induced habitat change. *Ecol. Appl.* 18 (Suppl.):S97–S125.

32 Tynan, C.T. and DeMaster, D.P. (1997). Observations and predictions of Arctic climate change: potential effects on marine mammals. *Arctic*. 50:308–322.

33 Lowry, L. (2000). Marine mammal–sea ice relationships. In: H. P. Huntington, editor. Impacts of changes in sea ice and other environmental parameters in the Arctic. pp. 91–96. *Report of the Marine Mammal Commission Workshop, 15–17 February 2000, Girdwood, Alaska.* Marine Mammal Commission, Besthesda, Maryland, USA.

34 Moore, S.E. and Huntington, H.P. (2008). Arctic marine mammals and climate change: impacts and resilience. *Ecol. Appl.* 18 (Suppl):S157–S165.

35 33. Laidre, K.L., Stirling, I., Lowry, L.F., Wiig, .., Heide- J.rgensen, M.P. and Ferguson, S.H. (2008). Quantifying the sensitivity of Arctic marine mammals to climate-induced habitat change. *Ecol. Appl.* 18 (Suppl.):S97–S125.

Why do changes to sea-ice associated biodiversity matter?

Key findings in the Arctic Biodiversity Trends 2010 report noted that changes in Arctic biodiversity have global repercussions and that changes are creating both challenges and opportunities for Arctic peoples[36]. This concern has been reiterated by the Convention on Biological Diversity (CBD - www.cbd.int) which noted that the loss of Arctic sea ice threatens biodiversity across an entire biome and beyond[37].

It is important to recognize that sea ice-associated species are trophically linked directly and indirectly to others in marine and terrestrial ecosystems and must be considered in any analysis of the effects of sea ice loss. Declines in Arctic biodiversity may affect the availability of traditional foods. This when coupled with decreasing access to freshwater and the unpredictability of winter ice may make sustaining traditional ways more difficult. However it is not all necessarily negative effects e.g. range extensions of southern species, shifting habitats, changes in resource use, among other factors, may provide opportunities to harvest new species. The recently released SWIPA (Snow, Water, Ice and Permafrost in the Arctic) report[38] found that changes to sea ice ecosystem will have effects on migratory species of mammals and birds from elsewhere in the world. Such change has major implications for biodiversity both within and beyond the Arctic[39].

What is being done to respond to these challenges?

In order to effect successful conservation in the face of such change requires accurate baseline data on long-term status and trends of Arctic biodiversity, habitats and ecosystem health. However a comprehensive understanding of the sea-ice ecosystem does not yet exist

36 Key Findings, *Arctic-biodiversity-trends 2010:selected indicators of change*, Conservation of Arctic Flora and Fauna, Biodiversity Working Group of the Arctic Council.

37 *Global Biodiversity Outlook 3* (2010), Convention on Biological Diversity

38 *Snow, Water, Ice and Permafrost in the Arctic* (SWIPA), 2010, Arctic Monitoring and Assessment Programme, Contaminants Working Group of the Arctic Council.

39 *Arctic-biodiversity-trends 2010:selected indicators of change*, Conservation of Arctic Flora and Fauna, Biodiversity Working Group of the Arctic Council/*Global Biodiversity Outlook 3* (2010), Convention on Biological Diversity

and baseline data regarding population and trends of ice-associated species is limited due to the difficulty in surveying in such an extreme and remote environment. Without such baseline data it is difficult to understand and predict the effects changes may have on sea ice associated biodiversity.

This need has been recognised and consideration of the effects of changes to sea ice on its associated biodiversity is underway. In 2010 the Arctic Biodiversity Trends 2010 report found that Unique Arctic habitats for flora and fauna, including sea ice have been disappearing over recent decades. In response CAFF has begun work on the Arctic Sea Ice Associated Biodiversity project (ASIB - www.caff.is/assessments)40 which will provide a summary of the current status and trends of ice-associated biodiversity, including direct effects on marine species and indirect effects on terrestrial species, discuss the expected reaction of these biota to lower occurrences of ice, reflect on the effects low ice and its impact on species biodiversity to northern peoples, and finally, recommend actions that might mitigate these changes.

The Sea Ice Associated Biodiversity project will build upon the recently released SWIPA report which focused on Climate Change and the Arctic Cryosphere. SWIPA provided a review of the biological impacts of changes to sea ice in the Arctic and summarized the role sea ice plays for several key species in the north. In addition to building on SWIPA, this project will contribute to the Arctic Councils Arctic Biodiversity Assessment (ABA – www.caff.is/aba) which is synthesizing and assessing the status and trends of biological diversity in the Arctic[41]. The ABA when complete will provide the baseline for the Circumpolar Biodiversity Monitoring Programme (CBMP – www.cbmp.is). The CBMPs marine monitoring plan has recently been endorsed by the Arctic Council and has started implementation and when complete will provide the means of understanding and interpreting changes being experienced by Arctic sea ice associated biodiversity.

40 This project is led within CAFF by Canada and the United States

41 This assessment is being developed by the Arctic Council working group - the Conservation of Arctic Flora and Fauna (CAFF)

For more information:

Further information can be found at www.caff.is/assessments and in the following reports:

- Arctic Sea Ice Associated Biodiversity project portal
- Arctic Sea ice Associated Biodiversity workshop report March 2011
- Arctic Sea ice Associated Biodiversity project description December 2010
- Arctic sea-ice ecosystems Indicator 10 from Arctic Biodiversity Trends 2010 report - October 2010
- CAFF Concept paper on Sea-ice dependent species – February 2010

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