The Circle

No. 4. 2009

The last Arctic sea ice refuge 6

One land, two hearts 10

Killer whales on the rise 20

The changing Arctic:

How species are being impacted

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ARCTIC SPECIES

Contents

Geoff York: **EDITORIAL: Preserving ecosystem functions in a land of change** 3
IN BRIEF: 4
Stephanie Pfirman: **The last arctic sea ice refuge** 6
Lee W. Cooper: **Ecosystem impacts of seasonal sea ice declines** 8
Bridget Larocque: **Gwich'in and the Porcupine Caribou – one land, two hearts** 10
Monte Hummel: **Climate and caribou** 12
Mark Mallory: **Arctic marine birds like it cold and icy** 13
Tom Arnbom: **Walrus – Facing new challenges in a changing Arctic** 15
Mads Peter Heide-Jørgensen: **The elusive narwhal in a rapidly changing Arctic** 17
Peter Ewins: **Bowhead Whales – What are the climate change impacts and adaptation prospects?** 19
Steven Ferguson: **Killer whales on the rise in the Canadian Arctic** 20

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Atlantic walrus at Svalbard, Norway.
Photo: Tom Arnbom,

COVER: Two walruses (Odobenus rosmarus) sit on sea ice in Hudson Bay, Nunavut, Canada.
Photo: Lee NARRAWAY/WWF-Canada

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Preserving ecosystem functions in a land of change

ALTHOUGH THE THEME of this volume is arctic species, the underlying storyline is change. We know from current observations and future projections of sea ice, temperature, and global atmospheric and oceanic processes that our world is changing. This rapid change stands to fundamentally alter the arctic ecosystem. It is not simply a matter of what may disappear into regional extirpation and extinction, but also of what will fill this newly created space; which species will win and which will lose and how the various elements of this rapidly evolving matrix will interact.

These fundamental changes will result in ecosystem shifts and new conservation challenges. How can we (or even – can we?) conserve such a rapidly changing system? Will the conservation tools of the present serve us in this unprecedented situation or will we need to develop a new understanding and a new set of tools? Do our current conservation laws and policies reflect the necessary adaptive management options we will likely need as the ground literally melts away before us?

Geoff York,
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Is our society prepared to watch as ice-related species are replaced by their pelagic counterparts? Orca replacing polar bear as the top predator, harbour seal replacing ringed and bearded seals? As caribou and reindeer populations decline globally, what will move into that niche? How will these significant changes impact the people who live in the north? Should we expect similar shifts where we all live? Are we ready?

> **"Is our society prepared to watch as ice-related species are replaced by their pelagic counterparts?**

Ultimately, the most important aspect for conservation may be to preserve ecosystem functions which can continue to supply ecosystem services in the future. Both functionality and services provided are likely to change over time and spatial scales and we must develop the tools to manage this dynamic process. Maintaining large areas of the Arctic as intact functional systems, and managing these places for change, not their current status, may give people, wildlife, and these wild places the best chance for adapting to the new climate regime.

It is time to focus on the conservation and livelihood adaptations needed for the changes already occurring and those to come. Even if we make the right choices this year in Copenhagen and beyond, the world will still continue on its current warming trend. We can alter the magnitude and duration of the warming by reducing green-house gas emissions, but we must still prepare for the changes headed our way. Changing species, changing landscapes, and the need for a change in the way we all live our lives and view this planet we call home. ○

Photo: www.icebearproject.org

Melting bears during climate talks

A MASSIVE ice bear will be part of the arctic presence during the climate negotiations in Copenhagen in December. The WWF-sponsored ice sculpture will be built onto a skeleton of bronze creating an ongoing presence as the ice melts away. The bear will be positioned in front of the WWF Arctic Tent and an arctic photo exhibition on Nytorv Square. The sculpting team will put the final touches to the bear as part of the opening ceremony for the tent on December 5th. A similar bear will be put up in Trafalgar Square in London. The bears are made by renowned sculptor Mark Coreth who is internationally known as a master sculptor of animals in motion. Coreth draws his inspiration from direct encounters with life in the wild, and has previously exhibited in London, Paris, New York and Sydney.

New circumarctic ecosystem resilience assessment project

WWF HAS LAUNCHED a new project designed to identify, map and raise awareness about significant ecosystem features and areas that would build social-ecological resilience across the circumarctic and that are likely to persist in future arctic climate change conditions.

The "Rapid Assessment of features and areas for Circumarctic Ecosystem Resilience in the 21st Century" ('RACER') project is designed to quickly provide guidance to government decision makers, industry and other stakeholders before climate change and rapid industrialization preclude important conservation options to ensure functional arctic ecosystems.

Several meetings of experts are to be conducted in the coming months and a final report with recommendations is scheduled for release in the spring of 2010. It is envisaged that this work will be followed by more in-depth comprehensive analysis and planning at national and regional scales to build social-ecological resilience across all arctic ecosystems.

Critical habitat for polar bears declared

IN OCTOBER, the US Department of the Interior announced proposed designation of key areas of polar bear habitat across Alaska. The requirement for the identification of 'critical habitat' was triggered by the listing of polar bears as threatened under the US Endangered Species Act in 2008.

The total area proposed for designation would cover approximately 200,541 square miles and is found entirely within the lands and waters of the United States.

"Designation of critical habitat affords important protections to the polar bear, a species imperiled by dramatic changes in its sea ice environment," says Geoff York, senior program officer for Polar Bear Conservation at WWF. "As sea ice habitat shrinks, it becomes increasingly important to protect areas that are crucial for the bears' survival."

Ice free Arctic within decade?

LONDON, UK – New data released by the Catlin Arctic Survey and WWF provides further evidence of thinning Arctic Ocean sea ice, supporting the emerging thinking that the Arctic Ocean will be largely ice-free in summer within a decade.

The more than 6,000 measurements and observations collected over a 450 kilometre, 73 day route across the northern part of the Beaufort Sea provided scientists with the latest ice thickness record and suggests the survey area is comprised almost exclusively of first year ice.

This is a significant finding because the region has traditionally contained older, thicker multi-year ice. The average thickness of the ice-floes measured 1.8 metres, a depth considered too thin to survive the next summer's ice melt.

"The findings provide yet another urgent call for action to world leaders ahead of the UN climate summit in Copenhagen this December to rapidly and effectively curb global greenhouse gas emissions, with rich countries committing to reduce emissions by 40% by 2020", said Dr. Martin Sommerkorn from the WWF International Arctic Programme.

Canadian oil and ice tour

Authors Andrew Nikiforuk (Tar Sands) and Ed Struzik (The Big Thaw) criss-crossed Canada and discussed the choices that will determine the future of the Arctic, and what can be learned from the tar sands. The WWF-Canada hosted Oil and Ice Tour, saw the authors speaking to enthusiastic audiences in ten cities from Newfoundland to British Columbia.

"Nations become what they produce. Bitumen, the new national staple, has redefined Canada's character. It has given us a petro loonie, eroded the manufacturing sector, and compromised the security of the world's third largest watershed." says Nikiforuk, author of Tar Sands: Dirty Oil and the Future of a Continent.

"Having spent much time in the Arctic, I have seen first-hand the peril that is facing the North," says Struzik, author of The Big Thaw: Travels in the Melting North. "Climate change is opening up the Arctic at an alarming rate and the stakes are high. What happens in the Arctic's future matters not only to culture, wildlife, the environment, security and sovereignty. It matters to the rest of the world."

To learn more about the tour or join the discussion online visit wwf.ca.

Reaching out from the polar bear capital of the world

For the second year running, WWF and Polar Bears International partnered on a series of outreach and education events from Tundra Buggy One (www.tundrabuggy.com) on the shores of Hudson Bay, Canada. Buggy One is a highly modified polar bear viewing buggy that functions as a mobile studio that streams live video of polar bears, and polar bear scientists around the world. This year, scientists broadcasted live lectures and conducted real time Q&A sessions with hundreds of students from as far away as Australia. Discussions focused on the impacts of climate change on polar bears and what individuals could do to help. While the situation in the Arctic is bleak, there is still time to act, and hope that we can turn things around!

Norwegian oil exploration postponed

THE WWF-SUPPORTED 'People's campaign for an oil-free Lofoten and Vesterålen', delivered over 53,000 signatures to the new Norwegian government this October, just before their new political platform for the next four years was announced.

The government subsequently committed to not opening the area outside of Lofoten and Vesterålen to petroleum activities in this parliamentary period, and to decide whether to conduct an environmental impact assessment for petroleum exploration in these areas when the Barents Sea Management plan is revised in 2010.

The 53,000 signatures that have been collected since the campaign was established in January indicate that there is a significant national interest in protecting the ocean outside of Lofoten and Vesterålen.

"The experience that the fishery sector so far has had with petroleum exploration in the area is that there is no space for both fishing and oil activities in the ocean", said the campaign leader Gaute Wahl, pointing to the particularly thin continental shelf in this area.

Coastline of Vestvågøy, Lofoten, Norway.
Foto: WWF-Norway/Frode Johansen/WWF-Canon

Opening the ocean for petroleum exploration in this area would not only put pressure on local fishing communities, but would also significantly contribute to Norwegian greenhouse gas emissions, long after these emissions should start decreasing.

The last arctic sea ice refuge

STEPHANIE PFIRMAN and her colleagues* argue that in a melting Arctic, if we want to maintain the remaining sea ice as a refuge for ice associated species, international planning and assessment is needed.

AS GLOBAL WARMING reduces the extent of summer sea ice in the Arctic Ocean, ecosystems that require perennial ice are likely to survive longest within and along the northern flank of the Canadian Arctic Archipelago and Greenland. Analyses of models and satellite data indicate that multiyear ice in this region is formed locally, as well as transported in from the central Arctic and Eurasian shelf seas. An integrated, international system of monitoring and management of this sea ice refuge, along with the ice source regions, has the potential to maintain viable habitat for ice-associated species, including polar bears, for decades into the future.

Some climate models project much of the Arctic may be seasonally free of sea ice during summer by about 2040 (Figure 1 and 2A). However, the Community Climate System Model (version 3, CCSM3 for the A1B global warming scenario) also indicates that a small amount of summer sea ice – perhaps a half million square kilometers – is likely to persist well into the 21st century along the northern flank of Greenland and the Canadian Arctic Archipelago. The reason for this is that sea ice formed each winter will continue to be pushed by dominant wind and ocean currents towards the North American continent where it will pile up and thicken. This region north of the Canadian archipelago is a "dead" zone with little ice motion caught in between the Beaufort Gyre in the western Arctic and the Transpolar Drift Stream in the central Arctic exporting ice south via the Fram Strait. Today, this is exactly the place where the thickest and oldest ice occurs (Figure 2B). In the future, species that rely on year-round sea ice for all or part of their life cycle will survive longest in this naturally formed sea ice refugium (Figure 2C).

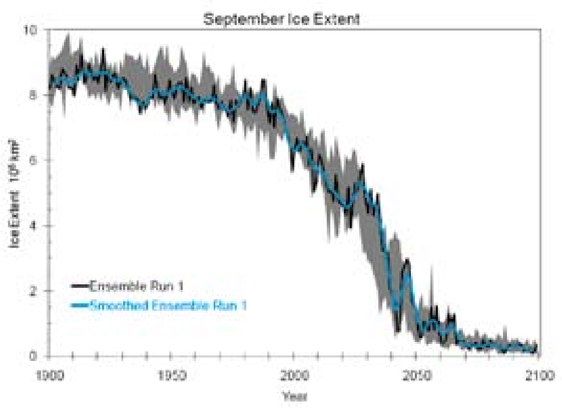

Figure 1: September mean (2040–2049) sea ice concentration projected by the Community Climate System Model (version 3, CCSM3), for the A1B global warming scenario
(http://www.realclimate.org/index.php/archives/2007/01/arctic-sea-ice-decline-in-the-21st-century/; Holland et al., 2006).

The consensus of models and observations on the location of the last sea ice refugium lays the foundation for developing an integrated, international system of monitoring and management in order to maintain viable habitat for ice-associated species, including polar bears. By mid-century, extensive summer sea ice melting will diminish optimal polar bear habitat around most of the rest of the Arctic, but some habitat is projected to persist in the refugium north of the Canadian Arctic Archipelago and Greenland (Durner et al., 2009; Figure 2C). As a result, this region, as well as the neighboring Canadian Arctic Archipelago, has the greatest likelihood for maintenance of a viable polar bear population through the 21st century.

Because the sea ice cover is dynamic, any management plan must include the "ice shed" that delivers sea ice to the refuge. Our results from models and satellite data over the past 30 years indicate that, in addition to ice that forms locally, some sea ice in this region is transported in from the central Arctic and shelf seas (Figure 2D). In the past, ice sources included regions as far away as the northeastern Russian and Alaskan shelves. Sea ice formed over

STEPHANIE PFIRMAN is Hirschorn Professor and co-Chair, Environmental Science Department, Barnard College, Columbia University and adjunct Associate Research Scientist, Lamont-Doherty Earth Observatory, Columbia University. Her research focuses on understanding transport and trajectories of Arctic sea ice in a changing world.

* This article written by **Stephanie Pfirman** is based on her work in cooperation with **Bruno Tremblay**, McGill University, Canada and Lamont-Doherty Earth Observatory of Columbia University, USA; **Charles Fowler**, University of Colorado at Boulder, USA; and **Robert Newton**, Lamont-Doherty Earth Observatory of Columbia University, USA.

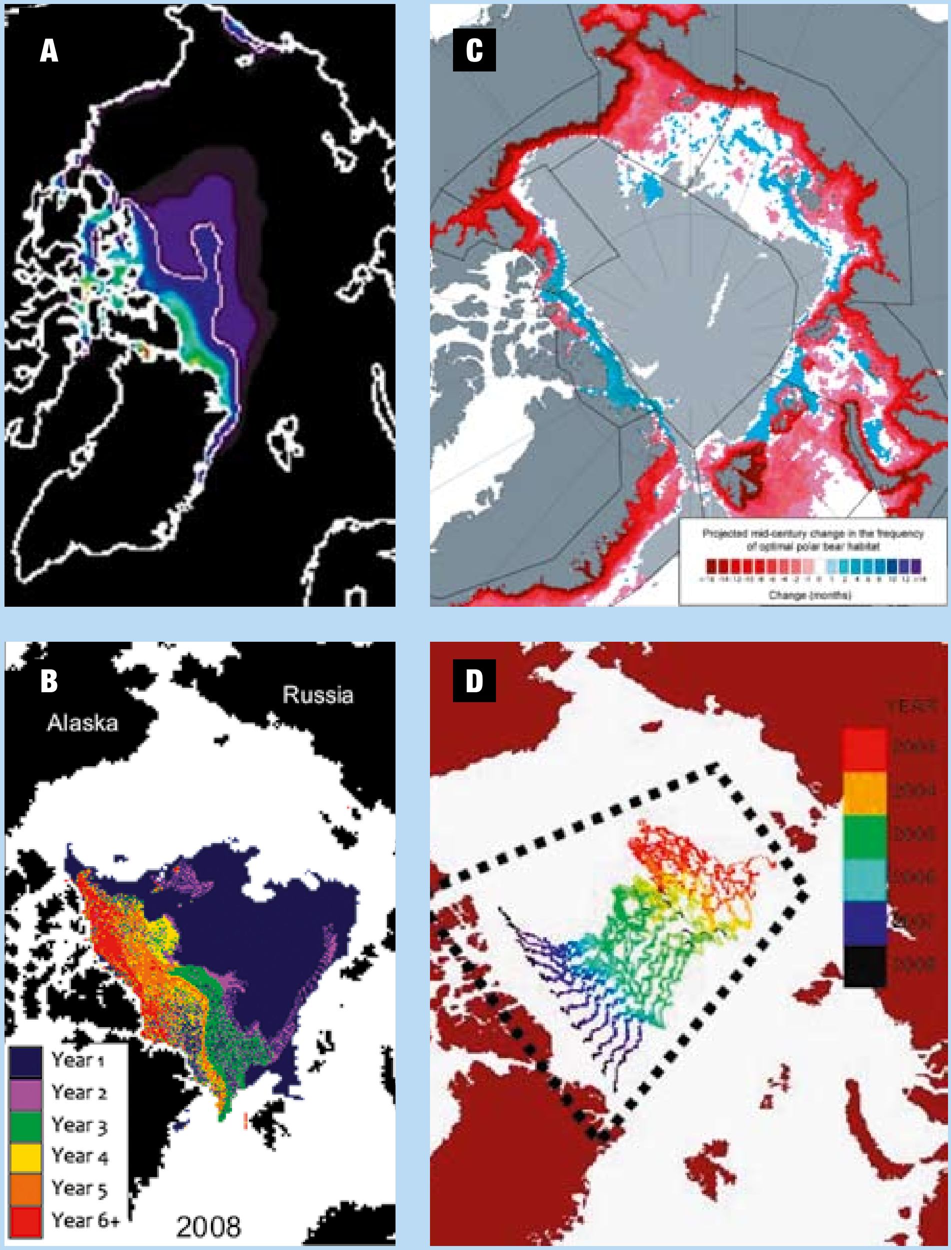

Figure 2:

A) Aerial distribution of September mean (2040–2049) sea ice concentration projected by the Community Climate System Model (version 3, CCSM3), for the A1B global warming scenario (http://www.realclimate.org/index.php/archives/2007/01/arctic-sea-ice-decline-in-the-21st-century/; Holland et al., 2006).

B) Distribution of arctic sea ice age at the end of the 2008 melt season showing collection of oldest ice immediately north of the Canadian Arctic Archipelago and Greenland. http://nsidc.org/images/arcticseaicenews/20080924_Figure3.jpg

C) Projected 21st century changes in frequency (number of months) of optimal polar bear habitat between the two decades 2001–2010 and 2041–2050 (Durner et al., 2009). Colors indicate change in months: blue = increased habitat, red = decreased habitat.

D) Back trajectories showing the origin of ice supplied to the continental shelf area north of the Canadian Arctic Archipelago and Greenland during the summer of 2008: colors change at yearly intervals, representing 5 years of drift. Trajectories are computed by reversing ice vector data. Box indicates approximate region of projected sea ice refuge including its "ice shed" of potential ice source areas.

these shelves during fall and winter would drift north, entering into the perennial pack ice of the central Arctic. Pushed by the wind and ocean currents, the ice would circulate in the clockwise Beaufort Gyre within the Arctic Basin. While much of the ice was exported out of the central Arctic within a couple of years through Fram Strait, east of Greenland, some ice continued circulating for years along the northern flank of Greenland, on towards the northern flank of the Canadian Archipelago, and then back around in the gyre.

In the future, as the area of sea ice that melts each summer increases, ice formed in winter over distant shelves may melt before it has a chance to reach the refugium. But model results and observations indicate that as the ice concentration and thickness decreases, drift speeds increase. For example, the Tara Expedition of 2006 drifted with the sea ice from northern Russia, across the central Arctic Basin to Fram Strait, in 1.2 years rather than the 3 years that was anticipated based on climatological ice drift speed. In addition, satellite data indicate that average sea ice transit times in recent years are shorter than in the 1980s (e.g. Rampal et al., 2009). The reason for the potential increase in ice speed is that wind energy will be transferred more efficiently to moving individual ice floes, rather than being dissipated laterally through the pack as is the case today when thicker ice floes move relative to one another. If drift speeds increase substantially, as our regional sea ice model suggests, then ice formed in winter north of Siberia could continue to be contributed to the refuge.

Maintaining the viability of the remaining arctic sea ice as a refuge for ice-associated species requires that we start international planning and assessment. The refugium itself lies in the Canadian and Greenland Exclusive Economic Zones (EEZs), while the ice sources that feed it could lie in the EEZs of Russia, the United States, and Norway. As sea ice thins and retreats, economic development is likely to increase in the region. New shipping routes and expansion of the extractive industries, for example, would need to be managed in the context of protecting the refugium habitat. As far as we are aware, recognition of a sea ice refugium, including its dynamic "ice shed", would be novel in international policy. It would require significant lead-time to be established and would take considerable international cooperation and diplomacy. In addition to ongoing research focused on understanding future sea ice extent, research also needs to be conducted on future sea ice drift patterns and rates. Development plans for resource extraction and shipping require consideration of the dynamic nature of arctic sea ice: they need to recognize that sea ice – along with any contaminants from accidents or spills – has the potential to drift from one country's continental shelf, into another's. ○

Durner, G.M., D.C. Douglas, R.M. Nielson, S.C. Amstrup, T. C. McDonald, I. Stirling, M. Mauritzen, E. W. Born, Ø. Wiig, E. DeWeaver, M. C. Serreze, S. E. Belikov, M. M. Holland, J. Maslanik, J. Aars, D. A. Bailey, and A. E. Derocher., 2009. Predicting 21st century polar bear habitat distribution from global climate models. Ecological Monographs, 79:25–58.

Rampal, P., J. Weiss, D. Marsan, 2009. Positive trend in the mean speed and deformation rate of Arctic sea ice,1979–2007, J. Geophys. Res. 114 http://dx.doi.org/10.1029/2008JC005066.

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Ecosystem impacts of seasonal sea ice declines

While charismatic mega fauna receive the majority of study, researching lower levels of the arctic food web will help to understand the scope and impact of climate change throughout the marine ecosystem, says **LEE W. COOPER**.

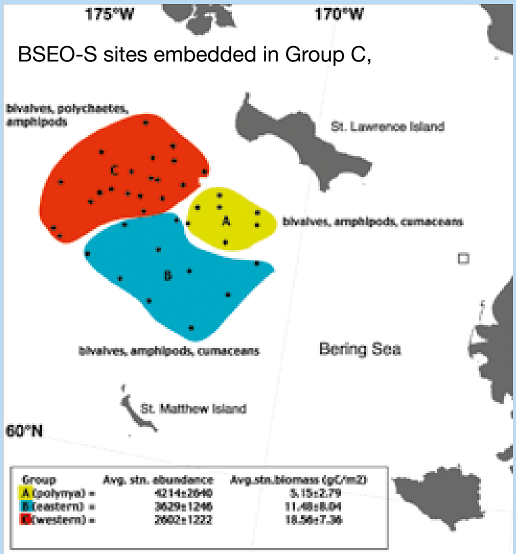
WHILE TEMPERATURE increases and decreases in seasonal sea ice provide clear evidence of warming in the Arctic and its marginal seas, the impacts of climate warming on many marine biological systems remain hidden from view. For example, a recent summary of ecosystem impacts of climate change documented during the International Polar Year and published in *Science*, discussed changes in treeline, vegetation, animal migration patterns and many other well-documented shifts that have occurred on land in the Arctic. However in the ocean system, examples of climate change vulnerability were limited to the "charismatic megafauna" of polar bears, walrus, and other ice-associated marine mammals that are specialists in using sea ice as a feeding or resting platform.

While these organisms are clearly vulnerable to the loss of seasonal sea ice in the Arctic, consideration of how the lower levels of the food web are changing is also necessary in order to understand the sheer scope of impacts throughout the marine ecosystem.

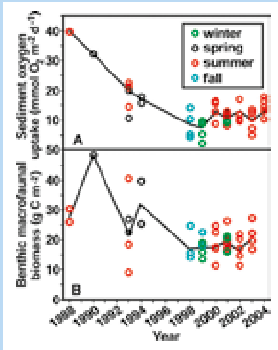
The Bering and Chukchi Seas form the largest continental shelf of the United States, which it shares with Russia, and together the two seas have the highest and richest biological productivity of any arctic marine system. This is due in part to the flow of cold, nutrient rich water of Pacific Ocean origin across the shallow shelf in the Bering Strait region. Because the northern shelf is shallow and largely surrounded by land where North America and Asia meet, it is subject to significant summer temperature variation, and in warmer years, fish that dominate the southern Bering Sea ecosystem can typically be found further north, where they compete for food with diving marine mammals such as gray whales, walrus and diving ducks that feed on the rich benthic communities on the sea floor.

Amphipods, a mainstay in the grey whale diet, have disappeared from portions of the Bering Sea.
Photo: Jerry McCormick-Ray, University of Virginia

Change in sediment oxygen uptake (indicator of carbon supply to benthos) and benthic macrofaunal biomass SW of St. Lawrence Island; trend lines through station means



[Simpkins et al. 2003, Polar Biology 26]



[Grebmeier et al. 2006, Science 311]

Long-term biological studies dating back to the 1970's indicate that biomass on the sea floor has in fact declined over the past several decades in many productive portions of the northern Bering Sea. In other portions of the Bering and Chukchi Sea ecosystem, whole-scale shifts in community structure on the sea floor are being observed. For example amphipods (small shrimp-like crustaceans that live in the sediments), that formerly were a critical food source for gray whales just north of St. Lawrence Island, have been replaced by dense worm aggregations that are feeding sculpin and other fish. It is unclear if the seafloor community declines and shifts are due to increasing fish predation on benthic (sea-floor) communities, decreases in organic carbon reaching the sea floor, changes in water currents providing nutrients, or more likely a complex mixture of factors. Whatever the cause, an increasingly warm and more ice-free Bering Sea will not only lead to seasonal sea ice decline, but also to fundamental re-organization of ecosystem structure.

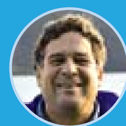
Studies published within the past few years indicate that it is possible with fish expansion northward and other shifts that the rich bottom communities of the Bering and Chukchi Sea will no longer be nourishing bottom feeding apex predators such as walrus, gray whales, and spectacled eiders. Gray whales have already been documented to shift further north in their summer foraging, but the problem is not as simple as changes in distribution.

Ultimately the shallow arctic continental shelf transitions to the deep Arctic basin, which is biologically unproductive and too deep for the shallow water diving animals that now utilize the Bering and Chukchi shelf. The disappearance of suitable summer habitat, including sea ice to use as a foraging platform, is likely to be behind the observations of female walruses and their young coming ashore on arctic beaches in both Alaska and Chukotka in recent years. This is a change from foraging as they have historically done while drifting over rich benthic communities on the extensive continental shelf from sea ice, which is no longer present in late summer over shallow waters where they could potentially feed.

Ultimately other processes will also influence ecosystem function such as the timing of sea ice melt. It has been hypothesized for example that earlier sea ice retreat mechanistically leads to more mature development of zooplankton populations and altered organic carbon cycling in longer food chains. These altered zooplankton communities are able to consume a larger fraction of organic production, which will also lead more to an ecosystem that is dominated by fish, as a smaller fraction of water column production reaches the bottom in unaltered, fresh condition for use by seafloor biological communities.

The intensity of primary production is also affected by varying wind fields that influence the boundaries between nutrient-rich water brought up from

> **"It is possible with fish expansion northward and other shifts that the rich bottom communities of the Bering and Chukchi Sea will no longer be nourishing bottom feeding apex predators such as walrus, gray whales, and spectacled eiders.**



LEE W. COOPER is a Research Professor at the University of Maryland Center for Environmental Sciences with a specialization in marine biogeochemical cycles. He has been working to a great extent on high latitude research questions over the past 25 years.

depth in the Bering Sea and nutrient-poor water on the Alaskan side of the Bering Sea. Consequently, climate warming by itself is only one aspect of the environmental change that is probably influencing the scope of re-organization in this productive northern ecosystem.

Modeling studies do not indicate that there is any likelihood that sea ice will permanently disappear from the Bering and Chukchi Seas in the foreseeable future, even while it is possible that the Arctic will be ice-free in the summer in the coming decades. However, winters will remain dark and cold enough for sea ice formation, both in the Arctic, as well as in its marginal seas such as the Bering and Chukchi. Moreover, local weather processes mean that ice extent in the Bering and Chukchi Sea over winter is largely de-coupled from ice extent in the summer months in the Arctic Ocean.

All of these factors dictate a need for an integrated approach to understanding the complexities of environmental change in the Bering and Chukchi Sea ecosystem. Some progress in improved ecological understanding has been made through the initiation of joint research programs between the National Science Foundation and the North Pacific Research Board that are currently focused on the Bering Sea, and the initiation of an Arctic Observing Network that is designed to provide better documentation of environmental changes in the Arctic as a whole. Particularly in the case of the Arctic Observing Network, however many of the initial observation systems in the marine environment are focused on physical features, i.e. the extent of sea ice, water temperature and current flow. Clearly these physical measurements are important to understanding and documenting climate change in the Arctic system, but integrating biological system change is also needed because of the complex and likely unanticipated ecosystem responses that are likely in the coming decades. ○

Gwich'in and the Porcupine Caribou – one land, two hearts

Gwich'in and the Porcupine Caribou have co-existed since time immemorial, says **BRIDGET LAROCQUE**. As climate change brings added pressure on caribou herds, the long-term survival of the Gwich'in may also be in doubt.

"We as Gwich'in people truly respect the VUTZUI (caribou) and take only what we need. This is our way of conserving. We are dependent on the caribou in many ways. We are grateful that caribou come back our way, close to Old Crow every year. Sometimes they are delayed; however, we still wait patiently because the caribou have never let us down yet. Our prayers have been answered when the hunter sees the caribou on Crow Mountain and calls out "Vutzui!" When they do this, everyone gets excited. Our stomach will be full again and we will continue to survive and be a proud and strong Nation. For this we say "Massi Cho!" (Thank you!)
– Mary Jane Moses, Old Crow, Yukon

GWICH'IN CREATION says that the Gwich'in and the caribou lived in harmony and had an agreement. "The Gwich'in would retain a part of the caribou heart and the caribou would retain a part of the Gwich'in heart…"

Gwich'in people live in a vast area extending from northeast Alaska in the U.S. to the northern Yukon and Northwest Territories in Canada. Oral tradition indicates that the Gwich'in have occupied this area since time immemorial or, according to conventional belief, for as long as 20,000 years.

Gwich'in life and culture have traditionally been based on the Porcupine Caribou herd, the people's main source of food, tools, and clothing. Fish and other animals supplement their diet. Caribou not only provides Gwich'in with physical strength and vitality but it connects back to their spiritual, social and cultural foundations.

Gwich'in practiced a nomadic lifestyle until the 1870's, when fur traders came into the area to establish forts and trading posts that later became settlements. Approximately 9,000 Gwich'in

> **"Gwich'in life and culture have traditionally been based on the Porcupine Caribou herd, the people's main source of food, tools, and clothing... Caribou not only provides Gwich'in with physical strength and vitality but it connects back to their spiritual, social and cultural foundations.**

Photo: Bridget Larocque

Gwich'in girls in traditional clothing, Gwich'in Gathering 2008, Old Crow, Yukon.

currently make their home in communities in Alaska, Yukon, and the Northwest Territories.

Due to thousands of years of Gwich'in relying on caribou for subsistence, social, nutritional, cultural and spiritual needs, the Gwich'in communities of Arctic Village, Venetie, Fort Yukon, Beaver, Chalkyitsik, Birch Creek, Stevens Village, Circle, and Eagle Village in Alaska; from Old Crow, Fort McPherson, Tsiigehtchic, Aklavik, and Inuvik in Canada reached consensus in their traditional way, and have elected to speak with a single voice when it comes to the protection of their very life line, the Porcupine Caribou.

Gwich'in, among numerous other indigenous peoples, experience many kinds of ecological changes in their northern communities. Several of these changes have adverse impacts on their traditional hunting, gathering, harvesting practices. From contaminants and variations in wildlife populations to forest fires and artic sea ice melt, to mining and oil and gas development, Gwich'in subsistence lifestyles are impacted. The new threat or opportunity, yet to be determined, is under the guise of climate change. A well respected Gwich'in elder Charlie Snowshoe calls such change "man made change." All changes being experienced are the result of industry which is driven by humans which coincides with elder Snowshoe's belief.

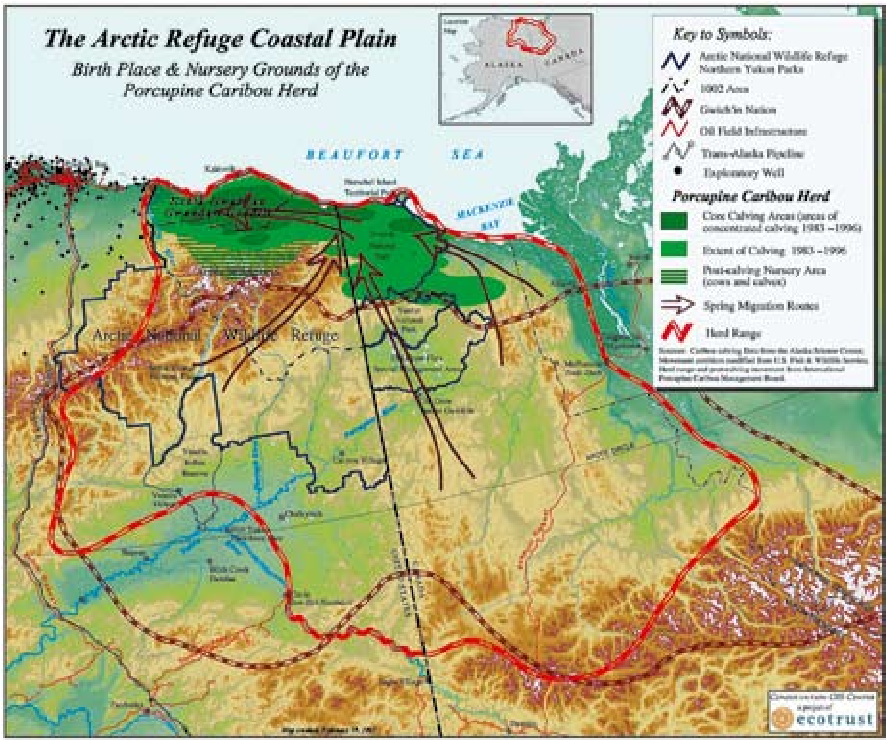
Due to the reality of climate change and unforeseen impacts Gwich'in are concerned about their resilience and health in relation to the social and ecological changes which threaten important human-environment relationships, now and in the future. This is the main investigative question which the Gwich'in will be seeking to answer through an IPY project they are involved in with other Aboriginal organizations and the universities of Alberta and Trent.

This question will bring knowledge from numerous communities, regions of Canada and from the circumpolar world as researchers explore the similarities, values and relationships indigenous, aboriginal people share when it comes to their threatened resource – the caribou.

Gwich'in through their social networks, traditional knowledge and skills, and governance and intuitional arrangements prepare to share their knowledge with researchers and partners in hopes to gain a better understanding of social-ecological health in their respective communities as they continue to accept the decline in caribou populations.

According to Chief Joe Linklater, Gwich'in have rights and those rights come with responsibilities. If we do not promote responsible hunting, trapping, gathering and harvesting all rights afforded Gwich'in such as treaty, self-government and modern day treaties will have little to no value.

As Gwich'in continue to develop sustainability plans, they do this with the Porcupine Caribou not only in their minds but in their hearts. Gwich'in have much doubt that they can exist without their caribou. When looking at their longevity and adaptability intuition, Gwich'in take from their oral history and current practices. ○



BRIDGET LAROCQUE is the Executive Director of Gwich'in Council International (GCI). GCI protects and promotes its sustainable development interest through its membership as a Permanent Participant of the Arctic Council.

Climate and caribou

While the size of caribou herds have risen and fallen in the past, **MONTE HUMMEL** says the question today is: Has climate change altered the environment in such a way that recovery is jeopardized? If so, should northern communities be compensated?

THERE IS HONEST DEBATE among hunters and scientists alike as to whether current dramatic declines in migratory tundra caribou herds, across the world's Arctic, are natural fluctuations consistent with historical experience. For example, the George River herd of northern Quebec and Labrador has been as low as 5,000, and as high as 800,000 animals.

Photo: Sherry Pettigrew

MONTE HUMMEL is President Emeritus of WWF-Canada, and co-author with Dr Justina C. Ray of *Caribou and the North; A Shared Future,* Dundurn Press, 2008.

However, the crucial question is whether the conditions for caribou *recovery* are comparable, and climate change represents a new threat that could make the present and future unlike the past. At the very least, it presents another hill, among many, which caribou must climb in order to come back.

Effects could be felt most importantly on both the quality and abundance of caribou food. For example, Alaskan researchers are already documenting replacement of cold-climate lichens with warm-climate vascular plants in critical feeding grounds. Wetter weather, followed by freezing, results in icing-over of food. This can also affect populations, as has occurred with endangered Peary caribou in the Canadian High Arctic Islands.

Coastal calving areas "green-up" just as the pregnant cows arrive in spring. These cool, windswept, remote locations also provide relief from flies and predators. But warming temperatures could upset such conditions and timing, as caribou get "squeezed" between the arctic coast and changing habitat moving northward. In Greenland, caribou have been arriving on calving grounds as much as two weeks too late, when the changed nutritional value and digestibility of food is affecting calf survival.

Warmer, drier forests are more vulnerable to fire, reducing both the quality (fewer arboreal lichens for food) and quantity of winter range. Changed climate could also increase insect populations, which already severely stress caribou on their summer range. Higher, more turbulent water levels, earlier in the spring, could lead to increased mass-drownings at traditional crossing points during migration.

Addressing climate change is unlike other potential threats, such as overharvesting and industrial impacts, which, although challenging, can at least be tackled in the short-term, locally. Climate change requires long-term commitments at a global scale, by nation-states whose capitals are both geographically and sociologically distant from caribou country.

Arctic caribou collapses have recently been compared to the northern cod and Pacific salmon crises in terms of their far-reaching economic and cultural significance. Migratory tundra caribou in North America have been valued at over $100 million per year, for food value alone. And the Gwich'in of northern Yukon and Alaska often refer to the future of caribou and associated climate change as a "human rights issue." If the southern fisheries merit judicial inquiries and national restoration policies, northern caribou deserve no less. ○

Photo: Monte Hummel

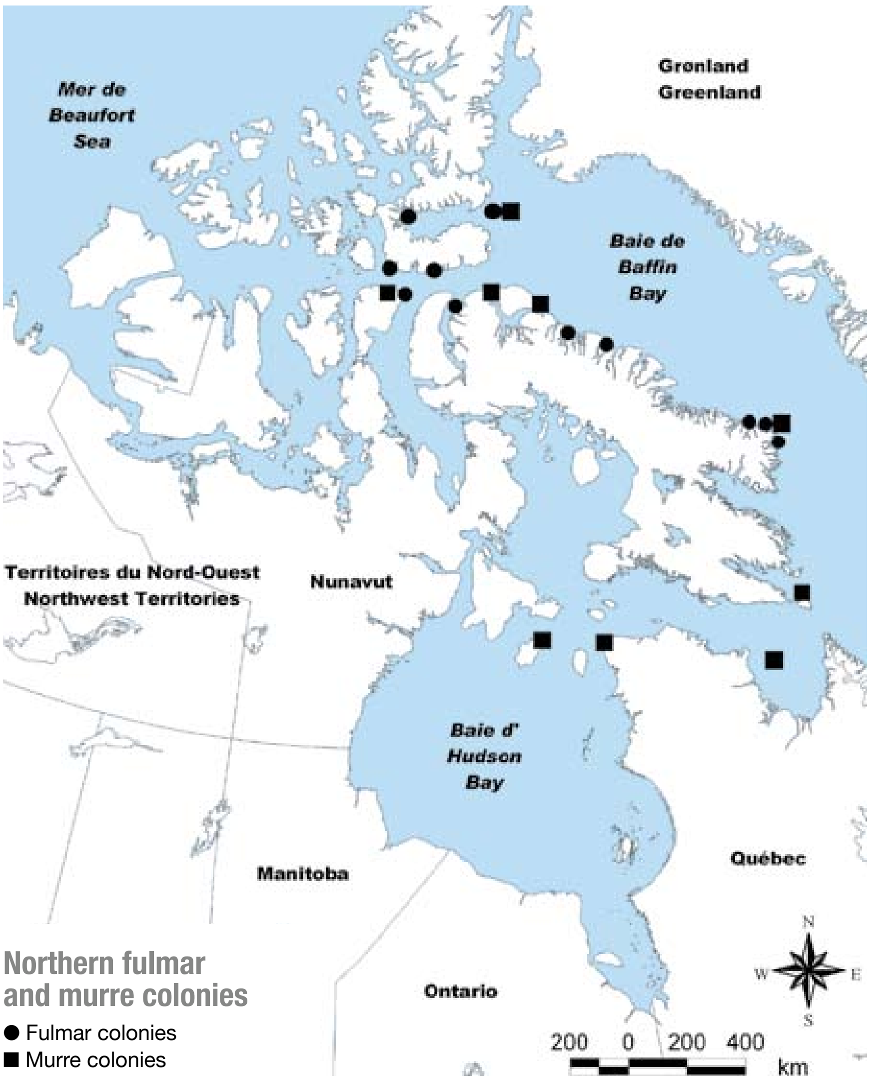
The Porcupine caribou herd crosses the Firth River in spring flood, taken from a high river bank.

Arctic marine birds like it cold and icy

A warming arctic will pose new challenges for arctic marine birds, says **MARK MALLORY**. Species composition and changes in population size may be the result.

MILLIONS OF MARINE BIRDS call the Arctic home during the brief summer, withstanding often harsh weather conditions to breed and exploit the abundant food resources that become available once the sea ice has broken up. It might seem like a warming climate should make conditions easier for these birds. However, the reality is complicated. How then is climate change affecting them?

Based on work in Canada, a warming climate will affect marine birds in 3 ways: 1) by altering the timing of sea-ice break-up; 2) by increasing the frequency and/or intensity of storms; and 3) by altering the existing balance between competitor species, parasites or diseases for existing bird populations.



Map: Jason Akearok, EC-CWS.

The timing of ice break-up is critical for the annual cycle of arctic marine birds for at least two reasons. First, birds need open water in which to feed, so solid sea ice forms a physical barrier to foraging, precluding birds from accessing many areas for much of the year. Second, through release of nutrients grown on the underside of ice, and by allowing light to penetrate the water column, the break up of sea ice initiates a pulse of marine productivity that "sets the clock" for annual production in the marine food web. Most arctic marine birds are tuned into this clock, and time their northward migration to their nesting sites to track break-up and available open water. In turn, their breeding is timed so that peak marine food supplies are available when adult birds are trying to raise chicks.

Environment Canada's northern seabird team, led by Dr. Tony Gaston, has been monitoring a colony of thick-billed murre (or Brünnich's guillemot, *Uria lomvia*) at the southern edge of its breeding range at Coats Island in northern Hudson Bay since 1981. This work found that the annual date by which half of the ice in Hudson Bay is gone has advanced by about 17 days. This has serious implications for the fish-eating murres, because the peak of food abundance in the nearby waters has also advanced 17 days. However, the timing of hatch of murre eggs has only

Photo: Grant Gilchrist

DR. MARK MALLORY is a Seabird Biologist with the Canadian Wildlife Service based in Iqaluit, Nunavut. He assesses the effects of anthropogenic activities on marine bird populations in Arctic Canada, particularly endangered species.

Northern Fulmars, Cape Vera, 2005.

Photo: Mark Mallory

advanced by five days over this period. In other words, murres are not keeping up with the rate of change of ice melt, and their breeding is now mismatched with the peak of food supplies.

Another impact that these murres must deal with is that their food has changed. Prior to 1990, these murres fed mostly Arctic cod (*Boreogadus saida*) to their chicks. This is a typical High Arctic, ice-associated, fatty fish. Since 1996, murres have brought mostly capelin (*Mallotus villosus*) to their chicks, a fish typical of subarctic waters, and which is not as heavy as cod for the same length of fish. The displacement of cod by capelin, and perhaps the mismatch with peak food supplies have had consequences; both adult mass and chick growth rates at the colony are now lower than they were in the past.

Thick-billed Murres, Prince Leopold Island, 2007.

Photo: Mark Mallory

In contrast, at another murre colony in the High Arctic near the northern limit of the species' range (Prince Leopold Island), there has been no long-term pattern of ice change. Interestingly, murres here fare better in years when the ice goes out earlier, presumably because birds do not have to fly as far to find food. However, even here, if ice eventually disappears, we expect similar effects as we see at Coats Island.

A second way that climate change might affect these birds is by exposing them to more storms. At Prince Leopold Island and at Cape Vera on Devon Island, I led work on northern fulmars (*Fulmarus glacialis*), a petrel also breeding near the northern limit of its range. We found that the main factor causing fulmar nest failure was severe storms, particularly those with heavy snowfall, strong winds or heavy rain. These storms either forced parents off of nests, allowing predatory gulls to steal eggs and chicks, or they buried eggs and chicks in snow. With continued warming, the Arctic is expected to experience more frequent and intense storms; this cannot be good news for Arctic marine birds.

Finally, a warming climate might change environmental or ecological conditions and provide an advantage to species currently constrained at existing colonies. For example, during abnormally warm years at Coats Island, the combination of heat stress and exceptionally high mosquito populations can cause murres to die on their nest. This may become a more common occurrence with global warming.

Arctic marine birds are built to thrive in the cold and ice. While they can tolerate natural variation in temperatures among years, a long-term warming and consequent loss of ice will lead to substantial changes in the species present and the population size of these arctic species. ○

Walrus – Facing new challenges in a changing Arctic

As Arctic sea ice diminishes, walruses are being forced to come ashore in large concentrated haul-outs, says **TOM ARNBOM**. This increases the chance of death caused by trampling and may impact females with calves as they must swim farther to feed and rest.

SUDDENLY, WITHOUT ANY visual reason, the upper part of the colony starts moving towards the safety in the sea. Thousands of blubber saturated and panic stricken walruses move like a road roller towards the shore, crushing hundreds of animals. This horrific scenario is part of the effects of climate change now occurring in the Arctic.

WALRUS

Walrus (Odobenus rosmarus) are the largest seal, or pinniped, species in the Arctic, and are highly adapted to their sea ice environment. They are the only living species in the Odobenidae family and Odobenus genus. They are gregarious and can often be seen in small groups however in some "haul-out" sites, tens of thousands may gather. The mating system is polygynous which means about one male will impregnate approximately ten females during the breeding period. After a 15–16 month pregnancy, the female will give birth to a single calf (with few exceptions) which is nursed for about two years. Walruses feed mainly on bivalve mollusks and are therefore normally confined to waters on the continental shelves. Walrus are circumpolar in distribution and consist of a single species, made up of at least two subspecies: the Atlantic walrus and the larger Pacific walrus. A third subspecies has been suggested, the Laptev walrus, but its status as a subspecies is not clear.

REMARKABLE COMEBACK

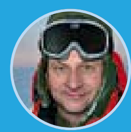
The walrus has been exploited by man for thousands of years and has always been important to the Inuit economy.

In some areas, walrus serve as a critical subsistence resource. Walrus meat feeds sled dogs as well as people, blubber produces good quality oil for burning, and ivory can be used for constructing tools and weapons, and more recently, carving.

During the last five hundred years, the walrus hunt changed in many areas from a subsistence hunt to a commercial one. The rapid depletion of walrus stocks by mainly foreign commercial hunters severely hampered life in local communities. By the1880's, as much as half of the Pacific walrus population was probably depleted. This had an immense impact on native communities and some, particularly on isolated on islands, were said to have experienced starvation.

By 1960, both American and Soviet governments began enforcing regulations which decreased the number of animals taken, and protected many coastal haul-out sites. Today the Pacific walrus population has recovered from overharvest, but now faces a more complicated and significant threat. The same story also applies to the Atlantic population, where hundreds of thousands of walruses were killed. Currently, the Atlantic population is only about 20,000 animals. In many areas, walruses continue to be hunted by indigenous people for subsistence living.

> **"In 2007, the Russian settlement of Ryrkaipiy saw more than 40,000 walruses suddenly come ashore ... Suddenly, they had the largest walrus colony in the world next door to the local school.**



TOM ARNBOM works for WWF-Sweden and is responsible for Arctic and Large Carnivores. He is also an Associated professor of Marine mammals. His PhD was on the southern elephant seal, and his Msc. focused on Sperm whales. A former member of IWC, he was earlier employed by the Swedish ministry of environment.

These hunts are normally regulated.

CLIMATE CHANGE A NEW THREAT

In addition to over-harvesting, walrus populations are threatened by noise pollution (such as under and over water sounds made by ships, aircraft, seismic activities and offshore drilling), pollution (oil spill and other contaminants), and interactions with fisheries (fisheries can compete directly with walruses for a food resource or damage their food supply by disturbing the bottom). There is also a risk with increasing tourism that more walrus haul-out sites will be disturbed if no regulations are in place and enforced. In addition, a new and very serious threat has emerged – that of climate change.

RESTING ON SUMMER SEA ICE

In winter, Pacific walruses are found in the open pack ice of the Bering Sea. In April, they migrate north through the Bering Strait into the Chukchi Sea and in the summer are widely distributed from the Kolyma River in the west to Point Barrow in the east. Walruses normally haul-out on the sea ice to rest between feeding bouts, and females with their dependent young literally rest on ice flows above their food, found 20–80 metres below on the sea floor.

Now however, walrus are experiencing a hard time in accessing their preferred feeding areas. Over the last ten years, summer sea ice has decreased dramatically north of Chukotka and has withdrawn northward from the continental shelves into very deep water. This has meant that in many areas, the distance between ice flow and ocean bottom is so great, mussels are now out of diving range.

GOING ASHORE

The lack of summer sea ice is causing more and more walruses to haul-out on shore. In 2007, the Russian settlement of Ryrkaipiy saw more than 40 000 walruses suddenly come ashore. Local people were astonished, as this area had never been a haul-out site. Suddenly, they had the largest walrus colony in the world next door to the local school. The noise and smell were incredible and many animals died of stampedes when walruses panicked and wanted to reach safety in the water. More than five hundred animals were crushed to death, causing a potential a health problem. Hundreds of dead, smelly, decomposing bodies were lying close to the village and in a few months, hundreds of polar bears would pass by on their annual winter migration. In order to prevent an unwanted conflict with the coming polar bears, walrus corpses were removed from the beach by tractors and stacked in big heaps away from the village in an attempt to keep the coming polar bears away from people.

NOW EVEN IN ALASKA

In 2007, more than 1,000 walruses were trampled to death in Chukotka, Russia. In 2008, it happened again, and in the autumn 2009 the same phenomenon occurred again, in Alaska.


Photo: Tom Arnbom.

Atlantic walrus at Svalbard, Norway.

The lack of summer sea ice is causing more and more walruses to go ashore. When the walruses stayed offshore on the sea ice, they were spread out over a huge area. Now onshore, they gather in large numbers in very tight haul-out sites increasing the risk of trampling deaths. As an added concern, mussels close to haul-out sites will most likely be depleted due to the sheer number of walruses. Females with calves also have a much longer distance to swim to get to feeding areas and back to shore for a rest. It is unknown how this will affect walrus body condition and survival.

We all know that climate change is causing a bleak future for the polar bear, but sadly the polar bear is not the only species affected in the Arctic. Ice living seals, narwhal, bowhead, reindeer and walrus are just some of many species that will have a difficult time surviving in a changing Arctic if nothing is done in time to decrease the emission of greenhouse gases. ○

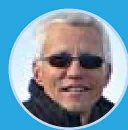
The elusive narwhal in a rapidly changing Arctic

While superbly adapted to life in the ice, narwhals may be vulnerable to larger ecosystem changes brought on by climate change, says **MADS PETER HEIDE-JØRGENSEN**. More research will be needed to balance the effects of climate change and human activities such as hunting.

WHEN MAKING a low altitude flight over Baffin Bay on a sunny winter day you first notice the vast areas of dense pack-ice of countless shapes with colors from pale white to light blue or almost black ice. There are no obvious signs of life in these endless ice fields only interrupted by an iceberg that is frozen into the pack. But the ice is jagged with a highly variable mosaic of plates of many square kilometres that are gently changing position driven by wind and currents. Occasionally the ice movements create a small crack in which open water reflects the sun. Most leads are only a few meters wide and some hundred meters long with several kilometers to the next lead. In the offshore deep-water areas a closer inspection of the cracks will reveal some black bodies that move slowly or rest at the surface, occasionally giving a blow or displaying a tusk. This is the main habitat of the narwhal, one of three whales that live year-round in the Arctic and definitely the one that is best adapted to life in the ice.

The narwhal is restricted to the Atlantic sector of the Arctic between Siberia and the Canadian High Arctic with a core distribution in Baffin Bay. It is very elusive and perhaps the most challenging mammal to study in the Arctic. The main reason for this is their preference for deep-water areas densely covered with pack ice. But narwhals provide at the same time a unique opportunity to gain insight into some of these least known areas; the deep basins in the Arctic.

Satellite tracking of narwhals from coastal summering grounds into the abyss of Baffin Bay has demonstrated the dependence of narwhals on the abundant resources of Greenland halibut along the edges of the continental shelf. Narwhals working as oceanographic platforms have also documented the increasing temperature in the deep waters of Baf-



MADS PETER HEIDE-JØRGENSEN is a senior scientist at the Greenland Institute of Natural Resources. Working in the Arctic since 1982, his main research field is arctic marine mammals, especially cetaceans, where he has provided data for the International Whaling Commission and the North Atlantic Marine Mammal Commission. He has pioneered new techniques for tracking whales by satellite and for surveying marine mammal populations.

Photo: Mads Peter Heide-Jorgensen:

fin Bay. And new research is focusing on the history of pollutants and climate changes that is archived in the tusks of 100 plus-year old narwhals.

Inuit inhabiting the shores of Greenland and Canada have for millennia used narwhals as a resource. The skin is considered a delicacy and is rich in vitamin C. The meat is used for humans and dogs and the conspicuous tusk, which in the old days was used for tools, is nowadays sold to generate a cash income. Although the trade in narwhal tusks is not endangering narwhal stocks, it is still subject to considerable international controversy.

MAP: Mads Peter Heide-Jorgensen

As for all slow reproducing species subject to hunting, it is essential to install population monitoring that can detect and inform wildlife managers about declines in population abundance. Canada and Greenland have documented that the current abundance exceeds 70,000 narwhals in the areas where they are hunted. To this should be added the abundance in remote areas free from hunting. Quota systems installed in both Canada and Greenland should, if followed properly, ensure stable if not increasing populations but error margins are large and it is required that population monitoring will continue and that impacts from other changes in the narwhal habitats, i.e. changes in sea ice conditions, are included in population assessments.

Narwhals are among the most climate sensitive of the arctic marine mammals. This is due to their restricted and specialized distribution, their limited diet, the low plasticity in migratory patterns and their low abundance. Furthermore narwhals occur in many small more or less isolated populations of which several are not yet identified.

It is a paradox that narwhals are both well adapted to life in dense pack-ice and also occasionally succumb in large numbers when sea ice forms during periods with sudden drops in temperature. However this may explain the extreme low genetic diversity, lower than for any other cetaceans, demonstrated for narwhals. In a warming arctic, ice entrapments may seem to be disappearing but for narwhals the issue is not as much the extension of the ice but rather how predictable the ice forms.

Rapid disruptions of the climate are a challenge for animals, like narwhals, with low behavioral and ecological plasticity. Narwhal behavior has developed over millennia and the low historical and modern genetic diversity demonstrates that evolutionary pressure on narwhals has remained low. This may change with the rapid temperature increase forecasted in the hockey stick model and will eventually affect narwhals by changes in sea ice regimes and oceanographic conditions that cascade through the food web and, for instance, affect the temperature sensitive Greenland halibut – the main prey of narwhals.

The challenge for the conservation of narwhals is to learn quickly before the Arctic changes and before it is too late to understand the aspects of narwhal biology that are needed for balancing the effects of climate change and human activities. In this perspective it seems important to identify the sub-populations of narwhals, especially those that supply the hunt, and to monitor the reaction of narwhal stocks to ongoing changes in sea ice and prey distribution. ○

Bowhead whales – what are the climate change impacts and adaptation prospects?

Bowhead whales have been around for more than two million years, says **PETER EWINS**, however current changes in the Arctic ecosystem brought on by climate change and industrial development have put their long-term survival in question.


Photo: Ben Wheeler

BOWHEAD WHALES (*Balaena mysticetus*) have been around for a long time. Their Balaena ancestors evolved 4–5 million years ago, and bowheads probably existed before the Pleistocene era, ie. more than 2.6 million years ago. The bowhead whale appears to have the maximum longevity of any extant vertebrate species – over 200 years has been recorded for a few individuals. Bowheads evolved in partially iced northern waters, and like the other ice-associated northern whales, beluga and narwhal, lack a dorsal fin. Inuit have reported that bowheads can break through ice 60 cm thick, and have the thickest blubber of any animal species (up to 50 cm thick). Bowheads feed primarily on copepod and euphausiid crustacean zooplankton throughout the water column, especially in areas of upwellings, polynya and other key oceanographic features.

Bowhead whales are currently distributed quite widely in four distinct subpopulations (see map), mainly over continental shelves, with some seasonal migration to sub-arctic seas. All subpopulations are still recovering from the impacts of heavy over-exploitation by commercial whalers from Europe and the United States who worked closely with arctic coastal communities in the 18th and 19th Centuries to capitalize on new world markets for whale oil and baleen.

It is likely that this species has experienced only two major threats to its survival – commercial whaling, and changes in climate/ice conditions. Now that whaling is far more tightly controlled, the main concern for persistence of bowheads is the unprecedented rapid rates of climatic change and their impact on arctic marine ecosystems.

The current and projected thinning and areal loss of sea ice cover due to rapid global warming present major challenges for bowheads, since they have evolved very specific characteristics superbly adapted to this slow, cold, silent, patchy environment, with sea ice a defining feature throughout. As for many arctic species, there is little evidence from the fossil record that this highly adapted lifestyle will be able to respond quickly to unprecedented rapid climate warming and all that it triggers.

Climate-related impacts on bowheads are already being noticed. Inuit and scientists alike have noted sharp increases in killer whale sightings in arctic waters in recent decades as open water areas persist for much longer periods in summer and autumn, with some bowhead carcasses and live animals showing distinctive killer whale teeth scars/marks. It is generally thought that the large dorsal fins of killer whales prevent them from entering areas of heavy ice cover, and so such areas are relatively safe and provide nursery and feeding areas for bowheads.

Most experts agree today that the rapid climate change-induced disruption to key arctic oceanographic features, like nutrient inflows, water stratification, salinity, and surface temperature, as well as sea ice loss leading to more pelagic characteristics, represent huge challenges to highly evolved


Photo: WWF-Canada/Bill Ivy

PETER EWINS is WWF-Canada's Senior Officer for Species Conservation, focusing mainly on the Arctic. He has worked and traveled extensively in Canada's northern communities and ecosystems.

> "While bowhead whales have survived few million years and a series of glacial periods, they have never confronted the unprecedented rates of warming now under way...

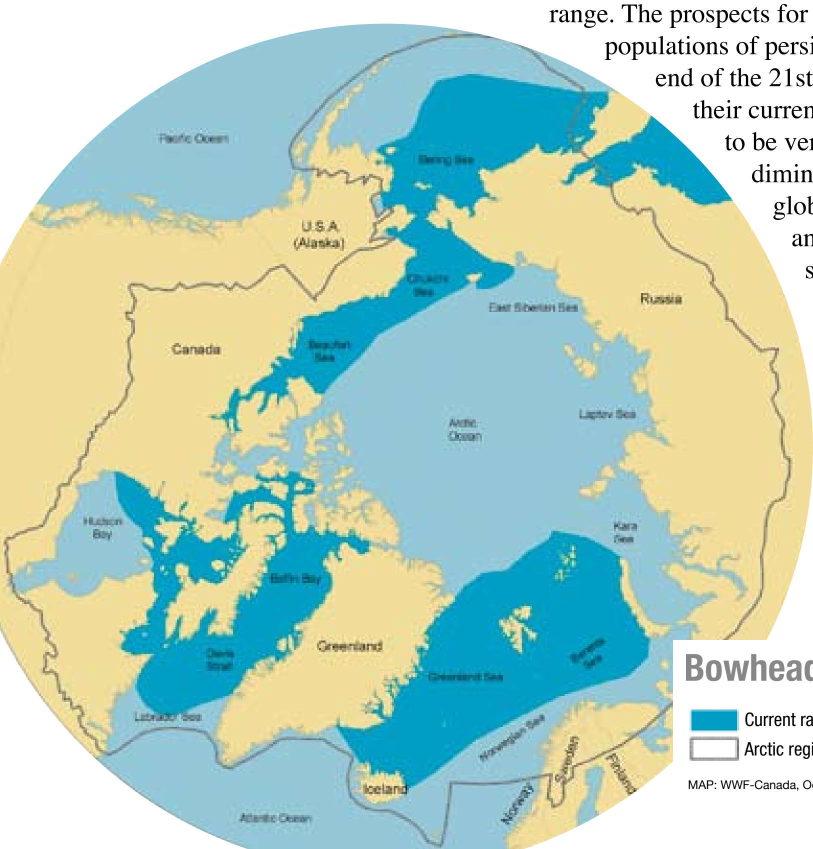
ice-associated species like bowhead whales. But few scientists are willing to speculate as to precise consequences for bowheads at this point, and how adaptable and resilient these depleted bowhead populations might be this century.

What we do know from published studies to this point is that major marine ecosystem shifts are already underway in the Arctic, and that they will only increase. It is quite possible that some shallow-water regions dominated by sea ice will pass critical thresholds and shift to more pelagic open-water conditions, with other baleen whales such as humpback, grey and even blue whales moving northwards into the arctic basin – perhaps accompanied by killer whales too.

As sea ice retreats further, so commercial shipping and offshore industrial venturing increases, and this brings greater disruption to acoustic communication by bowheads, and of course risks of oil pollution (for which, amazingly, there is still no proven technique for recovering oil spilled in partially iced waters). This will be especially significant in the vicinity of key bowhead feeding and nursery areas, and migration routes along continental shelves.

On the brighter side, in the relatively well-studied Bering-Beaufort-Chukchi marine ecosystem, bowhead numbers have been increasing (albeit from heavy commercial over-exploitation) at 3% per annum for the past two decades, despite reducing sea ice cover. Perhaps this is due to still abundant zooplankton, few competitors, and as yet low predation from killer whales.

While bowhead whales have survived a few million years and a series of glacial periods, they have never confronted the unprecedented rates of warming now under way, on top of cumulative industrial activities within their current range. The prospects for many bowhead populations of persisting to the end of the 21st Century in their current range appear to be very significantly diminished by rapid global warming and all the ecosystem changes it triggers. ○



Bowhead whales

Current range
Arctic region boundary (CAFF)

MAP: WWF-Canada, October 2009

Killer whales

As a melting Arctic opens up northern waters, killer whales are being seen more often in areas previously outside their normal range, says **STEVEN FERGUSON**. The impact of this new predator on other marine species and the surrounding ecosystem remains to be seen.

KILLER WHALES (*Orcinus orca*) have existed in arctic waters since time immemorial and their distribution has likely waxed and waned with the advancing and retreating ice associated with cycles in global climate. However, during the past few centuries, arctic killer whales that prey on other whales have seen an incredible reduction in their food supply due to extensive commercial whaling. More recently, as previously over hunted populations begin

Killer whales, Admiralty Inlet, Nunavut, 2009

Photo: Gretchen Freund

on the rise in the Canadian Arctic

to recover, big and small whales living in the Arctic are making a comeback and apparently so are the killer whales that feed on them.

The *Orcas of the Canadian Arctic* research group started four years ago by first creating an up-to-date sighting catalogue, second enlisting the support of northerners in providing information on new and old sightings, third deploying acoustic recorders to listen for killer whales, fourth starting a photographic-identification catalogue, fifth conducting an extensive Traditional Ecological Knowledge study in Nunavut communities, and sixth focal follow studies to obtain biopsy samples and tag killer whales with satellite transmitters. The research is early but we are starting to get an idea of the dramatic changes occurring in the Arctic both with global warming and killer whale predation.

A total of more than 450 sightings of killer whales in the Canadian Arctic were compiled from 1850 to 2008 with the number of sightings increasing exponentially over time [graphic 1].

Killer whale predation has been cited as a potential factor in the decline of several marine mammal populations but the topic remains controversial. We do know that killer whales use areas seasonally that provide predictable and abundant prey. We have photographically identified over 80 killer whales that regularly use Nunavut waters in the eastern Canadian Arctic [graphic 2]. The number of new killer whales identified each year has increased linearly and therefore we can assume more than 80 whales seasonally use the Canadian eastern Arctic.

Graphic 1: *Number of killer whale sightings per decade from 1850–2008.*

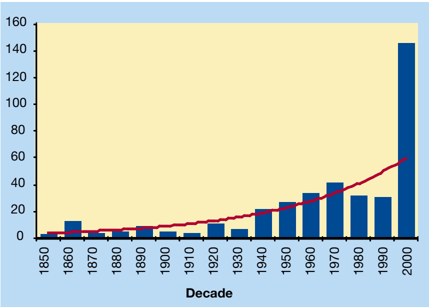
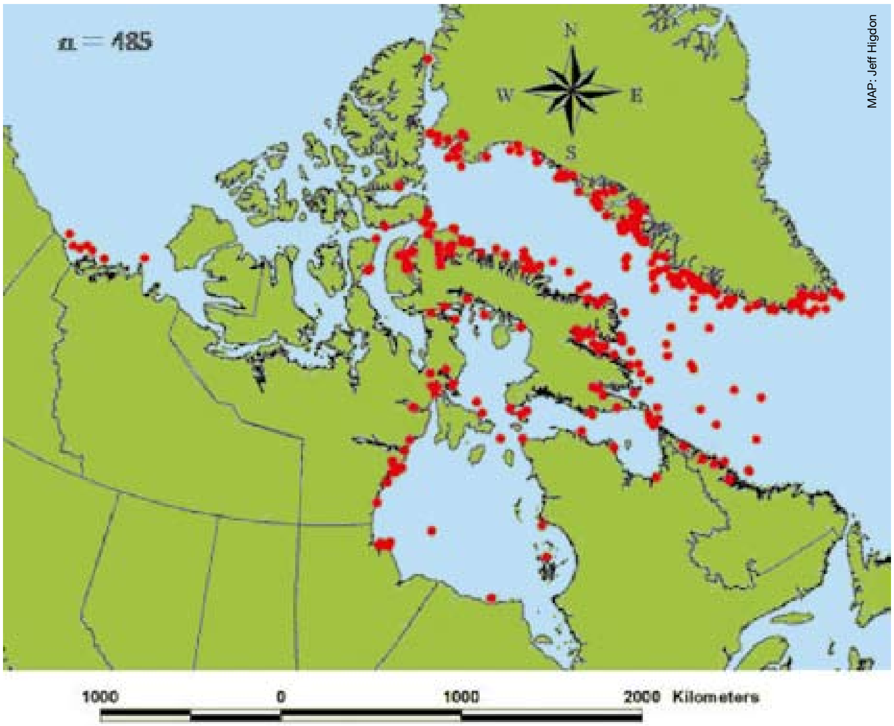


FIGURE: Donna Hauser

Inuit traditional knowledge holders make it clear that the majority, if not all killer whales, do not eat fish – they eat marine mammals that include bowhead, narwhal, beluga, and seals. Small toothed whales, narwhal and beluga whales, are the most frequently observed prey, followed by bowhead whales, and then seals (harp, ringed, bearded, and harbour), and last groups of mixed marine mammal prey. Average killer whale group sizes observed in the Canadian

STEVEN FERGUSON is a Research Scientist with Fisheries and Oceans Canada conducting research on marine mammals in the Canadian Arctic with a particular interest in changes in distribution and abundance with global warming.



Graphic 2: *Killer whale sightings in the western and eastern Canadian Arctic, including west Greenland.*

Arctic are 9 animals but group size varied depending on the prey pursued with the largest groups associated with bowhead whale predation followed by those associated with small toothed whale predation, which, in turn, were larger than those associated with seal predation. Killer whale group sizes in the Canadian Arctic are similar to west coast orcas that eat mammals.

No killer whale sightings occurred during winter, rather, sightings gradually increased from early spring to a peak in summer, after which sightings gradually decreased. Two clusters of killer whales regularly use Nunavut waters; one that moves through Baffin Bay along the northern shoreline of West Greenland, through Lancaster Sound and into Prince Regent Inlet and the Gulf of Boothia [graphic 3]. The second cluster enters the Arctic via Hudson Strait to use the greater Hudson Bay region during the ice-free summer and their presence has increased dramatically in recent years.

Killer whales in Hudson Bay concentrate their activities in northwest Hudson Bay where prey items are diverse and abundant [graphic 4]. Killer whales are now reported in western Hudson Bay on an annual basis, and sighting reports and anecdotal evidence suggest that killer whales are first observed heading through Hudson Strait in July and returning to the northwest Atlantic in September, but arrival and departure times likely vary with annual ice conditions. Looking at historical trends in sea ice conditions of the Hudson Bay area, we identified Hudson Strait as a choke point where killer whales did not enter until the mid-1900s. Killer whales are cautious in ice-covered areas due to their large dorsal fin and fear of ice entrapment. However, the sea ice has diminished in choke points like Hudson Strait, possibly as a result of global warming trends, and now killer whales have access to the large Hudson Bay region that was previously safe from their predation. We predict more choke point areas of the circumpolar arctic to open up with loss of sea ice and the killer whale range expansion will continue in a step-wise fashion.

Killer whales have been observed preying on a number of marine mammal species in Hudson Bay, with particular concern over bowhead predation in Foxe Basin, narwhal predation in northwest Hudson Bay, and beluga predation in southwest Hudson Bay; however their impact on marine mammal species is unknown. To estimate predation impact we used a simple mass-balanced marine mammal model that includes age structure, population size, and predation rate inputs. Preliminary findings for the Hudson Bay region that used sightings of killer whale predation events suggest that the Hudson Bay whales feed on narwhal, beluga, bowhead, and seals [graphic 5]. Our simple model predicts that a group of 30 killer whales using the area during the ice-free period could be taking 2% of the available beluga (n=631), 12% of narwhal (n=608), less than 1% of the seals (n=632), and 3% of bow-

Graphic 3. *Killer whale movements throughout the eastern Arctic based on satellite tagging, Inuit knowledge, and spatio-temporal patterns of reported sightings.*

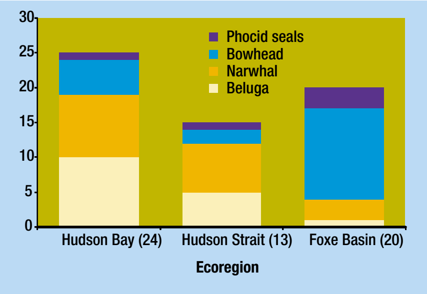


FIGURE: Jeff Higdon.

Graphic 4. *Reported killer whale predation sightings in the Hudson Bay region.*

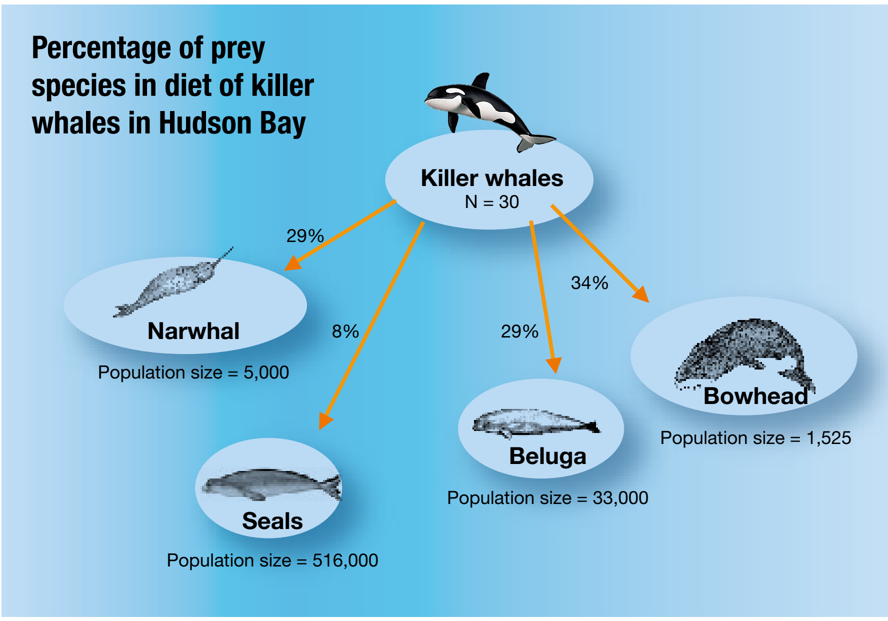
Photo: DFO

Killer whales in Pangnirtung, Nunavut 2008.

head (n=51). These predation estimates are not life-threatening to the Hudson Bay marine mammal populations with the possible exception of narwhal. Narwhal have been identified as one of the most vulnerable ice-adapted marine mammals and they are regular food for the Baffin Bay killer whale groups as well. These model results provide a cautionary note to conservation as we continue to lose arctic sea ice and killer whales advance more into traditionally safe areas that harbour marine mammal populations in summer.

Information on killer whale behaviour, group size, social structure, geographic movements, morphological characteristics, genetics, vocalizations, and foraging behaviour is needed to understand changes occurring in the Arctic. We emphasize the need for long-term studies and direct observation of killer whale hunting behaviour to determine the factors that influence predation rates. However, by defining population energetic requirement and considering population demography of prey, we can begin to assess the basic requirements of predator-prey dynamics in the arctic marine ecosystem.

Killer whales pose a potential dilemma for the arctic ecosystem as they can exert significant regulatory effects to prey populations. Killer whale research will provide context in understanding potential ecosystem shifts and predation consequences to other marine mammals. ○



GRAPHIC: Steven Ferguson

Graphic 5: *Simple model showing the percentage of marine mammal prey (beluga, narwhal, bowhead, seals) eaten by 30 killer whales spending summer in the Hudson Bay region.*

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The Picture

New threats to whales

Commercial whaling on Iceland grew out of an age-old tradition as depicted in this 16th century drawing of Icelanders flensing a whale (from from the Icelandic Reykjabók). Industrial whaling was once the major cause of a global decline in whale populations. Today however, climate change, caused by increasing CO_2 in the atmosphere produced far from arctic waters, poses an even greater threat to the long term survival of many northern whale species.