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.

STEPHANIE PFIRMAN is Hirschhorn 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.

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).

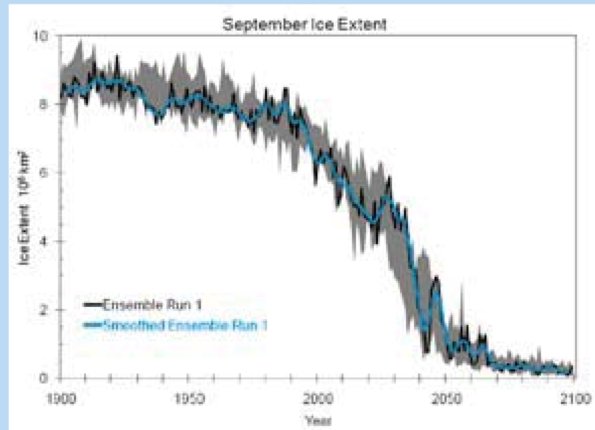


Figure 1: September mean (2040–2049) sea ice concentration projected by the Community Climate System Model (version 3, CCSM3), for the A1B global warming scenario
(http://www.realclimate.org/index.php/archives/2007/01/arctic-sea-ice-decline-in-the-21st-century/; Holland et al., 2006).

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

* 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.

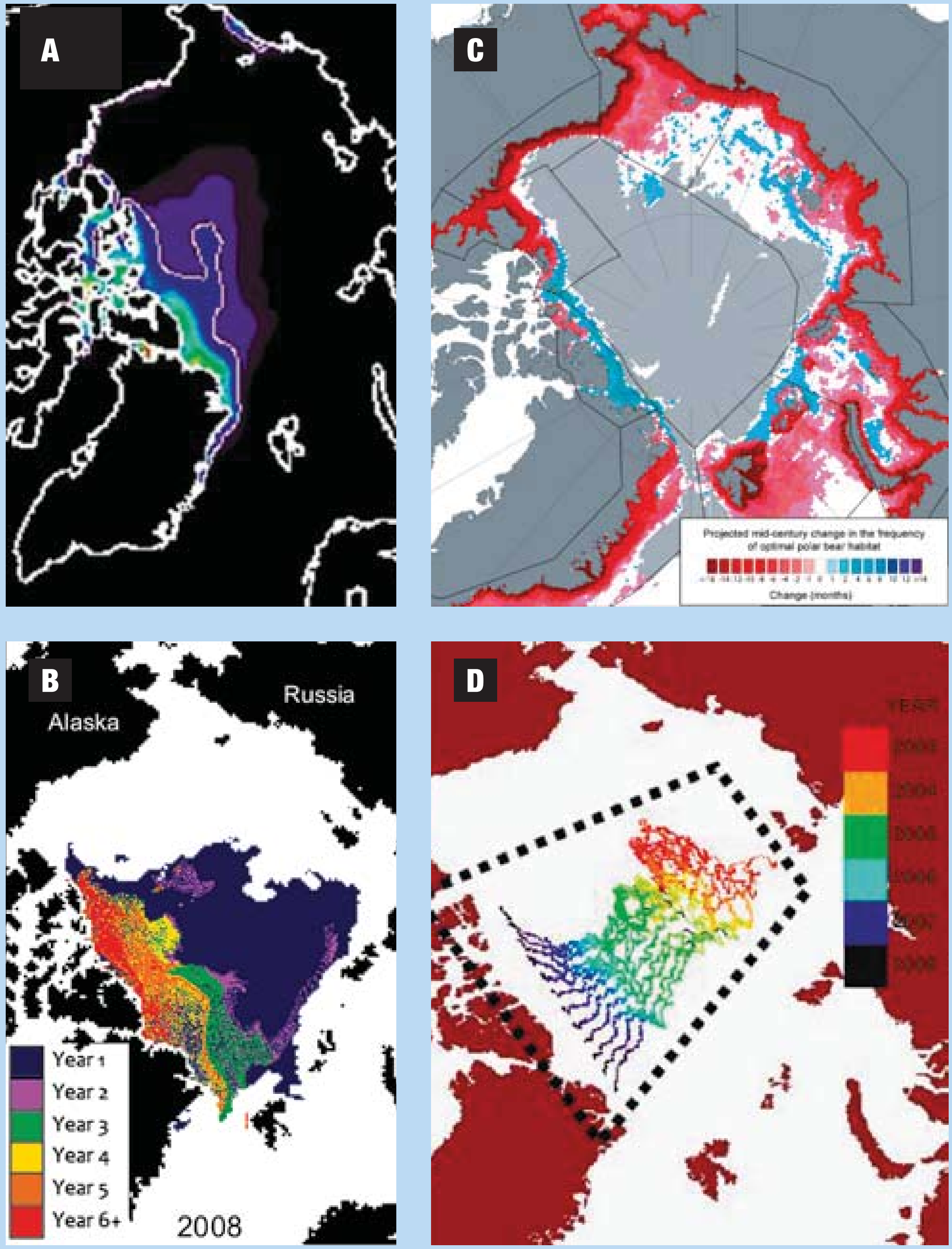
Figure 2:

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. ○

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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