ECOLOGY

Witnessing ice habitat collapse in the Arctic

Abrupt ice loss signals major changes ahead in a north polar conservation zone

By **Warwick F. Vincent**[1] *and* **Derek Mueller**[2]

Over a 2-day period at the end of July 2020, the Milne Ice Shelf underwent fracturing and collapse, losing 43% of its vast expanse as ice islands calved into the Arctic Ocean (see figure) (*1*). This sudden attrition of a thick Arctic ice shelf harboring diverse animal and microbial communities (*2*, *3*) is one of many recent events along Canada's far northern coastline that underscore the vulnerability of polar ice habitats to ongoing climate change. The observed impacts are of special concern given the conservation value of ecosystems in this High Arctic region.

The northern edge of Greenland and the Canadian Arctic Archipelago is the world's most northerly coastal zone. It contains the oldest, thickest sea ice in the Arctic Ocean and is considered the ultimate refuge for ice-dependent species in the rapidly warming North. In recognition of this global value, the Canadian government in partnership with the Qikiqtani Inuit Association designated a large portion of this "Last Ice Area" for interim protection as a Marine Protected Area (MPA) named Tuvaijuittuq, meaning "lasting ice" in Inuktitut (*4*). There is a strong reciprocal interaction between this marine system and the land margins of the High Arctic. These margins include Canada's northernmost land conservation region, Quttinirpaaq National Park, where extreme cold is critical to maintaining prominent ice features, including numerous glaciers, ice shelf remnants, ice-capped lakes, permafrost, and perennial snowbanks that feed water tracks across the polar desert landscape. Molecular analysis has shown that diverse microorganisms [including cold-water viruses (*5*)] thrive in all of these cryoenvironments.

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The Ward Hunt Ice Shelf, the largest platform of thick landfast ice in Arctic Canada, experienced several fracturing events in recent decades, and an automated camera (*6*) on Ward Hunt Island captured its collapse into ice islands over the summers of 2011 and 2012, leaving only two remnants on either side of its embayment. The initial fracturing in 2002 was accompanied by draining and complete loss of a freshwater lake overlying seawater (*2*). The lake dammed by the Milne Ice Shelf, with its distinctive microbial community (*7*), is the last of this ecosystem type in Canada and may be similarly close to disappearance.

Along the coast adjacent to the MPA, lakes that were once covered by thick, multiyear ice are now intermittently ice-free, with abrupt changes in their underlying ecosystems. The first observations of Ward Hunt Lake in the 1950s showed a summer ice cover of more than 4 m (*8*). Over subsequent decades, this perennial ice thinned, and three late-summer ice-out events have occurred in the past 10 years, including 31 days of ice-free conditions in 2016. That year also marked anomalously warm air temperatures at Ward Hunt Island and at Alert, Nunavut, 170 km east of the island, where melting degree-days (summation of daily mean temperatures above 0°C) were more than twice the 1951–2017 average (*8*). Weather extremes are becoming increasingly common throughout the Arctic and have the potential to drive lake ice, sea ice, and other cryoenvironments across thresholds, making them increasingly sensitive to year-to-year variations in climate.

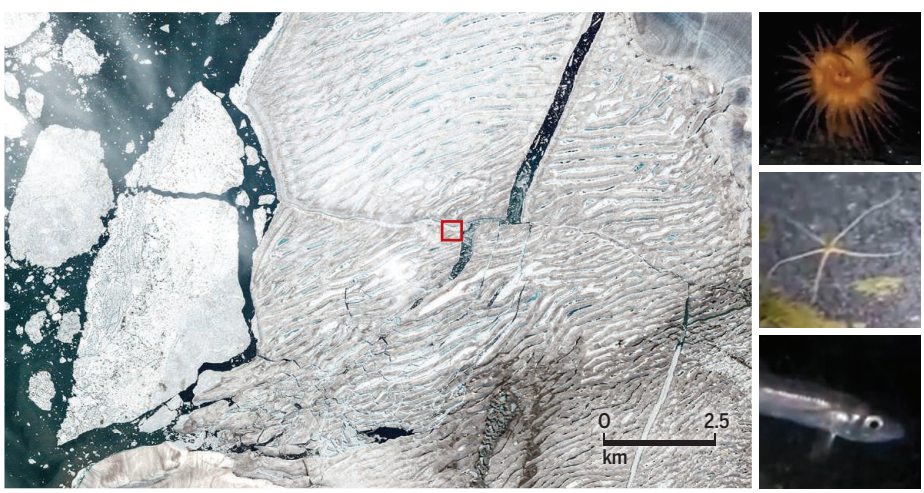
The surface area of glaciers along the northern margin of Ellesmere Island retracted by up to 5% between 1999 and 2015 (*9*), accompanied by reductions in supraglacial features such as cryoconite holes that provide microbial habitats. New cold-loving yeast species were recently discovered on Walker Glacier, 28 km east of Ward Hunt Island, but this cryohabitat is now undergoing accelerated melting and attrition (*10*). Summer meltwater on the surface of ice shelves and floating ice tongues collects in ponds and cryoconite holes that contain diverse microbial consortia. From 1998 to 2015, 51% of this habitat was lost as a result of episodic calving (*2*); little time may be left to fully characterize this component of Arctic biodiversity.

Thick multiyear landfast sea ice, some more than 50 years old, was a prominent feature of this coastline until recently, when all but the smallest remnants broke away (*2*). Mobile pack ice, including thick multiyear sea ice floes, are tightly concentrated in the coastal zone owing to the action of the Transpolar Drift and the clockwise Beaufort Gyre. The average thickness of this ice has decreased by 1.5 m since the 1970s, and this region is losing sea ice mass at double the rate of the Arctic Ocean (*11*). Ice supply to this region is highly variable and depends on currents that are readily modified by atmospheric circulation patterns, which may shift as the climate continues to warm. Increased ice advection and a marked drop in ice concentration in recent years underscore the vulnerability of this environment (*11*), which provides a cryohabitat for sea ice algae and associated biota (*12*). The implications of increased meltwater runoff from coastal lands to the marine ecosystem are unknown but could increase the occurrence of bloom-forming algae that may harm marine mammals (*13*)—this requires close monitoring.

The thick sea ice zone and its associated coastal land environments harbor diverse ecosystems that are only now being discovered. Conservation areas in this region, such as Tuvaijuittuq and Quttinirpaaq, are more important than ever for protection of these polar habitats and provide refuges that are free of additional stressors such as shipping and resource extraction. The Canadian MPA restrictions will expire in 2024 (*4*). This protection needs to be made permanent and extended across northern Canada and Greenland to include the entire thick ice zone and its associated coasts, despite the jurisdictional hurdles. Efforts to define, culture, and cryopreserve environmental microbiomes from this region should also be enhanced. Climate models underestimate the current acceleration of Arctic warming, and meeting the Paris Agreement carbon targets is essential to avoid abrupt future change (*14*). The ice attrition recorded over the past two decades shows that while this area of biological richness and ice-dependent ecosystems has been resistant to warming, it is not immune, and it can only be fully protected by the greenhouse gas mitigation that is urgently needed at a global scale. ■

Ice ecosystem collapse

An aerial view shows the breakup of the Milne Ice Shelf in late July 2020 (left) and animals found living in its ice cavity (right) at the site boxed in red (*3*). The ice shelf is in the so-called Last Ice Area, which observations and modeling (*15*) show as the band of thickest sea ice in the Arctic Ocean that occurs along the northern coast of Canada and Greenland.



PHOTOS: (LEFT) JOSEPH MASCARO/PLANET LABS INC.; (RIGHT) WATER AND ICE LABORATORY/CARLETON UNIVERSITY

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