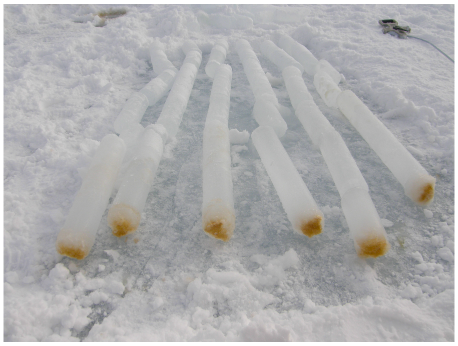
Rapid Arctic Environmental Change Disrupts Marine Ecosystems

THE ISSUE. Diminishing sea ice, changing snow patterns, and increasing water temperatures threaten organisms—from algae to mammals—adapted to the sea ice ecosystem.

WHY IT MATTERS. Globally, climate change is decreasing biodiversity (variety of life) with the potential to cause the sixth mass extinction in the Earth's history[1]. Arctic marine organisms are particularly vulnerable owing to their dependence on snow and ice and to the rapid pace of warming in the region — at least twice the global average. The well-being and economies of Arctic people are disrupted by changes in the Arctic marine ecosystems on which they depend for food and cultural affirmation[2]. Changing ice conditions have already diminished indigenous hunters' access to whales and walruses in Alaska.

STATE OF THE SCIENCE. The timing and extent of sea ice directly and indirectly influence the abundance and seasonal behavior of many species[3]. In recent decades, rapid warming has contributed to a year-round decline in sea ice thickness and a 50% reduction in ice area during summer months. Models consistently forecast a continued reduction in ice coverage and thickness as greenhouse gases continue to accumulate. While Arctic sea ice likely will persist in the dark winter months, summers will see little ice cover in coming decades.



Algae growing on the underside of sea ice is visible in ice cores. (Credit: S. Carpenter)

Over half of the organisms capturing the sun's energy (primary producers) in the Arctic Ocean are algae and phytoplankton that grow on or under sea ice. As ice diminishes, so will these primary producers along with the higher-level organisms that depend on them. Other species of phytoplankton may increase as more light penetrates thinning ice, although the effect of increased light may be offset by decreased nutrients. A massive bloom of phytoplankton observed under ice in the Chukchi Sea in 2011 was believed to be enhanced by thinning ice[4]. Whether a new suite of phytoplankton will support an abundance of higher organisms will depend on timing, location, nutrient availability, and the ability of different species to adapt to polar environments. A consensus on the net impact on Arctic Ocean productivity has yet to emerge from ongoing research.

Changes in the physical Arctic environment will result in winners and losers; some sub-Arctic species will shift their ranges northward into Arctic waters while some current species will be displaced by these new migrants through competition or predation. For example, Arctic cod—a species key in the diet of many Arctic fish, birds, and mammals—is adapted to sea ice habitats and, as ice diminishes, the species is being displaced by an Atlantic Ocean cod[5]. On the other hand, a species of amphipod that specializes in feeding on ice algae, may be resilient in the face of diminishing ice due to an ability to ride pole-ward currents that keep them in the ice[6].

More southerly species of marine mammals, such as Steller sea lions, are expanding northward as ice diminishes, while ice-dependent mammals are facing increasing challenges. Diminished sea ice has reduced food availability for some populations of polar bears[7] and walruses[8]. Walruses that used to rest and nurse their young on sea ice in summer are now forced to come ashore in large aggregations on land where they are vulnerable to predation and trampling[9]. Declining ice and, especially, snow cover are projected to reduce the birthing habitat for ringed seals by 70% by 2100[10].

The net impact of these dynamics on biodiversity of the region is uncertain. Increased primary production might favor increased biodiversity, while decreased habitat diversity would disfavor it. Adaptive strategies will, in part, be driven by genetic diversity and generation time (the average time between subsequent generations within a species). Species with high genetic diversity and short generation times have a greater likelihood of adapting to new environments. Conversely, species with unfavorably long generation times and low genetic diversity, such as the large marine mammals (polar bears, seals, whales, etc.), will be at greater risk.

Where the Science is Headed. Ecological observations and models of the Arctic Ocean are sparse. While such studies have accelerated in recent decades, they are proceeding slowly relative to the pace of environmental change[11]. We know from more thoroughly studied regions that ecosystems can experience sudden and rapid reorganization when thresholds are exceeded. Such thresholds are inadequately known for the Arctic Ocean. Multi-disciplinary and multi-scale studies are needed to understand how diminishing sea-ice and warming waters will ultimately alter Arctic marine ecosystems, including the health and behavior of key species on which Arctic people depend.

Ringed seals rest, give birth, and nurse their young in snow caves above Arctic sea ice. Early snow melts have led to the deaths of large numbers of ringed seal pups by predation and freezing. (Credit: B. Kelly)

Key References

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