INDICATOR
#10 | Arctic sea-ice ecosystems

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Thule, North Greenland Lars Witting/Arc-Pic.com

Sea ice represents a unique ecosystem in the Arctic, providing habitat to specialized ice-associated species that include microorganisms, fish, birds, and marine mammals. Individual species use sea ice in different ways depending on their biological needs. Ice algae form the base of the food web (Figure 10.1) [1]. Some algae stay attached to the bottom of the ice, some fall into the water column, and some fall to the bottom of the sea, and so provide food for species that feed at different depths. Protists (single-celled organisms) and zooplankton eat the algae which are then eaten by, for instance, Arctic cod, *Boreogadus saida* [2] and sea birds (e.g. dovekie, *Alle alle*), which in turn act as the major link to other fish and birds, seals, and whales [e.g.,3]. Polar bears, *Ursus maritimus*, prey upon seals from the ice and walrus, *Odobenus rosmarus*, forage on clams from drifting pack ice.

Arctic sea ice has changed in recent years, decreasing substantially in extent and thickness, with thin first-year ice replacing thicker multi-year ice [4]. These changes are happening faster than models predict and a nearly ice-free Arctic Ocean in late summer is likely within this century and possibly before mid-century [5]. The response of an individual ice-associated species to changes in sea ice depends on its ability to adapt, its natural history, and the scale of environmental changes. While these species are experiencing a variety of impacts as the sea ice changes, it is not clear exactly what will happen as the summer sea ice continues to disappear.
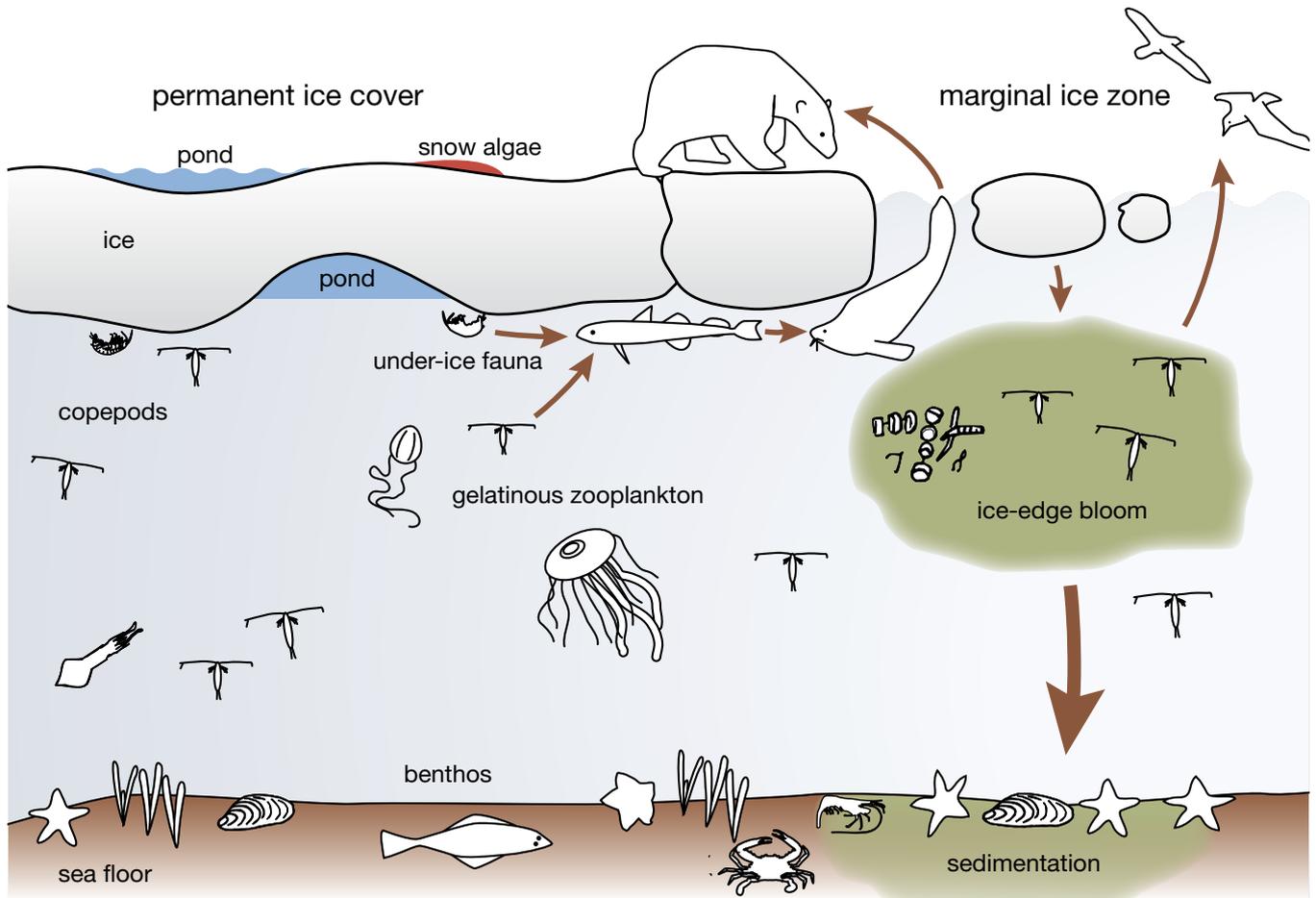
Figure 10.1: Schematic representation of the Arctic marine ecosystem and its interactions [1].

Population/ecosystem status and trends

A complete understanding of the sea-ice ecosystem does not yet exist. Comprehensive data regarding population and trends of ice-associated species are limited due to the difficulty in surveying them in an extreme and remote environment. The information below does not represent a comprehensive listing of ice associated species. Following are some examples of ice-associated species from different trophic levels with indications of their status and trends.

Ice algae

During spring, when light becomes available for photosynthesis, and throughout the summer, a large biomass of ice algae develops within the lowermost sections of the ice [1, 6–8]. These algae occasionally form long filaments that can extend several meters into the water. Previous studies have provided a glimpse of the seasonal and regional abundances of ice-associated biota. However, the biodiversity of these communities is virtually unknown for most groups and many taxa are likely still undiscovered [1].

Arctic cod, *Boreogadus saida*

Arctic cod, also known as polar cod, are frequently observed in close association with ice year-round, from their larval stage through to their juvenile stages [9]. The Arctic cod is a pivotal species in the Arctic marine food web and no other prey items compare in terms of abundance and energetic value [10]. Arctic cod use sea ice for protection from predators, as feeding habitat, and as a place to spawn in winter [11]. This species has not been extensively surveyed and trend data are not available. Summer surveys in 2008 in the Alaskan Chukchi and Beaufort Seas estimate Arctic cod biomass at 27,122 metric tons (mt) and 15,217 mt respectively, totaling 42,339 mt [12]. In northern Hudson Bay, researchers correlated reduced consumption of Arctic cod by thick-billed murres, *Uria lomvia*, from 1981–2002 with reduced ice cover and concluded there were decreases in fish abundance [13].

Ivory Gull, *Pagophila eburnea*

The ivory gull is a seabird which spends the entire year in the Arctic. The global breeding population is found in Canada, Greenland, Svalbard, and Russia where they rarely range far from sea ice [14]. They are often found along the ice edge and leads in pack ice, where they feed on small fish, including juvenile Arctic cod, squid, invertebrates, and macro-zooplankton [14–16]. They also scavenge carrion on the ice and forage on marine mammal

feces and placenta [14]. The global estimate of ivory gulls is 8,900–13,500 pairs [17, 18]. Studies indicate that Canadian populations are declining, the populations in Greenland and Svalbard are either declining or uncertain, and Russian populations are largely fluctuating with no trend data available [17, 18].

Ivory gulls forage around sea ice year-round, relying on visual prey detection. Thus, if winter sea ice retreats to the north where the days are shorter, the ivory gull will have less time available to forage each day. However, no data exists to establish a causative relationship between sea ice changes and ivory gull declines and further studies are required [17].

Spectacled Eider, *Somateria fischeri*, and King Eider, *Somateria spectabilis*

Spectacled eiders and king eiders are large sea ducks that live and breed in the Arctic. Both species associate with offshore dense pack ice in the winter to feed in openings in the ice. Roosting on sea ice uses less energy than being immersed in cold water such as when eiders dive for food [19, 20]. The ice pack may also dampen the effects of winter storms [21], allowing birds to feed in calmer conditions within the ice pack [19, 20].

The spectacled eider breeds in three locations, two in Alaska and one in Russia [22]. In winter, these three populations concentrate within a 50 km diameter circle in small openings in the sea ice in the central Bering Sea [19, 23]. The entire wintering population, and perhaps the worldwide population is estimated conservatively at 374,792 birds [23]. The population trend for the nesting population of the Yukon-Kuskokwim Delta in Alaska can be characterized as stable to slightly increasing from 1991–2001. The breeding population of the North Slope in Alaska does not show a significant decline throughout most of the 1990s but did show a downward trend of 2.6% per year [23].

From surveys done off Point Barrow, Alaska in the Beaufort Sea, the king eider population appeared to remain stable between 1953 and 1976 but declined by 56%, from approximately 802,556 birds in 1976 to about 350,835 in 1996 [24]. Reasons for the declines are unknown. Surveys of molting areas in West Greenland show 50% declines over the last 40 years [25, 26] and the Rasmussen Lowlands breeding area in Canada [27] indicate a decreasing population size [20].

Thick-billed murre, *Uria lomvia*

The thick-billed murre is an Arctic seabird that is associated with areas of seasonal and sometimes extensive sea-ice cover [28] and occurs mostly in Arctic waters in the winter [29]. The thick-billed murre seems to be dependent on plankton blooms stabilized by predictable sea ice break-up [30]. For population status and trends, please see Indicator #4 Seabirds – Murres (guillemots).

Marine Mammals

Several marine mammal species associate with sea ice [31]. These include polar bear, walrus, and ice seals bearded, *Erignathus barbatus*; ringed, *Phoca hispida*; hooded, *Cystophora cristata*; harp, *Pagophilus groenlandicus*; ribbon, *Histriophoca fasciata*; and spotted seal, *Phoca largha*). Three whale species also occupy Arctic waters year-round – narwhal, *Monodon monoceros*; beluga whale, *Delphinapterus leucas*; and bowhead whale, *Balaena mysticetus* [31]. Each species uses sea ice in different ways [32]. Abundance estimates are not available for one or more populations of most species, and trends are unknown for even more populations. Further, some of the available estimates are outdated. Those species for which sufficient data exist exhibit mixed population trends, with some populations of each species increasing while others are stable or declining. The available data are not sufficient for an analysis of trends by region. Below are brief summaries of the four marine mammal species considered most associated with sea ice [31, 33, 34]. Additional details about these and other ice-associated species are being developed by CAFF.

Polar bear, *Ursus maritimus*

For details on polar bear status and trends, please see Indicator #1 Polar Bears.

Walrus, *Odobenus rosmarus*

The population of Pacific walrus is estimated at 129,000 based on 2006 joint Russian-American surveys [35]. Abundance trends will be examined in more detail once all aspects of the analysis of the 2006 survey data have been completed [35].

The current total abundance of Atlantic walrus is very poorly known, but the most recent information suggests a population size of perhaps 18,000–20,000 [36–38]. Modeling indicates that the walrus populations in West Greenland and the North Water Polynya of Baffin Bay have been in steady decline, while the population in East Greenland has been increasing [39]. Walrus numbers at Svalbard have increased slowly during 1993–2006 [40]. The current global population trend is unknown [36].

Ringed seal, *Phoca hispida*

Of the five sub-species of circumpolar ringed seals, there is very little trend data [32]. The Lake Saimaa subspecies in Finland is increasing based on 2005 surveys [41], while trends in the Baltic Sea subspecies are mixed based on surveys from the 1990s [42].

Bearded seal, *Erignathus barbatus*

No recent information about population status and trends is available for bearded seals in their circumpolar range.

Jökulsárlón Lagoon, Iceland Daniel Sambraus/iStockphoto

Concerns for the future

The ongoing trend of declining sea ice [43] is likely to lead to changes in the sea-ice ecosystem shifting toward a pelagic, sub-Arctic ecosystem [44] over a larger area [45, 46]. Phytoplankton and zooplankton productivity is predicted to increase, with sub-Arctic species expanding their range and competing with existing Arctic species [45, 47, 48]. The increased production in open water will increase the prey concentrations for bowhead whales [46]. However, with less ice, there may be less ice algae which fall to the bottom, leaving less food for bottom-feeding marine species. Marine mammal species that are capable of using both pelagic and benthic prey may be less affected by the expected changes in the food web structure [46].

There may be mismatches with the life histories of ice-associated organisms if the timing of life functions shifts due to reduction of sea ice [45]. If one or more of the links between increased light penetration, higher production by ice algae, increased activity and breeding of zooplankton grazers and predators, and production and feeding of larval and juvenile Arctic cod fail, then effects may flow-through the sea-ice ecosystem on to top predators, such as ringed seals and birds and possibly polar bears [45].

More information on mismatches in life histories can be found in Indicator #12 (Reproductive Phenology in Terrestrial Ecosystems).

It is unclear how the reduction in sea ice is affecting Arctic cod. It is likely that a generalist species will replace Arctic cod as the main forage fish as sea ice decreases [11]. According to modeling, with warming temperatures and a retreat of the ice edge of 5 km per year, Arctic cod may be extirpated from most of its range in 30 years [49]. More information on the Arctic cod can be found in Indicator #16 (Changing distribution of marine fish).

Arctic marine mammal ranges are generally expected to shift northward to inhabit areas within their preferred metabolic temperature tolerances because conditions at the southern limits of their previous distribution will no longer meet their ecological needs [33]. Interannual changes in the onset and severity of seasonal sea ice may also affect the length of feeding seasons, timing of migrations, fecundity, and survivorship of marine mammal species [50]. Marine mammals will likely compete with one another on some level despite their different specializations [51]. If the climate continues to warm, a continued reduction in sea ice will follow and likely result in the northward expansion of some presently sub-Arctic species, with potential for increases in disease, predation, and competition for food [31, 33].

For the bird species discussed in this indicator, their relationship with sea ice is not entirely understood, nor how sea ice changes will affect them.