ARCTIC SEABIRDS: DIVERSITY, POPULATIONS, TRENDS, AND CAUSES

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Abstract.—Populations and trends of Arctic seabirds have been the subject of substantial research since the 1930s in Europe and Greenland and since the 1950s in North America. The marine waters of the Arctic support 44 species of seabirds comprising 20 genera. There are four endemic monotypic genera and an additional 25 species for which the bulk of the population is confined to Arctic and sub-Arctic regions. Most Arctic seabirds have large populations, with only two species comprising less than 100,000 individuals and many species numbering in the millions. Population trends for several widespread Arctic species have been negative in recent decades. Conversely, some sub-Arctic species are spreading northwards. Climate change with consequent changes in competition and predation, and intensifying development in the north, increasingly threaten Arctic seabirds. Changes in ice conditions are likely to have far-reaching and potentially irreversible results. *Received 22 February 2011, accepted 26 May 2011.*

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Seabirds have provided a source of food for Arctic peoples throughout their history and most major seabird colonies within the range of the post-Pleistocene Inuit expansion are associated with archaeological sites that attest to significant harvest and storage of seabirds (Freuchen and Salmonsen 1958, Nelson 1983). Some Arctic communities are heavily dependent on seabird harvesting (e.g., Ivujivik, Quebec, Gaston et al. 1985; Siorapaluk, Greenland, Malaurie 1985). Early European explorations in Arctic and sub-Arctic waters also made extensive use of seabirds for food (e.g., Henry Hudson's crew, Prickett 1611). Consequently, these birds have been of interest to people for a very long time.

Census of Arctic seabird colonies began in the 1930s in Greenland (Salomonsen 1950) and Russia (Uspenski 1956), the 1950s in eastern Canadian Arctic (Tuck 1961), the 1960s in Spitzbergen (Norderhaug et al. 1977, Mehlum and Bakken 1994), and the 1970s in the northern Bering and Chukchi seas (www.seabirds.net/maps/dev/north-pacific.php?v=14). Subsequent monitoring was sporadic in most regions until the 1980s, but has become more regular since then (CAFF Seabird Working Group, unpubl.). However, many breeding sites are extremely remote, in places where navigation is challenging and support for aircraft very distant. Consequently, although we have a good picture of distributions, and some idea of population sizes, our information on population trends is rather fragmentary and localised and our knowledge of causes behind change in populations is even less substantial (Gaston et al. 2009). This paper attempts to review what we do know of seabird population size and status, understanding that there is considerable uncertainty especially about population trends.

Species Richness and Distribution

Forty-four species of seabirds breed within the Arctic (Table 1), 23 in the High Arctic, 41 in the Low Arctic. They belong to 20 genera, the richest in species being *Larus* (10 spp.), *Gavia* (5 spp.) and *Stercorarius* (4 spp.). Six genera are monotypic. The majority are members of the order Charadriiformes, 34 species, including four endemic genera, all monotypic: Little Auk (*Alle alle),* Ivory Gull (*Pagophila eburnea),* Sabine's Gull (*Xema sabini),* and Ross's Gull (*Rhodostethia rosea*). Fifteen species are circumpolar in their distribution, occurring in Canada, Alaska and over most of the Russian Arctic. There are two 'bi-polar' genera, found at high latitudes in both hemispheres–the fulmars (*Fulmarus),* and the skuas and jaegers (*Stercorarius),* the former likely originating in the southern hemisphere (Voous 1949), the latter in the northern hemisphere (Furness 1987). All four species of *Stercorarius* found in the northern hemisphere are endemic to the Arctic and sub-Arctic, as is the single fulmarine petrel, all the loons, terns and auks and five species of *Larus* gulls.

Overall diversity is highest in the low-Arctic of the Pacific Basin (Chukchi and Bering seas and adjacent coasts) where 28 species occur in the Alaskan low-Arctic (including islands south to 60º N) and 26 species on the Asian side. Other biodiversity hotspots occur in West Greenland (24 spp.), eastern Canadian Arctic (Nunavut, northern Quebec and Labrador, 22 spp.), and Iceland (22 spp. excluding the sub-Arctic/boreal species found only on the south coast).

Several taxa have been elevated to species status only recently and were previously considered sub-species. These splits mainly involve distinguishing North American and Eurasian populations: Arctic/Pacific Loons (*Gavia arctica/pacifica),* American/European Herring Gull (*Larus smithsonianus/argentatus*). The large white-headed gulls of the genus *Larus* are divided into several poorly differentiated and mostly allopatric species in northern Asia and on the west coast of North America. Much of their diversity was regarded as infra-specific until recently (cf. Vaurie 1965, Olsen and Larsson 2003).

The distributions of many species of Arctic marine birds were poorly known until the latter half of the twentieth century. In addition, many species are long-lived and conservative in their breeding site adherence, making them slow to alter their breeding range. Consequently, we have few data on which to assess trends in range extent among Arctic seabirds. No strictly Arctic species has become extinct during historic times, although three sub-Arctic species, Spectacled Cormorant (*Phalacrocorax perspicillatus)* (Commander Islands), Labrador Duck (*Camptorhynchus labradorius)* (Labrador) and Great Auk (*Pinguinus impennis)* (Newfoundland and Iceland) were hunted to extinction by Europeans in the 19th Century (Fuller 2000). Ivory Gull and Ross's Gull are listed by IUCN/Birdlife International as threatened or endangered at a world scale.

There is some evidence for the recent northward spread of predominantly temperate or low-Arctic species: Ancient Murrelet (*Synthliboramphus antiquus)* in the Bering Sea (Gaston and Shoji 2010), Horned Puffin (*Fratercula corniculata)* in the Beaufort Sea (Moline et al. 2008), Mew (Common) Gull (*Larus canus)* in Iceland (Petersen and Thorstensen 2004), Black-headed Gull (*Chroicocephalus ridibundus)* in Labrador (Chaulk et al. 2004), Great Black-backed Gull (*Larus marinus)* and Razorbill (*Alca torda)* in Hudson Bay (Gaston and Woo 2008). At the same time there is evidence of a retreat for at least one high-Arctic species, with the range of the Ivory Gull contracting in northern Nunavut, with most colonies on northern Baffin Island and eastern Devon Island deserted while numbers have remained stable farther north on central Ellesmere Island (Environment Canada 2010). Southern colonies are also decreasing in Greenland (Gilg et al. 2009). The population trend in Russia is unclear (Gilchrist et al. 2008) but some colonies at their western extremity in the Barents Sea region have been deserted (Gavrilo 2010). The population of Kittlitz's Murrelet (*Brachyramphus brevirostris),* a species associated with tidewater glaciers in the low- and sub-Arctic of the North Pacific, is declining in its core breeding range in south central Alaska and perhaps elsewhere (Kuletz et al. 2003, Stenhouse et al. 2008). Similar changes have been noted by local people:

> *"I have started to notice birds which I used to only see on TV, little birds which have multi-coloured bills, that fly home with multiple cod in their beaks and that burrow into the soil. I think these are the Atlantic puffins* [Fratercula arctica]*, which are located some distance south migrating north due to the disappearance of the ice cover during the summer months"* (Pijamin: Elders Conference on Climate Change 2001).

With little evidence for range changes, it is difficult to ascribe causes. The spread of Razorbill in Hudson Bay has been linked to an increase in sandlance *Ammodytes* spp., perhaps related to diminishing ice cover (Gaston and Woo 2008). Reduced ice cover also is likely to be involved in the arrival of Horned Puffin in the Beaufort Sea. The association of Kittlitz's Murrelet with tidewater glaciers makes it likely that recent declines are caused by the retreat of many Alaskan coastal glaciers (Stenhouse et al. 2008). In the longer run, changes in ice cover must affect the distribution of ice-associated species such as Ross's and Ivory gulls and Thick-billed Murre (*Uria lomvia).*

Population Sizes and Densities

Most species have populations numbering in the hundreds of thousands and only two are believed to number less than 100,000 breeding individuals: Ivory Gull and Thayer's Gull (*Larus thayeri)* (Table 1). Among high-Arctic specialists, the Ivory Gull has decreased precipitously in Canada (by 80% since the 1980s), has decreased in Greenland, and shows range contraction in the northern Barents Sea. In all cases the southern parts of the range seem to be more affected than northern parts (Gilchrist and Mallory 2005, Gilchrist et al. 2005, Gilg et al. 2009, Environment Canada 2010). Of the other two exclusively high-Arctic species, population size for Thayer's Gull, which is confined to eastern and central parts of the Canadian high-Arctic and northwest Greenland, is very poorly known, but certainly numbers less than 100,000 (AJG, M.L. Mallory and H.G. Gilchrist unpubl.). The Little Auk, although well-distributed in small pockets around the Arctic Ocean, is numerically concentrated into a single location in northwest Greenland (Crimson Cliffs and adjacent coasts of Thule District) where the population, although difficult to count, is believed to greatly exceed ten million birds (Renaud et al. 1982). Censusing such an aggregation is almost impossible and no information is available on trends. Some small colonies in southern Greenland and in Iceland have disappeared since the 1930s (Nettleship and Evans 1985).

Thick-billed and Common Murres (*Uria aalge*)are among the most abundant seabirds in the Northern Hemisphere with both species exceeding 10 million adults (Gaston and Jones 1998). Both have circumpolar distributions. The more northern species, *U. lomvia,* occurs mostly in Arctic waters, where it constitutes a higher proportion of seabird biomass than any other species. Both species of murre have shown regional population changes over the

Table 1. Seabird species occurring in the circumpolar Arctic, by region, with global population estimate (orders of magnitude and IUCN status).

		Alaska	NWT	Nunavut Quebec Labrador	Greenland	Iceland	Svalbard	Europe Russia	Siberia	World pop'n[1]	IUCN Status
Loons	**Gaviidae**										
Red-throated Loon	*Gavia stellata*	X	X	X	X	X	X	X	X	6	LC
Black-throated Loon	*Gavia arctica*	X					X	X	X	6	LC
Pacific Loon	*Gavia pacifica*	X	X	X					X	6	LC
Great Northern Loon	*Gavia immer*	X	X	X	X	X				6	LC
Yellow-billed Loon	*Gavia adamsii*	X	X	X	X			X	X	5	LC
Petrels	**Procellariidae**										
Northern Fulmar	*Fulmarus glacialis*	X		X	X	X	X	X	X	8	LC
Cormorants	**Phalacrocoracidae**										
Great Cormorant	*Phalacrocorax carbo*				X	X				6	LC
European Shag	*Phalacrocorax aristotelis*					X		X		6	LC
Pelagic Cormorant	*Phalacrocorax pelagicus*	X							X	6	LC
Gannets	**Sulidae**										
Northern Gannet	*Morus bassanus*					X		X		6	LC
Jaegers/Skuas	**Stercorariidae**										
Great Skua	*Stercorarius skua*					X	X	X		5	LC
Pomarine Skua	*Stercorarius pomarinus*	X	X	X	X			X	X	6	LC
Parasitic Jaeger	*Stercorarius parasiticus*	X	X	X	X	X	X	X	X	7	LC
Long-tailed Jaeger	*Stercorarius longicaudus*	X	X	X	X		X	X	X	7	LC

Table 1. (continued)

		Alaska	NWT	Nunavut Quebec Labrador	Greenland	Iceland	Svalbard	Europe Russia	Siberia	World pop'n[1]	IUCN Status
Gulls and Terns	**Laridae**										
Black-headed Gull	*Chroicocephalus ridibundus*					X				8	LC
Mew Gull	*Larus canus*	X	X			X		X	X	7	LC
G. Black-backed Gull	*Larus marinus*			X	X	X	X	X		6	LC
Glaucous Gull	*Larus hyperboreus*	X	X	X	X	X	X	X	X	6	LC
Iceland Gull	*Larus glaucoides*			X	X					6	LC
Thayer's Gull	*Larus thayeri*			X	X					4	LC
Amer. Herring Gull	*Larus smithsonianus*		X	X						6	LC
Lesser Black-backed Gull	*Larus fuscus*				X	X		X	X	6	LC
Herring Gull	*Larus argentatus*					X		X		7	LC
Vega Gull	*Larus vegae*								X	6	LC
Slaty-backed Gull	*Larus schistisagus*	X							X	6	
Ivory Gull	*Pagophila eburnea*			X	X		X	X		4	NT
Ross's Gull	*Rhodostethia rosea*			X	X				X	5	LC
Sabine's Gull	*Xema sabini*	X	X	X	X		X		X	6	LC
Black-leg. Kittiwake	*Rissa tridactyla*	X		X	X	X	X	X	X	8	LC
Arctic Tern	*Sterna paradisaea*	X	X	X	X	X	X	X	X	7	LC
Aleutian Tern	*Onychoprion aleuticus*	X								5	LC
Auks	**Alcidae**										
Little Auk	*Alle alle*	X		X	X	X	X	X	X	8	LC
Common Murre	*Uria aalge*	X			X	X	X	X	X	7	LC
Thick-billed Murre	*Uria lomvia*	X		X	X	X	X	X	X	8	LC
Razorbill	*Alca torda*			X	X	X		X		6	LC
Black Guillemot	*Cepphus grylle*	X		X	X	X	X	X	X	7	LC
Pigeon Guillemot	*Cepphus columba*	X								6	LC
Kittlitz's Murrelet	*Brachyrhamphus brevirostris*	X							X	5	CE
Parakeet Auklet	*Aethia psittacula*	X							X	7	LC
Crested Auklet	*Aethia cristatella*	X							X	7	LC
Least Auklet	*Aethia pusilla*	X							X	7	LC
Atlantic Puffin	*Fratercula arctica*			X	X	X	X	X		8	LC
Horned Puffin	*Fratercula corniculata*	X							X	7	LC
Tufted Puffin	*Fratercula cirrhata*	X							X	7	LC

[1](orders of magnitude, breeding individuals)

past three decades, with trends in the North Pacific and Northwest Atlantic generally positive or stable when trends in the European Arctic were negative and vice versa (Irons et al. 2008). By combining population trend data from around the Arctic with information on sea surface temperature changes (SST) and decadal-scale climate-ocean oscillations, Irons et al. (2008) showed that population growth was most often positive where conditions remained relatively stable and negative when change, either colder or warmer, was large. This result suggests that not only the direction but the magnitude of change may be important in determining biological outcomes of climate. Trends in different regions switched direction with regime shifts. However, *U. lomvia* populations have declined in all regions except the Canadian eastern Arctic since the 1970s, whereas no single global trend can be identified for *U. aalge*.

The population of Thick-billed Murres in Central West Greenland is much depressed compared to numbers in the early nineteenth century, as a result of heavy harvesting of adults at colonies (Evans and Kampp 1991), as well as drownings in gill-net fisheries (Tull et al. 1972) and shows no sign of recovery, with the population south of Thule District remaining at <20% of historical levels (Kampp et al. 1994, Merkel et al. 2007, F. Merkel pers. comm. 2010). Numbers in East Greenland, although small, have also declined. Similarly, numbers in Novaya Zemlya are considerably lower than in the early twentieth century when the population numbered several million birds. Currently, there are thought to be in the region of one million breeders (Bakken and Pokrovskaya 2000). In Spitzbergen, numbers of Thick-billed Murres were thought to be stable up to the 1990s, but have since decreased, especially in the southern part of the archipelago (CAFF Circumpolar Seabird Working Group, unpubl.)

In Iceland, numbers of Thick-billed Murres decreased at 7% per year between 1983–1985 and 2005–2008, while numbers of Common Murres decreased abruptly between 1999–2005 after modest increases earlier (Gardarsson 2006). Northern Fulmar (*Fulmarus glacialis*), Black-legged Kittiwake (*Rissa tridactyla*) and Razorbill also decreased, although some small colonies increased (Gardarsson et al. 2009).

Causes of Population Changes

The causes of population and range changes can rarely be confidently attributed to a single source. The decline of Ivory Gulls in the Canadian Arctic illustrates a case where several potential contributory causes can be identified: heavy hunting of adults in Greenland (Stenhouse et al. 2004), high levels of mercury in eggs (Braune et al. 2006) and changes in ice conditions associated with global warming (Environment Canada 2010). All may have contributed to recent population decline. Only where population declines are abrupt and associated with strong environmental signals, can causes be confidently assigned. This was the case for Common Murre populations in the southern Barents Sea in 1985–87 when numbers fell by 80% in response to starvation following the collapse of the Barents Sea Capelin (*Mallotus villosus)* stock (Anker-Nilssen et al. 1997). The population subsequently recovered to near its former level (Krasnov et al. 2007). Similarly, an 80% decrease in Lesser Black-backed Gulls in northern Norway coincided with a collapse in the stock of spring spawning Herring (*Clupea harengus)* (Bustnes et al. 2010).

Most changes in demography and population status of Arctic seabirds that have been linked with climate changes have, to date, been ascribed to causes operating through the food chain (Harris et al. 2005, Sandvik et al. 2005, Durant et al. 2004, 2006, Irons et al. 2008). However, a few cases where direct effects have occurred have been documented. Mallory et al. (2009) reported a wide range of weather-related mortalities at Arctic seabird colonies and suggested that some types of mortality, especially those associated with increases in extreme weather events, could create heavier mortality in the future. In northern Hudson Bay in the late 1990s, a combination of warm summer weather and earlier emergence by mosquitoes, leading to heavy blood-sucking, caused the death of some incubating Thick-billed Murres through a combination of dehydration and hyperthermia. In addition, some birds left their eggs unattended for periods of several hours, resulting in many losses to predatory gulls (Gaston et al. 2002). These effects had not been recorded previously in 20 years of observations. Changes in the timing of snow-cover and ice-melt affect the availability of breeding sites to crevice, scree and burrow-nesting species, such as puffins and Little Auks (Birkhead and Harris 1985). Such changes in accessibility can result in altered interactions with predators, as observed for Antarctic Petrels (*Thalassoica antarctica)* by van Franeker et al. (2001).

Although both species of murre are currently abundant, many populations have been declining for several decades (Johnsen et al. 2010). Problems facing murres include fisheries interactions, contaminants and oil spills and, in some parts of their range, hunting (especially of *U. lomvia*). For *U. lomvia,* changes in the extent and timing of sea-ice cover over the past several decades are leading to changes in phenology and reproduction with adverse consequences for nestling growth (Gaston et al. 2005). These changes seem likely to intensify. Levels of some contaminants, especially mercury, have increased in murre eggs in the North American Arctic since the 1970s, although they remain at sublethal levels (Braune et al. 2001). If climate change leads to increased shipping and oil and gas exploitation in Arctic waters, the increased risk of spills would also pose a potential hazard for murres, which are extremely susceptible to mortality from oil pollution (Wiese and Robertson 2004). In the long-term, range contraction of *U. lomvia* in response to the retreat of Arctic sea ice appears likely. Eventually it may be replaced by *U. aalge* and other more southern auks.

Substantial research has been carried out in the Barents Sea region and in the Canadian Arctic on concentrations and trends in contaminants, especially organohaline compounds and heavy metals (Braune et al. 2001, Letcher et al. 2010). Very high levels of mercury (Braune et al. 2006) and organohaline compounds (Miljeteig et al. 2009) have been found in the eggs of Ivory Gulls from Canada and Svalbard and high organohaline concentrations occur also in Glaucous Gulls (*Larus hyperboreus*) from Svalbard (Bustnes et al. 2003, 2004), perhaps causing mortality in some cases (Gabrielsen et al. 1995, Sagerup et al. 2009). These species scavenge marine mammal carcasses, putting them high up the food chain and hence subject to high biomagnification effects. They may also frequent garbage dumps around human population centres. Levels of contaminants in other species generally do not approach those likely to impact populations (Gabrielsen 2007, Letcher et al. 2010), except in the case of point-source pollution resulting from industrial sites (e.g., Kuzyk et al. 2003).

Changes in the timing of seasonal events for high-latitude marine birds have been identified for many southern hemisphere species (Croxall et al. 2002, Rolland et al. 2010), as well as some Arctic seabird populations (Gaston et al. 2005, Byrd et al. 2008a,b, Moe et al. 2009). For some Arctic species, reproductive success is inversely correlated with date of laying, e.g., Little Auks (Moe at al. 2009), but this relationship may vary among geographical areas; it is true for Thick-billed Murres breeding at Prince Leopold Island, Nunavut, but not for the same species breeding in northern Hudson Bay (Gaston et al. 2005). The importance of timing of breeding in determining the dynamics of Arctic seabird populations is supported by a correlation found between colony size and the timing of sea ice withdrawal in adjacent waters for Thick-billed Murres in Greenland (Laidre et al. 2008).

Mismatching of breeding initiation with the seasonal peak of food availability may be a common phenomenon among seabirds confronted with rapidly changing seasonal timing (Bertram 2001, Wilhelm et al. 2008, Watanuki et al. 2009). It has been identified as a likely cause of reduced nestling growth for Thick-billed Murres in northern Hudson Bay (Gaston et al. 2009), as well as accounting for some of the variation in reproductive success of Black-legged Kittiwakes and Common Murres in sub-Arctic Alaska (Suryan et al. 2006, Schultz et al. 2009) and Newfoundland (Wilhelm et al. 2008).

Changes in seabird diets, both from year to year and over decades, have been reported from many sites. Diet switching is likely a fairly routine aspect of seabird biology (e.g., Montevecchi and Myers 1995, 1997, Barrett 2002). At Coats Island, northern Hudson Bay, Thick-billed Murres switched from feeding their chicks predominantly the ice-associated Arctic Cod (*Boreogadus saida)* to the more sub-Arctic Capelin in the mid-1990s (Gaston et al. 2003). The change was associated with an advance in the date of sea-ice clearance in the region.

Not all prey are equally suitable, especially for rearing nestling birds, and some prey switches can result in reduced productivity among seabirds (Litzow et al. 2002, Wanless et al. 2005, Gremillet et al. 2008). In the southwest Barents Sea in recent decades Herring has come to dominate over Capelin as a forage fish. This change has coincided with a decline in numbers of breeding Back-legged Kittiwakes (–8% per year after 1995). Apparently Herring is not as satisfactory as Capelin as food for kittiwakes (Barrett 2007). At the Pribilof Islands, Sinclair et al. (2008) also observed a reduction in the proportion of Capelin in Black-legged Kittiwake and Thick-billed Murre diets between the 1980s and 2000s, while changes in the zooplankton diet of Least Auklets (*Aethia pusilla)* was also observed over the same period (Springer et al. 2007, Sheffield Guy 2009). These changes were associated with a warming of the adjacent surface waters and a retreat of winter sea ice. Similarly, in Iceland, the diet of most seabirds switched from sandlance to other fishes in the 2000s (Gardarsson 2006), a change also observed in boreal waters of the North Sea (Wanless et al. 2005). This diet change was contemporary with declines in most seabird populations.

Many seabirds are very conservative in their breeding sites, returning faithfully to large colonies that, in some cases, have been in existence for millennia (Gaston and Donaldson 1996). If climate change alters environmental conditions around such colonies it is unlikely that a mass exodus will take place in search of new colony locations. There are examples of large colonies suffering repeated reproductive failure over many years without any substantial emigration (e.g., Atlantic Puffins at Rost, Norway reared few chicks between 1969–1982, Anker-Nilssen and Rostad 1993). However, parasites and predators may be more mobile in response to climate change and may initiate or expand their activities at new sites. Some examples of such expansions have already been observed, with an increase in the incidence of tapeworms in alcids in Labrador and Greenland since the 1960s (Bin Muzaffar 2009) and the appearance of the parasitic tick (*Ixodes uriae)* on murres in Svalbard after 2000 (Coulson et al. 2009). The implications of these parasite range expansions are not yet clear but adverse consequences for the seabird populations involved are possible.

Currently Golden Eagles (*Aquila chrysaetos)* and White-tailed Sea-eagles (*Haliaeetus albicilla),* both of which cause disruption to nesting seabirds, only reach the fringes of the Arctic. Their northward spread could create problems for gulls, murres and other open-nesting seabirds. Increasing predation of birds and their nests by Polar Bears (*Ursus marinus)* has also been observed, probably as a result of the bears coming ashore earlier in the season

(Rockwell and Gormezano 2009, Smith et al. 2010). This could affect especially accessible species such as Little Auks (Stempniewicz 2007). Because of the potential for alternative prey, it is extremely difficult to predict how seabird populations will respond to changes in predator distributions.

Conclusions

The Arctic is an important area for marine bird diversity and endemism. Most Arctic seabird populations for which information is available over several decades have shown negative trends in recent years. These trends are superimposed on a situation where several important populations were substantially depressed by anthropogenic mortality, compared with numbers in the first half of the twentieth century (especially Thick-billed Murres in Greenland and Novaya Zemlya).

Only a few instances are available where recent trends can be traced to particular causes but stressors include fisheries activities, pollution, and climate change. The last, especially as manifested in changes in the timing of the open water season, is affecting the timing of seasonal events in marine ecosystems and this is affecting the optimal timing of breeding, especially in low-Arctic areas. Changes in ice conditions, especially, are likely to have far-reaching and potentially irreversible consequences. These changes are also encouraging the northward expansion of sub-Arctic species, although such changes in range are relatively small, as yet. Changes in the distributions of predators and parasites have also been noted and these may have important consequences for Arctic seabirds. Because of the number of Arctic endemic seabird taxa, the decline of Arctic marine birds presages a significant loss of global biodiversity.

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