3.5 Seabirds

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Snapshot

- Although seabird trends are variable, many species have declined within the Atlantic Arctic, including colonies in Norway, Iceland, and the Faroe Islands.
- The sea-ice-associated ivory gull has declined in the Arctic Archipelago and Atlantic Arctic by an estimated 80-90% over the past 20 years. In Russia, ivory gull distribution has shrunk, which correlates with the summer ice edge moving northward.
- Some seabird species have adapted their feeding behaviours because of shifts in their food supply due to climate change and reduced ice-cover—in some cases travelling farther for food or foraging on less nutritious species. The consequences vary, but have resulted in lower breeding success for some species, including black guillemots.
- Reduced ice cover has led to increased bear predation on ground-nesting common eiders and cliff-nesting murres, potentially leading to local population declines.
- More southern seabird species are now more commonly reported in Arctic regions, for example, albatross in the Bering and Chukchi Seas and ancient murrelets in the Pacific Arctic, which are thought to follow northward-moving prey species and/or currents. There is also evidence of individuals moving between Atlantic and Pacific Arctic regions.
- Most Arctic States have at least one long-term seabird monitoring program that makes it possible to examine population trends. Colony-based monitoring occurs regularly or annually, although most sites do not have fully implemented plans (diet and survival data are often lacking). At-sea surveys are more opportunistic, and often occur in conjunction with resource exploration and extraction.

3.5.1 Introduction

Seabirds link marine and terrestrial ecosystems because they nest on land but forage at sea, and, thus, they are important components of Arctic ecosystems and are part of the Circumpolar Biodiversity Monitoring Program (CBMP). Seabirds provide ecosystem services, notably as human food in many Arctic regions, major tourist attractions, as well as being an important link to the Arctic food web and returning nutrients from the oceans to coastal areas (Şekercioğlu et al. 2004, Şekercioğlu 2006, Merkel and Barry 2008, CAFF 2010, Ganter and Gaston 2013, Green and Elmberg 2014). Changes in seabird populations and diversity will affect regional sustainability for Arctic communities and ecosystems. Seabirds are also widely distributed and easier to observe than other marine taxa, making them useful study subjects. Seabirds function as indicators of the condition of their marine habitats, because they integrate the effects of abiotic stressors acting on lower trophic levels (Piatt et al. 2007, Sydeman et al. 2012, Green and Elmberg 2014). The CAFF *Arctic Biodiversity Assessment* (Ganter and Gaston 2013) also recognizes that the migratory behavior of most seabird species requires international cooperation throughout the circumpolar regions to address conservation needs.

The *Circumpolar Seabird Monitoring Plan* (CSMP; Irons et al. 2015) recognizes 64 species as part of the Arctic ecosystem: five tubenoses, six cormorants, four sea ducks, four skuas and jaegers, 18 gulls, six terns, 20 auks, and the northern gannet (*Morus bassanus*). Of these 64 species, about half (30) breed only within the Conservation of Arctic Flora and Fauna (CAFF) boundaries of the Arctic. Based on circumpolar distribution and factors such as importance to society, national priorities, conservation, science, or as ecological indicators, 23 species were initially chosen as priority species, and by applying further criteria, four species or species groups were selected as Focal Ecosystem Components (FECs; Gill et al. 2011).

The FECs represent different foraging strategies, including black-legged kittiwakes (*Rissa tridactyla*) (surface-feeders), murre species (thick-billed (*Uria lomvia*) and common (*Uria aalge*); sub-surface divers), and common eiders (*Somateria mollissima*) (bottom feeders). While birds are ideally identified to species, they have at times been combined into a 'murre' group when conducting census counts or visual productivity plots.

While most seabird species can eat a variety of prey, the CSMP uses the primary prey preferences and foraging behavior of seabirds to categorize birds into six basic foraging guilds: surface piscivores, surface planktivores, diving piscivores, diving planktivores, benthic feeders, and omnivores (Petersen et al. 2008, Gill et al. 2011, Irons et al. 2015). The Circumpolar Seabird Expert Group identified eight 'priority species' (Table 3.5.1) that represent five of the foraging guilds (there were no surface planktivore species that adequately represented either the Pacific or Atlantic). The black-legged kittiwake (an FEC) represents surface piscivores, and diving planktivores are represented by two species of small auks (one for the Pacific and one for the Atlantic Arctic). The two murre species (also FECs) represent diving piscivores, and the common eider (an FEC) represents benthivores. Omnivores are represented by two gull species. However, national monitoring programs also continue for species that may be or are not on the priority list, if they are already part of national efforts planned or underway (Appendix 1).

Although the CBMP identified eight Arctic Marine Areas (AMAs), the CSMP recognizes 22 ecoregions, which reflect geographic differences in seabird ecology and habitat, and includes geographic areas outside the AMAs (i.e., northern Gulf of Alaska, the southern Bering Sea, North Sea, and the Baltic Sea; Fig. 3.5.1). While this report focuses on the AMAs, the Circumpolar Seabird Expert Group notes where CSMP ecoregions are relevant to seabird trends in the AMAs.

Table 3.5.1. Seabird species selected as priority species for monitoring by the Circumpolar Seabird Expert Group (CBird). Asterisks indicate which species are also FECs (Gill et al. 2011).

Foraging guild	Common name	Scientific name	Distribution
Omnivore	Glaucous gull	*Larus hyperboreus*	Circumpolar
	Ivory gull	*Pagophila eburnea*	Atlantic
Diving planktivore	Least auklet	*Aethia pusilla*	Pacific
	Little auk	*Alle alle*	Atlantic
Diving piscivore	Common murre*	*Uria aalge*	Circumpolar
	Thick-billed murre*	*Uria lomvia*	Circumpolar
Surface piscivore	Black-legged kittiwake*	*Rissa tridactyla*	Circumpolar
Benthivore	Common eider*	*Somateria mollissima*	Circumpolar


Glaucous gull.
Photo: Kristine Sowl/USFWS, Alaska


Ivory gull.
Photo: Martha de Jong-Lantink, Flickr.com


Least auklet.
Photo: R. Duggan/USFWS


Little auk.
Photo: Carsten Egevang/ARC-PIC.com


Common murre.
Photo: David Thyberg/ Shutterstock.com


Thick-billed murre.
Photo: Morten Ekker


Black-legged kittiwake.
Photo: Robin Corcoran/USFWS, Alaska


Common eider.
Photo: Micha Klootwijk/Shutterstock.com

3.5.2 Current monitoring

The CSMP emphasizes the importance of established monitored plots (at key sites) or transects (at-sea surveys) that are surveyed regularly over the long-term to update seabird population trends, productivity (recruitment), survival, diets, phenology, and distribution at sea. In all ecoregions, monitoring efforts are balanced against other national priorities and limited resources.

The broad distribution of breeding colonies and post-breeding movements of species require collaborative efforts and technological innovations (Ganter and Gaston 2013). However, there is wide disparity among AMAs and countries in both the amount and completeness of monitoring activities (Fig. 3.5.2, Table 3.5.2). Nonetheless, colony-based monitoring occurs almost annually or at regular intervals at selected colonies in most countries. At-sea surveys are more opportunistic and often occur in conjunction with resource exploration and extraction (e.g., the Chukchi Sea in the Pacific Arctic, or the Davis Strait-Baffin Bay region).

Most circumpolar nations have at least one long-term seabird monitoring program that makes it possible to examine population trends. These long-term data sets and monitoring efforts are crucial to examining the effects of environmental drivers on seabird populations. The national recommendations and currently monitored parameters are provided in Irons et al. (2015). Key sites (CSMP-recognized colonies) must have two or more parameters collected per priority species, and have been categorized by the level of implementation relative to the monitoring plan. A 'fully implemented' site has data collected on half or more of the prioritized species, with at least one of the following: population trends, productivity and survival, conducted at the recommended interval. 'Partially implemented' sites do not have monitoring conducted at the recommended interval on at least one of the following parameters: population trends or productivity. 'Not implemented' sites have no data on population trends or productivity currently being collected.

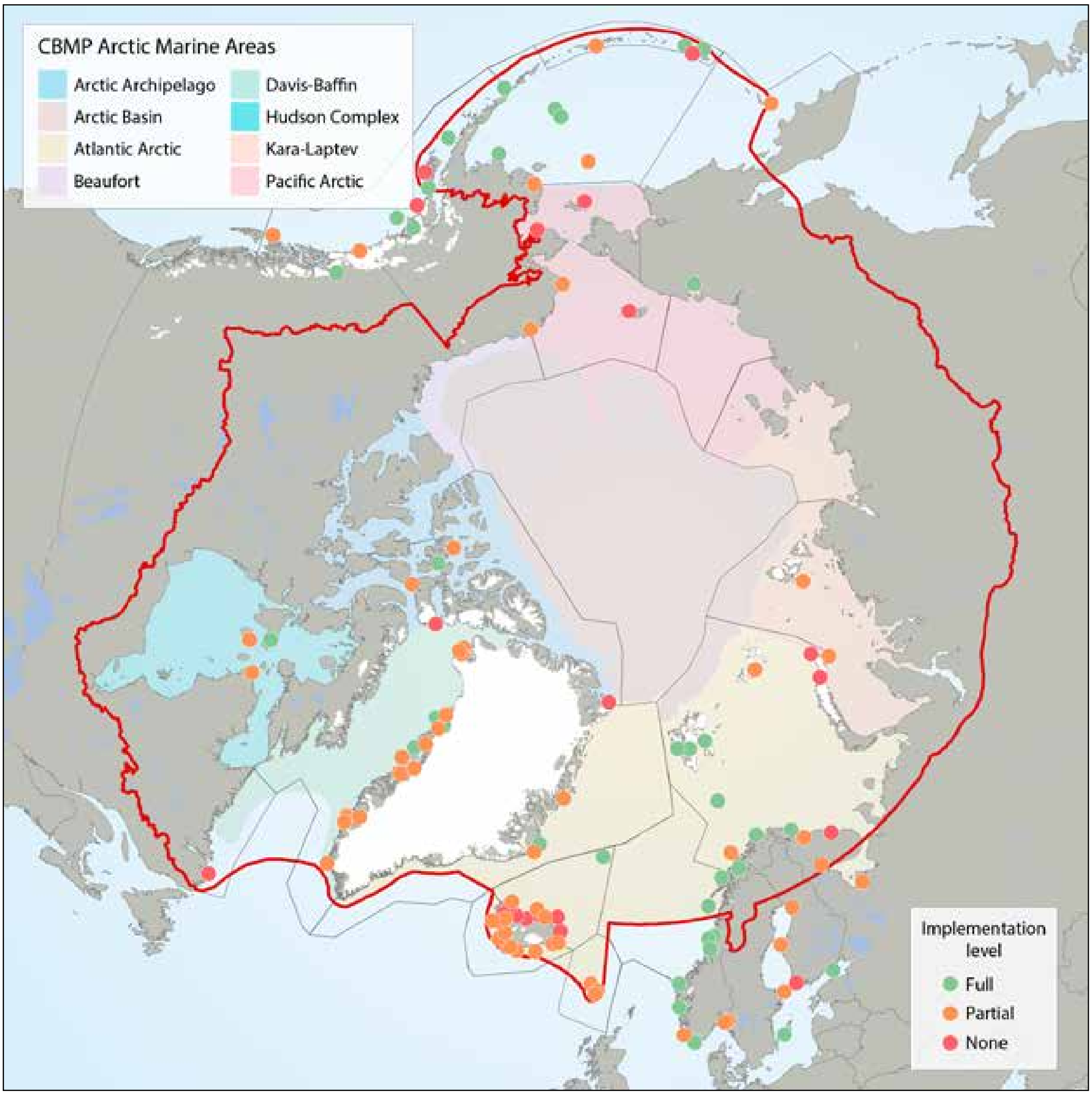


Figure 3.5.1. Boundaries of the 22 ecoregions (grey lines) as defined in the CSMP (Irons et al. 2015) and the Arctic Marine Areas (colored polygons with names in legend). Filled circles show locations of seabird colony sites recommended for monitoring ('key sites'). The current level of monitoring plan implementation are green = fully implemented, amber = partially implemented, red = not implemented. The CSMP provides implementation maps for each forage guild.

The following is a summary of monitoring activities of FECs by country, starting with the Canadian Arctic Archipelago and working clockwise around the Arctic. Because the efforts and responsibilities for historic data sets have been specific to national objectives and vary among countries, the Circumpolar Seabird Expert Group focused on each country's history and status. In addition, the long-term and current knowledge of local, Indigenous communities might be integrated with current scientific efforts to expand our temporal scale of knowledge.

Canada maintains historical colony-based monitoring at several locations (Prince Leopold Island, Digges Sound, Coats Island, East Bay, Gannet Islands, Hudson Strait Archipelagos) in the Canadian Arctic, dating back to 1975 (e.g., Gaston et al. 2012). Additionally, at-sea monitoring dates to the early 1970s, and has been revitalized as the Environment Canada Seabirds at Sea program, which continues (Wong et al. 2014). Another focus of monitoring efforts is the annual assessment of murre harvest in eastern Canada (Gaston and Robertson 2010). However, Indigenous harvest of marine birds is poorly monitored. Canada has initiated a community-based, seabird-health monitoring program in Nunavut and Nunavik, in collaboration with the Canadian Co-operative Wildlife Health Centre.

In Alaska, trends in colony status and reproductive or diet parameters are summarized in the annual Status and Trends of Breeding Seabirds in Alaska series (Dragoo et al. 2015), which summarizes results from the monitoring program of the Alaska Maritime National Wildlife Refuge (AMNWR) and others at 17 colonies throughout Alaska, which dates to the 1970s at some sites. Only two of those monitored colonies are in the Pacific Arctic AMA, yet some of the largest colonies in the Pacific are located on islands of the northern Bering Sea (Diomede, King, St. Lawrence) and central Bering Sea (St. Matthew and Pribilof Islands), which together host millions of nesting seabirds. The trends at colonies south of the Pacific Arctic may also be relevant to the AMA due to late summer and autumn use of the Chukchi Sea by birds that breed in the Bering Sea (Kuletz et al. 2015).

At-sea survey data for the Pacific Arctic is archived in the North Pacific Pelagic Seabird database (NPPSD); this database has > 300,000 km of effort and includes survey data from 1975-2015 (ongoing), albeit often opportunistically in accordance with broader ecosystem objectives. In the Pacific Arctic waters of Alaska, ~80,000 km of survey effort has been archived, primarily from 2006 to 2015. While most effort has been opportunistic or focused on federal oil lease sale areas of the Chukchi Sea, during which time frame seabird surveys within the internationally monitored areas of the Distributed Biological Observatory have been conducted at least annually and this effort is anticipated to continue. The NPPSD has been used to examine hotspots of seabird activity in the Chukchi Sea (Kuletz et al. 2015) and long-term trends in the seabird community (Gall et al. 2017). Biologging has been used to monitor changes in seasonal movements across vast oceanic regions that include areas outside the AMA (e.g., Orben et al. 2014, 2015). Scientific monitoring of seabird harvest, which occurs at many Alaska Indigenous communities, has been sporadic, with intermittent surveys occurring since the 1980s (Naves 2015).

Colony-based monitoring in Russia is traditionally based on its Specially Protected Areas (Strict Nature Reserves (SNR), and more recently, National Parks), but very few of them currently maintain seabird monitoring. The longest historical datasets (late 1920s to 1990s) were obtained in Kandalaksha SNR (Barents Sea and White Sea, CSMP region 19; Krasnov et al. 1995) and Wrangel Island SNR (Chukchi Sea, region 5) from the 1970s to 1990s.

These long-term datasets were disrupted in the 1990s and are not currently maintained on a full scale in Kandalaksha SNR. During past two decades monitoring has been initiated by Murmansk Marine Biological Institution on the Kola Peninsula and in Franz-Josef Land by the National Park Russian Arctic (NPRA, region 19). Since 2006, ivory gull monitoring in the Russian part of the species breeding range (regions 19, 20) is conducted by the NPRA on an opportunistic basis (Gavrilo 2015). Except for work on the spectacled eider (*Somateria fischeri*) in west Chukotka and ivory gull monitoring as mentioned above, seabird monitoring has not been conducted in the central Russian Arctic (AMAs Kara-Laptev and eastern Pacific Arctic). The recently established Beringia National Park in east Chukotka is hoped to fill this gap in the future.

Norway maintains colony-based monitoring for a variety of species and has the most fully implemented monitoring program in the Arctic (Fig. 3.5.2). Its comprehensive program collectively called 'SEAbird POPulation,' (SEAPOP) is a long-term monitoring and mapping program established in 2005. The most extensive monitoring, which includes population size, reproduction rates, survival rates and diets, is concentrated on 17 key sites evenly distributed along the borders of marine areas surrounding Norway, Svalbard and adjacent seas. Many of the key sites in Norway have been monitored annually since the 1980s, with a few series dating back to the 1960s (Fauchald et al. 2015). At-sea monitoring surveys in the Barents Sea in the autumn have been conducted since 2004.

Another program, SEATRACK (SEAbird TRACKing) is underway in the Atlantic AMAs and involves Norway, Russia, Iceland, the Faroe Islands and (outside the AMAs) Great Britain. The program uses geolocators to describe migratory routes, wintering areas and the variation in these between years, with the goal to link these with population dynamics, migration routes and wintering areas with marine environmental and anthropomorphic factors. Two FEC species, black-legged kittiwake and thick-billed murre, were the subjects of projects that used geolocator data loggers on birds from multiple colony sites to track breeding and post-breeding movements at a regional scale (Frederiksen et al. 2012, 2016). Nine other species at more than 30 colonies have been tagged and tracked during 2014-2016.

In Iceland, 28 key sites have been identified, most of which have population trends monitored (some since the 1980s) and some of which have productivity monitored (Fig. 3.5.2). Additionally, for several non-FEC species, colonies are monitored in aerial surveys and survival is monitored at colonies (Frederiksen and Petersen 1999, Garðarsson and Petersen 2009, Garðarsson and Jónsson 2011). Recommended and currently monitored parameters for Icelandic seabirds, revised in 2015, are provided in Irons et al. (2015). Annual seabird harvest information since 1995 is available online at the Environment Agency of Iceland and has been published during the period 1898-1942. Harvest of Atlantic puffin (*Fratercula arctica*) in the Westman Islands has been compiled for 1840-2015 (E.S. Hansen et al., unpubl. data).

The Kingdom of Denmark includes two countries with seabird monitoring activity in the Atlantic Arctic AMA. In the Faroe Islands, common murres and black-legged kittiwake colonies have been counted at about 10 year intervals since 1972 and 1987, respectively. Annual monitoring has occurred at one murre colony since 1972 and one kittiwake colony since 2001. Other non-FEC species are also monitored (Appendix 3.5.1). Greenland identified 24 key sites, with fully implemented population trends and productivity studies at three eider and one little auk colony, and partial implementation in 19 colonies with a variety of species (see Appendix 3.5.1). Since 1998, a monitoring program for thick-billed murre and black-legged kittiwake has been implemented, and a community-based program for common eider was initiated in 2001. In addition to the key sites, intermittent surveys are conducted at eider, murre, kittiwake and little auk colonies. The oldest colony surveys in Greenland go back to the early 20th Century, but in general, historical survey activity has been limited and non-systematic.

At-sea surveys (mainly ship-based, but also aerial surveys) near Greenland go back to 1988 and cover most waters of the Davis Strait-Baffin Bay and Atlantic Arctic adjacent to Greenland. Since the mid-2000s, it has been mandatory for ships conducting seismic surveys in Greenland waters to have seabird and marine mammal observers onboard and observations made from seismic vessels make up a large proportion of the data. Thus, survey effort is concentrated in areas with oil exploration activities, e.g., Disko Bay, Eastern Baffin Bay, Davis Strait-Baffin Bay and NE Greenland waters. In general, at-sea surveys (approximately 80,000 km of effort) have mainly been conducted in summer and autumn, corresponding to the open water season. Seabird harvest statistics have been compiled systematically in Greenland since 1993, using annual reports from hunters; statistics quantify the taking of birds (and mammals) on a monthly basis and since 2002, have included bycatch of seabirds in fishing gear and harvested eggs.

3.5.3 Status and trends of FECs

At a circumpolar scale, several studies have been implemented that relied on collaborative efforts and technological innovations to examine trends of focal seabird species. The two most widely studied species groups in circumpolar regions are the murres (common murre and thick-billed murre), which are diving foragers, and the black-legged kittiwake, a surface forager; these two species groups thus form the nexus of comparative studies across circumpolar regions. The benthic-feeding common eider has also been widely monitored (Table 3.5.2).

Recent population trends of thick-billed murres are mostly stable (or even increasing) in the Arctic, but declining in most of the Atlantic Arctic (Table 3.5.2). Common murres increase in the Pacific Arctic and CSMP region 19 of the Atlantic Arctic, but decrease in Davis Strait-Baffin Bay and other sites in the Atlantic Arctic.

Population trends of black-legged kittiwakes are being examined at the circumpolar scale in Descamps et al. (in prep.; Fig. 3.5.3). Overall, trends from 2001 to 2010 indicate kittiwake population declines, particularly in the Atlantic Arctic and Davis Strait-Baffin Bay AMAs (Fig. 3.5.3). Stable or increasing colonies occurred primarily in the eastern Bering Sea and Chukchi Sea of the Pacific Arctic, and to some degree in the Arctic Archipelago. More recently, key sites in

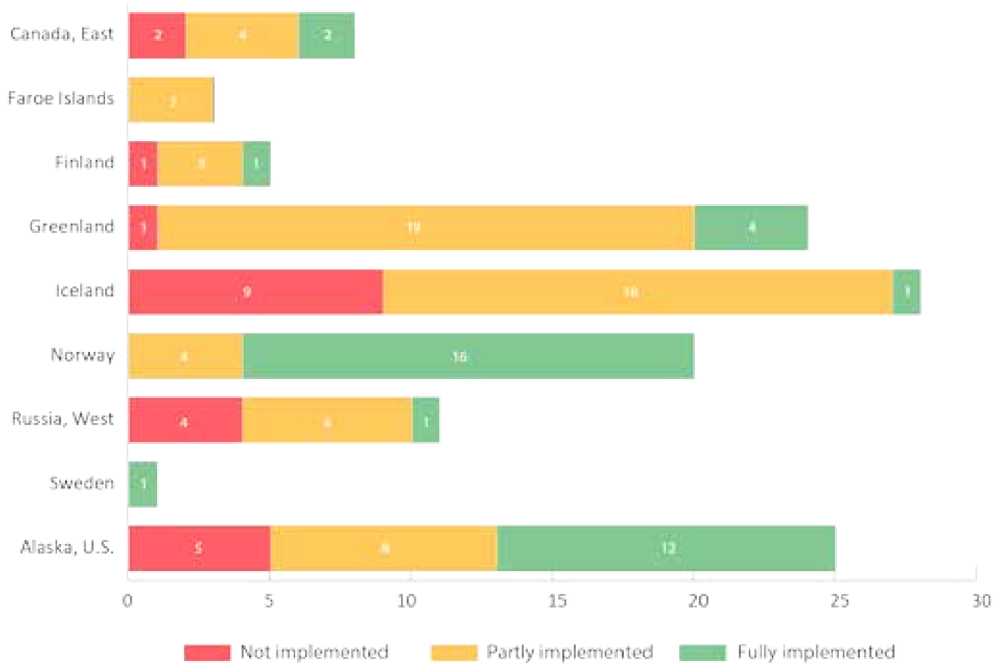


Fig. 3.5.2. The number of key sites (monitored colonies) for seabirds (in 22 CSMP ecoregions) by country (a total of 125 sites). Sites are categorized as having fully, partially, or not met the CSMP criteria for parameters monitored. Data were from Appendix 3 of the CSMP (Irons et al. 2015); the degree of implementation may have changed at some sites since this summary was compiled.

the Pacific Arctic, Arctic Archipelago and Davis Strait-Baffin Bay AMA do not indicate declines in kittiwake populations (Table 3.5.2). Colonies have also declined outside the AMAs, in the northern Gulf of Alaska (CSMP ecoregion 4). Tracking studies have shown that kittiwakes breeding at colonies spread throughout the Atlantic Arctic AMA may face similar threats because they overlap in winter distribution, thus stressors may not simply be occurring at the breeding sites (Frederiksen et al. 2012).

The glaucous gull is widely distributed across the Arctic in 2,768 colonies, but systematic long-term monitoring is rare (Petersen et al. 2015). Nonetheless, there is reported evidence of population declines at sites throughout the Arctic Archipelago and Atlantic Arctic, whereas populations appear to be stable or increasing in the Davis Strait-Baffin Bay region and the Bering as well as in the Russian part of the Atlantic Arctic (eastern portion of region 19) and the Chukchi Seas of the Pacific Arctic and the Kara-Laptev. In the recent summary of key sites (Table 3.5.2), population trends are mostly unknown, with mixed results in Davis Strait-Baffin Bay and regions of the Atlantic Arctic. A similar circumpolar examination is underway for the other omnivore priority species, ivory gull, which have declined in the Arctic Archipelago (Table 3.5.2) by an estimated 80-90% over the past 20 years (Gilchrist and Mallory 2005).

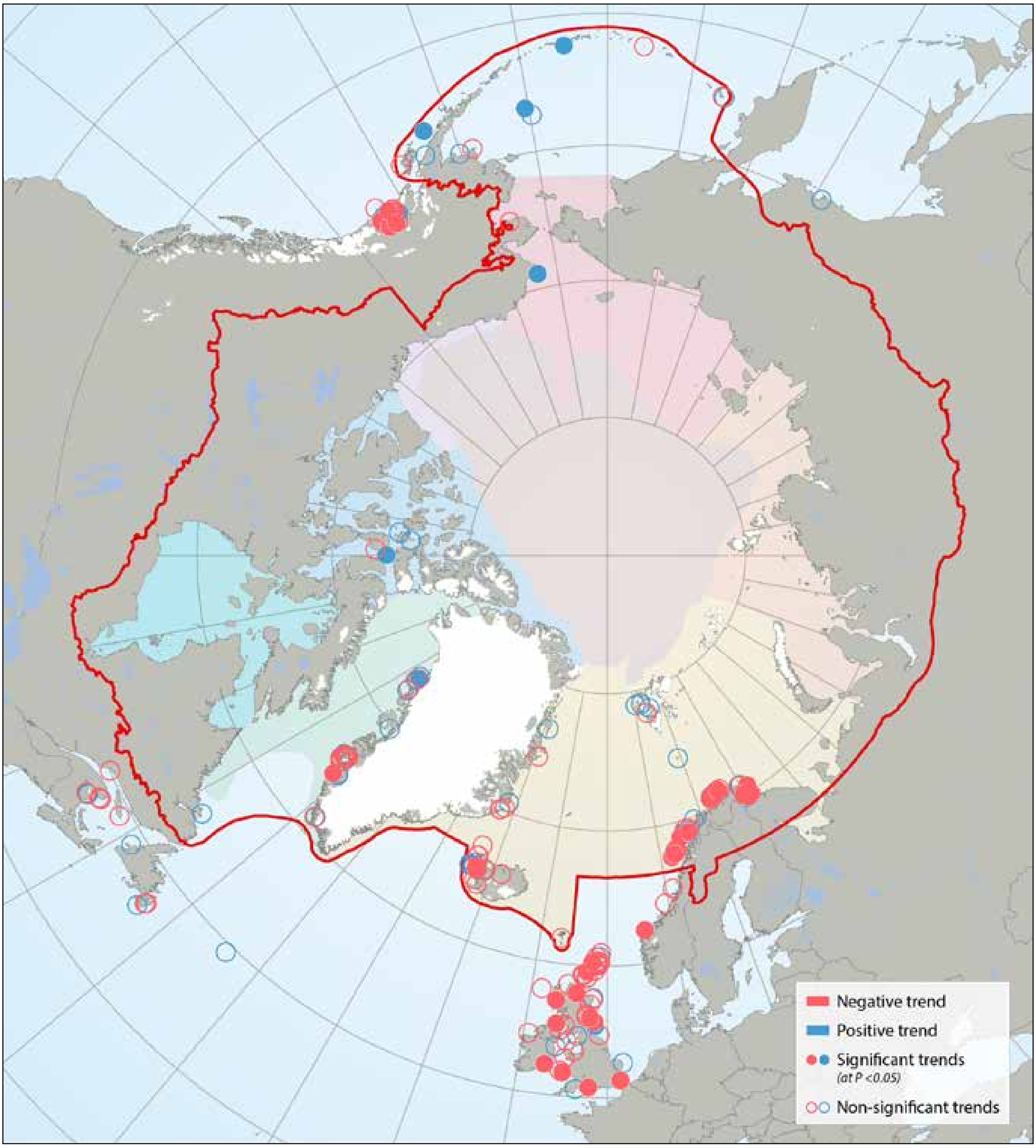


Figure 3.5.3. Trends in kittiwake colonies 2001-2010, based on linear regression with year as the explanatory variable. Slope of the regression is red = negative trend, blue = positive trend; shaded circle = significant trend (at p<0.05), open circle = non-significant trend. Non-significant deviation from zero could imply a stable population, but in some cases was due to low sample size and low power. Provided with permission from Descamps et al. (in prep).

Table 3.5.2. Population trends through 2015 for priority and FEC (*) species at key sites. CSMP Region is the ecoregion used by the Circumpolar Seabird Monitoring Plan, and regions that do not fall in the CBMP AMAs are not included here. Trend categories are increasing (i; green), stable (s; yellow), decreasing (d; red) or unknown (u) or rare (r; breeding status unknown); a dash indicates the species does not occur in that region. Population estimates and trends are from recent country reports, otherwise reported by members of the Circumpolar Seabird Expert Group.

CBMP Arctic Marine Area	CSMP region	Country	Ivory gull		Glaucous gull		Black-legged kittiwake		Thick-billed murre		Common murre		Common eider		Least auklet		Little auk	
			Total pop.	Trend	Total pop.	Trend	Total pop.	Trend	Total pop.	Trend	Total pop.	Trend	Total pop.	Trend	Total pop.	Trend	Total pop.	Trend
Pacific Arctic	5	Russia	-	-	U	S	U	U	U	U	U	U	U	U	U	U	-	-
	5	USA	-	-	843	-	57,047	I	125,880	I	147,722	I	173	U	972,500	U	R	-
Beaufort	6	USA	-	-	426	U	-	-	-	-	-	-	346	I	-	-	-	-
	6	Canada	0	-	U	U	-	-	400	S	-	-	45,000	D	-	-	-	-
Arctic Archipelago	7	Canada	100	D	U	U	-	-	-	-	-	-	-	I	-	-	-	-
	7	Greenland	200	D	500	U	-	-	-	-	-	-	-	-	-	-	-	-
	8	Canada	600	D	U	U	116,000	I	540,000	S	-	-	U	I	-	-	-	-
Davis-Baffin	8	Greenland	-	-	25,000	S	42,628	I	212,160	S	-		65,000	I	-		33 mil	U
	10	Canada	-	-	U	U	7,000	U	50,000	S	-	-	U	U	-	-	-	-
	10	Greenland	-	-	15,000	S	60,720	I	13,325	D	390	D	22,000	I	-		100	U
	11	Canada			1,800	D	2,000	S	4,500	S	33,600	D	17,374	D				
Hudson Complex	9	Canada	-	-	U	U	-	-	950,000	S	-	-	>200,000	I	-	-	-	-
Atlantic Arctic	12	Greenland	1,500	D	20,000	S	3,700	U	4,225	D			13,000	U	-		5 mil	U
	13	Iceland	-	-	800	D	407,200	D	205,000	D	405,600	D	300,000	I	-	-	-	-
	14	Iceland	-	-	1,600	D	173,700	D	121,800	D	292,500	D	U	I	-	-	-	-
	15	Faroe Islands					200,000	D			180,000	D	10,000	S				
	18	Norway	-	-	-	-	81,000	D	100	D	17,000	S	50,000	D	-	-	-	-
	19	Norway	2,000	S	4,200	U	255,000	D	725,000	D	133,000	I	17,000	U	-	-	>1 mil	U
	19	Russia	<3,000	U	>5,000	I	<500,000	D	<700,000	U	>10,000	U	<50,000	U	-	-	>500,000	U
Kara Laptev	20-21	Russia	<10,000	U	U	U	<50,000	U	<20,000	U	-	-	U	U	-	-	<100,000	U

Common eider populations show variable trends across the Arctic, with recent summaries of key sites (Table 3.5.2) showing mixed results in the Beaufort, mostly increasing populations in the Arctic Archipelago and Davis Strait-Baffin Bay regions, as well as Iceland in the Atlantic Arctic (Jónsson et al. 2013), a stable population in the Faroes, and decreases or unknown trends elsewhere. Since the early 2000s, populations in West Greenland have increased dramatically (Merkel 2010, Burnham et al. 2012), apparently in response to stricter harvest regulations in wintering areas. Populations have also increased in the southern end of Davis Strait-Baffin Bay AMA, Labrador (Chaulk et al. 2005), although recent studies indicate declines there (Table 3.5.2). Wintering population of the common eiders in the White Sea and Russian part of the Barents Sea (region 19) has been estimated in 2009 the largest ever recorded for this area (Krasnov et al. 2016).

While seabird trends in general are variable, many species have declined within the Atlantic Arctic, including seabird colonies in Norway, Iceland, and the Faroe Islands. For example, in Norway the estimated population of breeding seabirds was 30% lower (at 5.5 million pairs) in 2013 than the previous estimate made in 2003, consistent with declines extending over decades; the strongest negative trends were for pelagic foraging species. Concurrently, coastal seabirds have declined (Anker-Nilssen et al. 2015; Fauchald et al. 2015). Similar or greater declines have been detected in non-FEC species breeding in Iceland (Garðarsson et al. in press, Hansen and Sigurðsson submitted). In the Norwegian Sea (Faroe Islands), four piscivorous species, including surface-feeding black-legged kittiwakes and diving common murres, have declined over decades, resulting in hunting restrictions in the Faroe Islands (B. Olsen, unpubl. data.).

3.5.4. Drivers of observed trends

As the Arctic has longer seasonal ice-free periods due to ***climate change***, seabird communities are likely to change. In the Chukchi Sea of the Pacific Arctic, decadal shifts in seabird species composition and abundance at-sea have been documented (Box 3.5.1). Intensive studies in the Atlantic Arctic on little auk have found low survival rates of breeding adults, with potential population-level effects related to the impacts of climate warming on their main prey, large Arctic copepods (Hovinen et al. 2014). Because most seabird species migrate among breeding, staging (i.e., for molting), and overwintering sites, conditions south of the AMAs can have implications for Arctic breeding populations (Frederiksen et al. 2012, 2016, Orben et al. 2015). Outside of the AMAs, in the Baltic Sea, numbers of over-wintering waterbirds have responded to climate change over decades, and the numbers have correlated with early-winter temperature and open water (Fraixedas et al. 2015).

Changing ice conditions affect the diet of seabirds and reveal species plasticity in response to climate change and sea ice conditions (Grémillet et al. 2012, 2015). Changes in ice coverage might have positive or negative impacts on seabirds. For example, planktivorous seabirds appear to have increased at sea in the Chukchi Sea of the Pacific Arctic (Box 3.5.1), whereas a Beaufort population of black guillemot (*Cepphus grylle*), which generally feed close to their colonies, experienced increased breeding failures as sea ice coverage declined between 1975 and 2012. Guillemots feeding their chicks had to switch from ice-associated polar cod to prey of lower quality (e.g., sculpins), and subsequently had lower breeding success (Divoky et al. 2015). Ivory gulls have also shown negative trends during past decades expressed in deacreasing colony size and mismatch breeding events throughout their breeding range in Russia, which correlates with the northward shift of the summer ice edge (M. Gavrilo 2011 and unpubl. data). In spring and early summer, Arctic seabirds rely on open leads and polynyas, which may provide good foraging conditions combined with resting areas (Lovvorn et al. 2015). Early ice reduction may degrade or eliminate these protected and important feeding areas.

Indirectly, changes in sea ice affects the physical characteristics of habitats for seabird and coastal birds; less sea ice leads to coastlines being more exposed to erosion from wave impacts, and compounded by sea level rise. In the Arctic Archipelago/Hudson Bay Complex, annual variation in sea ice extent plays a dominant role in the timing of reproduction, reproductive effort and success for most marine bird species (Gaston et al. 2005, Mallory and Forbes 2007, Love et al. 2010). Reduced ice cover has also led to increased bear predation on ground-nesting common eiders, ivory gulls, as well as little auks and cliff-nesting murres (Box 3.5.2), potentially leading to local population declines (Gaston and Elliott 2013, Iverson et al. 2014, Prop et al. 2015, M. Gavrilo, unpubl. data).

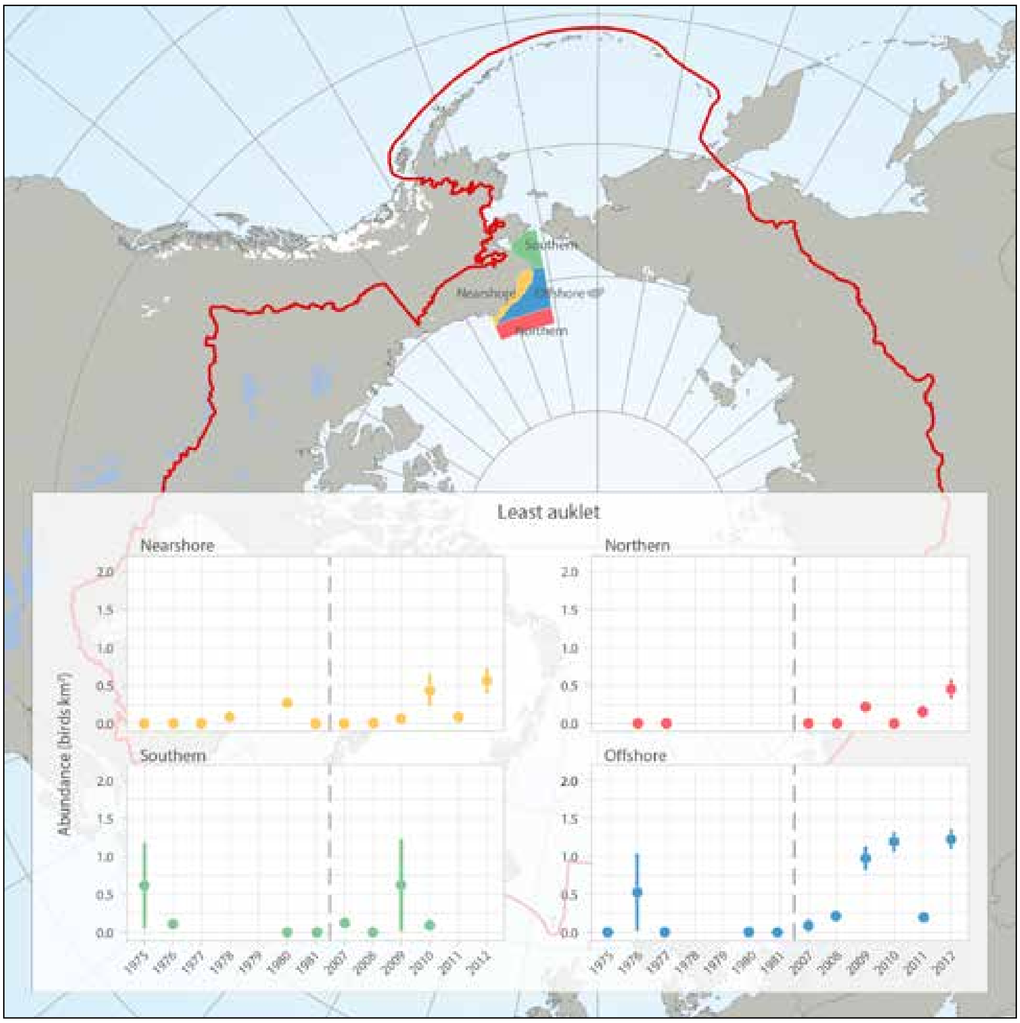
The longer ice-free period in the Arctic also increases ***vessel traffic (e.g., shipping and tourism) and opportunities for mineral (e.g., oil and gas) and biological (e.g., fisheries) resource extraction,*** which may eventually impact seabirds. Where water, wildlife, and humans must pass through 'choke points' between the Arctic and adjoining seas, overlapping activities put seabirds at risk (Humphries and Huettmann 2014). The Bering Strait is one such narrow passage between the Bering and Chukchi Seas. During summer and autumn, the Bering Strait is rich in nutrients and prey, and birds foraging and moving through the strait result in consistently high seabird densities there (Wong et al. 2014, Kuletz et al. 2015). The increase in Arctic vessel traffic has potential to displace foraging birds, which could be particularly important near nesting colonies in summer.

The circumpolar regions may offer a unique opportunity to examine the impacts of broad-scale shifts in ***ocean temperatures*** on upper trophic levels. For example, a circumpolar-level analysis of the impacts of climate on murre populations showed that murres respond negatively to large (0.5-1ºC) changes in sea surface temperature, in either direction, resulting from large-scale climatic shifts (Irons et al. 2008). Sea surface temperatures and climate can also affect species that nest on tundra, such as common eiders (Jónsson et al. 2013).

Warmer ocean temperatures have been associated with more frequent ***blooms of harmful algae*** and ***coccolithophore plankton blooms***, which in turn could change the distribution and abundance of seabird prey (NOAA 2015). In the southern Bering Sea (south of the Pacific Arctic AMA), a conservative estimate of 32,000 seabirds (primarily thick-billed or common murres) died offshore in August 2014, in association with warmer than normal sea surface temperature and

Box 3.5.1. Seabird community changes in the Chukchi Sea

The impacts from changes occurring in the Arctic marine environment vary among different types of seabirds. In the Chukchi Sea of the Pacific Arctic, the community of seabirds observed during ship-based surveys has changed over the last 40 years, with sub-Arctic species, especially planktivores (seabirds that eat zooplankton) increasing as the number of ice-free days has increased there. Based on at-sea surveys spanning 1975-2012, Gall et al. (2017) compared two time periods, 1975-1981 versus 2007-2012. They found that in early years, fish-eating (piscivorous) birds predominated, primarily black-legged kittiwakes, thick-billed murres and common murres. In the last decade, however, planktivores have become more abundant in the at-sea surveys. Currently, one of the most abundant species is the least auklet (Box fig. 3.5.1), which eats copepods. The other super-abundant species is the short-tailed shearwater (*Ardenna tenuirostris*), which eats mostly euphausiids (the northern 'krill') and does not breed in Alaska. Over decades, the longer ice-free season has created conditions that lead to greater northward transport of nutrients (and perhaps zooplankton) through the Bering Strait in summer (Woodgate et al. 2012), more wind-driven mixing of the water column (Carmack and Chapman 2003), and subsequent increases in stocks of copepods and euphausiids (Ershova et al. 2015), which are important prey for planktivorous seabirds. Physical barriers (e.g. water temperature) likely prevent the expansion of fish stocks into the Chukchi Sea (Sigler et al. 2011). There are few seabird colonies on the eastern Chukchi coast, which has little appropriate nesting habitat (i.e., rocky, steep cliffs and islands) and the few existing colonies consist of fish-eating species such as murres, puffins and kittiwakes. Land-based counts indicate that murre and kittiwake populations have increased since the 1980s at Cape Lisburne, Alaska, one of the major seabird colonies in the eastern Chukchi Sea (Dragoo et al. 2016). Nonetheless, as the ice retreats throughout summer and autumn, post-breeding or non-breeding seabirds arrive to take advantage of abundant zooplankton, with their numbers at sea surpassing those of locally breeding birds. These visitors come from colonies in the Bering Sea or, in the case of shearwaters, from breeding sites in the southern hemisphere. Combined, the planktivorous seabird species have altered the offshore seabird community, perhaps signaling major changes in the marine food web.



Box figure 3.5.1. Abundance (birds/km^2) of least auklets in four regions (see map) of the eastern Chukchi Sea, 1975-1981 and 2007-2012, based on at-sea surveys (archived in the North Pacific Pelagic Seabird Database). Figures provided by Adrian Gall, ABR, Inc. and reprinted with permission.

a large coccolithophore bloom (NOAA 2015). While a coccolithophore bloom is not toxic, it is associated with opaque blue water that may affect seabird foraging or prey distribution (Bauduini et al. 2001). This late summer die-off was followed in 2015 with high ocean temperatures that extended into the northern Bering and Chukchi Seas (Pacific Arctic). Murres and kittiwakes exhibited widespread reproductive failures in the eastern Bering Sea and northern Gulf of Alaska (H. Renner, unpubl. data), and murre die-offs were unprecedented in numbers and duration in 2015-2016 (K. Kuletz, unpubl. data). However, inadequate monitoring made it impossible to determine if the impact extended into the Arctic.

In the Atlantic Arctic, the weakening of the sub-polar gyre in the mid-1990s was associated with a basin-scale regime shift in the Northeast Atlantic and a warming of the sea. Changes in oceanographic conditions in this area affected many components of the North Atlantic marine fauna (Hatun et al. 2009), and similar conditions may have been a key driver of the decline in Svalbard's thick-billed murre population (Descamps et al. 2013). The warming of the Atlantic has led to a shift in copepod prey species, with the larger, lipid-rich *Calanus glacialis* and *C. hyperboreus* being replaced by smaller, less energy-rich *C. finmarchicus* (Welcker et al. 2009). During this time period, the planktivorous little auk has demonstrated changes in diet and foraging distances while raising chicks, which suggests adaptability to changes in prey and foraging grounds (Gremillet et al. 2012). However, continued warming could lead to negative trends in some populations (Karnovsky et al. 2010, Hovinen et al. 2014).

Shifts in prey distribution can affect seabirds. Some species, not always Arctic breeders, may be increasing their presence

Box 3.5.2. Increased polar bear predation on seabirds

One of the unexpected effects of reduced sea ice in the Arctic has been an increase in polar bear predation on seabird nests. Affected birds include ground-nesting seabirds such as glaucous gulls and common eiders, and even cliff-nesting murres. Since the 1970s, ice has left coastal areas earlier in summer, which has made it difficult for bears to hunt seals. As a result, bears prowl coastal beaches in early summer and have been observed inland with greater frequency. The bears prey on seabird eggs and chicks, or their presence near the colonies disturbs the adult birds, which subsequently abandon their nests. Local populations of eiders have lost up to 90% of nests (Prop et al. 2015) and murres have lost up to 30% (Gaston and Elliott 2013). Polar bear predation on seabird nests was rarely observed in the past, but is increasingly observed in the Hudson Strait area of the Canadian Arctic (Iverson et al. 2014), and in Svalbard and east and west Greenland of the Atlantic Arctic (Prop et al. 2015). Models indicate that, for ground-nesting birds, the increased rate of predation and nest abandonment could result in population declines, or force birds to move to new areas. However, in Canada the loss of seabird nests to bears was lower at colonies closer to Inuit villages, presumably because bears avoid people. Thus, a warming climate affects polar bear hunting behaviour, which then results in predation pressure on local seabirds during the nesting season. The impact to affected seabirds could result in lower reproductive success and eventual population decline, as well as changes in the bird's choice of nesting sites.

Polar bear searching for eggs on murre cliff in Novaya Zemlya, Russia.
Photo: Jenny E. Ross/naturepl.com

in Arctic or sub-Arctic seas, presumably because suitable prey has become more available. Historically, it was noted by Fisher (1952) that northern fulmar (*Fulmarus glacialis*) increased in abundance and range over 200 years throughout the Atlantic Arctic, perhaps in response to availability of offal from commercial fisheries and whaling ships. Changes in forage fish stocks have also affected seabird populations, in some cases abetted by commercial fisheries on these prey. For example, while sandeels (*Ammodytes* spp.) are not fished in Iceland, the Icelandic sandeel stock crashed in 2003-2005 (Lilliendahl et al. 2013). During the same time period capelin (*Mallotus villosus*), which is fished, shifted in distribution of its nursery grounds from north of Iceland to southeast Greenland (Pálsson et al. 2012); both events negatively impacted seabirds in the Atlantic Arctic (e.g., colonies in Iceland; Lilliendahl et al. 2013, Garðarsson et al. in press).

Recent examples of shifts in seabird distributions have been documented in the Pacific Arctic. Based on 40 years of data in the NPPSD, three albatross species (*Phoebastria* spp.) have become more abundant with a more northerly distribution in the Bering Sea than in past decades (Kuletz et al. 2014). Changes in abundance and distribution of albatross's primary prey, squid, could be a likely factor. New species have been observed in the Chukchi Sea in recent years, including the first Arctic record of an albatross in 2011 (short-tailed albatross). Other species that were rarely observed there historically, such as ancient murrelet (*Synthliboramphus antiquus*), are now regularly recorded during surveys in late summer and autumn, thousands of kilometres from breeding sites (Day et al. 2013). In addition, open water in the Arctic's Northwest Passage may be allowing Atlantic species to follow prevailing currents into the Pacific Arctic, indicated by recent sightings of northern gannets in the North Pacific (Day et al. 2013). Presumably, Pacific species could also follow open water to the Atlantic side.

Despite their breeding areas being far from large sources of human-caused pollution, Arctic seabirds are exposed to ***contaminants*** that might affect their populations or the people that rely on seabirds for subsistence. Ivory gull eggs collected in Canada, Greenland, Svalbard, and Russia had high levels of Persistent Organic Pollutants (POPs), including the insecticide DDT (Miljeteig et al. 2009, Lucia et al. 2015), and the high levels of DDT may have caused reduced eggshell thickness (Miljeteig et al. 2012). Glaucous gulls may also show population-level impacts from persistent organic pollution at colonies in the Atlantic Arctic (Erikstad et al. 2013). Point et al. (2011) suggested that loss of sea ice could accelerate the amount of biologically accessible methylmercury throughout the food chain, and they found that the deposition of mercury in murre eggs increased with latitude. Arctic seabirds benefit the land via transport of nutrients from the sea, but they might also transport contaminants; for example, Arctic ponds near large colonies of northern fulmars had higher levels of POPs and mercury (Blais et al. 2005). The accumulation and transport of contaminants might be a concern to indigenous peoples that rely on seabirds and adjacent colony sites for subsistence.

A possible indirect effect of climate change is the increased prevalence of ***diseases*** in Arctic regions that can affect seabird populations. Avian cholera, a fatal disease associated with waterfowl in temperate climes, was first detected in common eiders in the Canadian Arctic Archipelago in 2004, and in 2006 led to a 75% reduction in the largest eider colony in eastern Canada over six years (Descamps et al. 2012). Although still present in the region and monitored by local communities (Box 3.5.3; Iverson et al. 2016), population level effects of cholera have abated. In the Pacific Arctic, avian cholera was first detected in the northern Bering Sea during a seabird die-off in November 2013 in nearshore waters of St. Lawrence Island, Alaska (Bodenstein et al. 2015). A conservative estimate of 36,000 birds died in this event – primarily common murre and crested auklet (*Aethia cristatella*).

Seabird mortality imposed directly by ***human use*** (e.g., hunting or egg collection), and potentially indirectly (e.g., displacement of foraging birds), occurs throughout most of the circumpolar nations and may represent an important driver for some species (Merkel and Barry 2008). Where programs are in place to monitor subsistence use of seabirds, indigenous communities are important allies in providing harvest data to assist monitoring and management of birds. Overharvesting may contribute to substantial decrease in breeding populations, such as occurred for common eiders in Greenland and Canada (Gilliland et al. 2009) and thick-billed murres in Greenland (Merkel et al. 2014). The reverse has also been documented, i.e., rapid population recovery of common eider in Greenland following a large reduction in hunting pressure (Merkel 2010). However, in most countries, hunting levels are declining (Merkel and Barry 2008), so the future impact of this driver may also be declining.
Incidental catch of seabirds (***bycatch***) in commercial fisheries remains a potential anthropogenic driver worldwide (Zydelis et al. 2013) and long-line and gillnet fisheries in the Atlantic Arctic kill tens of thousands of birds annually (Fangel et al. 2015, Hedd et al. 2016). Overall, seabird bycatch is widespread, but not well monitored (Chardine et al. 2000, Hedd et al. 2016). Species taken as bycatch varies by fishing method (i.e., gillnets take diving birds and long-lines take surface-plungers), location and season. For example, Hedd et al. (2016) found highest seabird bycatch in summer and autumn, with waters near breeding colonies in the Davis Strait-Baffin Bay region having particularly high bycatch rates. Murres are often the most common bycatch in gillnets of Pacific and Atlantic fisheries, although bycatch in the North Pacific occurs south of the AMAs (Chardine et al. 2000, NOAA 2015). Even fisheries with relatively low bycatch rates can have significant bycatch if they are extensive temporally and spatially, such as the Atlantic cod fisheries of Norway (Fangel et al. 2015). In Icelandic waters, bycatch by cod gillnets has decreased by approximately 80% since the peak fishing effort in 2001, to about 6,100 birds (primarily common murres) in 2013 (Pálsson et al. 2015). The lower bycatch may be partially due to reduced gillnet use (in favour of long-lines), but could also be a consequence of the general seabird population decline over the same period (Garðarsson et al. in press). Current long-line annual bycatch in Iceland is estimated to be around 5,000 birds (G. Sigurðsson pers. comm.) Bycatch in the lumpsucker fishery was estimated to take about 5,300 birds and could have a large impact on seabirds in the Atlantic Arctic, particularly for black guillemots, with small, coastal populations (Fangel et al. 2015, Pálsson et al. 2015).

Despite a generally small human population in the Arctic, seabirds are subject to ***indirect mortality from human***

Box 3.5.3. Tracking infectious disease emergence in Arctic seabirds using Inuit community-based surveillance

Community-based research team investigates common eider nesting colony. Photo: Samuel Iverson

A poleward expansion of infectious diseases appears to be occurring in association with the effects of economic globalization and climate change. This expansion may threaten the viability of wildlife populations that are important for ecosystem function and human subsistence. However, disease surveillance in remote, sparsely settled regions like the Arctic is a tremendous logistic, financial, and safety challenge. In the Canadian Arctic, Inuit participation in ecological monitoring and the inclusion of indigenous ecological knowledge in decision making have become fundamental components of wildlife co-management. Inuit have increasingly contributed to wildlife disease surveillance and control efforts. A recent example involves the sudden appearance of avian cholera at common eider nesting colonies located on offshore islands in the Hudson Strait region.

Avian cholera is a virulent disease of birds that has long circulated in temperate regions of North America. Its appearance at Arctic common eider nesting colonies is a new phenomenon. Inuit harvesters are very familiar with the location and status of common eider colonies near their communities because they regularly visit them during summer to collect feather down for use in clothing and blankets. Indeed, Inuit eider down harvesters were the first to notice avian cholera outbreak events in the ecosystem and report them to conservation authorities.

A collaborative research initiative is now underway that integrates scientific expertise with Inuit local ecological knowledge (Iverson et al. 2016). The objectives of the initiative are to collect samples for laboratory testing, map disease-distribution patterns, and determine the host species range and extent of mortality. These data are fundamental to determining conservation threat and predicting the risk of further spread of disease. Inuit participation as sentinels on the land, experts helping in the development of a study plan, and as guides leading research teams into the field have been integral to project success.

activity. Fishing and other vessel traffic can result in light-induced bird strikes; these events typically occur during darkness or poor visibility due to weather (Merkel and Johansen 2011). In southwest Greenland, common eider accounted for 95% of seabird mortality from vessel strikes over three winters (Merkel and Johansen 2011). Plastic ingestion, which has long been documented in the world's oceans, has been documented in northern fulmars in the Arctic for >15 years (e.g., Mallory 2008, Provencher et al. 2014), and now has also been found in thick-billed murres in the Arctic Archipelago and Hudson Complex of eastern Canada (Provencher et al. 2010). However, models suggest that in general, seabirds face lower risk of plastic ingestion in high northern latitudes than they do in southern latitudes (Wilcox et al. 2015).

Mammalian predators introduced by humans into Arctic regions, intentionally or not, include red fox (*Vulpes vulpes*), rats (i.e., *Rattus norvegicus*) and American mink (*Neovison vison*). Introduced predators have had negative impacts on seabird populations south of the AMAs (e.g., Aleutian Islands; Byrd et al. 2005), but there is less evidence for population-level effects in the AMAs. Two exceptions may be American mink in the Atlantic Arctic (reviewed in NDNM 2011) and historically, rats in the Faroes (Bengtson and Bloch 1983). Mink were introduced to Norway and Russia in the 1920s and recent increases in mink at some common eider breeding sites have been coincident with high predation of eider nests and population declines (NDNM 2011).

Oil spills and chronic oil pollution also affect Arctic seabirds. A series of major oil spills likely contributed to low over-winter survival of common murres in the North Atlantic (Votier et al. 2005). Population modelling indicated that chronic oil pollution, combined with the hunting of thick-billed murres in the eastern Canadian Arctic, could reduce the population growth rate by 0.047 per year (Wiese et al. 2004). Determining the population-level impacts from such catastrophic events, or chronic levels of pollution, highlight the need for regional data on survival and demography for affected species. Impacts to specific colonies may be difficult to detect, partly because accidents often occur in winter, and multiple breeding populations intermingle in wintering areas (Votier et al. 2005, Frederiksen et al. 2012, 2016).

3.5.5 Knowledge and monitoring gaps

Throughout the circumpolar regions, the enormous geographic scale and lack of infrastructure constrain the scope and frequency of monitoring efforts to adequately address the priorities of the CSMP. Most of the circumpolar regions are lacking in consistently funded seabird monitoring efforts, but efforts and results are foremost missing from AMAs adjacent to Russia (Table 3.5.2), which spans the Atlantic Arctic, Kara-Laptev and Pacific Arctic (Fig. 3.5.1). Equally problematic is the lack of any monitoring at large colonies in the Pacific Arctic, St. Lawrence Island in the north Bering Sea, and the Diomede islands in Bering Strait. In both Russia and Alaska, local communities could efficiently assist monitoring efforts. They also serve as first responders to report unusual events and can conduct surveys to estimate mortality, such as occurred with the seabird die-off from avian cholera on St. Lawrence Island in 2013 (Bodenstein et al. 2015). In addition to the benefit of local residents being able to provide *in situ* observations and collect data (e.g., Box 3.5.3; Iverson et al. 2016), they also hold a wealth of current and historical Traditional Knowledge (TK) that is needed to better understand trends.

Among the priority species selected in the CSMP, it was not possible to determine population trends for roughly a third of the region-species, as sampled data could not be used to determine trends. The two priority species representing diving planktivores were notably lacking useful data on population trends. In the Atlantic, the little auk is well studied in terms of diet, foraging behaviour, productivity and survival (e.g., Karnovsky et al. 2010, Gremillet et al. 2012, 2015, Hovinen et al. 2014), but detecting population trends for this abundant, crevice-nesting seabird is challenging. The least auklet, also a crevice nester, may be the most abundant seabird in the Pacific Arctic, but it is difficult to monitor and only a few sites in the southern Bering Sea and Aleutian Islands have been studied over time (Dragoo et al. 2015), south of the AMA.

Data gaps exist on the distribution of seabirds during non-breeding season, including migratory paths and staging areas (Ganter and Gaston 2013). For example, at-sea surveys in the Chukchi Sea since 2007 identified new hotspots for post-breeding least and crested auklets, with auklets taking advantage of late summer peaks in zooplankton abundance far from breeding areas, when many birds molt and are flightless (Kuletz et al. 2015, Gall et al. 2017). Applications of biologgers and satellite tags have made it possible to identify the distribution of birds during seasonal periods when they are not at their breeding sites. Recent findings highlight the need to expand conservation efforts for circumpolar species beyond AMA boundaries; examples include the post-breeding migration of black-legged kittiwakes from the Bering Sea to the central Pacific (Orben et al. 2015) and murres, kittiwakes and other species that nest in the Atlantic Arctic moving south to the Newfoundland banks (Frederiksen et al. 2012, 2016).

Two additional major gaps in monitoring efforts are the lack of current information on seabird diets and insufficient demographic data. Collection of birds for dietary samples has not been used frequently over the last two decades and methods such as stable isotope analysis, while useful for basic information, does not provide data on specific dietary items at a given location. New methods for assessing diet will be required to follow changes in the ecosystem. Concurrently, data on survival is essential to make the link between diet, environmental and human stressors, and how they affect seabird populations.

Beyond monitoring, there is only localized or opportunistic and sporadic data relative to known sources of seabird mortality, particularly the true mortality level caused by chronic oiling, predation by introduced mammals, and incidental take in fisheries; this lack of information is especially true for Russian waters. Finally, improved data on prey species and the impact that climate warming will have on them will require multi-disciplinary research and management efforts.

Little auks.
Photo: Incredible Arctic/Shutterstock.com

3.5.6 Conclusions and key findings

To summarize by AMA ecoregions, based on recent trends at CSMP key sites (Table 3.5.2), the Pacific Arctic and Beaufort have shown increasing or stable populations of six of eight priority (including FEC) species (with exception of common eiders in the Canadian Beaufort). However, these regions have few sites with available data relative to other AMAs. Most species in the Arctic Archipelago and Hudson Complex are also increasing or stable, except for the ivory gull, which shows declines throughout most of its breeding range (the exception being in CSMP region 19 in Norway). Davis Strait-Baffin Bay AMA shows mixed results, and indeed appears to be a zone of transition between Pacific/Arctic Archipelago regions and the Atlantic Arctic, with the latter showing primarily population decreases. Nearly 70% of the region-species samples in the Atlantic Arctic show declines and this pattern cuts across foraging guilds (omnivores, piscivores, benthivores).

An avenue to explore is whether the Atlantic Arctic population declines are linked to the cumulative impact of stressors, including commercial fisheries of forage fish species (i.e., sandeels and capelin), incidental take in commercial fisheries, introduced predators, harvest, contaminant load, and oil extraction and transport. Alternatively, this ecoregion simply has more complete data, which allows us to detect seabird trends, compared to other Arctic regions. There is a notable lack of population trend data for diving planktivores (least auklet in the Pacific and in the Atlantic) and for all species in Russia, which crosses three AMAs.

Optimally, national monitoring efforts should be combined with collaborative approaches, i.e., integrated and standardized sufficiently to allow synthesis across the circumpolar regions. Collaborative efforts from the Circumpolar Seabird Expert Group include: 1) the circumpolar population trends of murres relative to sea surface temperatures (Irons et al. 2008); 2) differing trends in eastern versus western Atlantic populations (Frederiksen et al. 2016); 3) black-legged kittiwake trends driven by oceanographic factors linked to climate patterns (Descamps et al. in prep); 4) documentation of genetically indistinguishable ivory gull populations, which has implication for its conservation (Yannic et al. 2016); 5) a conservation plan for ivory gulls (Gilchrist et al. 2008); 6) circumpolar status and trends of glaucous gulls (Petersen et al. 2015); 7) CAFF strategy and conservation plans for murres and eiders (CAFF 1996, CBird 1997) and the Circumpolar Seabird Monitoring Plan (Irons et al. 2015).

For most Arctic ecoregions, additional monitoring is recommended and should strive to include a more complete array of parameters, in particular, diet and measures of survival, as well as higher frequency of monitoring. In most cases, the current frequency of monitoring makes it difficult to identify mechanisms or causes of changes in populations. At-sea surveys will continue to be conducted mainly on a ship-of-opportunity basis, particularly during seismic survey activity, but targeted surveys and individual tracking studies would improve our understanding of seabird interactions at sea, where seabirds spend most of their time.

- Most circumpolar nations have at least one source of long-term seabird monitoring datasets, but efforts vary across regions. These long-term monitoring efforts are crucial to examining the effects of environmental drivers to changes in seabird populations.
- Some of the most widely studied species groups in circumpolar regions include the FECs, i.e. common and thick-billed murres (diving piscivores), black-legged kittiwakes (surface piscivores), and common eider (benthivores); these species groups make it possible to conduct comparative studies across circumpolar regions.
- To better represent all foraging guilds, which sample different components of the marine ecosystem, additional species (priority species) have been selected for monitoring at a circumpolar or regional scale: glaucous gull and ivory gull (omnivores), and least auklet and little auk (diving planktivores).
- Population trends for seabirds vary within and among regions, making it difficult to assess circumpolar trends. Nonetheless, among key sites, current trends indicate that most of the stable or increasing populations are in the Pacific Arctic and Arctic Archipelago, while most of the declining populations are in the Atlantic Arctic.
- The declines in seabird populations in the Atlantic Arctic cut across foraging guilds, including the three FEC species/groups (kittiwakes, murres, common eider); of these, murres have shown the greatest declines. The ivory gull is declining throughout its range; notably, this species is one of the more ice-associated species.
- Important drivers for seabird population changes include climate change, reduced sea-ice, changes in sea temperatures, changes in food webs and species interactions, disease outbreaks, hunting, fisheries bycatch, and pollution (contaminants and oil pollution).
- National monitoring efforts combined with collaborative approaches, when integrated and standardized sufficiently to allow synthesis across the circumpolar regions, would be optimal.
- Most of the circumpolar regions are lacking in consistently funded seabird monitoring efforts, but seas near Russia, spanning three ecoregions, are particularly lacking in seabird monitoring efforts and represent a clear data gap.
- Demographic data are lacking for most species and colony sites.
- New methods for assessing diet will be required to follow changes in the ecosystem and how they affect seabird populations. Most dietary data are not current or rely on what adults feed their chicks (which can be different from what the adults themselves eat).
- Recent findings about migration routes and over-wintering areas highlight the need to expand conservation efforts for circumpolar species beyond the AMA boundaries.
- People from local communities are important 'first responders' to catastrophic events. In addition, we should continue or increase community engagement in monitoring of seabird populations in order to connect monitoring initiatives across spatial scales.

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Appendix 3.5.1.

Seabird species monitored at one or more key monitoring sites for each Arctic country. Seabird species names in bold are FECs. Asterisks indicate the species is one of eight priority species identified in the Circumpolar Seabird Monitoring Plan (Irons et al. 2015).

Species	Canada	Alaska, U.S.	Russian Federation	Finland	Norway	Iceland	Faroe Islands	Greenland
Northern gannet					x	x	x	
Fork-tailed storm-petrel		x						
Leach's storm petrel		x				x		
Northern fulmar	x	x			x	x		
Great skua					x		x	
European shag					x	x		
Great cormorant			x	x	x	x		
Pelagic cormorant		x	x					
Common eider*	x	x	x	x	x	x		x
King eider		X						
Arctic tern		x	x	x		x	x	x
Common gull					x	x		
Black-legged kittiwake*	x	x	x		x	x	x	x
Ivory gull*	x		x		x			x
Glaucous gull*	x	x	x		x			
Glaucous-winged gull		x						
Great black-backed gull			x	x	x	x		
Herring gull	x		x	x	x			
Lesser black-backed gull					x			
Least auklet*		x						
Little auk*					x			x
Black guillemot				x	x	x		
Pigeon guillemot		x	x					
Atlantic puffin	x				x	x		
Tufted puffin		x						
Common murre*		x	x		x	x	x	
Thick billed murre*	x	x	x		x	x		x
Razorbill					x	x		

Bowhead whale.
Photo: Vicki Beaver, Alaska Fisheries Science Center, NOAA