Incubating red knot *Calidris canutus* after a snowfall at Cape Sterlegova, Taimyr, Siberia, 27 June 1991. This shorebird represents the most numerically dominating and species rich group of birds on the tundra and the harsh conditions that these hardy birds experience in the high Arctic. Photo: Jan van de Kam.
Chapter 4

Birds

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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 puffins, which are located some distance south migrating north due to the disappearance of the ice cover during the summer months.

SUMMARY

The Arctic is seasonally populated by roughly 200 species of birds, corresponding to about 2% of global avian species diversity. In contrast to more southerly latitudes, the dominant ecological and taxonomic groups among Arctic birds are waterfowl, shorebirds and seabirds, while songbirds are less prominent and much less diverse than at lower latitudes. The vast majority of species only spend a small portion of each year in the Arctic – but it is here that reproduction takes place.

Of the 162 species for which more than half of their breeding range falls in the terrestrial or marine Arctic, about half have a circumpolar distribution while the others are confined to either the Nearctic or Palearctic or to the Atlantic or Pacific ocean basins. A particularly high species richness is found on both sides of the Bering Strait. Overall, species diversity is more than twice as high in the low Arctic than in the high Arctic.

Because of the migratory nature of most Arctic birds, these animals connect the Arctic to all other parts of the globe. Arctic birds winter as far south as the southern tips of the continents, and some even reach Antarctica. The extent of migratory behavior also means that the population sizes and trends of Arctic birds are sometimes affected, either positively or negatively, by events and activities occurring outside the Arctic. There are many examples of such extra-Arctic effects. As a consequence, conservation of Arctic birds will almost always necessitate international cooperation throughout the range of the migratory species. This is especially critical for the endangered species among Arctic birds, such as the Siberian crane *Leucogeranus leucogeranus* or the spoon-billed sandpiper *Eurynorhynchus pygmeus*, the latter currently facing extinction.

Global climate change has the potential to influence Arctic bird populations in many ways, through effects acting in the Arctic itself as well as on migration routes or in wintering areas. However, although there are some indications that climate-induced changes are already taking place, the anthropogenic factors that are independent of climate – disturbance, habitat loss, fishing, hunting, agricultural intensification – have a much larger impact on populations at present.

4.1. INTRODUCTION

Despite its harsh environment, the Arctic is populated by a variety of different bird species. Arctic breeding birds benefit from a short but strong seasonal outburst of food availability, be it growing plants for herbivores, invertebrate biomass for insectivores or zooplankton for seabirds and their fish prey. This plentiful seasonal food supply is coupled with relative safety from predation created by continuous daylight, a low diversity of predators and the sheer numbers of prey swamping predator pressure (McKinnon *et al.* 2010). Diseases and parasites are also less prevalent than in warmer climates (Kutz *et al.* 2005). After the breeding season, however, most birds leave the Arctic to spend the winter in warmer climate zones; in fact, the majority of ‘Arctic birds’ spend only a small fraction of each year on their Arctic breeding grounds (Meltofte 1996, Newton 2007). Their migrations connect the Arctic to all other parts of the globe.

Being highly visible and audible as well as diurnally active, birds are one of the groups of organisms that are best known to humans worldwide. Hence, Arctic birds also have a strong cultural significance to the indigenous peoples of the Arctic. The arrival and departure of migratory birds marks the changing of the seasons, and in addition to their significance as a food source birds also play a role for festivals and the planning of family and community events.

Roughly 200 bird species breed in the Arctic, amounting to 2% of the global avian biodiversity. However, the relative weight of higher taxonomic groups is different from the global total. The Anseriformes (waterfowl) and Charadriiformes (shorebirds, gulls, auks) make up the majority of avian diversity in the Arctic and are therefore treated in detail in separate sections of this chapter. By contrast, the songbirds, being the most diverse group elsewhere, are underrepresented in the Arctic and are treated together with the other ‘landbirds’ below.

Whereas some species occur mostly in temperate latitudes and only reach the Arctic at the fringes of their distribution, others are more or less confined to the Arctic during the breeding season. These ‘true Arctic’ species will be the main focus of the analyses below. Among them there are species with a circumpolar distribution while others are confined to one of the hemispheres or have even more restricted distributions. The diversity of distributions create variation in species richness within the Arctic. In this chapter we address these species richness patterns as well as the current status, trends and future prospects of individual species.

4.2. STATUS OF KNOWLEDGE

4.2.1. Sources and regions

Species distributions were considered on the basis of known breeding ranges. Separate brief consideration is also given to wintering birds. Data on bird breeding distributions were obtained from standard sources (Del Hoyo *et al.* 1992-2009, Poole 1992-2011, Beaman & Madge 1998, Sibley 2000, Olsen & Larson 2003) and vetted by local corresponding authors. Species names and classification follow the list compiled by the International Ornithological Congress (Gill & Donsker 2012). Data on IUCN red listed species was obtained from (IUCN 2012).

Our analysis concentrates on species using habitats north of the tree-line, within the geographical areas defined as low and high Arctic in the Circumpolar Arctic Vegeta-
tion Map (CAVM Team 2003). We include the whole of Iceland (apart from the south coast) and areas of oceanic tundra (e.g. Aleutian Islands). Many species occur to the limit of trees, and a large number of predominantly boreal species touch the low Arctic zone around the mouth of the Mackenzie Valley. We have omitted from our Arctic list those species which only reach the low Arctic there (e.g. spruce grouse *Falcipennis canadensis*, northern hawk-owl *Surnia ulula*, yellow-rumped warbler *Dendroica coronata*), but include species which cross the low Arctic boundary across a broader geographical area (e.g. wandering tattler *Tringa incana*, lesser yellowlegs *Tringa flavipes*, golden eagle *Aquila chrysaetos*, great grey shrike *Lanius excubitor*).

In the Neartic, the western mountain ranges contact the Arctic in Alaska, allowing several Arctic species to extend southwards into boreal latitudes (e.g. ptarmigans *Lagopus* spp., white-crowned sparrow *Zonotrichia leucophrys*, grey-crowned rosy finch *Leucosticte tephrocots*), but in Asia there is only slight contact between the mountains of central Asia and the Arctic and no typically Arctic birds extend south in this way. In Europe, a few otherwise Arctic species extend southwards through the mountains of Scandinavia and into the uplands and islands of northern Britain (e.g. red-throated loon *Gavia stellata*, dunlin *Calidris alpina*, Eurasian dotterel *Charadrius morinellus*, snow bunting *Plectrophenax nivalis*). Likewise, in the Baltic Sea several marine birds occur in

**Figure 4.1.** Avian biodiversity in different regions of the Arctic. Charts on the inner circle show species numbers of different bird groups in the high Arctic, on the outer circle in the low Arctic. The size of the charts is scaled to the number of species in each region, which ranges from 32 (Svalbard) to 117 (low Arctic Alaska).
essentially a boreal climate (e.g. common eider Somateria mollissima, Arctic tern Sterna paradisaea, ruddy turnstone Arenaria interpres; Snow & Perrins 1998).

For discussion of distributions we have divided the terrestrial Arctic into Nearctic (four regions, including Greenland; Fig. 4.1) and Palearctic (eight regions, including Iceland), partly based on convenient political boundaries (North America) and partly on geographical boundaries (Siberia). Seabirds were divided by ocean basins into those breeding predominantly on Atlantic, Pacific or Arctic Ocean coasts. In addition, each region was divided into high and low Arctic, where appropriate. Species were classified as high Arctic specialists where most of their breeding distribution (> 50% by area) fell in the high Arctic, low Arctic specialists where most fell in the low Arctic, sub-Arctic where most of the range fell within the taiga/boreal forest zone and cosmopolitan where the range encompassed both Nearctic and Palearctic and included areas outside the Arctic and boreal zones.

Diversity is analyzed mainly in terms of species richness, as reliable population estimates to allow the calculation of more sensitive diversity indices are not available for many Arctic species. We also discuss diversity at higher taxonomic levels and the prevalence of endemcity within the Arctic. Taxa were considered endemic to the Arctic if > 90% of the population or breeding range fell within the low and high Arctic.

Information on population trends was sparse and varied among taxonomic groups, with substantial information available for waterfowl, colonial seabirds and a few raptors, especially those populations wintering in western Europe or North America. Much less is known about trends in non-colonial seabirds, shorebirds and landbirds and especially for populations wintering in Asia, Africa and Latin America. Even where populations trends are known, the assignment of causes may be speculative.

Among landbirds, only the raven Corvus corax, the ptarmigans, the gyrfalcon Falco rusticolus, the snowy owl Bubo scandiaca and the Arctic redpoll Acanthis hornemanni remain over substantial areas of the Arctic throughout the winter, along with some marine birds (black guillemot Cepphus grylle, thick-billed murre Uria lomvia, ivory gull Pagophila eburnea and Ross’s gull Rhodostethia rosea) and the eider ducks. Practically all shorebirds and most members of other groups migrate away from the Arctic in winter (93% of species), some moving to peripheral areas in the boreal and temperate regions (most waterfowl, passerines, owls, birds of prey, auks and gulls), some to the tropics (some shorebirds, phalaropes, Sabine’s gull Xena sabini) and a few to austral temperate, Antarctic or sub-Antarctic regions (some shorebirds, Arctic tern, some jaegers/skuas Stercorarius spp.) (Fig. 4.2). Because of the widespread dispersal of Arctic birds to lower latitudes in winter, population trends in migrant species are not necessarily determined by changes in Arctic environments. For example, Arctic-breeding snow goose Chen caerulescens populations have expanded enormously in North America over the past 30 years, predominantly as a result of the geographical expansion and increased productivity of agricultural crops in their wintering areas (Jefferies et al. 2004). Likewise, the decline in Arctic-breeding red knot Calidris canutus ssp. rufa has been attributed to changes in feeding conditions in their staging area, on Delaware Bay, USA (Morrison et al. 2004), rather than to changes on their Arctic breeding grounds. The only Arctic bird to become extinct in historical times, the eskimo curlew Numenius borealis (‘Possibly extinct’; Butchart et al. 2006) was the victim.

Figure 4.2. Major flyways of Arctic birds. Bird migration links Arctic breeding areas to all other parts of the globe. (Adapted from ACIA 2005).
of hunting on its migration areas in E North America (Bodsworth 1963).

4.2.2. Biogeography

The avifauna of the Arctic is dominated by birds of the orders Charadriiformes (76 spp.), and the Anseriformes (32 spp.). Species richness is generally low in Arctic avian communities, compared with those at lower latitudes (see Fig. 2.1 in Payer et al., Chapter 2). Among the Charadriiformes, the families Scolopacidae (sandpipers and allies), Laridae (gulls) and Alcidae (auks); the latter two sometimes treated as sub-families and among the Anseriformes the subfamilies Mergini (sea ducks) and Anserini (geese) contribute most species to the Arctic avifauna. These two orders comprise 108 of 162 species (67%) for which more than half their breeding range falls within either the terrestrial or marine Arctic. Conversely, the highly diverse order of Passeriformes (songbirds), which comprises more than 50% of bird species worldwide, is represented in the Arctic by only 34 species (21%). The difference is even more striking when we consider only the high Arctic, where Anseriformes and Charadriiformes make up 70% of 68 species and Passeriformes only 13%.

Two families are mainly confined to the Arctic and sub-Arctic: the loons/divers (Gaviidae) and the auks (Alcidae), while the geese (11 species in the Arctic) and sandpipers and allies (39 species) reach their highest diversity there. At the level of genus, the ducks Somateria and Polysticta (eiders) and Melanitta (scoters), the turnstones Arenaria, the Pluvialis plovers, the little auk Alle alle, the monotypic gull genera Xema, Rhodostethia and Pagophila and the passerine buntings Plectrophenax and the passerine wheatears Oenanthe, longspurs Calcarius.

Species richness is generally low in Arctic avian communities, compared with those at lower latitudes. However, this generalization does not apply to seabirds, where species richness peaks in subpolar waters (Gaston 2004) or shorebirds where breeding diversity is highest on lowland Arctic tundra (Taylor 2006). Within ecoregions, altitude and distance from the coast are both important predictors of avian biodiversity in the Arctic, with species richness falling off quickly with altitude, especially in the high Arctic and, in some regions, being inversely related to distance from the coast, as coastal species form an important fraction of the species richness.

4.2.3. Climate and ecosystem change

“Birds breeding in alpine and arctic habitats suffer a seasonal reproductive disadvantage compared to birds at lower latitudes or elevations because the breeding window is short and in late years, nest failure may be high with little opportunity for renesting. Coping mechanisms may only be effective below a threshold of climactic extremes. Despite strong resilience in fecundity parameters, when snowmelt is extremely delayed breeding success is greatly reduced... [they] will be further challenged as they attempt to cope with anticipated increases in the frequency and severity of weather events (climate variability), as well as general climate warming” (Martin & Wiebe 2004).

Ongoing changes in global climate are well known and disproportionately affect high latitudes (IPCC 2007). Changes in the timing of events in the physical environment over the past several decades, especially an advance in the date of Arctic spring sea ice break-up (Parkinson & Cavalieri 2008, Perovich & Richter-Menge 2009), and substantial increases in air temperatures, both in summer and winter, at many Arctic stations (Tedesco et al. 2009) have been well documented. A wide range of phenological changes in components of biological systems have also been documented, with many species of plants and animals showing advances in the timing of seasonal events (e.g. Visser & Both 2005, Hoye et al. 2007, Jia et al. 2009, Gauthier et al. 2011a). For birds, such advances have been seen in timing of migration (Sparks 1999) and reproduction (Winkler et al. 2002, Both et al. 2004, Thackeray et al. 2010). Although timing effects may be mediated by advances in the timing of food resources, there is evidence that birds may respond to temperature per se (Both et al. 2006, Visser et al. 2009).

As the timing of seasonal events changes under the influence of changing climate, corresponding adjustment in the timing of crucial life-history events for birds (e.g. breeding, migration, molt) becomes an important issue. For example, in species where the timing of reproduction is determined by invariant mechanisms, such as day length, or on regional rather than local conditions (Frederiksen et al. 2004a), the ability to adjust to changes in the physical environment may be limited, resulting in a mis-match between physical and biological events (Coppack et al. 2001, Stenseth & Mysterud 2002, Nussey et al. 2005, but see also Durant et al. 2005). Where adjustment of life history events fails to keep pace with changes in the timing of prey availability (generally referred to as ‘life history mis-match’; Visser & Both 2005) reproduction and other seasonal events may be compromised (e.g. Dickey et al. 2008). Conversely, in situations where late snow-melt or sea-ice breakup sometimes reduces reproduction, general warming may make breeding more predictable for some populations (e.g. Gaston et al. 2005a, 2005b, Love et al. 2010).
Arctic birds are highly susceptible to variation in weather conditions during breeding (Ganter & Boyd 2000, Meltofte et al. 2007a, Dickey et al. 2008). In particular, the timing of snow melt determines the availability of suitable nesting and feeding areas for many species, and in general, because species may be breeding close to the limits of their physiological tolerance, adverse weather conditions are more likely to cause breeding failure than at lower latitudes (Martin & Wiebe 2004). Given the likely amelioration in climate over coming decades, we might assume that conditions for breeding of many Arctic species will improve (e.g. Jensen et al. 2008) – at least until expanding vegetation types from the south overtake their habitats (Meltofte et al. 2007a). However, climate change will also bring new competitors, predators and diseases, as well as rearranging the structure of biological communities (Kutz et al. 2004, 2005, Bretagnolle & Gillis 2010, Brommer & Møller 2010). Depending on the rate of change of different factors, any number of different scenarios is possible. The empirical evidence reviewed here is based on a small number of studies in very localized areas, many peripheral to the Arctic, and involving, for the most part, only tiny fractions of total populations. We should be extremely cautious about any future scenarios based on such a tiny sampling of the regional avifauna.

4.3. WATERFOWL: DUCKS, GEESE AND SWANS

When the geese first arrived, they didn’t stay only in one place. They went to the areas where the snow had melted first, like on the riverbanks. They look for available food. When it is time to lay their eggs, they probably nest where food is available. After the eggs hatch, the parents bring their goslings all over the tundra and they are no longer seen. They stay mostly around the eyget (Carex subspathacea). They say that when they molt, even though there are lots, they become quiet. It is said that they are scared. You could see a lot of their tracks on the mud between the small grasses.

(Michael John of Newtok, Alaska, in Fienup-Riordan 1999).

The waterfowl (family Anatidae) are one of the most diverse and visible groups in the Arctic bird fauna with numerous large-bodied and abundant species, many of which breed exclusively in the Arctic. Most species leave the Arctic after the breeding season to winter in temperate regions of the Northern Hemisphere; the seaducks, however, largely remain in Arctic waters in the winter. Some species undergo molt migration within the Arctic prior to leaving for southern wintering areas, as observed e.g. by indigenous peoples of Nunavut:

Canada geese are numerous now, but they do not nest here. Rather, they come here to fledge their feathers and there are so many that they do not flee.

(Novalinga: Elders Conference on Climate Change 2001).

Because waterfowl are large, numerous, migratory and palatable there has long been a close relationship between waterfowl and humans through hunting. Most species are hunted during migration and in winter, resulting in major impacts on population sizes and dynamics that occur away from the Arctic breeding grounds. Hunting and egg collecting also occur in the Arctic, but at present are generally less relevant to populations compared with hunting during migration (Kostin 1996, Arctic Goose Joint Venture Technical Committee 2008, Merkel & Barry 2008). Until the mid-20\textsuperscript{th} century, however, the impact of persecution on the breeding grounds was probably significant for some populations (Storå, 1968, Nowak 1995; see also Fig 4.3 and Box 4.1).

Hunting of waterfowl has considerable economic importance, and thus much attention is paid to management of populations along the flyways. Arctic-breeding waterfowl populations are subject to various international protection agreements (e.g. African-Eurasian Waterbird Agreement (AEWA), Ramsar, North American Waterfowl Management Plan (NAWMP)). However, there is a large discrepancy between the intensity of population monitoring and management in the Western Hemisphere and W Palearctic as opposed to the E Palearctic, where flyway populations are less well monitored and hunting is less regulated.

Another important factor acting on population sizes, especially of the herbivorous geese, is change in agricultural practice on staging areas along migration routes and in wintering areas. During recent decades, Arctic-breeding geese have increasingly benefitted from foraging opportunities in agricultural fields on the wintering grounds and along the flyways of North America and Europe (Jefferies et al. 2004, Fox et al. 2005, Gauthier et al. 2005, van Eerden et al. 2005).

4.3.1. Species richness and distribution

4.3.1.1. Status

Of a total of 39 species of waterfowl breeding in the Arctic, 21 occur in the high Arctic, but none are confined to the high Arctic. There are two species of swans (Cygnus), the tundra swan Cygnus columbianus being an Arctic specialist. The geese (Anser, Chen and Branta) have the center of their distribution in the Arctic; 13 species occur here and 11 of them are more or less confined to tundra habitats during the breeding season, while two have ranges extending further south into northern temperate regions. These three genera include only four other species which breed entirely outside the Arctic. The ducks are represented by 24 species, the dabbling ducks being mostly boreal species with part of their distribution in the low Arctic while most of the diving ducks and seaducks also occur in the high Arctic. Eight species of ducks, all of them diving ducks or seaducks, are Arctic specialists, among them the endemic genera Somateria (eiders, 3 species), Polysticta and Clangula (Steller’s eider and long-tailed duck, both monotypic).
Overall diversity is highest along and near both sides of the Bering Strait, i.e. in the low Arctic of W North America and E Siberia, with 22 species breeding in Arctic Alaska, 20 in the W Canadian Arctic and 20 in the Russian Far East Arctic. The other low Arctic zones have between 15 and 17 breeding species of waterfowl, with the exception of Greenland where only eight species breed in the low Arctic. In the high Arctic zones, between five and 11 species occur, with the European Russian zone (i.e. the islands of Novaya Zemlya and Vaigach) having the highest diversity.

Several taxa have been elevated to species status only recently and were previously considered sub-species. These splits mainly involve distinguishing Eurasian and North American populations (Eurasian/green-winged teal Anas crecca/carolinensis, common/black scoter Melanitta nigra/americana, velvet/white-winged scoter Melanitta fusca/deglandi), but also the larger-bodied (Branta canadensis) and smaller-bodied (Branta hutchinsii, now cackling goose) forms of Canada goose. Moreover, the tundra bean goose Anser serrirostris has been split from the boreal taiga bean goose Anser fabelis. On the other hand, the previously separated Bewick’s (Eurasia) and white-bellied (North America) swans are now considered a single species, the tundra swan Cygnus columbianus.

Many Arctic-breeding waterfowl species have very large ranges, and for some of them several morphologically distinct subspecies are recognized. Examples are dark Branta bernicla bernicla, black B. b. nigricans and light-bellied brant geese B. b. hrota; lesser Chen c. caerulescens and greater snow geese C. c. atlantica. The specific taxonomy of Canada and cackling geese is unclear. Some subspecies are confined to small breeding ranges, such as the Greenland race of mallard Anas platyrhynchos conboschas and the Greenland white-fronted goose Anser albifrons flavirostris.

### 4.3.1.2. Trends

In the Kivalliq region, we are the northernmost people, and we are not yet subjected to the changes to the degree the other delegates have noted, but things are changing nonetheless. However, geese were quite rare in our area, both snow and Canada geese. We now have geese in more areas, not just in Qaggiqalik, which was the main area for hunting geese. (Qaunaq: Elders Conference on Climate Change 2001).

Trends in ranges of Arctic-breeding waterfowl appear to be always connected to trends in numbers (see Section 4.3.2). In recent decades, range expansions have been recorded for a number of goose species. In the Nearctic, breeding snow geese have expanded southwards along the coast of Hudson Bay (Mowbray et al. 2000), and Canada geese have expanded into W Greenland where they continue to increase (Malecki et al. 2000). Similarly, Ross’s geese Chen rossii showed a major eastward expansion as the species now breed in large numbers in areas such as west Hudson Bay or south Baffin Island where only snow geese used to breed (Kelley et al. 2001, Kerbes et al. 2006). Dark-bellied brant geese have expanded eastwards, and Pacific black-bellied brant have expanded westwards in Siberia, so that both subspecies now meet in the Lena Delta, where they interbreed; both populations have moved into the gap left by the Asian population of black-bellied brant which is close to extinction (Syroechkovskiy 2006). Russian barnacle geese Branta leucopsis have expanded their range towards the W and SW; while they were confined to the islands of Novaya Zemlya and Vaigach in the 1980s they are now breeding along the mainland further to areas W and with tens of thousands of pairs on the island of Kolguev (and, in addition, have expanded their range outside the Arctic, SW to the coasts of the Baltic and W Europe, where they now breed with several thousand pairs; van der Jeugd et al. 2009). By contrast, the breeding range of the lesser white-fronted goose Anser erythropus has contracted and it has now almost disappeared from northern Scandinavia and the European part of the Russian Arctic (Morozov 2005). No strictly Arctic waterfowl species has gone extinct during historic times, however, the sub-Arctic Labrador duck Camptorhynchus labradorius was hunted to extinction in the late 19th century (Fuller 2000).

In Greenland, there are two examples of recent northward range expansions of duck species: common eiders have expanded their range within Greenland (Boertmann & Nielsen 2010), and Eurasian teal together with northern pintail Anas acuta have recently been breeding or supposed to breed, respectively, in Greenland (Boertmann 1994, Glahder & Walsh 2010, Meltote & Dinesen 2010, Jensen & Rasch 2011). Apart from these, we are not aware of any records of boreal or temperate duck species expanding their range northwards into the Arctic as is the case with some shorebirds (see Section 4.4.1.2). However, ducks are generally less well researched on the breeding grounds than are geese, especially in the Palearctic. Still, there are some reports from local people about range changes of several duck species. In sub-Arctic northernmost Finland, the late Saami reindeer herder Ilmari Vuolab had noted that ducks were increasing again after a time when all kinds of ducks were disappearing from the region.

But then again, what we call sea birds, like long-tailed ducks, velvet scoters and common scoters – they are all gone. There used to be great flocks of them and now they are so few. (Helande et al. 2004).

### 4.3.1.3. Causes and prospects

Range expansions are expected to continue as long as populations continue to grow (see Section 4.3.2.3). A model of the distribution of pink-footed goose Anser brachyrhynchus on Svalbard under even modestly warmer climate scenarios (1-2 °C increase in summer temperatures) predicted a large north- and eastward expansion of the breeding range on Svalbard (Jensen et al. 2008).
4.3.2. Population sizes and densities

4.3.2.1. Status

Order of magnitude population sizes for Arctic-breeding waterfowl are given in Appendix 4. Population sizes are typically monitored on the wintering grounds through the International Waterbird Census (Wetlands International 2012), and for those species that have only part of their breeding distribution in the Arctic it is often impossible to separate Arctic breeders from boreal or temperate birds at the time of counting. Therefore, we discuss status and trends of population sizes only for species that are predominantly (> 50% of the population) confined to the Arctic during the breeding season (Category 1 and 2 in Appendix 4). All but three of these species have populations numbering in the hundreds of thousands (7 species) or millions (7 species). Only the lesser white-fronted goose, the emperor goose Chen canagicus and the red-breasted goose Branta ruficollis have numbers less than 100,000 birds; these species are classified by the IUCN as vulnerable, endangered and near threatened, respectively, and are subject to conservation efforts. Despite large population sizes the Steller’s eider Polysticta stelleri, the long-tailed duck Clangula hyemalis and the velvet scoter Melanitta fusca are listed as vulnerable or endangered because of rapid population declines in recent decades. Some of the more numerous species, have (sometimes morphologically distinguishable) populations that use distinct breeding areas and migration corridors; some of these populations number less than 10,000 individuals. Because international agreements focus on conservation at the population level, special

Box 4.1. Common eiders: circumpolar sea ducks

The common eider Somateria mollissima has a circumpolar distribution breeding mainly on small islands in Arctic and boreal marine areas in Alaska (Bering Sea region), Canada, Greenland, Iceland, N Europe and the Barents Sea region. In mainland Russia, there is a gap in distribution from the Yugorski Peninsula (Kara Sea) to Chaunskaya Bay in E Siberia (Box 4.1). Important wintering areas include the Gulf of Alaska/Bering Sea/Aleutian region, SE Canada, SW Greenland, Iceland and NW Europe. Six or seven subspecies are recognized, of which four occur in North America (Bustnes & Tertitski 2000, Goudie et al. 2000).

The common eider is a highly valued living resource in the Arctic. The birds or their products are harvested throughout most of the circumpolar region. As the largest duck in the Northern Hemisphere, it is important for traditional food and lifestyle not only in many Arctic communities, but also in SE Canada and the Baltic region (Merkel & Barry 2008). In some countries, especially Iceland, down feather collection constitutes a significant commercial industry (Bédard et al. 2008).

The common eider is dependent on benthic organisms in shallow marine waters for food throughout the year, making it a potential indicator of the health of marine coastal environments. This is similar to situations in which fish-eating seabirds can indicate changes in the pelagic marine ecosystem (Wanless 2007). Year-round movements have been studied intensively over the past 10-15 years by satellite telemetry (e.g. Mosbech et al. 2006, Petersen 2009), and this provides a good foundation for monitoring change in the future.

The world population of common eiders probably ranges from 1.5 to 3.0 million breeding pairs (Bustnes & Tertitski 2000). Around the early 1990s, it was clear that common eiders in the Arctic, along with other eider species, had generally suffered large declines over several decades, and the need to stabilize and manage eider populations was increasingly recognized. As part of the Arctic Environmental Protection Strategy, signed in 1991, the Circumpolar Seabird Group under CAFF developed a Circumpolar Eider Conservation Strategy and Action Plan (1997).

The factors behind several eider population declines reported in the 1980s and 1990s (including populations in Alaska, Canada, Greenland and Russia) were often unknown, but in some cases involved human disturbances, excessive harvest of eggs and birds together with severe climatic events (Robertson & Gilchrist 1998, Suydam et al. 2000, Merkel 2004a). The current trend of common eider populations varies but at least some populations in Alaska, Canada and Greenland (see Fig. 1.4 in Meltofte et al., Chapter 1) are now recovering with improved harvest management as a likely contributing factor (Goudie et al. 2000, Chaulk et al. 2005, Gilliland et al. 2009, Merkel 2010, Burnham et al. 2012). Breeding populations in the Barents Sea region appear reasonably stable (Bustnes & Tertitski 2000).

Along with other gregarious bird species, common eiders are sometimes affected dramatically by diseases. A recent outbreak (2005-present) of avian cholera in the Hudson Strait of E Canada abruptly reversed a population increase and reduced the population of a large colony there by 30% in just three years (Buttler 2009). By-catch in fisheries gillnets is also a significant problem in some areas (Bustnes & Tertitski 2000, Merkel 2004b, Merkel 2011) and may be a more widespread concern. The search for oil and gas reserves in the Arctic is increasing and may put eider ducks at further risk in the future. The direct response of eiders to climate change is currently under investigation in several countries. In Iceland, local weather conditions appear to affect nesting dates and clutch sizes, although not consistently between colonies (Jónsson et al. 2009). The management of human harvest of eiders or their products, and the management of introduced predators such as foxes and mink, will remain important issues in the conservation of common eider populations.
attention is paid to such small populations, such as the E Atlantic light-bellied brant goose, the ‘grey-bellied brant goose’ *B. b. hrota/nigricans* of the W Canadian high Arctic or the Tule white-fronted goose *Anser albifrons gambeli*.

Geese of the genera *Chen* and *Branta* as well as eiders tend to be colonial nesters. Colonies can consist of only a few pairs on an islet, but some species, especially barnacle goose and snow and Ross’s goose can form very large aggregations. These colonies sometimes number more than 100,000 pairs (Alisauskas *et al.* 2006), with densities of up to 3,000 pairs/km² (Baranyuk *et al.* 2001, Mooij *et al.* 2011). The other species are generally dispersed nesters with lower densities over large ranges. Examples for goose densities in the genus *Anser* are c. 1 pair/km² (van den Bergh 1999) or 20-80 pairs/km² (Kondratyev & Zaynagutdinova 2008).

Large and dense aggregations of birds can also be formed by non-breeding and post-breeding birds during molt, often in specific molting areas that are not used as breeding sites but are reached after a molt migration within the Arctic (e.g. Petersen *et al.* 1999, Flint *et al.* 2008). Because waterfowl are flightless for several weeks during wing molt, they are particularly sensitive to predation and disturbance at this time (Mosbech & Glahder 1991, Miller 1994, Madsen *et al.* 2009).

**4.3.2.2. Trends**

Most Arctic-breeding goose populations have increased markedly in the last 30-50 years, many of them recovering from alarmingly low population levels in the mid-20th century. In the W Palearctic, 12 out of 14 Arctic-breeding goose populations belonging to seven species

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**Box 4.1 Figure 1.** Breeding and wintering range of common eiders *Somateria mollissima* in the circumpolar region (not all southern breeding areas included). (Modified from CAFF 2010).
had positive long-term (20-50 yr) population trends with annual growth rates between 1.1% and 7.8%, with the largest increases in barnacle geese (Fox et al. 2010). The exception is the lesser white-fronted goose, where the N European population has declined to almost zero and the larger Russian population appears to be stable. In theNearctic, snow and Ross’s geese have experienced dramatic and ongoing population growth on all flyways during the past decades, while greater white-fronted goose numbers now appear to be stable and there is currently no clear trend for brant geese (Canadian Wildlife Service Waterfowl Committee 2011).

By contrast, populations of four goose species breeding in the E and far E Russian Arctic and wintering in E Asia (mainly China) have undergone steep declines in the late 20th century (Syroechkovskiy 2006). Red-breasted geese that breed in central N Siberia and Steller’s eiders with a circumpolar but patchy breeding distribution are also declining (Wetlands International 2012). The other species of eider have stable population sizes (see Box 4.1); no consistent global trends have been reported for tundra swan, greater sculp Aythya marila and the circumpolar long-tailed duck, although the large wintering population of the latter in the Baltic Sea has apparently declined by two thirds in the past 20 years (Skov et al. 2011).

4.3.2.3. Causes and prospects

Cause for declines in red-breasted geese (Fox et al. 2010) and Steller’s eiders (Petersen et al. 2006) are unclear and need further examination. The lesser white-fronted goose is threatened by hunting on migration and in winter, when it mixes with the morphologically similar and much more numerous greater white-fronted goose, which makes it vulnerable to accidental shooting despite its protected status (Lorentsen et al. 1999).

The marked and continuing increases in many North American and W Palearctic goose populations have been attributed to a combination of two main factors: agricultural change on staging and wintering areas providing plentiful food resources for geese, and reduction of hunting pressure during migration and in winter. The latter applies especially to the W Palearctic and is a result of conservation measures initiated in the second half of the 20th century when populations of brant and barnacle geese were threatened with extinction (Madsen et al. 1999). In addition, intensive persecution of geese on the Russian breeding grounds until the first half of the 20th century (see e.g. Storå 1968 and Fig. 4.3) may have further decimated populations, and this is no longer the case (Nowak 1995).

Beginning in the mid-1990s, increased population size of lesser snow geese in the North American mid-continent and of greater snow goose Chen c. atlantica in E North America was identified as a conservation problem because rapidly growing numbers of geese increasingly degrade sub-Arctic and Arctic coastal habitats in the vicinity of breeding colonies and at staging sites (Ankney 1996, Batt 1997, 1998; see Ims & Ehrich, Chapter 12). Subsequently, unprecedented management efforts were made to increase hunting pressure and thereby reduce survival of adult geese to ultimately reverse population growth. However, these efforts failed to have the desired effect, and population size of mid-continent snow geese was estimated to be between 15 and 25 million in 2006, about twice as many as in 1995 (Alisauskas et al. 2011).

In contrast, these management actions were much more successful in stabilising the population of the greater snow goose between 800,000 and 1,000,000 birds in recent years after the population had exceeded the 1 million mark for the first time in 1999 (Reed & Calvert 2007). In this population, management efforts will have to be maintained at a high level to prevent further popula-

Figure 4.3. Mass captures of up to 3,000 flightless geese in one go and up to 26,000 flightless ducks in three days took place in northern Eurasia well up into the 20th century, probably contributing to the critically low population sizes in several goose populations in the middle of the century (from Storå 1968).
tion growth. In the W Palearctic, a management plan for preventing the Svalbard population of pink-footed geese from further increase is under development among the range states (Madsen & Williams 2012).

Jensen et al. (2008) predict that climate change may lead to a further growth in population size of many Arctic breeding geese. As conditions on the Arctic breeding grounds ameliorate with climatic warming, density-dependent mechanisms that regulate population size on the breeding grounds may relax through prolonged breeding seasons and improved access to more nesting and feeding areas (see also Madsen et al. 2007). However, other mechanisms may counteract these positive impacts of climate warming. In several areas, wetlands used by geese are formed by patterned ground, i.e. tundra polygons. The stability of these polygons depends on the integrity of the frozen ground, and they are particularly vulnerable to the rapid melting of ice-wedges in the ground (Fortier et al. 2007). Recent degradation of these ice-wedges due to thermal erosion has drained several wetland areas on Bylot Island (Godin & Fortier 2010), which led to a rapid shift toward drier plant communities and a loss of feeding habitat for broods (Gauthier et al. 2011a). Such phenomena are likely to increase with climate warming. Sea ducks may benefit from improved access to marine benthic food sources through reduced ice cover in time and space. On the other hand, Fox et al. (2010) report a trend for decline in reproductive output in many W Palearctic goose populations, which may be a first sign of density-dependent processes impeding further population growth at present.

Away from the breeding grounds, predicted future changes in agricultural land use in the staging and wintering areas of Arctic waterfowl may be detrimental to populations (van Eerden et al. 2005, Wisz et al. 2008). Increased human population pressure on wintering areas may lead to habitat loss for wintering waterfowl. Those species that utilize specialized food resources during winter and migration, such as brant geese feeding on seagrass Zostera spp. (Ganter 2000) or tundra swans feeding on pondweed Potamogeton spp. (Drent 1996), are especially sensitive to changes in the availability of these forage species e.g. caused by eutrophication (e.g. Meltofte & Clausen 2011). The situation, however, may not apply to some goose populations that have thoroughly adapted to the agricultural landscape during winter (e.g. Jefferies et al. 2004, Gauthier et al. 2005).

For many of those Arctic waterfowl populations that are faring less well, the main stressor appears to be hunting during migration and on wintering grounds. This is rather well managed and carefully monitored in North America and the W Palearctic, but much less controlled in Asia.

For seaducks wintering in Arctic waters, often concentrated in small areas at high density, spills from oil exploration and increased shipping in Arctic waters constitute a potentially serious threat if offshore oil exploitation increases as currently expected (AMAP 2007). Spectacled eiders Somateria fischeri wintering in polynyas in the Bering Sea are dependent on both benthic food sources and opportunities to rest on sea ice. Increased sea temperatures could lead to a major shift in benthic communities and at the same time will cause loss of sea ice, potentially threatening the well-being of this species (Grebmeier et al. 2006, Lovvorn et al. 2009).

4.3.3. Other issues

4.3.3.1. Changes in phenology

Herbivorous waterfowl follow the wave of new growth of forage plants northwards during spring migration and through brood rearing (van der Graaf et al. 2006). If phenology of spring plant growth changes with climate change in the Arctic, herbivorous waterfowl will have to adjust their migration schedules to ensure sufficient food resources during brood rearing. Some goose populations can apparently adapt their migration schedules to changed patterns of food availability and climate as shown by case studies on changing use of European stopover sites by pink-footed and barnacle geese (Bauer et al. 2008, Tombre et al. 2008, Eichhorn et al. 2009). Residents of European Russia have noticed a local decline in migrating geese despite the overall population increase, probably reflecting changes in migration routes and/or stopover schedules. Arkady Khodzinsky, a reindeer herder from Lovozero community on the Kola Peninsula has observed the following:

> There is very little goose now. It used to be that they were all over. Before, when we were at the camp and we would see geese we would know the spring is coming. Nowadays we see no geese. Occasionally one or two flocks fly over but this is a rare event. (Cherenkov et al. 2004).

However, not all populations may show such flexibility, in particular those migrating to the high Arctic. In E North America, greater snow geese nesting on Bylot Island have not advanced their laying date over the past 20 years despite a significant advance of spring in the area (Dickey et al. 2008). In very early years, this causes a mismatch between the hatching date of goslings and the phenology of their food plants, which reduces gosling growth. As the climate warms, this mismatch will likely increase, which may reduce the recruitment into the population (Gauthier et al. 2011a).

4.3.3.2. Predator-prey interactions

Together with other breeding birds of the central N Siberian Arctic (see Section 4.4.3.1), brant geese have been showing a marked boom-and-bust pattern of reproductive performance that is closely linked to the cyclical dynamics of the populations of lemmings (Lemmus spp. and Dicrostonyx spp.) and their predators (Summers & Underhill 1987), a relationship that also applies to other species in several parts of the Arctic (Béty et al. 2002,
Madsen et al. 2007b, Morrissette et al. 2010). In lemming peak years, the densities of predators such as Arctic fox Vulpes lagopus build up; in the following year, after the collapse of lemming populations, when numbers of foxes are still high, they switch to alternate prey such as shorebird and waterfowl eggs and chicks (Roselaar 1979, Summers & Underhill 1987, Bêty et al. 2002, Lecomte et al. 2008). Under changed climatic regimes, lemming cycles tend to be less pronounced in some areas (Ims et al. 2008, Kausrud et al. 2008, Gilg et al. 2009a, Reid et al., Chapter 3, Ims & Ehrich, Chapter 12), which is expected to have implications for the entire Arctic food web. Ebbinge (2009) already reported a lack of regularity in lemming peaks in central N Siberia in recent years affecting the breeding success of brant geese: while breeding success had in previous decades shown regular peaks of up to 30% juveniles in the wintering population in every third year, following lemming peaks in the preceding summer, this pattern has been more irregular since the early 1990s.

Another recent example of changes in predator-prey relations is the apparently increasing predation on breeding geese by polar bears Ursus maritimus on the Hudson Bay coast and in other areas. As receding sea ice is causing bears to spend more time ashore during the summer months, increased predation of goose eggs and adults by polar bears has been reported from various places in the Arctic in recent years (Stempniewicz 2006, Drent & Prop 2008, Smith et al. 2010, Rockwell et al. 2011). By contrast, breeding brant geese on Svalbard suffer heavily from predation by polar bears in years when sea ice makes their breeding islands easily accessible for these predators (Madsen et al. 1998), and they may thus benefit from reduction in spring sea ice cover.

Lecomte et al. (2009) recently showed that water availability and rainfall could affect the interaction between geese and another important predator, the Arctic fox. They found that egg predation was reduced in years of high rainfall because fox predation occurs mostly when incubating females leave their nest to drink or feed and the probability of a successful attack increases with distance of the female from her nest. High rainfall increases water availability near the nest, which reduces the distance traveled by females to drink and increases her ability to defend her nest from a predator attack. Because climate change should affect precipitation regimes in the Arctic (IPCC 2007), this may impact nesting success of geese by changing water availability for incubating females.

4.3.4. Conclusions

Waterfowl are one of the dominant species groups in the breeding bird communities of Arctic wetlands, and the geese (Anser spp., Chen spp. and Branta spp.) and the seaducks (Somateria spp., Melanitta spp., Polysticta and Clangula) are largely Arctic specialists. Because of their migratory nature and their exploitation by humans on the one hand and utilization of anthropogenic food resources in temperate regions on the other hand, population sizes and trends of many Arctic waterfowl species are largely influenced by events outside the Arctic. However, climate change may have major impacts, both positive and negative, on breeding opportunities for waterfowl in the Arctic in the future. New areas of the Arctic may become suitable for breeding and wintering, while at the same time interactions with competitors and predators may change to the worse. Also, Arctic developments (both on- and offshore) are expected to have impacts, with an increase in Arctic shipping particularly affecting the seaducks.

4.4. SHOREBIRDS: OYSTERCATCHERS, PLOVERS, SANDPIPERS AND SNIPES

Although they typically spend only several weeks each year on the Arctic breeding grounds, shorebirds are one of the most prominent groups of the circumpolar Arctic bird species assemblage. Many of them breed exclusively in the Arctic, and several species are specialized breeders of the high Arctic. Practically all Arctic shorebirds are long-distance migrants, linking the Arctic breeding grounds to all other continents including the southern tips of Africa, South America and Australia and even islands near the Antarctic Peninsula. Not only the Arctic as a whole, but also geographically restricted areas within the Arctic can be connected to various continents through migrating shorebirds (Fig. 4.4). The combination of breeding in harsh conditions in remote high Arctic areas and record performances on migration (Gill et al. 2009) contributes to the charisma of this species group.

4.4.1. Species richness and distribution

4.4.1.1. Status

A total of 59 shorebird species breed in the Arctic, 18 of which have their main distribution south of the Arctic, while 41 breed in the Arctic only. Twenty-nine have breeding ranges extending into the high Arctic. None is confined to the high Arctic only, but three (red knot, sanderling C. alba and curlew sandpiper C. ferruginea) occur mainly there.

The majority of Arctic shorebirds are representatives of the two families, Charadriidae (plovers) and Scolopacidae (sandpipers and snipes); in addition, one member of the cosmopolitan oystercatchers (Haematopodidae) reaches the Arctic in a few places. While the plovers are a large family with only a few Arctic species, the Scolopacidae, and especially the calidrine sandpipers, have their center of diversity in the Arctic. Of 93 species of Scolopacidae, 50 occur in the Arctic and 34 breed in the Arctic only, including 18 of 19 sandpiper species of the genus Calidris (see Fig. 1.2 in Meltofte et al., Chapter 1) and two of three species of phalaropes Phalaropus.
Shorebird genera that are endemic to the Arctic and sub-Arctic (at least during the breeding season) are *Arenaria* (turnstones, two species) and the monotypic genera *Aphriza* (surfbird), *Eurynorhynchus* (spoon-billed sandpiper) and *Tryngites* (buff-breasted sandpiper). The monotypic genera *Limicola* (broad-billed sandpiper) and *Philomachus* (ruff) have a mainly sub-Arctic and boreal breeding distribution and penetrate into the Arctic in various places.

As in waterfowl, overall diversity is highest in the low Arctic zones on either side of the Bering Strait, with 38 species of shorebirds breeding in the low Arctic of the Russian Far East and 30 species in low Arctic Alaska. The remaining low Arctic zones have between four (Greenland) and 24 different breeding shorebird species. In the high Arctic zones, between seven (Svalbard) and 20 (Russian Far East) species breed. Hence, the Russian Far East has by far the highest diversity of shorebirds in the Arctic.

Some species have small or very small breeding ranges: bristle-thighed curlew *Numenius tahitiensis*, black turnstone *Arenaria melanocaphala* and surfbird *Aphriza virgata* are confined to Alaska, great knot *Calidris tenuirostris* and the endangered spoon-billed sandpiper to the Russian Far East, western *Calidris mauri* and rock sandpipers *C. ptilocnemis* (the latter highly substructured with at least four recognised subspecies; Gill et al. 2002) to both sides of the Bering Strait. Sharp-tailed sandpipers *Calidris acuminata* and red-necked stint *C. ruficollis* breed in central and E Siberia only. By contrast, grey plover *Pluvialis squatarola*, common ringed plover *Charadrius hiaticula*, ruddy turnstone and dunlin *Calidris alpina* together with red-necked *Phalaropus lobatus* and red phalarope *P. fulicarius* occur throughout the Arctic in nearly all of the zones. Pacific *Pluvialis fulva* and American golden plover *P. dominica* were only recognized as separate species in the 1980s, and the Nearctic Wilson’s snipe *Gallinago delicata* has recently been split from the Palearctic common snipe *G. gallinago*.

Molecular studies of subspecific diversity in a number of species with circumpolar distributions have yielded contrasting results: the genetic structure of the sub- and low Arctic dunlin shows very old splits between populations probably resulting from isolated refugia during late Pleistocene glaciations (Wenink et al. 1993), while population structuring in the high Arctic red knot appears to be much more recent, suggesting recolonisation of the entire Arctic after a severe population bottleneck during the last glaciation, possibly followed by survival of small populations in tundra refugia during the most recent thermal optimum when high Arctic tundra was reduced to a minimum (Buehler & Baker 2005). The widely distributed ruddy turnstone shows no genetic substructuring, again indicative of a relatively recent severe population bottleneck (Wenink et al. 1994). A recent molecular study of Temminck’s stint *Calidris temminckii* showed low genetic diversity as well as signs of recent population expansion, and the existence of two lineages in the mitochondrial DNA suggested recolonisation of the present range from two glacial refugia (Rönkä et al. 2011).

4.4.1.2. Trends

Recent range expansions have been reported for several Arctic species in Russia. The semipalmated plover *Charadrius semipalmatus* has recently expanded across the Bering Strait into the Russian Far East; semi-palmated...
4.4.2. Population sizes and densities

4.4.2.1. Status

Order of magnitude population sizes for Arctic-breeding shorebirds are given in Appendix 4. Of the 41 shorebird species that are confined to the Arctic during the breeding season, most have populations numbering in the hundreds of thousands (20 species) or millions (12 species). Six species have population sizes of tens of thousands of birds, among them the buff-breasted sandpiper, which is listed as near threatened by the IUCN because it has failed to recover from a hunting-induced population low in the 1920s. The bristle-thighed curlew numbers less than 10,000 birds; this species is listed as vulnerable because its population is now small and believed to be declining, largely as a result of predation on the wintering grounds, when perhaps more than 50% of adults are flightless during autumn molt (IUCN 2012). The spoon-billed sandpiper is critically endangered with the remaining population now probably under 1,000 individuals and continuing to decline (Syroechkovskiy 2005, Zöckler et al. 2010a). The eskimo curlew, although still listed as critically endangered by the IUCN, is most probably extinct (Gill et al. 1998). Recently, the great knot and the semipalmated sandpiper were uplisted to the categories vulnerable and near threatened, respectively, because of marked population declines (see 4.4.2.2).

Although population sizes and range sizes often correspond, there are also species with small ranges despite large population sizes. For instance, western sandpipers number about 3.5 million birds (Wetlands International 2012) despite a rather restricted breeding distribution around the Bering Strait within which they can reach very high nesting densities (Wilson 1994).

4.4.2.2. Trends

Population estimates of shorebirds are usually derived from counts on migration sites or wintering grounds at great distances from the Arctic breeding areas (Wetlands International 2012). Because shorebirds are mostly small-bodied and often have widespread wintering areas, precise counts of entire populations are hard to achieve and trends are accordingly difficult to determine with certainty. Additionally, climate change has been shown to cause distribution shifts of wintering shorebirds (MacLean et al. 2008), so that long-term population counts in the same wintering areas may suggest numerical trends that are in fact geographical shifts to different areas.

Thus, most trend estimates have to be treated with some caution.

Of 28 Nearctic-breeding shorebird populations for which Morrison et al. (2006) compiled population estimates, 16 were thought to be stable or had unknown trends, 10 were thought to be possibly decreasing, and for two (semipalmated sandpipers and the red knot subspecies Calidris canutus rufa, see Box 4.2) there was good evidence for a decline. For shorebirds breeding in the W Palearctic there are recent trend estimates from the Russian breeding grounds (Lappo et al. 2012) and from the W European Wadden Sea, a major migratory stopover site (Laursen et al. 2010). Nearly all populations in this part of the Arctic appear to be stable or increasing. In the Wadden Sea, a clear decrease was noted only for the ruff, a mainly boreal and sub-Arctic breeder, and this may be the result of a range shift (see 4.4.1.2).

Trend estimates for E Palearctic shorebirds are available from winter counts in Australia where large proportions of many populations winter and rather precise counts are possible. According to Garnett et al. (2011), eight Arctic-breeding shorebird species wintering in...
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Box 4.2. Red knots: connecting continents

The red knot Calidris canutus, a typical representative of high Arctic shorebirds, is an exemplar of a long-distance migrant shorebird; it has been the subject of extensive research worldwide including the breeding cycle, winter ecology and stopover sites. It is one of nature’s most prodigious travelers, and excites the interest of wildlife enthusiasts, scientists and conservationists around the world. For this reason, its migration system is among the best known of all shorebirds; even so many mysteries remain.

Red knots have a disjointed Arctic breeding distribution ranging from just south of the Arctic Circle at 63° N (C.c. rufa and C.c. rogersi) to 83° N, nearly the most northerly land in the world (C.c. islandica). They nest in areas of sparse vegetation, often close to a damp area where the chicks can feed. They arrive on the breeding grounds in late May to early June, and the eggs hatch from around 1 July whereupon the females depart from the nesting area leaving the chicks in the care of the males. The males leave in late July or early August and the young during the following month.

Breeding success can be very variable depending mostly on weather conditions and the abundance of predators. If there is a late snowmelt, or if the weather is cold leading to a reduction in invertebrate food for the young, and/or if there is an abundance of egg or chick predators such as Arctic foxes and jaegers, breeding success can be almost negligible. But in years when such factors have least impact, as many as half the birds seen on the non-breeding grounds may be juveniles. Year-to-year variation in breeding success arises from random changes in Arctic weather and the often cyclic abundance of predators.

Together, the six red knot subspecies have a circumpolar Arctic breeding distribution though each breeds in a discrete area and mainly winters separately. Non-breeding sites range as far south as New Zealand, South Africa and Tierra del Fuego (Box 4.2 Fig. 1). Of the six subspecies, by far the largest populations are those of C.c. canutus and C.c. islandica. C.c. canutus winters mainly in W Africa and has its breeding grounds entirely on the Taimyr Peninsula of N Siberia. C.c. islandica winters in NW Europe and breeds in high Arctic Greenland and NE Canada. Large numbers of both populations, however, are highly dependent on one very large site, the Wadden Sea. In the part of the Wadden Sea belonging to the Netherlands, mechanical shellfish harvesting has so severely depleted the food supply that regional numbers of red knots have declined and negative effects on the two populations as a whole were thought possible (van Gils et al. 2006). However, recent analyses of long-term count data from the entire Wadden Sea show stable numbers of red knots over the past 20 years (Laursen et al. 2010). Mechanical shellfish harvesting was stopped in 2006, but it is too early to know whether it has had a beneficial effect on the regional population (van Gils et al. 2006).

Box 4.2 Figure 1. Worldwide distribution of the six recognized subspecies of the red knot Calidris canutus. All breeding areas (dark purple shading) are on high Arctic tundra where the adults spend June-July. After their long-distance migrations they spend the non-breeding season (August-May) mainly in intertidal, soft-sediment habitats (red dots, which are scaled according to mid-winter population size). (Modified from CAFF 2010).
Box 4.2. continued

The two red knot subspecies of the E Asian-Australasian Flyway, *C. r. rogersi* and *C. r. piersmai*, are both thought to be declining with several sites recording lower non-breeding numbers in recent years (Garnett et al. 2011). Their relative status is not clear because although most *C. r. piersmai* are found in NW Australia and most *C. r. rogersi* are found in E Australia and New Zealand, there appears to be considerable overlap. The migration route of both subspecies takes them through the coastal regions of E Asia, especially along the shores of the Yellow Sea. These regions are currently undergoing extensive development with whole estuaries being reclaimed for human use. Quite likely it is loss of habitat in this region that is having a detrimental impact on both populations, but this has yet to be proved (Rogers et al. 2010).

The populations of both Western Hemisphere subspecies, *C. r. rufa* and *C. c. rosetaari*, appear to be vulnerable. The status of *C. c. rosetaari*, which breeds in Alaska and on Wrangel Island and winters along the American Pacific coast, is unclear. The population of *C. r. rufa* was thought to be as high as 170,000 as recently as 2001 (Brown et al. 2001), but is now down to 30,000 (Niles et al. 2008). Undoubtedly, the most significant factor has been the depletion of the food supply at the final northbound stopover in Delaware Bay on the eastern seaboard of USA. There, knots and other shorebirds time their migration to coincide with the mass spawning of horseshoe crabs *Limulus polyphemus*, and in the past they made rapid mass gains to fuel their onward migration by feeding on crab eggs. Since the mid-1990s, the horseshoe crab population has been overharvested for use as bait, and the supply of eggs has been greatly reduced (Niles et al. 2008). Studies have shown that red knots which fail to gain sufficient mass in Delaware Bay have lower survival (Baker et al. 2004).

With a total world population of a little over one million, the red knot is not at present threatened as a species, but there are good reasons to be concerned for its future. Like most long-distance migratory shorebirds, red knots are highly dependent on a limited number of key stopover and wintering sites, making them particularly vulnerable to habitat change. Among the most vital sites are the last major stopovers before the final flight to their Arctic breeding grounds. These are of key importance because in those places the birds require sufficient food resources not only to sustain their long flight but also to ensure their survival during the first time on the breeding grounds when Arctic food resources can be scarce (Mellofot et al. 2007a). Other sites may be of equal importance when they form part of a chain of 'stepping stones' in which each link is indispensable.

Australia have suffered severe declines over the last c. 25 years, and their conservation status has accordingly been changed to a less favorable category since 2000. Declines have been especially severe for grey plover, bar-tailed godwit, great knot and red knot. From the Russian breeding grounds, trend information is reported as unclear (13 spp.), presumably stable (9 spp.) or slightly increasing (9 spp., mostly as a result of range expansions, see 4.4.1.2), whereas eurasian dotterel and red knot are thought to be declining (Lappo et al. 2012). The most severe decline, however, has been experienced by the far eastern spoon-billed sandpiper, and this species is now facing imminent extinction (Zöckler et al. 2010a, Lappo et al. 2012).

**4.4.2.3. Causes and prospects**

For the highly migratory shorebirds, the known causes of changes in population size are found mainly outside the breeding grounds. The vast majority of Arctic-breeding shorebirds winter in littoral areas, many of them in the Southern Hemisphere, and during migration depend on coastal sites for stop-over and refueling, making use of the rich invertebrate food resources of intertidal mudflats. Many coastal areas within both staging and wintering ranges are subject to high human population pressure, and large-scale habitat alterations have taken place in recent decades such as in the Yellow Sea, which supports an estimated two million shorebirds on migration, whereas about 600 million people live in the area (Barter 2006, Kelin & Qiang 2006, MacKinnon et al. 2012). Vast intertidal areas have been reclaimed and lost to shorebirds, and in the remaining areas shorebirds are competing with fisheries and other forms of development (see Box 4.2). There is good evidence that the loss of staging habitat and/or food resources and thereby loss of refueling opportunities for migrating birds has led to severe population declines at least in one subspecies of red knot in the Nearctic (see Box 4.2) and in the E Palearctic great knot (Moores et al. 2008, Garnett et al. 2011, MacKinnon et al. 2012, Wetlands International 2012).

In addition, intertidal shorebird staging and wintering habitats are threatened by sea level rise resulting from climate change (Rehfisch & Crick 2003, Galbraith et al. 2005). Intertidal areas may become subtidal with rising sea levels, or be overgrown with mangroves, as has been reported from estuaries in SE Asia and Australia (Straw & Saintilan 2006).

Comparing with staging and wintering grounds, the Arctic breeding grounds are still relatively undisturbed. Here, climate warming is expected to have a major effect on the distribution of habitats. With the northward movement of vegetation zones it is expected that high Arctic species such as red knot, sanderling or curlew sandpiper will eventually run out of suitable breeding habitat, while the already observed trend of sub-Arctic/boreal species expanding their ranges northwards is likely to continue. Shorebirds breeding in the high Arctic benefit from a reduced predation pressure on their nests compared with
those breeding at lower latitudes (McKinnon et al. 2010). However, as climate warms and some predators expand their range northward, this may negatively impact the productivity of high Arctic-nesting shorebirds.

Some species benefit from human development. For example, common ringed plovers start breeding near man-made structures in previously undisturbed tundra almost immediately upon arrival (Pashkalny 2004, Lappo et al. 2012) and appear to have increased in many places in the Russian Arctic. Development may favor populations of some predators of ground-nesting birds, however, resulting in potential negative impacts on breeding shorebirds (Liebezeit et al. 2009).

The Eskimo curlew was brought to (near or complete) extinction by market hunting in the late 19th and early 20th centuries in combination with habitat loss outside the breeding area, and hunting continues to be an issue especially for the larger shorebird species. Subsistence harvest of large-bodied shorebirds in Alaska may be substantial (Alaska Shorebird Group 2008), and Arctic shorebirds are hunted for food and sport in staging and wintering areas in the Carribean, South America, Africa and Asia. For the semipalmated sandpiper, there are indications that hunting in South America negatively affects population size (Hicklin & Gratto-Trevor 2010). In the Russian Arctic, hunting during migration may be at least partially responsible for the decline in numbers of the great snipe Gallinago media on their European and W Siberian breeding grounds. For the spoon-billed sandpiper, hunting on the wintering grounds in Myanmar, although mainly directed at larger-bodied shorebird species, is probably the main cause for the recent precipitous population decline (Zöckler et al. 2010b). However, reliable data on the overall impact of hunting on Arctic shorebird populations are currently not available, and much more information is needed to properly evaluate the situation.

4.4.3. Other issues

4.4.3.1. Predator-prey interactions

Predation risk appears to play a central role in the reproductive ecology of Arctic-nesting shorebirds at several spatial scales (McKinnon 2011). The breeding success of many Arctic shorebirds is closely linked with the cyclical dynamics of lemming populations because predators like foxes will switch to other prey when lemmings crash (see Section 4.3.3.2). However, because shorebird eggs and chicks may be more an incidental prey than a genuine alternative prey, predation risk for shorebirds may result from a complex interaction between lemming abundance and more profitable alternative prey such as goose eggs (McKinnon 2011). With climate change, lemming cycles have been reported to have been reduced and more irregular in Arctic and alpine ecosystems in Greenland and Europe (Ims et al. 2008, Kausrud et al. 2008, Gilg et al. 2009a, Reid et al., Chapter 3, Ims & Ehrich, Chapter 12) and the same may occur elsewhere, with the potential of markedly altering the dynamics between predators, shorebirds and other prey species.

Interspecific interactions between shorebirds and terns have been reported from Greenland, where the disappearance of Arctic tern colonies from a number of islands was followed by a steep decline in the number of breeding red phalaropes Phalaropus fulicarius, suggesting that red phalaropes benefit from tern colonies as a defense against predators (Egevang et al. 2006). Similarly, semipalmated plovers in the Canadian Arctic had higher nest survival when breeding in the vicinity of Arctic terns (Nguyen et al. 2006).

4.4.3.2. Changes in phenology of shorebirds and their prey

Arctic-breeding shorebirds feed mostly on terrestrial invertebrates during the breeding season, and they depend on the short seasonal outbreak of insect abundance from the time of their arrival and egg-laying through the period of rapid chick growth (Meltofte et al. 2007a, 2007c). However, late arrival of birds in spring or early emergence of insects may result in a mis-match between hatching and insect abundance. During years of mis-match, growth of chicks is reduced (McKinnon et al. 2011). Tulp & Schekkerman (2008) showed that in Taimyr in central N Siberia the peak of insect abundance now occurs earlier than 30 years ago. If this trend continues, birds will have to adjust their breeding and migration schedules to avoid a mis-match between timing of breeding and seasonal food availability or face higher rates of reproductive failure.

4.4.4. Conclusions

The Arctic supports a large portion of shorebird diversity, especially in the family Scolopacidae. Shorebirds spend only a short period of the year on their Arctic breeding grounds, and anthropogenic stressors such as habitat loss or hunting currently are far greater during southward migration and wintering than on the breeding grounds.

Global climate change is expected to affect shorebirds at various stages of their annual cycle (Boyd & Manssen 1997, Lindström & Agrell 1999). On the breeding grounds, a northward shift of vegetation zones may negatively affect high Arctic breeders and favor boreal species; northward range shifts of boreal shorebirds have already been reported. In addition, northward expansion of the range of some predators may negatively affect shorebird productivity. During migration and in winter, sea level rise may reduce the amount of intertidal feeding habitat, which is already being restricted even further through human activities.

Because of the strongly migratory nature of shorebirds, all conservation efforts will have to take place in an international framework covering entire flyways from Arctic breeding grounds to – often Southern Hemisphere – wintering areas.
4.5. SEABIRDS: LOONS, PETRELS, CORMORANTS, JAEGERS/SKUAS, GULLS, TERNs AND AUks

Unlike most animals, seabirds are more abundant and as diverse in cold seas as they are in warm ones (Gaston 2004). This is principally because diving birds (auks, penguins, diving petrels and marine cormorants) are practically absent from the tropics. In both hemispheres, diving seabirds reach their maximum diversity in subpolar latitudes (Fig. 4.5), and the species richness of non-diving seabirds is little affected by latitude. In the Northern Hemisphere the highest breeding densities of seabirds occur in Arctic waters (Cairns et al. 2008). The Arctic supports several endemic seabird genera as well as a number of endemic, or near-endemic species. Because of this concentration of numbers and endemic taxa, seabirds have a disproportionate influence on Arctic marine ecosystems and on Arctic biodiversity compared with lower latitudes (see also Michel, Chapter 14).

Substantial research has been devoted to studying seabirds as indicators of marine environmental change or of fisheries (Mallory et al. 2006, Einoder 2009). Their sensitivity to changes in the availability of major prey species has been demonstrated frequently (Cairns 1992, Monaghan 1992, Monteverchi & Myers 1995, 1997, Davoren & Montevercchi 2003, Wanless et al. 2005). Because of the large literature relating seabird biology to changes in marine environments, we have focused specifically on links between changes in Arctic populations and diversity and changes in Arctic marine environments.

Examination of many seabird populations worldwide has demonstrated that populations are seldom stable, so that monotonic trends on a scale of decades can be considered normal and may not signal any recent change in environmental conditions. Instead, such trends may relate to residual effects from changes on a scale of centuries, such as ecosystem adjustments following overfishing of whales and other marine resources (Conroy 1975, Croxall & Prince 1979, Fraser et al. 1992) or reduction (Montevecchi & Tuck 1987) or intensification (Kampp et al. 1994) of harvest. These background trends have not been clearly identified for Arctic seabirds, but are likely to have occurred following the destruction of large whale populations in the Arctic during the 18th–19th centuries (Bockstoece 1986), as well as overfishing of certain commercial fish stocks, such as that of the Barents Sea capelin Mallotus villosus (Barrett & Krasnov 1996, Barrett 2007; see also Fig 1.3 in Meltofte et al., Chapter 1, Christiansen & Reist, Chapter 6 and Michel, Chapter 14).

In the Bering Sea, declines in seal and sea lion populations over the past 40 years have been attributed to redirected predation by orcas Orcinus Orca following the near-elimination of large whale stocks in the 19th century (Springer et al. 2003). Reverberations from these adjustments may also have extended to marine birds through the redirection of predation by bald eagles Haliaeetus leucocephalus from sea otters Enhydra lutris to seabirds (Anthony et al. 2008). Such wide-ranging ecosystem adjustments complicate the identification of causal mechanisms relating to population trends (Croxall et al. 2002).

4.5.1. Species richness and distribution

4.5.1.1. Status

Forty-four species of marine birds breed within the Arctic, including 23 in the high Arctic and 41 in the low Arctic. The majority are members of the order Charadriiformes (34 species, including four endemic genera, all monotypic (little auk, ivory gull, Sabine’s gull, Ross’s gull). Fifteen species are circumpolar in their distribution, occurring in Canada, Alaska and over most of the Russian Arctic. Among non-circumpolar species, nine occur only in the Atlantic Basin (E Canada-Svalbard) and 12 in the Pacific Basin (E Siberia-Canada). The diversity of high Arctic specialists is similar in Atlantic and Pacific basins (5 species in each). 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 petrel, northern fulmar Fulmarus glacialis.

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 60° N) and 26 species on the Asian side. Other biodiversity hotspots occur in W Greenland (24 species), the E Canadian Arctic (Nunavut, N Quebec and Labrador, 22 species), and Iceland (22 species excluding the sub-Arctic/boreal species found only on the south coast).

Figure 4.5. Numbers of seabird species in the Northern Hemisphere in relation to latitude, by 10° N zones, beginning at the Equator. Only Atlantic and Pacific species are included (compiled from maps in Harrison 1996).
Diversity at the sub-species level is relatively low, and most often comprises divergence between Pacific and Atlantic populations (common *Uria aalge* and thick-billed *U. lomvia* murreles, black-legged kittiwakes *Rissa tridactyla*, northern fulmars) with only a few species having more than one Arctic race within an ocean basin. However, many species have different races in temperate latitudes, with morphological characteristics often intergrading clinaly with the Arctic race (lesser black-backed gull *Larus fuscus*, common murre [Atlantic and Pacific], black guillemot *Cepphus grylle*, Atlantic puffin *Fratercula arctica*).

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 (black-throated/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 N Asia and on the W coast of North America. Much of their diversity was regarded as intra-specific until recently (cf. Vaurie 1965, Liebers et al. 2004, de Knijff et al. 2005).

### 4.5.1.2. Endemicity

There are two near-endemic families: Alcidae (auks; 23 species, of which eight are endemic to Arctic and sub-Arctic waters and the remainder are found exclusively in temperate and sub-Arctic waters of the Northern Hemisphere; Gaston & Jones 1998) and Gaviidae (loons; five species, three of which are endemic to the sub-Arctic and Arctic and the other two occur in both Boreal and Arctic regions). Within the Laridae (gulls and terns), in addition to the three endemic genera mentioned above (*Pagophila*, *Rhodostethia*, *Xema*), two species of tern are endemic or near endemic to the Arctic and sub-Arctic (Arctic tern, Aleutian tern *Onychoprion aleuticus*) and within the cosmopolitan genus *Larus* there are four Arctic endemic species: Vega *Larus vegae*, Thayer’s *L. thayeri*, Iceland *L. glaucoides* and glaucous gulls *L. hyperboreus* (*thayeri* and *glaucoides* are sometimes regarded as conspecific; Snell 2002).

Iceland supports an endemic race of the black guillemot *Cepphus grylle islandica*, and this species, along with the razorbill *Alca torda* and common murre, also has separate races on either side of the Atlantic (Gaston & Jones 1998). Franz Joseph Land and Severnaya Zemlya support a distinct race of little auk *Alle alle polaris* which, at least in Franz Joseph Land, differs in some details of its breeding biology from the nominate race found elsewhere (Stempniewicz et al. 1996).

### 4.5.1.3. Trends

The distributions of many species of Arctic marine birds were poorly known until the latter half of the 20th 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 with which to assess trends in biodiversity among Arctic seabirds. No strictly Arctic species has become extinct during historic times, although two sub-Arctic species, spectacled cormorant *Phalacrocorax perspicillatus* (Commander Islands) and great auk *Pinguinus impennis* (Newfoundland, Greenland and Iceland) were hunted to extinction in the 19th century (Fuller 2000). Two species are listed by IUCN/Birdlife International as near-threatened, threatened or endangered at a world scale, yellow-billed loon *Gavia adamsii* and ivory gull (*IUCN 2012*). The sub-Arctic red-legged kittiwake *Rissa brevirostris* is considered vulnerable.

There is some evidence for the recent northward spread of predominantly temperate or low Arctic species: ancient murrelet *Synthliboramphus antiquus* (Gaston & Shoji 2010) and glaucous-winged gull *Larus glaucescens* (Winker et al. 2002) in the Bering Sea, horned puffin *Fratercula corniculata* in the Beaufort Sea (Moline et al. 2008), common gull *Larus canus* in Iceland (Petersen & Thorstensen 2004), great skua *Stercorarius skua* in Svalbard (Anker-Nilssen et al. 2000, Krasnov & Lorentsen 2000), black-headed gull in southernmost Greenland (Salomonsen 1979, Boertmann 1994, 2004), and Labrador (Chaulk et al. 2004), great black-backed gull *Larus marinus* in Greenland (Boertmann 1994), razorbill in Hudson Bay (Gaston & Woo 2008) and lesser black-backed gull in Greenland, the latter now breeding as far as 74° N (Boertmann 2008, Jensen & Raw 2009). 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 N Nunavut, and most colonies on N Baffin Island and E Devon Island deserted, while numbers have remained stable farther north on central Ellesmere Island (Environment Canada 2010). Southern colonies are also decreasing in Greenland (Gig et al. 2009b).

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 Alaska, as well being distributed in low and sub-Arctic of the North Pacific, may be declining in its core breeding range in central S Alaska and perhaps elsewhere (Kuletz et al. 2003, Stenhouse et al. 2008).

### 4.5.1.4. Causes and prospects

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 sand lance *Ammodytes spp.*, perhaps related to diminishing ice cover (Gaston & Woo 2008). A change in diet has been observed for little auks in Svalbard where the large copepod *Calanus hyperboreus* is replaced in warmer conditions by the smaller *C. finmarchicus* with potentially negative consequences for chick-rearing (Karnovsky et al. 2010). Reduced ice cover 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.

4.5.2. Population sizes and densities

4.5.2.1. Status and trends

The population sizes of Arctic-breeding seabirds are given in Appendix 4. Most species have populations numbering in the hundreds of thousands, and only seven are believed to number less than 100,000 breeding individuals: yellow-billed loon, great skua, Thayer’s gull, ivory gull, Ross’s gull, Aleutian tern and Kittlitz’s murrelet (Birdlife International 2009, Wetlands International 2012). Among high Arctic specialists, the ivory gull appears to have decreased precipitously in Canada (by 80% since the 1980s), has decreased in southern Greenland and shows range contraction in the N Barents Sea, although individual colonies in Russia fluctuate widely, making trends there hard to discern. In all cases, the southern parts of the range seem to be more affected than northern parts (Gilchrist & Mallory 2005a, 2005b, Gilg et al. 2009b, Environment Canada 2010).

Of the other two exclusively high Arctic species, population size is poorly known for Thayer’s gull, which breeds only in E and central parts of the Canadian high Arctic, although the population appears to be stable (Gaston et al. 2012). The little auk, although well-distributed in small pockets around the Arctic Ocean, is numerically concentrated into three major colony assemblages around Thule in NW Greenland with about 70 million individuals (Egevang et al. 2003), Scoresby Sund in E Greenland with 3.5 million individuals (Kampp et al. 1987) and Svalbard with > 1 million (Isaksen & Gávrilo 2000). Censusing such aggregations is almost impossible, and no information is available on trends. Some small colonies of this species farther S in Greenland and in Iceland have disappeared since the 1930s (Nettlehouse & Evans 1985).

Black-legged kittiwake, an abundant species throughout circumpolar Arctic and Boreal waters, has shown significant population declines almost throughout the Atlantic sector of the Arctic, especially around the Barents Sea (Barrett et al. 2006), in Iceland (Gardarsson 2006) and in W Greenland (Labans et al. 2010), as well as farther south, in Britain (Frederiksen et al. 2004b).

Thick-billed murre and, to a lesser extent, common murre populations have shown downward trends over much of their range in the past thirty years (see Box 4.3). The population of thick-billed murres in central W Greenland is much depressed compared with numbers in the early 20th century, as a result of heavy harvesting of adults at colonies (Evans & Kampp 1991, Kampp et al. 1994) and perhaps, drownings in gill-net fisheries (Tull et al. 1972; but see also Falk & Durinck 1991, Kampp 1991 and Kampp et al. 1994). Furthermore, it shows no sign of recovery, with the population south of Thule District remaining at < 20% of historical levels, and at least 18 out of 31 small and large colonies having been exterminated (Kampp et al. 1994 and unpubl., F. Merkel unpubl.; see also Box 18.5 in Huntington, Chapter 18). Numbers in E Greenland, although small, have also declined.

Similarly, numbers in Novaya Zemlya are considerably lower than in the early 20th century when the population numbered two million birds. Currently, there are thought to be about one million breeders (Bakken & Pokrovskaya 2000). In Svalbard, 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, black-legged kittiwake and razorbill also decreased, although some small colonies increased (Gardarsson et al. 2009).

4.5.2.2. Causes and prospects

With the exception of overharvest dealt with in Section 4.5.2.1, 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: mortality from hunting of adults in Upernavik District, Greenland (Stenhouse et al. 2004), high levels of mercury in eggs (Braune et al. 2006) and changes in ice conditions associated with global warming (Gilchrist et al. 2008, Environment Canada 2010). All may have contributed to the recent population decline, although shooting of ivory gulls in Greenland is thought to have declined since the 1980s when most band recoveries occurred (Gaston et al. 2008, Gilchrist et al. 2008). 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 S Barents Sea in 1985-87 when numbers of birds attending colonies fell by 80% in response to starvation following the collapse of the Barents Sea capelin stock (Anker-Nilsen et al. 1997). The population subsequently recovered to near its former level (Krasnov et al. 2007; see Fig. 1.3 in Meltofte et al., Chapter 1). Similarly, an 80% decrease in lesser black-backed gulls in N 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 (Durant et al. 2004, 2006, Harris et al. 2005, Sandvik et al. 2005, Irons et al. 2008). However, there are a few cases where direct effects have been documented. White et al. (2011) have shown that expansion of the great cormorant population in central W Greenland may be related to increased sea surface
Chapter 4 • Birds

The two species of murres, thick-billed *Uria lomvia* and common *U. aalge*, both have circumpolar distributions, breeding in Arctic, sub-Arctic and temperate seas from California and N Spain to N Greenland, high Arctic Canada, Svalbard, Franz Josef Land and Novaya Zemlya (Box 4.3 Fig. 1). The more northern thick-billed murre occurs mostly in Arctic waters, where it constitutes a higher proportion of biomass than any other species of seabird. It occurs commonly in the vicinity of sea ice throughout the year, making its distribution strongly dependent on sea ice occurrence. Common murres, although overlapping extensively with thick-billed murres in the Pacific, are more characteristic of sub-Arctic and temperate waters. Murres are among the most abundant seabirds in the Northern Hemisphere with both species exceeding 10 million adults (Gaston & Jones 1998).

Murres feed from coastal to pelagic waters, with common murres concentrating over the continental shelf and slope, while in winter thick-billed murres are spread more or less throughout Arctic and sub-Arctic waters (Gaston & Hipfner 2000). While breeding, both species are tied to feeding within ~150 km of their breeding colonies. They take a wide range of small fish (< 50 g) and invertebrates, especially crustaceans and squid. Adults of both species dive regularly to depths greater than 100 m, reaching a maximum depth of approximately 150 m. Their diving capacity, allied to their typical foraging radius of up to 150 km, means that murres sample a relatively large volume of the marine environment around their colonies (Falk et al. 2000, Elliott et al. 2008).

(continues ->)

Box 4.3. Murres as indicators of a changing Arctic

The two species of murres, thick-billed *Uria lomvia* and common *U. aalge*, both have circumpolar distributions, breeding in Arctic, sub-Arctic and temperate seas from California and N Spain to N Greenland, high Arctic Canada, Svalbard, Franz Josef Land and Novaya Zemlya (Box 4.3 Fig. 1). The more northern thick-billed murre occurs mostly in Arctic waters, where it constitutes a higher proportion of biomass than any other species of seabird. It occurs commonly in the vicinity of sea ice throughout the year, making its distribution strongly dependent on sea ice occurrence. Common murres, although overlapping extensively with thick-billed murres in the Pacific, are more characteristic of sub-Arctic and temperate waters. Murres are among the most abundant seabirds in the Northern Hemisphere with both species exceeding 10 million adults (Gaston & Jones 1998).

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(continues ->)
Several decades are leading to changes in phenology and reproduction and to changes in the extent and timing of sea-ice cover over the past three decades, with trends in the North Pacific and NW Atlantic generally positive or stable when trends in the European Arctic were negative and vice versa (Box 4.3 Fig. 2). The sensitivity of murre populations to changes in environmental conditions has been demonstrated on a hemispheric scale in recent studies by the Seabird Working Group of CAFF (Irons et al. 2008). Trends in different regions switched direction with regime shifts. Generally, thick-billed murre populations have declined in all regions except the E Canadian Arctic since the 1970s, whereas no unidirectional global trends can be identified for common murres.

Apart from hunting induced decreases in Greenland and Novaya Zemlya, both species have shown regional population changes over the past three decades, with trends in the North Pacific and NW Atlanticgenerally positive or stable when trends in the European Arctic were negative and vice versa (Box 4.3 Fig. 2). The sensitivity of murre populations to changes in environmental conditions has been demonstrated on a hemispheric scale in recent studies by the Seabird Working Group of CAFF (Irons et al. 2008). Trends in different regions switched direction with regime shifts. Generally, thick-billed murre populations have declined in all regions except the E Canadian Arctic since the 1970s, whereas no unidirectional global trends can be identified for common murres.

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 both species tended to show negative population trends where there was a large change in SST. Colony growth was most often positive where conditions remained relatively stable (Box 4.3 Fig. 3) 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 (Irons et al. 2008).

Climate change is already affecting the foraging of thick-billed murres in places: e.g. Arctic fishes have been replaced by more southerly species in the diet of nestlings in N Hudson Bay (Gaston et al. 2003). Drowning in fishing nets and crashes in the forage-fish prey stocks have caused population declines in several countries (e.g. Norway; Barrett & Krasnov 1996), but populations have generally recovered.

Although both species of murre are currently abundant, many populations have been declining for several decades (Box 4.3 Fig. 2). Problems facing murres include fisheries interactions, contaminants and oil spills and, in some parts of their range, hunting (especially of thick-billed murres; see Section 4.5.2.1). For thick-billed murres, 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. 2005a). 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 & Robertson 2004). In the long term, range contraction of thick-billed murres in response to the retreat of Arctic sea ice appears likely. Eventually they may be replaced by common murres and other more southern auks.
temperature. 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 increased frequency of extreme weather events, could create increased mortality in the future. Changes in the timing of snow and ice melt affect the availability of breeding sites for crevice, scree and burrow-nesting species, such as puffins and little auks (Birkhead & Harris 1985). Such changes in accessibility can result in altered interactions with predators, as observed for Antarctic petrels Thalassoica antarctica where access to nest sites is critical in evading predation by skuas (van Franeker et al. 2001).

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, Helgason et al. 2008, Letcher et al. 2010). Very high levels of mercury have been found in the eggs of ivory gulls from Canada (Braune et al. 2006) and high levels of organohaline compounds in those from Svalbard (Miljeteig et al. 2009). High organohaline concentrations occur also in glaucous gulls from Svalbard (Busnes 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 biomagnification effects. They may also frequent garbage dumps around human population centers. 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).

4.5.3. Other issues

4.5.3.1. Changes in seasonal events

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. 2005a, 2005b, Byrd et al. 2008a, 2008b, Moe et al. 2009, Wojczeniak-Jakubas & Bech 2009). For some Arctic species, reproductive success declines as the season progresses so that late laying birds fare worse than early layers (e.g. little auks; Moe et 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 N Hudson Bay (Gaston et al. 2005a). 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 (Lairdreg et al. 2008).

Mismatching of breeding initiation with the seasonal peak of food availability may be a common phenom-
cases, have been in existence for millennia (Gaston & Donaldson 1995). 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 Røst, Norway, reared few chicks between 1969 and 1982; Anker-Nilssen & 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 (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 (see also Hoberg & Kutz, Chapter 15). Range expansion or population increase of other seabirds can also lead to novel interspecific transmission (Brooks & Hoberg 2007): this may explain the recent discovery of a gull cestode in Atlantic puffins in Newfoundland (Muzaffar *et al.* 2007).

Currently, golden eagle and the northern sea-eagles (*Haliaeetus leucocephalus,* *H. albicilla,* *H. pelagicus*), all of which cause disruption to nesting seabirds by killing breeding adults and disturbing many others, occur principally in the sub-Arctic. Their northward spread could create problems for gulls, murres and other open-nesting seabirds (Hipfner *et al.* 2011), a phenomenon that is being seen especially in N Norway, where the increase in white-tailed eagles *Haliaeetus albicilla* has caused declines in murres and black-legged kittiwakes (Barrett *et al.* 2006). In Finland, waterbirds make up more than half of white-tailed eagle diet (Sulkava *et al.* 1997). Increasing predation of birds and their nests by polar bears has also been observed, probably as a result of the bears coming ashore earlier in the season (Rockwell & Gormezano 2009, Smith *et al.* 2010). This could affect especially accessible species such as local little auks (Stempniewicz 2007) and ivory gulls. Because of the availability of alternative prey, it is extremely difficult to predict how predators will affect seabird populations, or how those populations will respond to changes in predation pressure (Gaston & Elliott 2013).

### 4.5.4. 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 20th 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. 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.

### 4.6. LANDBIRDS: RAPTORS, CRANES, PTARMIGANS AND SONGBIRDS

Although most Arctic land areas support one or more landbird species, this group is not well-represented in the Arctic, compared with more temperate latitudes. In addition, most Arctic landbirds are small passerines which are not hunted either in their breeding areas by northern residents or on their wintering grounds by southerners, and hence have little economic value. Such
birds do not attract much research. Only the groused relatives (Phasianidae) and the cranes (Gruidae) attract any significant attention from hunters. Several species of raptors are also present in the Arctic and play an important role as top predators of the tundra food web (Legagneux et al. 2012, Therrien 2012).

Landbird ranges in North America are taken from species accounts in Birds of North America (Poole 1992-2011), and in Eurasia from Snow & Perrins (1998) and Beaman & Madge (1998). Population trends are not monitored directly within most Arctic regions, but may be assessed from surveys of migrating and wintering birds at lower latitudes. In North America, Christmas Bird Counts (National Audubon Society n.d.; see also Niven et al. 2004), Project FeederWatch (Cornell Laboratory of Ornithology and Bird Studies Canada n.d.) and the Canadian Migration Monitoring Network (Butcher & Niven 2007, Bird Studies Canada n.d.) all provide information for some Arctic species of interest. The Northwest Territories-Nunavut Bird Checklist Survey (NNBCS) provides information on range changes for the period since 1987 (Canadian Wildlife Service – Prairie & Northern Region 2009). Recently, Gauthier et al. (2011c) and Watson et al. (2011) reviewed the status of several species of Arctic raptors. Except for those referred to below, similar overall data are not available for Arctic landbirds in Eurasia.

4.6.1. Species richness and distribution

Most landbird species belong to genera widespread at lower latitudes. There is a strong negative gradient of species richness from sub-Arctic to high Arctic, with the northern limit of trees and shrubs bounding many distributions. Consequently, defining the species to be included in this section has been somewhat arbitrary.

4.6.1.1. Status

There are no landbird families endemic to the Arctic and only a few endemic genera, although the longspurs (Passeres: Calcariidae) are mainly found in the Arctic (4/6 species). All other species belong to families widespread in the Northern Hemisphere. Only two genera are endemic to the Arctic, sub-Arctic and contiguous mountains: the ptarmigans (Lagopus spp.) and the snow buntings (Plectrophenax spp.) The snowy owl (Bubo scandiacus), gyrfalcon, rough-legged buzzard and Arctic redpoll breed only in the low and high Arctic. The Siberian crane (Grus leucogeranus), a low Arctic/sub-Arctic species, is considered by some authorities to constitute a monotypic genus (Leucogeranus) that separated from other cranes as far back as the Miocene (Krajewski et al. 2010). All other species have substantial parts of their ranges within the sub-Arctic, many extend into boreal regions and a few are cosmopolitan (raven, peregrine falcon (Falco peregrinus)). The pipits and wagtails (Passeres: Motacillidae) form the most diverse family in the low Arctic, with nine species occurring there (20% of Arctic-breeding passerines).

Many Arctic landbirds are circumpolar in distribution, including all non-passerine genera (except for Leucogeranus, the Siberian crane), and all genera extend their breeding ranges into the high Arctic. Among non-circumpolar genera, seven are Nearctic in distribution and five Palearctic. However, small adjustments to the sub-Arctic/low Arctic boundary would qualify or disqualify many species, so these numbers have little significance. Within the Arctic, few species are differentiated into subspecies, either between Arctic and sub-Arctic, or among different Arctic regions. Some, such as the gyrfalcon, appear to have colonized their current range entirely during the past 10,000 years from a single glacial refugium (Johnson et al. 2007). The wagtails are exceptions with both white wagtail (Motacilla alba) and yellow wagtail (M. flava) comprising several regional races (Vaurie 1963). The eastern race of yellow wagtail, which extends into Alaska, is now considered a separate species, eastern yellow wagtail (Motacilla tephronotus). The horned lark (Eremophila alpestris) has two races in Arctic North America and several more farther south (Beason 1995).

Only six species remain in the Arctic during the winter: the two ptarmigans, raven, snowy owl, gyrfalcon and Arctic redpoll, although parts of the populations of the last three species frequently move at least as far as boreal regions. White-tailed eagles remain year-round in Greenland. Most fruit- and seed-eating species (thrushes (Turdidae) [most], accentors (Prunellidae), longspurs (Calcariidae), buntings/sparrows (Emberizidae) and finches (Fringillidae)) and raptors are relatively short-range migrants, wintering in temperate and boreal regions (Newton 2007), although some Arctic-breeding peregrine falcons travel to tropical and subtropical regions (Fuller et al. 1998). Conversely, most insectivores migrate to the Mediterranean or tropical regions (wagtails/pipits [most], Eurasian flycatchers (Muscicapidae), Old World warblers (Sylvidae), New World warblers (Parulidae)).

4.6.1.2. Trends

The most obvious change in species richness over the past several decades has been the appearance of sub-Arctic species in the low Arctic. Northward movement of range boundaries for sub-Arctic species has been documented in Finland (Brommer 2004) and seems likely elsewhere. There are numerous anecdotes and comments from northern peoples to this effect, but the evidence is slight from scientific surveys, possibly because the numbers involved are still small. In Iceland, several sub-Arctic or boreal species have colonized in the past century, including blackbird (Turdus merula) and goldcrest (Regulus regulus) (Hilmarsson 2000). These range expansions may relate to land use changes rather than to climate amelioration. However, the rock ptarmigan, a near-endemic in the Arctic, is declining in Iceland despite little habitat change (Storch 2007). Increases in southern species and decreases in more typically sub-Arctic species have been noted in forest habitats in Finland (Brommer 2008, Virkala & Rajasarkkä 2011), while the redwing (Turdus iliacus) has begun to breed in
Greenland in recent years (D. Boertmann unpubl.). Northward range expansion has also been reported for some raptors (Gauthier et al. 2011c). In North America, the peregrine falcon expanded its range in several areas in the 1980s (e.g. Mossop 1988, White 1994). Range expansion of the short-eared owl Asio flammeus in the eastern Canadian Arctic has been recently documented on Bylot Island, 1,000 km north of the previously documented northern limit of their range in eastern North America (Therrien 2010). In western Siberia, the snowy owl moved northward in Yamal, with possibly a contraction of its range in the south. For instance Osmolovskaya (1948) found several nests as far to the south as 67.5° N, but in recent decades all those reported were north of 69.5° N. Likewise, Potapov (2011) suggested that the southern range boundary of gyrfalcon in Siberia has retreated northwards.

4.6.2.1. Status

Population numbers can be estimated for very few landbirds, mainly those with very small populations. Estimates for North American populations have been attempted, based on extrapolations from densities and range extents, but these estimates do not consider habitat quality and probably represent orders of magnitude only (Niven et al. 2004, Rich et al. 2004). Only one species is considered endangered by IUCN/BirdLife, the Siberian crane, which has decreased from tens of thousands to only a few thousand since the mid-20th century. The cause of its decline is thought to be hunting and habitat degradation on migration routes and in wintering areas in E and S Asia, rather than any causes specific to the Arctic (Meine & Archibald 1996). McKay’s bunting Plectrophenax hyperboreus is considered near threatened on the basis of its small range and a population size estimated at 6,000 birds (Rich et al. 2004). The two ptarmigan species, although both abundant and widespread, are listed as ‘Lower Risk’ (Storch 2007).

4.6.2.2. Trends

In North America, Christmas Bird Count (CBC) indices suggest significant declines in wintering numbers of snowy owl, Arctic redpoll, American tree sparrow Spizella arborea and buff-bellied pipit Anthus rubescens, while snow bunting has decreased by 40% since the 1970s, although the decrease does not reach statistical significance (Downes et al. 2011). Arctic redpoll, snow bunting and snowy owl may be wintering farther north than in earlier decades, with a greater proportion of the population remaining outside of the area commonly covered by the CBC in recent years. Consequently, these declines need to be interpreted with caution. However, snowy owls are thought to be declining in Siberia (E. Lappo unpubl.) and Nunavut (see below). The wintering ranges of American tree sparrow and buff-bellied pipit are well covered by CBCs, and buff-bellied pipit is also showing significant reductions at some migration monitoring sites in Canada (National Audubon Society 2012). According to CBC records, the American tree sparrow has declined by > 2% per year since the 1970s (Downes et al. 2011). Its breeding range is almost entirely in the low Arctic, while that of the buff-bellied pipit includes all the low Arctic, as well as the southern parts of the high Arctic (Naugler 1993). The horned lark and Lapland longspur Calcarius lapponicus have also shown a decline since the 1960s.

The Lapland longspurs are disappearing in our area and I have noted that a late frost in the spring killed hundreds of small birds, which were caught unprepared for a lasting cold snap.

(Qaunaq: Elders conference on Climate Change 2001).

In fact, according to the CBC, none of the Arctic songbirds covered has increased since the 1960s (Fig. 4.7). Conversely, several species characteristic of the sub-Arctic show increasing numbers at migration monitoring stations; e.g. white-crowned sparrow and yellow-rumped warbler (Bird Studies Canada 2012), suggesting population increases.

Preliminary results from the NWT-Nunavut Bird Checklist Survey for 1987-2007 also suggest that the Arctic redpoll and snowy owl may be contracting their
range in N Canada (B.L. Collins unpubl.). Those species showing the greatest decreases on these surveys are all raptors or owls: rough-legged buzzard, gyrfalcon and short-eared owl. The only landbird species showing a significant increase is the sub-Arctic savannah sparrow *Passerculus sandwichensis*.

On the Yukon north slope (British Mountains and coastal plain), historical data indicate a cyclic pattern of population change of nesting gyrfalcons attributed to cyclic changes in the abundance of their primary prey, willow ptarmigan *Lagopus lagopus* (Mossop 2011). Surveys of gyrfalcon nests in this area since 2002 showed decreasing numbers of nesting birds and low productivity of nests. This may be a low phase of another population cycle, or may represent an overall decline in the abundance of this species. Similarly, in the Yamal Peninsula, Russia, gyrfalcon numbers decreased after the 1990s (Mechnikova et al. 2011). However, gyrfalcons in the Colville River valley, Alaska, showed no change in numbers between 2001 and 2005 (Swem & Matz 2011). Nor is there any evidence for changes in the number of gyrfalcons in northern Fennoscandia over the past 150 years (Koskimies 2011).

In the European Arctic, numbers of breeding horned larks underwent a marked decline during the second half of the 20th century. This decline may have been caused by habitat loss on their wintering quarters through embankment of salt-marshes in W Europe (Dierschke 1997).

Some Arctic populations of peregrine falcons were affected by the accumulation of organochlorine pesticides during the 1950s and 1960s, but most have since recovered (Rowell et al. 2003, Vorkamp et al. 2009). However, Franke et al. (2010) showed that a population near Rankin Inlet, Nunavut, has decreased since 1982, simultaneous with a halving of chick production and a 40% decline in the number of chicks reared per pair. This observation may not be explained by pesticide pollution and could be related to climatic changes in the region.

### 4.6.2.3. Causes and prospects

For the most part, there is no clear indication of what is driving trends in Arctic landbirds. Gyrfalcons in Russia are strongly affected by the taking of young birds for falconry (Mechnikova et al. 2011, Potapov 2011). Such poaching has also occurred in North America (Watson et al. 2011), but is unlikely to affect other species. In North America, where most Arctic landbirds seem to be in decline, such widespread trends suggest some general cause. The possibility that the common cause is some derivative of climate change cannot be excluded, but at present the way in which such an effect might be operating is unclear. The gradual northward advance of the tree-line and retreat of permafrost will undoubtedly create conditions for sub-Arctic species to spread northwards: in some places this is already happening. For instance, at the southern border of low Arctic Alaska, elder Betty Anagick, an Inupiaq woman, made an observation of a new bird in the community:

> I have seen hummingbird here, which is strange.

(Mustonen et al. 2009).

How these changes will affect the current avifauna of the Arctic remains to be seen, but the eventual loss of some specialist species seems inevitable.

### 4.6.3. Other issues

#### 4.6.3.1. Predator-prey interactions

Several species of tundra raptors such as the snowy owl and rough-legged buzzard feed primarily or entirely on lemmings (Gauthier et al. 2011b, Therrien 2012). Popu-

![Figure 4.7. Trends in Arctic landbirds from Christmas Bird Count records between 1966 and 2005 (data courtesy of National Audubon Society and P. Blancher).](image-url)
4.6.3.2. Movements of raptors
Recent satellite tracking of some tundra predators such as snowy owls and gyrfalcons revealed a previously unsuspected wintering strategy (Burnham & Newton 2011, Therrien et al. 2011). These studies confirmed that both species winter predominantly in the Arctic in E Canada and Greenland. However, they also revealed that both species may winter on sea ice: adult female snowy owls marked on Bylot Island spent up to 101 days on the sea ice between December and April every winter (Therrien et al. 2011), concentrating their activity in the Hudson and Davis Straits and in Hudson Bay at a median distance of 40 km from the coast but sometimes as far as 210 km. These owls were primarily gathering around polynyas, presumably feeding on seabirds (Robertson & Gilchrist 2003). The satellite tracking of snowy owls also showed that individuals can breed from one year to the next in areas far apart, showing a remarkable average annual breeding dispersal distance of 725 km (Therrien et al. 2012). The large-scale movements allowed owls to settle in an area where lemmings are at peak densities.

4.6.3.3. Anticipated threats related to climate change
In many areas of the circumpolar world such as N Fennoscandia or NE Greenland, a recent collapse of lemming population cycles has been reported (see 4.3.3.2, 4.4.3.1, Reid et al., Chapter 3 and Ims & Ehrich, Chapter 12). This may represent a significant threat for the populations of many species of predatory birds as their breeding success is so closely tied to the abundance of small mammals. The decline of snowy owls reported in Fennoscandia is mainly due to the recent absence of lemming peaks in these areas (Jakobsen 2005), though during the lemming peak of 2007 several pairs were breeding successfully in Finnmark. In central E Greenland (Traill Island), no snowy owls and very few long-tailed jaegers Stercorarius longicaudus have successfully nested since the collapse of the lemming cycles in the early 2000s (B. Sittler and O. Gilg pers. com.).

The use of the sea ice by snowy owls and gyrfalcons suggests that they may not only be vulnerable to changes affecting their prey base in the tundra but also to those in the marine environment. Change in the sea ice regimes due to climate warming will likely alter the abundance and distribution of wintering seabirds, their primary prey in this environment (Gauthier et al. 2011b).

Another threat facing some species of raptors may be the collapse of nesting structures during the nesting season. In northern Yukon, rough-legged buzzards, peregrine falcons and snowy owls often build their nests on mud or sandy cliffs. In a recent study in northern Yukon, up to half of the nests monitored failed when the soil cliffs collapsed due to permafrost thaw under these slopes (Gauthier et al. 2011c). Such nest loss was not reported in the 1980s and thus may be a recent phenomenon due to climate warming.

4.7. CONCLUSIONS AND RECOMMENDATIONS
With about 2% of the global species total, the Arctic supports only a small fraction of the world’s avian biodiversity, but adaptation to the harsh Arctic environment has created a variety of highly specialized species and a number of Arctic endemics. Because almost all Arctic birds are migratory, population trends for many species are driven by events outside the Arctic. For year-round resident Arctic birds, little trend information is available. Where trends are known for migratory populations, the main pattern of trends can be summarized as follows: increases in many Nearctic and W Palearctic waterfowl populations, especially geese; and decreases in many shorebird populations and waterfowl of the E Palearctic. For some species wintering in E Asia, habitat loss and hunting in the wintering grounds have been identified as the main causes of population decline. Problems with food supply on critical staging areas have also been diagnosed for a few shorebirds migrating through the Americas. Because of the international nature of migratory birds, conservation action for endangered Arctic breeders must include international cooperation on a flyway level both in and outside the Arctic, to ensure safeguarding of critical habitats and proper management of hunting. This is especially critical for highly endangered migratory species such as the spoon-billed sandpiper and the Siberian crane.

On the Arctic breeding grounds, known causes of population changes have been excessive harvest and climate variability, while potential threats include oil, gas and mineral exploitation. Oil exploitation at sea and increased transport of oil through Arctic waters, with its associated risks of oil spills, is especially hazardous for the great number of marine and coastal birds of the Arctic. The aggregation of very large numbers of birds in breeding colonies or molting sites, often associated with areas of high productivity and a high diversity of other taxa (e.g. fish, marine mammals), makes the protection of such colony and molting sites and adjacent waters from the risk of oil spills a priority. Breeding and molting birds can also be negatively affected by disturbance resulting from industrial development and tourism, which can increase predation and/or keep birds from using suitable habitats. Again, this is especially severe where large concentrations of birds are affected. The overharvesting of Arctic birds is a problem mainly of inhabited regions, principally in the sub-Arctic or the fringes of the Arctic. In some cases these problems are
either solved or on the way to solution: eider populations affected by over-harvesting in the late 20th century are recovering, and the greatly diminished population of thick-billed murres in Novaya Zemlya has stabilized.

In the true Arctic, some heavily harvested species, particularly geese, are increasing rapidly. Because ‘overabundant’ geese are causing degradation of sensitive habitat in some Arctic areas, management efforts have been initiated to reduce population sizes through increased hunting outside the Arctic. The problem with use of hunting as a management tool is that the massive shooting needed to significantly reduce numbers may cause high culling rates, greatly increased shyness and create widespread disturbance of other waterfowl species on the staging and wintering grounds (Madsen & Fox 1995, Noer & Madsen 1996).

Climate change may act on Arctic bird populations in various indirect ways (Boyd & Madsen 1997). These include changes in food supply; predators, prey, parasites and diseases; mis-match between the peak of availability of food and the timing of arrival on breeding grounds, hatch, brood rearing or migration. The northward shift of vegetation zones will affect both food and habitat, in addition to habitat loss due to permafrost thawing in some areas. However, even though single effects have been shown at a local scale for some bird populations, the complexity of these interacting factors makes it very hard to predict future impacts of a warming climate on Arctic bird populations. Some effects, like the impact of egg-eating by polar bears, may attenuate, as bear populations at lower latitudes decline (see Reid et al., Chapter 3).

Some species found mostly or entirely in the Arctic are showing signs of population decline which may be related to climate change (ivory gull, thick-billed murre, gyrfalcon, perhaps snowy owl). The exact causes are unknown, but may relate directly or indirectly (e.g. through changes in their food supply) to increasing temperatures. We need much more extensive monitoring, especially in Canada and Siberia, to better assess the causes of population change. Greater integration of national monitoring programmes under the Arctic Monitoring and Assessment Programme, the Arctic Breeding Bird Condition Survey (ABBCS) and the Circumpolar Seabird Data Portal (Seabird Information Network 2012) would be useful and the CAFF seabird group could provide the necessary incentive. We particularly need better information on the non-game Arctic endemics: gyrfalcon, snowy owl, shorebirds, ivory, Sabine’s and Ross’s gulls, jaegers/skuas and little auks. With their breeding distributions restricted to Arctic biomes, these birds are likely to be the first to exhibit symptoms of climate change effects. Likewise, we need regular monitoring of important wintering areas for Arctic seabirds and waterfowl, such as SW Greenland (Boertmann et al. 2004), waters off Newfoundland and Labrador (Frederiksen et al. 2011) and polynyas supporting eiders in the N Bering Sea (Petersen & Douglas 2004).

If climate change proceeds as predicted, many of the bird species characteristic of the northern taiga and sub-Arctic are likely to expand northwards as temperatures increase. However, this cannot be viewed as an improvement in the richness of the Arctic avifauna, but rather constitutes a contraction in the area of the Arctic, as we have hitherto defined it in biological terms. Ultimately, much of the region now characterised by a high Arctic fauna may become low Arctic in character, and the eventual disappearance of typically high Arctic birds such as gyrfalcon, ivory gull and little auk seems probable.

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