Red knot. Photo: Danita Delimont/Shutterstock.com

3.3 BIRDS

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There are few true Arctic specialist birds that remain in the Arctic throughout their annual cycle. They include the willow and rock ptarmigan (Lagopus lagopus and L. muta), gyrfalcon (Falco rusticolus), snowy owl (Bubo scandiacus), Arctic redpoll (Carduelis hornemanni) and northern raven (Corvus corax)—a cosmopolitan species with resident populations in the Arctic. All other terrestrial Arctic-breeding bird species migrate to warmer regions during the northern winter, connecting the Arctic to all corners of the globe. Hence, their distributions are influenced by the routes they follow. These distinct migration routes are referred to as flyways and are defined by a combination of ecological and political boundaries and differ in spatial scale. The CBMP refers to the traditional four north–south flyways, in addition to a circumpolar flyway representing the few species that remain largely within the Arctic year-round (Figure 3-20).

The CBMP–Terrestrial Plan identifies five FECs for monitoring terrestrial birds; herbivores, insectivores, carnivores, omnivores and piscivores. Due to their migratory nature, a wider range of drivers, from both within and outside the Arctic, affect birds and their associated FEC attributes compared to other terrestrial FECs. Figure 3-21 illustrates a conceptual model for Arctic terrestrial birds that includes examples of FECs and key drivers.

This summary is based on Smith et al. (2020) which provides the most recent and comprehensive analysis—and literature references—of status and trends of Arctic terrestrial bird FECs. Additional information is drawn from Fuglei et al. (2020), Franke et al. (2020), Fox & Leafloor (2018) and references therein. For information not included in these papers, key references are provided. This report uses international English names for bird species (Gill & Donsker 2019). Scientific names are found in Table 3-2.

3.3.1 PATTERNS AND TRENDS OF FECS AND THEIR ATTRIBUTES

While over 200 species of birds are known to breed regularly in the Arctic, this assessment focuses on 88 terrestrial species (Table 3-2). The list excludes seabirds and some sea ducks that are included under the CBMP Arctic Marine Biodiversity Monitoring Plan (Gill et al. 2011) but includes waders/shorebirds and geese that are also partly considered under the Arctic Coastal Biodiversity Monitoring Plan (CAFF 2019a). The CBMP–Terrestrial Plan FECs are; insectivores (waders, passerines), carnivores (birds of prey), herbivores (geese, swans, ptarmigan) and omnivores (cranes, ducks, raven). For some analyses, species are grouped into foraging guilds, which are equivalent to the CBMP–Terrestrial Plan FECs with the addition of piscivores which are included with the other omnivores in the CBMP FECs. Status and trends are reported for both the FECs and taxonomic groupings (waterfowl, waders, other water birds, land birds) (Table 3 2).

Although the CBMP–Terrestrial Plan defines desirable monitoring attributes for the FECs, only some are widely or regularly monitored, including CBMP's essential attributes; abundance, demographic parameters and distribution for herbivores, carnivores, and insectivores (Figure 3-22).

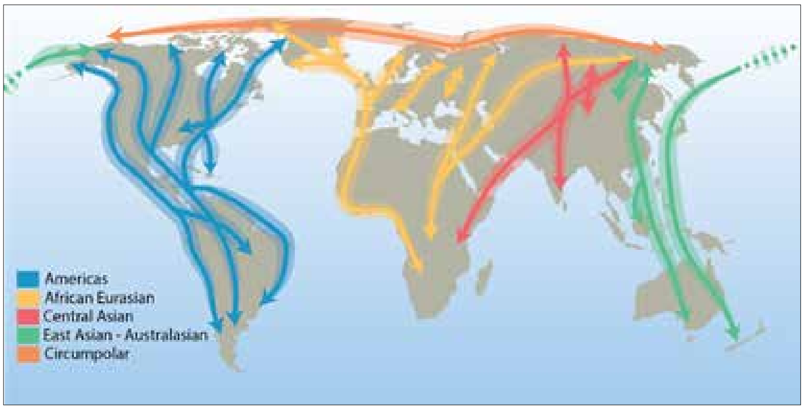


Figure 3-20. Simplified illustration of the global migratory bird flyways.

Modified based on Arctic Migratory Birds Initiative and Deinet et al. (2015).

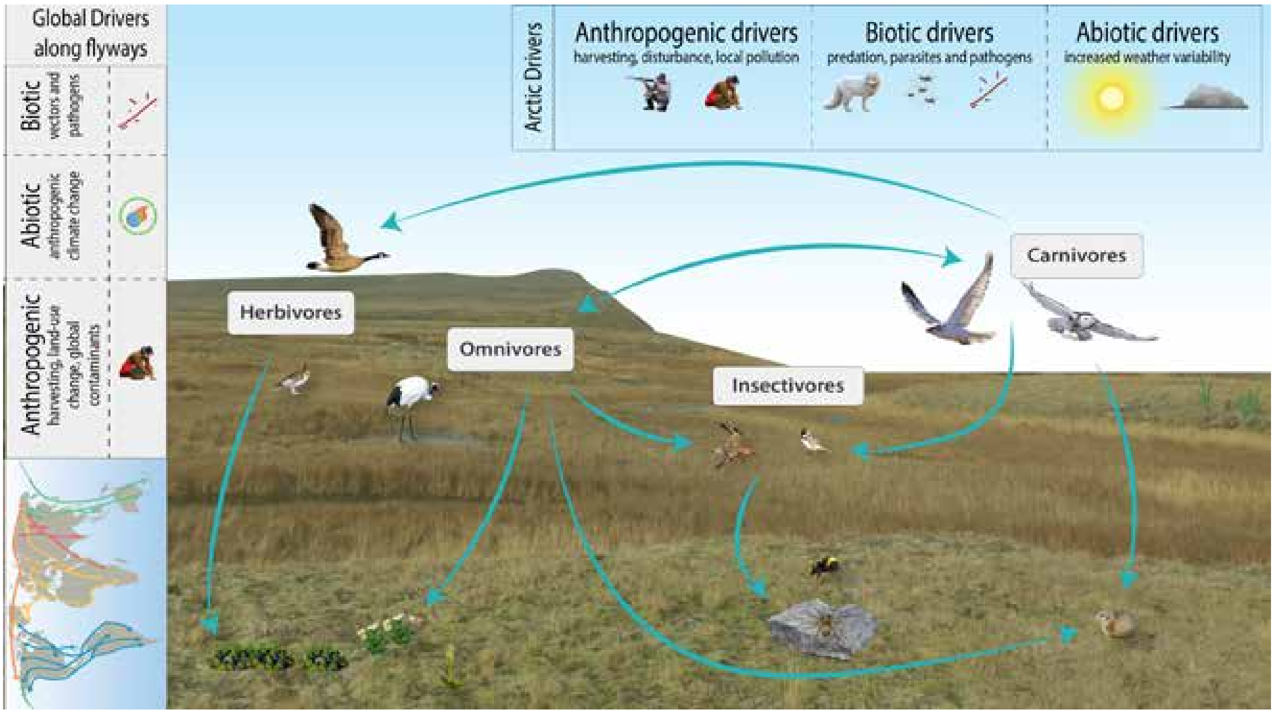


Figure 3-21. Conceptual model for Arctic birds, illustrating examples of FECs and key drivers at different scales.

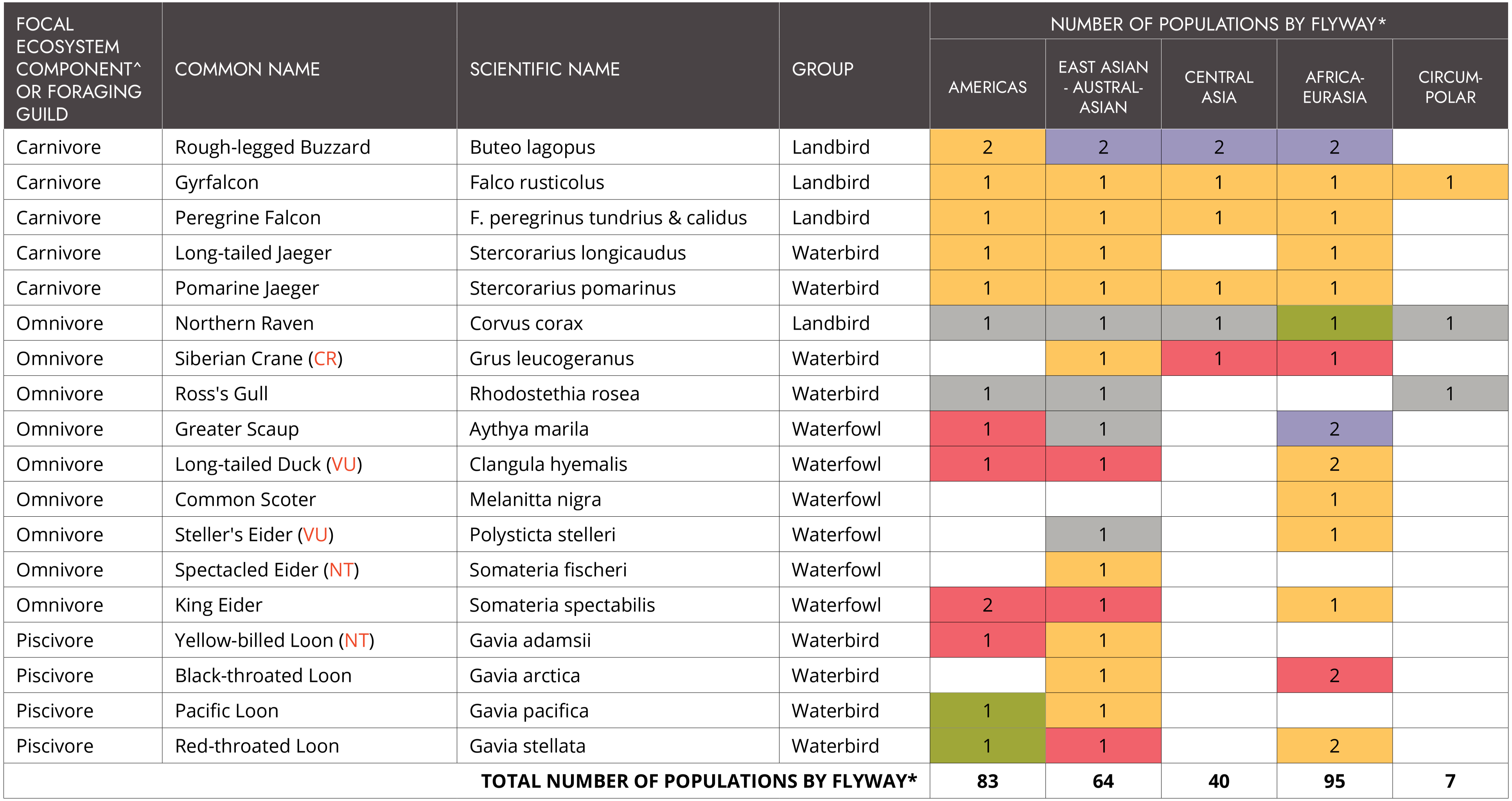
Table 3-2. Trends in Arctic terrestrial bird populations by flyway. Birds are included in this table if the (sub)species has 50% or more of their breeding range confined to the Arctic or is known to occupy the Arctic and is non-migratory; for species on the global red list (IUCN 2012a), respective IUCN categories are indicated in red font after species names. Redrawn from Smith et al. (2020).

TREND COLOUR CODES	
🟩 Increasing	🟥 Decreasing
🟦 Increasing/Stable	🟪 Mixed
🟨 Stable	▨ Unknown
🟧 Stable/Decreasing	⬜ Out of range

FOCAL ECOSYSTEM COMPONENT^ OR FORAGING GUILD	COMMON NAME	SCIENTIFIC NAME	GROUP	NUMBER OF POPULATIONS BY FLYWAY*				
				AMERICAS	EAST ASIAN - AUSTRAL-ASIAN	CENTRAL ASIA	AFRICA-EURASIA	CIRCUM-POLAR
Herbivore	Willow Ptarmigan	Lagopus lagopus	Landbird	🟥 1	🟥 1	🟥 1	🟪 1	🟪 1
Herbivore	Rock Ptarmigan	Lagopus muta	Landbird	▨ 1	🟪 1	🟪 1	🟪 1	🟪 1
Herbivore	Greater White-fronted Goose	Anser albifrons	Waterfowl	🟪 3		🟪 3	🟪 5	
Herbivore	Pink-footed Goose	Anser brachyrhynchus	Waterfowl				🟩 2	
Herbivore	Lesser White-fronted Goose (VU)	Anser erythropus	Waterfowl			🟥 2	🟥 2	
Herbivore	(Tundra) Bean Goose	Anser fabalis (rossicus/serriristris)	Waterfowl		🟨 3	🟥 1	🟪 2	
Herbivore	Brant Goose	Branta bernicla	Waterfowl	🟨 2	🟨 2		🟩 3	
Herbivore	Cackling Goose	Branta hutchinsii	Waterfowl	🟪 4				
Herbivore	Barnacle Goose	Branta leucopsis	Waterfowl				🟩 3	
Herbivore	Red-breasted Goose (VU)	Branta ruficollis	Waterfowl				🟩 1	
Herbivore	Snow Goose	Chen caerulescens	Waterfowl	🟩 4				
Herbivore	Emperor Goose (NT)	Anser (Chen) canagica	Waterfowl		🟨 1			
Herbivore	Ross's Goose	Chen rossii	Waterfowl	🟩 1				
Herbivore	Tundra Swan	Cygnus columbianus	Waterfowl	🟩 2	🟩 1		🟦 2	
Insectivore	Red-throated Pipit	Anthus cervinus	Landbird		🟨 1		🟨 1	
Insectivore	Buff-bellied Pipit	Anthus rubescens	Landbird	🟥 1	🟥 1	🟥 1		
Insectivore	Lapland Longspur	Calcarius lapponicus	Landbird	🟩 1	🟥 1	🟥 1	🟥 1	
Insectivore	Smith's Longspur	Calcarius pictus	Landbird	🟩 1				
Insectivore	Common Redpoll	Carduelis flammea	Landbird	🟩 1	🟩 1	🟩 1	🟩 1	
Insectivore	Arctic Redpoll	Carduelis hornemanni	Landbird	▨ 1	▨ 1	▨ 1	▨ 1	▨ 1
Insectivore	Little Bunting	Emberiza pusilla	Landbird		🟨 1	🟨 1	🟨 1	
Insectivore	Horned Lark	Eremophila alpestris	Landbird	🟥 1	🟥 1	🟥 1	🟥 1	

FOCAL ECOSYSTEM COMPONENT^ OR FORAGING GUILD	COMMON NAME	SCIENTIFIC NAME	GROUP	NUMBER OF POPULATIONS BY FLYWAY*				
				AMERICAS	EAST ASIAN - AUSTRAL-ASIAN	CENTRAL ASIA	AFRICA-EURASIA	CIRCUM-POLAR
Insectivore	Citrine Wagtail	Motacilla citreola	Landbird			1	1	
Insectivore	Savannah Sparrow	Passerculus sandwichensis	Landbird	1				
Insectivore	McKay's Bunting	Plectrophenax hyperboreus	Landbird	1	1			
Insectivore	Snow Bunting	Plectrophenax nivalis	Landbird	1	1	1	1	
Insectivore	Siberian Accentor	Prunella montanella	Landbird		1	1		
Insectivore	American Tree Sparrow	Spizella arborea	Landbird	1				
Insectivore	Surfbird	Aphriza virgata	Wader	1				
Insectivore	Ruddy Turnstone	Arenaria interpres	Wader	2	1	1	3	
Insectivore	Black Turnstone	Arenaria melanocephala	Wader	1				
Insectivore	Sharp-tailed Sandpiper	Calidris acuminata	Wader		1			
Insectivore	Sanderling	Calidris alba	Wader	1	1	1	2	
Insectivore	Dunlin	Calidris alpina	Wader	2	4	1	4	
Insectivore	Baird's Sandpiper	Calidris bairdii	Wader	1				
Insectivore	Red Knot (NT)	Calidris canutus	Wader	2	2		2	
Insectivore	Curlew Sandpiper (NT)	Calidris ferruginea	Wader		1	1	2	
Insectivore	White-rumped Sandpiper	Calidris fuscicollis	Wader	1				
Insectivore	Stilt Sandpiper	Calidris himantopus	Wader	1				
Insectivore	Purple Sandpiper	Calidris maritima	Wader	1			4	
Insectivore	Western Sandpiper	Calidris mauri	Wader	1				
Insectivore	Pectoral Sandpiper	Calidris melanotos	Wader	1	1			
Insectivore	Little Stint	Calidris minuta	Wader			1	2	
Insectivore	Least Sandpiper	Calidris minutilla	Wader	1				
Insectivore	Rock Sandpiper	Calidris ptilocnemis	Wader	3	3			
Insectivore	Ruff	Calidris pugnax	Wader			1	2	

FOCAL ECOSYSTEM COMPONENT^ OR FORAGING GUILD	COMMON NAME	SCIENTIFIC NAME	GROUP	NUMBER OF POPULATIONS BY FLYWAY*				
				AMERICAS	EAST ASIAN - AUSTRAL-ASIAN	CENTRAL ASIA	AFRICA-EURASIA	CIRCUM-POLAR
Insectivore	Semipalmated Sandpiper (NT)	Calidris pusilla	Wader	3				
Insectivore	Red-necked Stint (NT)	Calidris ruficollis	Wader		1			
Insectivore	Temminck's Stint	Calidris temminckii	Wader		1	1	2	
Insectivore	Great Knot (EN)	Calidris tenuirostris	Wader		1	2	1	
Insectivore	Common Ringed Plover	Charadrius hiaticula	Wader	1			3	
Insectivore	Semipalmated Plover	Charadrius semipalmatus	Wader	1				
Insectivore	Eurasian Dotterel	Eudromias morinellus	Wader			1	1	
Insectivore	Spoon-billed Sandpiper (CR)	Eurynorhynchus pygmeus	Wader		1			
Insectivore	Broad-billed Sandpiper	Limicola falcinellus	Wader		1		1	
Insectivore	Long-billed Dowitcher	Limnodromus scolopaceus	Wader	1				
Insectivore	Hudsonian Godwit	Limosa haemastica	Wader	2				
Insectivore	Bar-tailed Godwit (NT)	Limosa lapponica	Wader		2		3	
Insectivore	Eskimo Curlew (CR)	Numenius borealis	Wader	1				
Insectivore	Whimbrel	Numenius phaeopus	Wader	2	1	1	4	
Insectivore	Bristle-thighed Curlew (VU)	Numenius tahitiensis	Wader		1			
Insectivore	Red Phalarope	Phalaropus fulicarius	Wader	2			1	
Insectivore	Red-necked Phalarope	Phalaropus lobatus	Wader	1	1		1	
Insectivore	European Golden Plover	Pluvialis apricaria	Wader				3	
Insectivore	American Golden Plover	Pluvialis dominica	Wader	1				
Insectivore	Pacific Golden Plover	Pluvialis fulva	Wader	1	1	1		
Insectivore	Grey Plover	Pluvialis squatarola	Wader	3	1	1	2	
Insectivore	Spotted Redshank	Tringa erythropus	Wader			2	2	
Insectivore	Buff-breasted Sandpiper (NT)	Tryngites subruficollis	Wader	1				
Carnivore	Snowy Owl (VU)	Bubo scandiacus	Landbird	1	1	1	1	1



FOCAL ECOSYSTEM COMPONENT^ OR FORAGING GUILD	COMMON NAME	SCIENTIFIC NAME	GROUP	NUMBER OF POPULATIONS BY FLYWAY*				
				AMERICAS	EAST ASIAN - AUSTRAL-ASIAN	CENTRAL ASIA	AFRICA-EURASIA	CIRCUM-POLAR
Carnivore	Rough-legged Buzzard	Buteo lagopus	Landbird	2	2	2	2	
Carnivore	Gyrfalcon	Falco rusticolus	Landbird	1	1	1	1	1
Carnivore	Peregrine Falcon	F. peregrinus tundrius & calidus	Landbird	1	1	1	1	
Carnivore	Long-tailed Jaeger	Stercorarius longicaudus	Waterbird	1	1		1	
Carnivore	Pomarine Jaeger	Stercorarius pomarinus	Waterbird	1	1	1	1	
Omnivore	Northern Raven	Corvus corax	Landbird	1	1	1	1	1
Omnivore	Siberian Crane (CR)	Grus leucogeranus	Waterbird		1	1	1	
Omnivore	Ross's Gull	Rhodostethia rosea	Waterbird	1	1			1
Omnivore	Greater Scaup	Aythya marila	Waterfowl	1	1		2	
Omnivore	Long-tailed Duck (VU)	Clangula hyemalis	Waterfowl	1	1		2	
Omnivore	Common Scoter	Melanitta nigra	Waterfowl				1	
Omnivore	Steller's Eider (VU)	Polysticta stelleri	Waterfowl		1		1	
Omnivore	Spectacled Eider (NT)	Somateria fischeri	Waterfowl		1			
Omnivore	King Eider	Somateria spectabilis	Waterfowl	2	1		1	
Piscivore	Yellow-billed Loon (NT)	Gavia adamsii	Waterbird	1	1			
Piscivore	Black-throated Loon	Gavia arctica	Waterbird		1		2	
Piscivore	Pacific Loon	Gavia pacifica	Waterbird	1	1			
Piscivore	Red-throated Loon	Gavia stellata	Waterbird	1	1		2	
		TOTAL NUMBER OF POPULATIONS BY FLYWAY*		**83**	**64**	**40**	**95**	**7**

* - Note that bird population totals on this figure are not additive by species due to instances of populations that share multiple flyways, or species that are not divided into populations, but are present in two or more flyways. In these cases, a ‘1’ was inserted into all columns that share a population or a species that is not split into populations.

^ - See Arctic Terrestrial Biodiversity Monitoring Plan (Christensen et al. 2013) for more information on Focal Ecosystem Components

Migrant insectivore passerine: Lapland longspur. Photo: Knud Falk

Resident herbivore: rock ptarmigan. Photo: Knud Falk

Resident carnivore: gyrfalcon. Photo: Knud Falk

Migrant herbivore: snow geese. Photo: Martin Robarts/WCS

Migrant insectivore: dunlin with geolocator for migration tracking. Photo: Ryan Askren/USGS

Migrant piscivore: yellow-billed loon. Photo: Bob Wick/BLM

Figure 3-22. Example of Arctic terrestrial bird species and their FEC/foraging guilds.

3.3.1.1 Herbivores

In Arctic tundra habitats, geese are the dominant herbivores—ptarmigan and tundra swans are the other herbivorous species. An estimated 39 million wild geese belonging to 68 populations of 15 species use Arctic habitats for part of their lifecycle. Of these, 42 populations of 11 species are primarily Arctic tundra birds. The 68 populations are distributed throughout all four north-south flyways, with the greatest diversity in the African–Eurasian and Americas flyways.

The Arctic 'white' geese (genus ***Chen***) of North America are most numerous—17.1 million individuals in six populations. All have increased in abundance and distribution over the last decade mostly due to changing conditions (e.g., increased access to agricultural food) on stop-over and wintering grounds, with several considered overabundant by management authorities in Canada and the United States (see Box 3-1). The Arctic taxa of 'black' geese (genus ***Branta***) number approximately 6.1 million individuals in 15 populations from four species. All but one of these populations have been stable or increasing over the long term (more than 30 years). The Arctic 'grey' geese (genus ***Anser***) comprise 21 populations of four species, totalling approximately 6.4 million individuals. Of these, seven populations have declined in abundance over the long term, seven have increased and the remaining five were stable.

Rock and willow ptarmigan belong to the Circumpolar Flyway and are resident across the Arctic; although the latter occurs mainly outside the Arctic (Birdlife International 2016a, 2016b). Both are important harvested species and are prey species for endemic Arctic predators. No reliable global population estimates exist, however, crude estimates are 5 to 25 million rock ptarmigan and 10 to 30 million willow ptarmigan. Although ptarmigan population sizes are poorly understood, variation in relative abundance is monitored across the Arctic (Fuglei et al., 2020). Rock ptarmigan showed an overall negative trend in Iceland (between 1980 and 2015) and Greenland (between 1995 and 2017), a positive trend in Svalbard (between 2000 and 2017) and no significant trend in Alaska (between 1978 and 2016). For willow ptarmigan, a negative trend was found in eastern Russia, while northern Fennoscandia and North America[4] showed no significant trends. Some periods of population cycles—3 to 6 year 'short' and 9 to 12 year 'long' cycles—were evident in both species, with cyclicity changing through time. Collapses and emergences of cycles over time within the same populations seems to be emergent properties of ptarmigan population dynamics in the Arctic.

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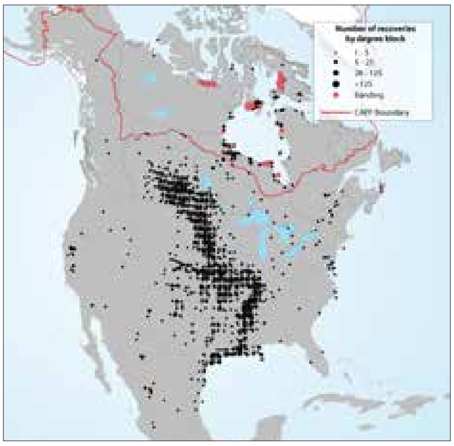
[4] Data for North American includes the island of Newfoundland in Canada which is outside the Arctic.

BOX 3-1. MIGRATING GEESE; CONTRASTING EXAMPLES

Geese are the most abundant Arctic avian herbivore, with many species, subspecies and sub-populations distributed across the circumpolar Arctic (see Fox & Leafloor 2018). Arctic goose populations provide a good example of the variation within a FEC in level of knowledge, population trend, spatial distribution, and influence of external drivers outside the Arctic.

In North America, mid-continent lesser snow geese have been monitored since 1955 using midwinter counts on the wintering grounds in the southern U.S. and from the mid–1960s until 2013 using photographic surveys of known Arctic breeding grounds. Most recently, abundance has been estimated using mark-recapture methods. The population increased from less than a million adult birds in 1955 to 12.6 million on average between 2006 and 2015. It was legally designated as overabundant in 1999, allowing for spring harvesting of the population (Koons et al. 2013). The rapid population increase is largely a result of increased survival in response to increased access to food in agricultural areas in winter. It follows an increased use of nitrogen fertilizers that resulted in increased yields of rice, corn, and wheat on the wintering grounds and along the flyways (Abraham et al. 2005).

In contrast, the lesser white-fronted goose in the Palaearctic is distributed in many small, distinct breeding and moulting sites (some yet unknown) across the vast Russian tundra with sub-populations using different migration flyways and facing highly diverse conditions in relatively few distinct wintering sites. The eastern main population almost exclusively winters within the Yangtze River floodplain in China, where the birds are increasingly concentrated at one single site. Such concentration makes the population extremely vulnerable to local land management; a risk recognised by CAFF's Arctic Migratory Birds Initiative (AMBI, CAFF 2019b). Population trends are based on sparse data, but it is thought that as many as 65,000 geese wintered in China in late 1980s, while winter counts from 2002 to 2009 showed a maximum of 18,000 individuals.



Mid-continent lesser snow goose; red areas (ringing sites) on the map above are approximate breeding areas, black dots are ring recoveries; inserted graph shows midwinter counts in the southern U.S., 1955–2016.

Lesser white-fronted goose breeding, moulting and staging areas; blue arrows indicate the inferred routes taken by the western main and eastern main populations, respectively; green and yellow lines indicate migration routes of the small Fennoscandian population (all examples from CAFF 2018).

3.3.1.2 Insectivores

At the species level, Arctic terrestrial birds are dominated by waders, comprising 41 of the 88 species (47%). When waders and insectivorous land birds are combined into an insectivore guild, the guild is clearly dominant across all flyways. Several small passerine species have distributions that extend across the entire circumpolar Arctic and the five species within this guild with the largest population sizes are all passerines. The most abundant Arctic terrestrial bird, the Lapland longspur (Figure 3-22) is estimated to have a global population size of approximately 130 million individuals. This is greater than the sum of all non-passerine's species combined.

Most passerine species monitored in the Arctic appear to show stable or increasing abundance over the long-term. However, continuous time series from North American wintering grounds suggests that in the last decade, many passerine species have begun to show declines. There are also observations of declines of insectivorous passerines in some parts of Russia and sharp declines of Lapland longspur populations in Scandinavia over the last 20 years. Despite their ubiquity, the quality of trend information for these species is poor, partly due to difficulties in combining regional trend estimates across their broad and contiguous geographic ranges.

Waders in the Arctic may number up to 50 million individuals with special concentrations on the Arctic coastal plain and the Yukon–Kuskokwim delta of northern and western Alaska, and in the Indigirka, Yana, Kolyma, and Lena Deltas of Russia. Figure 3-23 summarises trends in wader populations.

3.3.1.3 Carnivores

Only four species of birds of prey are considered true Arctic tundra species—snowy owl, gyrfalcon, peregrine falcon, and rough-legged buzzard—and each is distributed broadly across the circumpolar Arctic. The first two are largely Arctic residents belonging to the Circumpolar Flyway (although some move to boreal areas in winter), while the latter two are migratory. Estimates of population size are uncertain. The rough-legged buzzard is the most abundant with an estimated 0.3 to 1 million adult individuals. The peregrine falcon population in the Arctic is estimated to be well over 20,000 pairs (of different subspecies) and the gyrfalcon population is estimated to be fewer than 21,000 pairs. Population size for the snowy owl—a small mammal specialist in the breeding areas, with local breeding densities fluctuating widely in response to cyclic small mammal abundance—has been the subject of debate. In 2013, the population was estimated at 200,000 individuals, subsequently revised to be as low as 28,000 adult individuals (Birdlife International 2017a).

Breeding parameters of gyrfalcons (Barraquand & Nielsen 2018), snowy owls and rough-legged buzzards are strongly linked to prey exhibiting cyclical abundance patterns (i.e., ptarmigan and microtine rodents). In Scandinavia, the rough-legged buzzard population has declined by almost 50% since the 1970s and has been partly decoupled from rodent cycles (Hellström 2014). Populations of both falcon species are considered stable; most low- and sub-Arctic peregrine populations have increased over the past four decades as they recovered from the pesticide-induced population crash,

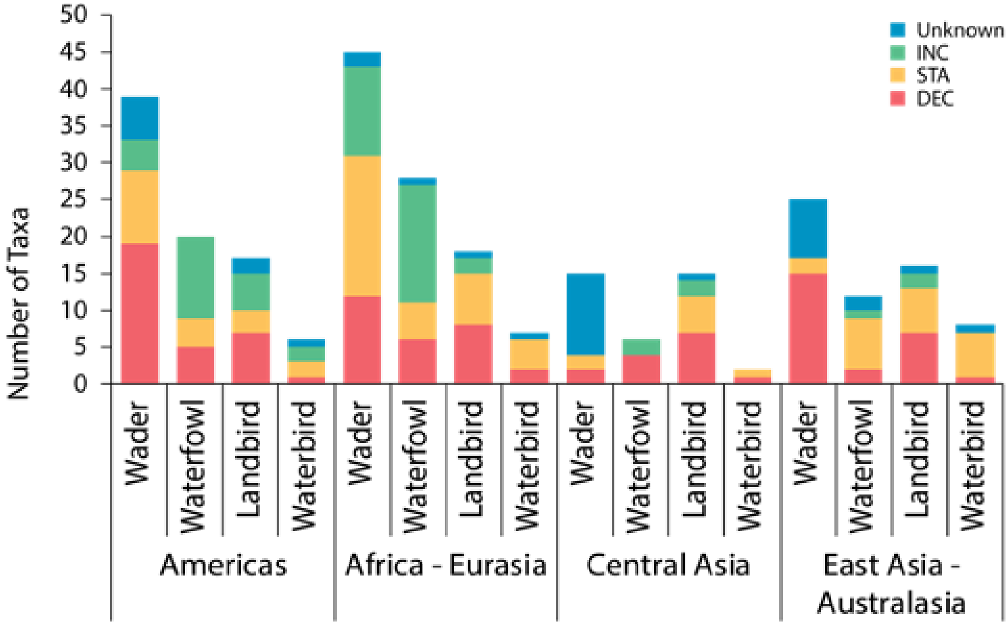


Figure 3-23. Trends in Arctic terrestrial bird population abundance for four taxonomic groupings in four global flyways. Data are presented as total number of taxa (species, subspecies). Modified from Smith et al. 2020.

which reached a low in mid–1970s. As an Arctic resident preying mainly on ptarmigan, ground squirrels and waterfowl, the gyrfalcon was not exposed to pesticide residues that affected the peregrine.

Although the CBMP–Terrestrial Plan includes the northern raven in the carnivore group, it is more accurately described as an omnivore. While no systematic monitoring of raven populations occurs in the Arctic, data indicate populations in North America and Europe have increased, likely due to increased availability of food and nest structures associated with anthropogenic disturbance and decreased persecution (Birdlife International 2017b).

3.3.1.4 Overall Trends

Data were insufficient to assess trends for 14% of Arctic terrestrial bird taxa (species, subspecies, or populations). Excluding those taxa from the analysis, declines were most prevalent in waders (51% of 91 taxa with estimated trends) and least prevalent in waterfowl (25% of 61 taxa). Conversely, increasing population trends were most common in waterfowl (47% of 61 taxa) and least common in waders (15% of 91 taxa) and other waterbirds (13% of 15 taxa) (Figure 3-23).

These broad patterns were generally consistent across flyways, with some exceptions. Fewer waterfowl populations increased in the Central Asian and East Asian–Australasian Flyways. The largest proportion of declining species was among the waders in all but the Central Asian Flyway where the trends of a large majority of waders are unknown. Although declines were more prevalent among waders than other taxonomic groups in both the African–Eurasian and Americas Flyways, the former had a substantially larger number of stable and increasing species than the latter (Figure 3-23).

Regional differences are more pronounced in the insectivore guild (Figure 3-24). Although diversity of waders was moderate in the East Asian–Australasian Flyway, 88% (15 of 17) of taxa with known trends were declining—the largest proportion of any group. Both short-term (the last 15 years) and long-term (more than 30 years) trends were available for 157 taxa. Trends were unchanged over the two time periods for 80% of taxa, improved for 11% and worsened for 9%.

Estimates of quantitative indices of trends within North America are possible due to continuous time series monitoring data for most waterfowl and waders. Current estimates of Arctic-breeding waterfowl abundance tripled relative to the 1980s—largely due to increases in white geese—while Arctic-breeding waders halved in abundance and land birds declined by one-fifth.

While several taxa are declining, 10 species (in some cases subspecies) are currently included on the global Red List (see criteria in IUCN 2012a) as either Critically Endangered—three species, including the possibly extinct Eskimo curlew; Endangered—one species (great knot); or Vulnerable—six species. In addition, nine species are ranked in the less critical category Near Threatened (see the ranking of the species in Table 3-2). Nevertheless, based on current data many waders in North America meet the criteria for various Red List categories but formal designation is pending status review by IUCN (see further in Section 3.5).

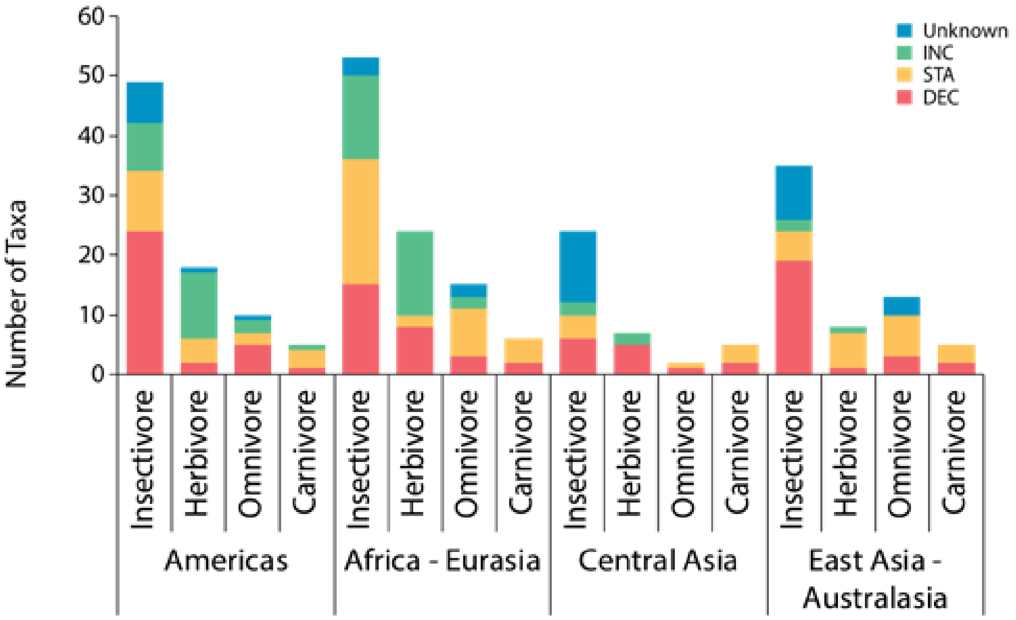


Figure 3-24. Trends in population abundance for four guilds of Arctic terrestrial bird species across flyways. Data is presented as total number of taxa. Modified from Smith et al. 2020.

3.3.2 EFFECT OF DRIVERS ON FECS AND THEIR ATTRIBUTES

Weather and Climate Stressors in the Arctic

Reproductive success of Arctic birds is highly variable across space and time for many reasons. For waders, predation—the primary cause of nest failure—may decrease with increasing latitude, vary with snow conditions, and weather, or change with variation in predator abundance and their preferred small mammal prey. Increased variability in snow cover observed in some of the Arctic breeding areas, as a manifestation of changing climatic conditions, can influence both the timing and the success of breeding efforts of ground-nesting waders. Whatever the underlying cause, recent results suggest declines in reproductive success of Arctic tundra waders since the 1990s, potentially contributing to the documented accelerating population declines. For some top predators, more variable weather during the breeding season, including increased frequency of heavy rain events and massive blackfly outbreaks in warm spells, is considered a contributing factor to reduced breeding success in some Arctic breeding populations of peregrine falcons (Anctil et al. 2014, Franke et al. 2016, Carlzon et al. 2018).

Changes in climate, and the resulting northward shifts in habitats, are expected to result in a corresponding shift in the range of Arctic species. For some bird species in northern regions this can result in improved living conditions, while for high Arctic species in particular, it may cause an 'Arctic squeeze' as suitable conditions are pushed northwards and upwards. There have been no long-term, multi-species reviews of distributional changes of Arctic birds, although standardised atlas censuses in sub-Arctic parts of Scandinavia have shown northward range shifts of 0.7 kilometres per year for northern bird species. The ***Arctic Biodiversity Assessment*** (CAFF 2013a) provides examples of range shifts, including snowy owls breeding further north in western Siberia and the range expansion of short-eared owl into the high Arctic in eastern Canada. In addition, in 2017, Lapland longspurs were found breeding six latitudinal degrees further north of the previous known range in east Greenland (Lee 2018). A slightly longer summer has been suggested as a reason for expanding peregrine falcon population in high Arctic northwest Greenland (Burnham et al. 2012). Modelling of future changes suggest that shrubification of tundra habitat and a shrinking high Arctic climate zone may influence the breeding ecology of Arctic-breeding raptors mediated through impacts on their prey, particularly for gyrfalcons via early season ptarmigan availability. For wader species, modelling has shown that climatically suitable breeding conditions could shift, contract, and decline over the next 70 years, with 66–83% of species losing the majority of currently suitable area, and that predicted spatial shifts of breeding grounds could affect the species composition of the world's major flyways (Wauchope et al. 2017).

Phenological mismatches are considered among the leading stressors of wildlife populations arising from climate change. The accelerated rate of warming at high latitudes advances spring causing arthropod activity to start and peak, potentially resulting in a mismatch in phenology between long-distance migrant bird populations and their food resources in the Arctic breeding grounds. For herbivores, mismatched timing of breeding can impair chick growth because of a reduced nutrient content of forage plants later in the growing season. However, the consequences of mismatch are arguably most acute for migrating breeding insectivorous species and, potentially, their predators. Arctic-nesting waders, for example, travel thousands of kilometres each spring to take advantage of a burst of arthropod prey during the Arctic summer. A phenological mismatch between the timing of reproduction and the period during which these arthropods are abundant is one of the key hypothesised effects of climate change on Arctic insectivores, with evidence of reduced growth rates of chicks due to mismatch, and reduced body size of juvenile red knots during years of early snowmelt in high Arctic Siberia. However, not all studies concur; Hudsonian godwits in Alaska remain appropriately timed with respect to arthropods, sanderling chicks in Greenland have not been affected by the apparent mismatch documented there, and evidence shows that temperature increases can alleviate some of the negative effects of phenological mismatch for waders via reduced thermoregulation costs. Similarly, for geese, higher spring temperatures result in less snow cover, elevated nesting densities, earlier nesting, and greater nesting success, although other aspects of warmer summers may negate such demographic benefits at other stages of the breeding season. For more information on phenology, see Box 3-3.

Stressors along the Flyways

Causal factors for trends in many taxa are found outside the Arctic along the flyways. Declines among waders in the East–Asian Australasian Flyway are thought to be related to a greater than 65% loss of intertidal habitat in the Yellow Sea (between China and the Korean Peninsula). The proportions of species' populations staging in the Yellow Sea was the strongest predictor of population trend, suggesting that failure to accrue sufficient resources during staging impacted a birds' survival post departure. Similarly, in the west Atlantic portion of the Americas Flyway, individuals of the endangered subspecies of red knot have been shown to have reduced survival when they depart the primary staging site, Delaware Bay, U.S., in poor body condition, as a consequence of reduced availability of their preferred forage, the eggs of horseshoe crabs (***Limulus polyphemus***). A study of bar-tailed godwits migrating from West Africa to the Siberian Arctic showed that the birds tried to catch up with earlier snow melt and main insect emergence in the breeding grounds by reducing refuelling time at their European staging site. Hence, conditions in the temperate zone may determine the ability of godwits to cope with climate-related changes in the Arctic. Finally, differential migration strategies may explain why Curlew sandpipers within the East Asian-Australasian Flyway are declining rapidly (9.5%– 5.5% per year) while Red-necked stints remain relatively stable (-3.1%–0%): While Curlew sandpipers rely mainly on the Yellow Sea region, which has recently experienced a sharp decline in suitable habitat, Red-necked stints make use of additional sites and spread their relative time en-route across sites more evenly (Lisovski et al., 2020).These examples demonstrate the crucial importance of conditions at migratory staging sites for Arctic waders, most of which are long-distance migrants. In addition, sea level rise may lead to the loss of dry tidal flats – along with other factors like aquaculture and infrastructure development – on the key stopover sites for Arctic waders along their flyways (Murray et al. 2019, Reneerkens 2020).

Similarly, most Arctic goose populations, that stage or winter in North America and western Europe, have increased as a result of reduced hunting pressure and increased food availability in agricultural landscapes outside of the breeding season. In Arctic North America, goose populations have increased to such an extent that they are adversely affecting some staging and breeding habitats through intensive grazing and consumption of the below-ground plant parts (known as grubbing). In some cases, this leads to lasting vegetation loss. Climate change has also been linked to the increase in the east Greenland population of white-fronted geese due to warmer and wetter conditions in the staging (Iceland) and wintering areas (Scotland and Ireland) affecting survival rates (Doyle et al. 2020). In contrast, many goose populations are declining in central and eastern Asia, in particular where species are confined outside of the breeding period to natural habitats of declining quality.

Figure 3-25. Geographical coverage of terrestrial bird FEC monitoring in the Arctic.

Much of the information on populations of migrant species summarised in this section builds on monitoring on wintering and staging sites outside the Arctic (not mapped). Modified from Taylor et al. 2020.

3.3.3 COVERAGE AND GAPS IN KNOWLEDGE AND MONITORING

Spatial and Temporal Coverage

Many population counts of gregarious migrant species, such as waders and geese, take place along the flyways and at wintering grounds outside the Arctic which stresses the importance of continued development of movement ecology studies. Monitoring of FEC attributes related to breeding success and links to environmental drivers within the Arctic takes place in a wide network of research sites across the Arctic, although with low coverage of the high Arctic zone (Figure 3-25). For some species, such as ptarmigan and carnivores, the coverage of monitoring sites is most dense in parts of North America, Europe, and western Russia, while vast areas of eastern Russia, the Canadian Archipelago and Greenland are sparsely covered. Nevertheless, a lack of geographical as well as temporal coverage of monitoring efforts is a problem across the circumpolar Arctic, limiting the ability to detect key changes. The monitoring coverage is currently uneven across FECs as well. Detecting and monitoring change requires comparisons across long time scales. For several terrestrial Arctic bird taxa, several decades of monitoring data from either breeding, staging, or wintering grounds are available. Examples include most geese populations (Fox and Leafloor, 2018), some waders (Deinet et al. 2015), ptarmigan (Fuglei et al. 2020) and falcons (Franke et al. 2020) – see these for discussion on variable data quality over decades of monitoring with shifting efforts and methods. Time spans covered by the monitoring programmes also differs widely across the Arctic with a tendency of longest time series from Europe and North America.

Data Quality

Despite efforts to monitor bird populations throughout the Arctic, ongoing efforts to improve and coordinate monitoring through the development of schemes such as the CBMP–Terrestrial Plan, important data gaps remain. Nearly half of all populations of Arctic tundra birds have monitoring information that is considered poor or worse. More than a quarter of tundra bird populations lack trends in abundance and the quality of monitoring information has not improved over the last 15 years compared with trends over longer time periods.

The quality of the monitoring data documenting trends in population abundance varies widely among regions and taxonomic groups (Figure 3-26). Trend data were lacking altogether, for any time period, for 36 of 224 taxa (16%). In all flyways, waterfowl and waders had the highest quality monitoring data followed by land birds and then water birds. The quality of monitoring in the Americas and African–Eurasian Flyways was markedly better than for the East Asian–Australasian and Central Asian Flyways. Population estimates and trends are generally best for species that congregate at well-identified staging sites during migration or winter, such as geese and some waders, and less precisely known for widespread species, such as many passerines, or solitary and thinly dispersed species such as the carnivores.

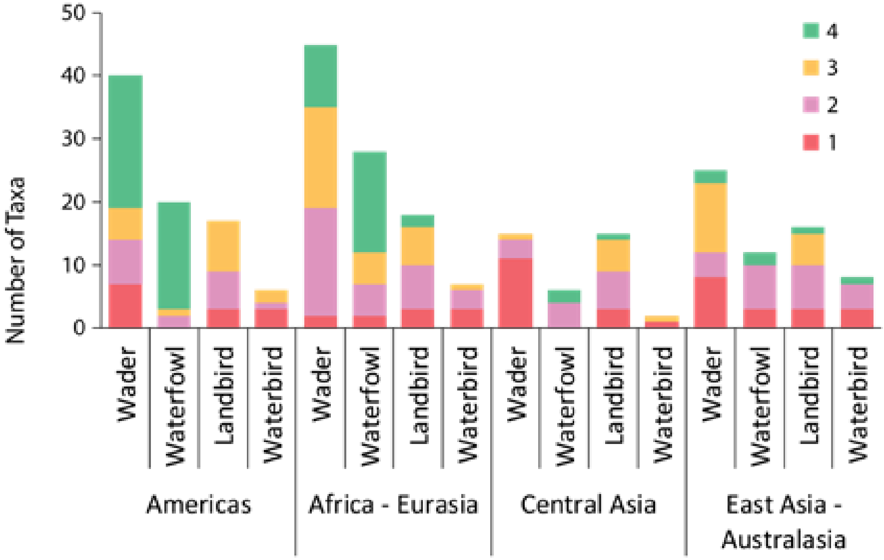


Figure 3-26. Quality of monitoring information used to describe trends in abundance for the taxonomic groups in four global flyways.

Trend quality categories are: (1) data are lacking such that trends are unknown, (2) regional and site-specific monitoring allow for assumptions of trend, (3) international monitoring allows estimation of trend direction, and (4) rigorously designed international monitoring programmes yield estimates of precision. Modified from Smith et al. 2020.

Willow ptarmigan. Photo: Nick Pecker/Shutterstock.com

However, it should be noted that the wintering ranges of some Arctic bird species populations overlap, reducing the reliability of population estimates based on winter counts. Moreover, flyway delineations of many biogeographic populations of Arctic migratory birds are still insufficiently known. Hence, there is a need to expand on the efforts of identifying and delineating flyways as well as on conducting censuses on the breeding grounds.

Information on status and trends in demographic parameters is generally even more fragmentary and is lacking for the majority of species in even the best monitored flyways. However, data on juvenile ratios have been collected for half a century, particularly by British ringing groups on Arctic and sub-Arctic wader populations. If the huge data sets could be worked up and published it would be a significant contribution to monitoring of CBMP–Terrestrial Plan FEC attribute 'demography' and benefit northern wader conservation (see Robinson et al. 2005). For some species, such as widespread Arctic passerines, even population structure is poorly defined, making regional gaps in monitoring difficult to identify.

The coverage of the 'essential' and 'recommended' FEC attributes across foraging guilds is best for 'abundance' and 'distribution'; for some guilds/species also 'temporal cycles', 'demography' (productivity) is relatively well monitored in parts of the Arctic.

As noted above, climate-related phenological mismatches are among the leading stressors of wildlife populations arising from anthropogenic climate change. Nevertheless, studies to date have shown considerable variation in the extent and effects of mismatch among species, which could be due to the short-term nature of many studies, the influence of local environmental drivers across study sites, life-history traits across species, or a combination of all of these factors. Thus, additional long-term, coordinated monitoring of wader and arthropod populations at different sites is required to improve our understanding of variation in mismatch vulnerabilities and the potential for population level effects.

There is also inadequate monitoring of expected shifts in distribution due to climate change. Consistent large-scale monitoring efforts that have shown range shifts in Scandinavia are lacking from the North American and Russian Arctic, making similarly rigorous analyses impossible. In addition, the network of research sites in the high Arctic is relatively limited, making range expansions and density changes difficult to detect. Wider involvement of community-based observations and citizen science can serve as an important gap-filler in monitoring shifts in bird species distributions.

3.3.3.1 Recommended Revisions to FECs and Key Attributes

The FEC attributes for birds are listed in Table 2-1. However, the FECs contain widely differing groups so additional distinction is required for practical monitoring and for interpreting the information in relation to ecosystems and effects of drivers. Table 3-3 recommends some revised groupings of FECs and 'essential' attributes for the future.

Table 3-3. Summary and recommended revisions of bird FECs and key attributes.

Recommended revisions are shown in ***bold italics*** *with the current category in brackets. The attribute considered most important for reporting for each FEC is highlighted in* ***orange****.*

'E' means essential attributes. 'R' means recommended attributes. Dashes indicate attributes not deemed as key for the particular FEC.

		FEC ATTRIBUTES							
FEC	GROUP	ABUNDANCE	DEMOGRAPHY (PRODUCTIVITY, SURVIVAL ETC.)	PHENOLOGY	DIVERSITY (COMMUNITY, GENETIC)	HEALTH (PATHOGENS, BODY CONDITION, CONTAMINANTS)	DISTRIBUTION (SPATIAL STRUCTURE, MIGRATION)	TEMPORAL CYCLES (PREDATOR-PREY INTERACTIONS)	REASONS FOR RECOMMENDED CHANGES
Herbivores	ptarmigan	***E***	E	E	R	R	E	E	Arctic residents, cyclic patterns in population density/productivity
	waterfowl (geese)	***E***	E	E	R	R	E		Migratory
Insectivores	waders	***E***	E	E	R	R	E	R	Long-distance migrants, partly aquatic ecology, monitored in Arctic and stopover/wintering sites
	passerines	***E***	E	E	R	R	E		Largely short -distance migrants, entirely terrestrial ecology, very limited monitoring in and outside Arctic
Carnivores	falcons, rough-legged buzzard, snowy owl, jaegers	E	***E***	E	R	***E*** (R)	E	***E*** (R)	Cyclic patterns in occupancy and productivity (except peregrine falcon); top predators ideal for continued contaminant monitoring
Omnivores	cranes, ducks, raven	***E***	E	E	R	R	E		Raven moved from carnivores; ducks recommended move to CBMP Freshwater or Coastal
Piscivores	loons, grebes	-	-	-	-	-	-	-	Not a terrestrial FEC, recommended move to CBMP Freshwater or Coastal

3.3.4 CONCLUSION AND KEY FINDINGS

The 88 Arctic-breeding terrestrial bird species are an integral component of Arctic ecosystems. They are both affected by biotic and abiotic factors and affect ecological change themselves. Overall, declines were most prevalent in waders and least prevalent in waterfowl (geese) and ptarmigan. Increasing population trends were most common in geese and least common in waders and other water birds. Within flyways, increases were generally most common in geese and least common among waders and water birds. Fewer waterfowl populations were increasing in the Central Asian and East Asian–Australasian flyways. The largest proportion of declining species was among the waders in all but the Central Asian Flyway, where a large majority of waders had unknown trends. Although declines were more prevalent among waders than other taxonomic groups in both the African–Eurasian and Americas flyways, the former had a substantially larger number of stable and increasing species.

Key Findings

Most species showed contrasting trends between different populations/flyways. This variation complicates drawing broad conclusions, except that since most bird species leave the Arctic in winter they are affected by a wider range of drivers and geographical scales than other FECs. A meta-view on 88 terrestrial Arctic tundra birds shows that:

- Many populations are stable or increasing; for some populations (mainly geese) the increase may be effects of global change – including land use outside the Arctic – allowing populations to increase beyond levels likely under undisturbed conditions.
- Variability across FECs is high, with more than half of all wader species ***declining*** and nearly half of all geese ***increasing***. Variability across flyways is also high, even within FECs. For example, 88% of waders are declining in the East Asian - Australasian Flyway, compared with 70% of wader populations stable or increasing in the African - Eurasian Flyway.
- For more than half of all species, there are reasons for concern for some flyway populations—57% of all species had at least one population in decline and for 21% of the species ***all*** populations were declining.
- Trends are unknown for at some populations in a quarter of species—mostly in the Central Asian Flyway; for the remaining species, the quality of trends information is highly variable.
- Ten species are ranked in the global 'threatened' categories according to IUCN criteria— including two species as Critically Endangered.
- Populations of both ptarmigan species showed both positive and negative trends with no clear links to geographical regions, and most populations displayed short and long population cycles linked to cycles in other herbivore species or driven by predation.
- Among the predators, breeding parameters of gyrfalcons, snowy owls and rough-legged buzzards are linked to prey with cyclic abundance like ptarmigan and rodents—for both falcon species, it is likely that breeding populations in the Arctic are relatively stable.
- Climate change affects different species and populations very differently with no consistent pattern—examples include breeding failure in ground-nesting waders in years of late snow melt, reduced breeding success in peregrine falcons due to increased frequency of heavy rain events and massive blackfly outbreaks in warm spells, and possible range expansion of peregrine falcons due to longer summer season in high Arctic. Although evidence is diverse, phenological mismatches are considered among the leading potential stressors of wildlife populations arising from climate change. The accelerated rate of warming at high latitudes advances spring, causing arthropod activity to start and peak, potentially resulting in a mismatch in phenology between long-distance migrant bird populations and their food resources in the Arctic breeding grounds.
- Main drivers of population change—positive as well as negative—outside the Arctic include harvesting and intensified land management (including agricultural practises, land reclamation and urban development).

Northern goshawk.
Photo: Andrei Stepanov/Shutterstcok.com

BOX 3-2. INDIGENOUS KNOWLEDGE AND ARCTIC BIRD RESEARCH AND CONSERVATION

Few people are more in tune with their environment and the wildlife they depend upon than Arctic Indigenous Peoples. Indigenous Knowledge[5] is essential for daily life and cultural resilience amongst Arctic Peoples. This knowledge can also help inform bird research, monitoring, management, and conservation. Due to the remoteness of most of the Arctic, scientific studies by non-resident scientists can be expensive, time-consuming and are often limited to small areas or short time periods.

Indigenous Knowledge holders carry lived experience, as well as wisdom passed down through millennia. This knowledge often covers larger areas, encompasses entire annual cycles, and covers more extended time periods than scientific studies. This long-term perspective provides unique insights into emerging issues and research priorities, and can help researchers select suitable species, locations, and habitats for studies. The rich historical context of Indigenous Knowledge offers baseline information that is otherwise unattainable but critical for identification of changes. Research pairing Indigenous Knowledge with mainstream science, the “two-eyed seeing” approach as developed by Mi’kmaw Elder Dr. Albert Marshall, is more robust and can lead to more effective and sustainable conservation outcomes. Partnerships between Indigenous Knowledge holders and visiting researchers build relationships through long-term monitoring and habitat management, which facilitates future collaborations. Much progress has been made at increasing the awareness of the scientific community of the need for meaningful collaboration with Indigenous Knowledge holders. However, there is room for increased partnership and cross-training.

Examples of successful collaborations include:

- Inuit from the Kivalliq region of Nunavut, Canada, along with Environment and Climate Change Canada (ECCC), had mutual concerns about changes occurring in coastal tundra wetlands due to climate change and degradation caused by increasing goose populations, and how these changes might influence bird populations in Nunavut. Inuit and scientists collaborated to define the research priorities and undertook a series of scientific and Indigenous Knowledge (Inuit Qaujimajatuqangit; IQ) studies to establish current status and reconstruct baselines of distribution and abundance that stretched back to the 1940s, far beyond the scientific records.
- The Kangut Project trained local researchers to carry out an IQ study in the communities of Arviat and Coral Harbour, Nunavut, Canada. This IQ study provided entirely new insights into snow goose nesting and moulting locations, timing of migration, and changes over time. Moreover, it provided crucial local perspectives on management concerns and priorities.

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[5] Indigenous Knowledge is a systematic way of thinking and knowing that is elaborated and applied to phenomena across biological, physical, cultural, and linguistic systems. Indigenous Knowledge is owned by the holders of that knowledge, often collectively, and is uniquely expressed and transmitted through Indigenous languages. It is a body of knowledge generated through cultural practices, lived experiences including extensive and multi-generational observations, lessons and skills. It has been developed and verified over millennia and is still developing in a living process, including knowledge acquired today and in the future, and it is passed on from generation to generation (ACPP 2014).

Members of the Ahiak Comanagement Committee, composed of five Inuit and one staff from Environment and Climate Change Canada. Photo: Vicky Johnston/ECCC

BOX 3-3. PHENOLOGICAL SHIFTS: CAN ARCTIC BIRDS KEEP UP WITH CHANGING CONDITIONS?

The Arctic is warming at a greater rate than other places on earth, with spring arriving up to two weeks earlier in some areas, compared to 3-4 decades ago. With rapid climate change, the potential for phenological mismatches increases, when the timing of ecological events and the responses of bird behaviours change at different rates, potentially leaving birds lacking necessary resources – a phenological mismatch. Arctic migratory birds may be particularly susceptible to the changes due to the narrow window of ideal conditions on breeding grounds. Climate changes and subsequent ecological alterations to habitat, food sources, predators and competitors could impact egg hatching success, chick fledging success and adult survival, all of which could affect bird species populations; see map below for Arctic sites where phenological mismatch has been studied.

Arctic-breeding birds expend energy resources and face risks migrating long distances each year. Over millennia, despite annual variability in reproductive output, this strategy has proven worthwhile. Birds use environmental cues in wintering and migratory stopover habitats to determine timing of migration and arrival on the breeding grounds. The timing of spring in the Arctic has always been variable, and Arctic-breeding bird species have adapted to survive this level of unpredictability over time, at the population level. Determining the best time for migration is important to an individual's breeding success and survival. Early arriving individuals may face snow and cold temperatures, while late arrivals may miss peak food resource availability, or may not allow enough time for their offspring to grow, fledge and gain energetic reserves for migration prior to the arrival of fall.

A few case studies illustrate the changes the Arctic is experiencing and the response of breeding birds:

- Around Utqiaġvik, Alaska, between 2003 and 2016, eight wader species showed an advancement of nest initiation between 0.1 to 0.9 days per year, while snowmelt advanced 0.8 days per year. This rate of change in snowmelt timing was six times faster than the rate of change over the previous 60-year period. The waders showed flexible nest initiation dates, varying from June 11 to June 21. No species appeared to be able to advance egg laying at the pace of snowmelt change. Species with an opportunistic nesting settlement strategy were more likely to respond to changing snowmelt conditions and later nesting species exhibited higher response rates to changes in snowmelt. A related recent seven-year study indicated that waders are experiencing phenological mismatches with invertebrate food resources from earlier snowmelt. Birds that nested earlier generally had more food availability during brood rearing. However, food availability related not only to initial invertebrate emergence timing but to variable daily weather conditions following initial emergence (Saalfeld & Lanctot 2017, Saalfeld et al. 2019).
- From 1977 to 2008, researchers monitored the arrival time of 12 wader species in the Yukon-Kuskokwim Delta, Alaska. Mean arrival dates for all species occurred over a 16-day period in May but species showed variability of over two weeks year to year. This arrival of most species correlates with the timing of 10% snow cover. To date, birds appear to be adjusting arrival in response to the variable annual spring conditions and show no long-term trends of change in arrival date (Ely et al. 2018).
- As Spring temperatures warm, certain reproductive strategies become advantageous. In Alaska, lesser snow geese and greater white-fronted geese are benefitting from improved foraging conditions due to warm temperatures arriving earlier, while black brant may be at a disadvantage. Snow geese and white-fronted geese utilise on-site resources at their Arctic breeding sites to provide fat and protein for egg development, while brant rely on resources accumulated prior to arrival at their nesting sites. Over time, as the warming trend continues, these changes could have significant population-level effects and potentially initiate other ecological consequences (Hupp et al. 2018).
- Studies of phenological mismatches between timing of reproduction and peak abundance of food in some species are shown in the map below. For example, for sanderlings in East

> Greenland, an increase in phenological mismatch of 22 days was observed in a period of 18 years (Reneerkens et al. 2016). Other species, for example Bar-tailed Godwits in the central-Russian Arctic, have been able to keep their timing of reproduction in synchrony with peak abundance of food, as observed during a study period of 17 years (Rakhimberdiev et al. 2018). Despite the differences in phenological mismatch, the fitness consequences of mismatches apparently vary and are still under scientific debate.

Many questions remain: What happens when climate continues to change at different rates in breeding areas versus migration and wintering habitats? Will changing conditions favour some species over others? What ecological effects will the changes in species composition have on other species and their habitat? The answers will likely vary by species, population, and location. Further ecological studies, combined with increased climatological data, will continue to increase the understanding of these changes, and will allow for informed adjustments in species and habitat management.

Study sites across the Arctic where phenological mismatches between timing of reproduction and peak abundance in food have been studied for terrestrial bird species. **Grey symbols** show study sites where this phenomenon has been studied for <10 years, **light red** symbols show sites with >10 years of data but no strong evidence of an increasing mismatch, and **dark red symbols** indicate sites with >10 years of data and strong evidence of an increasing mismatch. **Circles** indicate studies of shorebirds, **squares** for waterfowl and **diamonds** for both shorebirds and passerines. Graphic: Thomas Lameris, adapted from Zhemchuzhnikov (submitted).

Greater white-fronted goose nesting in snow. Photo: Dan Ruthrauff/USGS

Ruddy turnstone arriving in high Arctic breeding area, at Zackenberg, northeast Greenland. Photo: Erik Thomsen