



Arctic fox (*Vulpes lagopus*). Photo: Lars Holst Hansen

3.4 MAMMALS

The CBMP described six FECs for the monitoring of Arctic terrestrial mammals: large herbivores (*Rangifer*—reindeer/caribou, muskoxen, moose); medium-sized herbivores/omnivores (hares, ground squirrels); small herbivores (lemmings, voles); large predators (wolves, bears); medium-sized predators (wolverine, lynx, fox); and small predators (small mustelids, shrews). Not all mammal FECs are found throughout the circumpolar Arctic and this is particularly true for individual species within a FEC. For this reason, the CBMP–Terrestrial Plan focused on three FECs comprising four species that occupy a major role in the ecosystem and have circumpolar (or near circumpolar) distribution: large herbivores (*Rangifer*, muskoxen); small herbivores (lemming); and medium-sized predators (Arctic fox) (Figure 3-27). It also identified key attributes considered to be essential or recommended for monitoring of these functional groups (Table 2-1).

This section summarises the primary biotic, abiotic, and anthropogenic drivers of the terrestrial mammal populations and how they influence the various FECs (Figure 3-28), with a focus on the large and small herbivores

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Figure 3-27. Examples of Arctic terrestrial mammal species representing the large herbivore, small herbivore, and medium-sized predator FECs.

(a) Lemming, Photo: Anna Smirnova/Shutterstock.com, (b) Muskoxen (*Ovibos moschatus*), Photo: NaturesMomentsuk/Shutterstock.com, (c) Caribou/reindeer, Photo: Streamside Adventures/Shutterstock.com, and (d) Arctic fox (*Vulpes lagopus*), Photo: Joanna Perchaluk/Shutterstock.com.

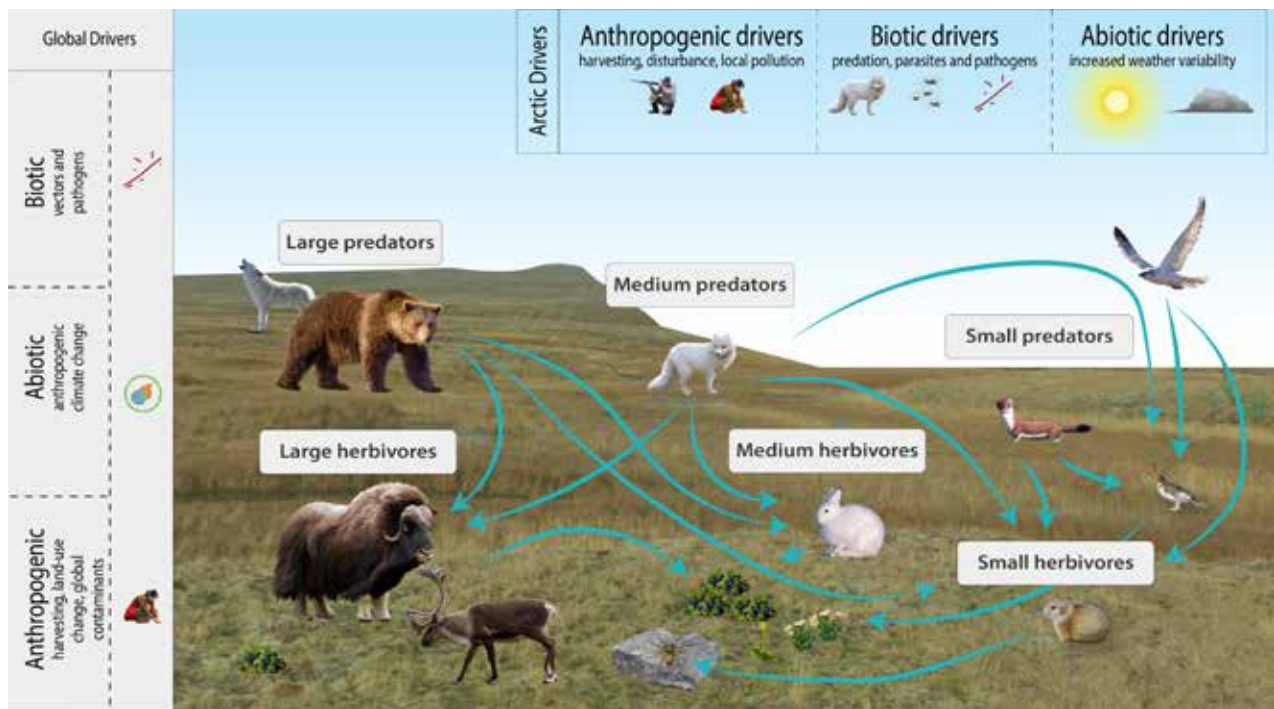


Figure 3-28. Conceptual model of Arctic terrestrial mammals, showing FECs, interactions with other biotic groups and examples of drivers and attributes relevant at various spatial scales.

and medium-sized predators for which international monitoring networks have been established. It is largely based on Berteaux et al. (2017), Cuyler et al. (2020) and Ehrich et al. (2020). For information and references not included in these articles, references are provided. The information for *Rangifer* is from the Circumarctic Rangifer Monitoring and Assessment (CARMA) network, the Committee on the Status of Endangered Wildlife in Canada (COSEWIC), Environment and Climate Change Canada, the Alaska Department of Fish and Game and the Canadian provincial wildlife management agencies of Ontario, Quebec, and Yukon. The remaining three mammal FECs (large and small predators and medium-sized herbivores) remain challenging to summarise at this time in the absence of consistent, widespread monitoring efforts throughout the circumpolar Arctic.

Large Herbivores

The two large herbivore species this report focuses on are *Rangifer tarandus* and *Ovibos moschatus* (muskoxen). Both species are circumpolar in distribution. In North America and Greenland, *R. tarandus* is known as caribou, whereas the same species is known as reindeer in Eurasia. This report uses the term *Rangifer* to refer to the species collectively. In almost all Arctic nations, semi-domestic populations of *Rangifer* are managed as free-ranging livestock and, in some cases, these outnumber wild populations (for example in Sweden and Finland). This report however refers to the wild or native *Rangifer* unless otherwise specified.

While 12 subspecies of *Rangifer* are recognised, the ecology of local populations varies more in accordance with the available landscape than by genotype; thus, populations are more commonly classified into four 'ecotypes' delineated by local environmental conditions that influence habitat use and behaviour (Mallory & Hillis 1998). The migratory tundra or barren-ground ecotype of *Rangifer* is the most numerous and conspicuous in the Arctic, known for large aggregations of thousands of individuals and wide-ranging annual migrations of hundreds of kilometres between calving and winter ranges. The Arctic islands ecotype differs in that populations are constrained by available habitat and while some populations are migratory others are not. The mountain ecotype inhabits mountainous regions and migrations are limited to seasonal movements between high and low elevations to avoid predators and access resources. Finally, the forest or boreal ecotype inhabits sub-Arctic regions and typically occurs at the lowest population densities of all ecotypes and makes minimal seasonal migrations.

Muskoxen are split into two subspecies, *O. m. wardi* and *O. m. moschatus*. Unlike *Rangifer*, muskoxen exhibit very low genetic diversity, even when comparing the two subspecies. This low diversity is exacerbated by a number of translocated populations, often founded by low numbers of individuals from predominantly one source, northeast Greenland, which had already lost much of its diversity.

Rangifer and muskoxen play important roles in Arctic ecosystems. Muskoxen and some *Rangifer* populations are relatively sedentary, whereas the migrations of some *Rangifer* populations are among the longest of any land mammals (Tucker et al. 2018, Joly et al. 2019). This has important ramifications for ecosystem function as well as the availability of this resource to predators, including humans, in the Arctic. Both *Rangifer* and muskoxen alter the distribution of plant species and nutrients. In addition to their role in ecosystem function, they are important for food security in Arctic communities, the cultural identity of Northern Peoples and, in some instances, provide economic opportunities.

The CBMP–Terrestrial Plan identified both *Rangifer* and muskoxen as essential FECs for assessing status and trends. These species are tracked by international groups of experts. For *Rangifer*, this is the CARMA network. CARMA maintains data sets on migratory populations and gathers information on non-migratory populations. For muskoxen, the Muskox Knowledge Network (MOXNET) consists of government and non-governmental agencies, Indigenous Peoples, businesses, and academics, who exchange information.

Until the creation of the CBMP mammal networks, there was only minimal collaboration or interaction within or between states, jurisdictions or even among scientists. By including a broad variety of stakeholders, the CBMP networks are building bridges of communication and collaboration that can facilitate the creation and effective implementation of standardised monitoring protocols. With collaboration, integrating the cumulative effects of the drivers (essentially climate and anthropomorphic related) changing species abundance and demographics will be possible. Ultimately, integration across ecosystems is the goal.

Small herbivores

This report focuses on the status and trends of lemmings as representing the truly Arctic small herbivores. Voles, the other small herbivores present in the low Arctic, are mainly boreal species that are also found in the Arctic. Lemmings are a key component of Arctic food webs and changes in their dynamics can affect the whole ecosystem through:

- ▶ flow of energy from plants to avian and mammalian predators, with effects on the vertebrate food web;
- ▶ population cycles with large (periodic) outbreaks, impacting predator–prey dynamics and vegetation;
- ▶ pulses of herbivory and resources for predators; and
- ▶ indirect effects of lemming cycles on many tundra-breeding birds, such as geese and waders, which serve as alternative prey for predators.

Brown lemmings (*Lemmus spp.*) and collared lemmings (*Dicrostonyx spp.*) are central FECs of Arctic ecosystems because they are the only small rodents with natural distributions in high Arctic regions. They are also found

throughout the low Arctic, where they usually co-exist with vole species. Both genera are widespread throughout the Arctic and often occur together; but there is never more than one species per genus at a given locality.

Brown lemmings include the Siberian brown lemming (*L. sibiricus*), the Norway lemming (*L. lemmus*), the Wrangel Island brown lemming (*L. portenkoi*) and the Nearctic brown lemming (*L. trimucronatus*) (the only species of brown lemming in North America). Collared lemmings include four species in the Nearctic (North America and Greenland)—Nearctic collared lemming (*D. groenlandicus*), Nelson’s collared lemming (*D. nelsoni*), Richardson’s collared lemming (*D. richardsoni*) and Ungava collared lemming (*D. hudsonicus*)—and two species in the Palaearctic—Palaearctic collared lemming (*D. torquatus*) and Wrangel Island lemming (*D. vinogradovii*). The exact number of geographic species/sub-species has been revised several times during the last decades (Wilson & Reeder 2005).

Medium-sized Predators

This report focuses on the status and trends of Arctic fox (*Vulpes lagopus*), the only medium-sized terrestrial mammalian predator that occurs throughout the circumpolar Arctic. It is recognised as an FEC due to its circumpolar distribution, role in the trophic dynamics of the tundra—where they often are the main predator and mediator of indirect trophic interactions—and strong sensitivity to climate change (IUCN 2009). As a widespread predator, Arctic foxes use a variety of resources. Two different ecological strategies have been identified in Arctic foxes, one focused mainly on lemmings and the second focused on birds, marine food, or large mammal carcasses, although recent research emphasises that these are two extremes of a gradient of strategies. While Arctic fox is the focal medium-sized predator in this report, red fox (*V. vulpes*) occur at over half of the Arctic fox monitoring sites. Typically, this overlap occurs at study sites where mean summer temperatures are above 8°C.

3.4.1 PATTERNS AND TRENDS OF FECS AND THEIR ATTRIBUTES

3.4.1.1 Large Herbivores

Rangifer

Abundance of *Rangifer* populations vary substantially through natural cycles and fluctuations due to density-dependent processes. Variations in abundance can exceed ten-fold through population cycles over several decades. Trends in *Rangifer* populations should be assessed in this context. Some populations are also vulnerable to stressors such as a warming climate and industrial impacts—including habitat fragmentation and degradation and disturbance from noise, dust, and light. These multiple and interacting stressors are cause for concern and may contribute to the historic lows currently observed in some populations. Although not all populations fluctuate synchronously, there can be a strong degree of synchrony among adjacent populations in large regions, for example mainland Canada (CARMA 2020).

In 2017, the migratory tundra population of *Rangifer* was approximately 2.2 million individuals in the U.S. (Alaska), Canada, Greenland, and Russia (Table 3-4). This represents a decline from about 5 million in the 1990s, when many populations were at peak size. This global declining trend has critical implications for the food security of Arctic Peoples (CARMA 2020).

Between 2003 and 2017, three Alaskan populations declined by an average of 54%. Two other populations, shared with Canada, are increasing. One population, the Forty-Mile, is increasing due to targeted conservation efforts that have permitted natural rebounded from approximately 5,000 individuals in the 1970s to 73,000 individuals in 2017. The second population shared with Canada, the Porcupine, increased by an exponential rate of 0.05 between 2001 and 2017 (Table 3-4, Figure 3-29). Caribou populations are an important resource for subsistence harvesters in Alaska and Canada.



Reindeer. Photo: Evgenii Mitroshin/Shutterstock.com

Table 3-4. Population estimates and trends for Rangifer populations of the migratory tundra, Arctic island, mountain, and forest ecotypes where their circumpolar distribution intersects the CAFF boundary.

Population trends (**Increasing**, **Stable**, **Decreasing**, or **Unknown**) are indicated by shading. Data sources for each population are indicated as footnotes.

POPULATION	ECOTYPE	JURISDICTION	MOST RECENT SURVEY YEAR	POPULATION ESTIMATE AND TREND
Mulchatna ¹	Migratory tundra	U.S. (Alaska)	2013	18,308
Northern Peninsula ²	Migratory tundra	U.S. (Alaska)	2013	2,700
Southern Peninsula ³	Migratory tundra	U.S. (Alaska)	2013	877
Unimak ⁴	Migratory tundra	U.S. (Alaska)	2013	192
Adak ⁵	Migratory tundra	U.S. (Alaska)	2012	2,900
Western Arctic ⁶	Migratory tundra	U.S. (Alaska)	2016	201,000
Teshekpuk ⁶	Migratory tundra	U.S. (Alaska)	2015	41,542
Central Arctic ⁶	Migratory tundra	U.S. (Alaska)	2016	22,630
Forty Mile ⁷	Migratory tundra	U.S. (Alaska)/Canada (Yukon)	2017	73,009
Porcupine ⁸	Migratory tundra	U.S. (Alaska)/Canada (Yukon)	2013	197,000
Tuktoyaktuk Peninsula ⁸	Migratory tundra	Canada (Northwest Territories)	2015	1,701
Cape Bathurst ⁸	Migratory tundra	Canada (Northwest Territories)	2015	2,259
Bluenose West ⁸	Migratory tundra	Canada (Northwest Territories)	2015	15,268
Bluenose East ⁸	Migratory tundra	Canada (Northwest Territories/ Nunavut)	2015	38,592
Bathurst ⁸	Migratory tundra	Canada (Northwest Territories/ Nunavut)	2015	19,769
Ahiak/Beverly ⁸	Migratory tundra	Canada (Northwest Territories/ Nunavut)	2011	195,529
Boothia Peninsula ⁸	Migratory tundra	Canada (Nunavut)	1995	6,658
Lorillard and Wager Bay ⁸	Migratory tundra	Canada (Nunavut)	2002	41,000
Qamanirjuaq ⁸	Migratory tundra	Canada (Nunavut/Northwest Territories/Saskatchewan/ Manitoba)	2014	264,661
Baffin Island ⁸	Migratory tundra	Canada (Nunavut)	2014	4,856
Southampton Island ⁸	Migratory tundra	Canada (Nunavut)	2015	12,297
Coats Island ⁸	Migratory tundra	Canada (Nunavut)	1991	500
Cape Churchill ⁹	Migratory tundra	Canada (Manitoba/Ontario)	2007	2,937
Southern Hudson Bay ⁹	Migratory tundra	Canada (Ontario)	2011	16,638
Leaf River ⁹	Migratory tundra	Canada (Quebec)	2016	199,000
George River ⁹	Migratory tundra	Canada (Quebec/Labrador)	2016	8,938
Inglefield Land	Migratory tundra	Greenland	1999	2,260
Olrik Fjord	Migratory tundra	Greenland	2001	31
Nuussuaq Halvø	Migratory tundra	Greenland	2002	1,164
Naternaq	Migratory tundra	Greenland	1995	271
Kangerluusuaq–Sisimiut ¹⁰	Migratory tundra	Greenland	2010	98,300**
Akia–Maniitsoq ¹⁰	Migratory tundra	Greenland	2010	24,000**
Ameralik	Migratory tundra	Greenland	2012	11,700**
Qeqertarsuaatsiaat	Migratory tundra	Greenland	2012	4,800
Qassit	Migratory tundra	Greenland	2000	196
Neria	Migratory tundra	Greenland	2000	1,600
Ivittuut	Feral reindeer	Greenland	N/A	

POPULATION	ECOTYPE	JURISDICTION	MOST RECENT SURVEY YEAR	POPULATION ESTIMATE AND TREND
Taymyr ¹¹	Migratory tundra	Russia	2003	500,000
Lena–Olenyk ¹¹	Migratory tundra	Russia	2009	95,000
Yana Indigurka ¹¹	Migratory tundra	Russia	2015	34,000
Sundrun ¹¹	Migratory tundra	Russia	2002	28,500
Chukotka ¹¹	Migratory tundra	Russia	2005	93,700
Dolphin and Union ¹²	Arctic Island	Canada (Nunavut/Northwest Territories)	2015	18,413
Banks–Victoria ¹³	Arctic Island	Canada (Nunavut/Northwest Territories)	2015	2,252
Western Queen Elizabeth ¹³	Arctic Island	Canada (Nunavut/Northwest Territories)	2013	7,300
East Queen Elizabeth ¹³	Arctic Island	Canada (Nunavut)	2007	3,173
Prince of Wales – Somerset – Boothia ¹³	Arctic Island	Canada (Nunavut)	2005	6
Svalbard ¹⁴	Arctic Island	Norway	2016	22,435
Novaya Zemlya Island ¹⁵	Arctic Island	Russia	Ca.2015	5,000
Severnaya Zemlya Islands ^{15,16}	Arctic Island	Russia	Ca.1985	300
New Siberian Islands ¹⁵	Arctic Island	Russia	Ca.2005	10–15,000
Bonnet Plume ¹⁷	Mountain	Canada (Yukon/Northwest Territories)	1982	5,000
Coal River ¹⁷	Mountain	Canada (Yukon/Northwest Territories)	2008	450–700
Finlayson ¹⁷	Mountain	Canada (Yukon)	2003	3,100
Hart River ¹⁷	Mountain	Canada (Yukon)	2015	2,660
Tay River ¹⁷	Mountain	Canada (Yukon)	1991	3,750
Redstone ¹⁷	Mountain	Canada (Yukon/Northwest Territories)	2012	10,000
South Nahanni ¹⁷	Mountain	Canada (Yukon/Northwest Territories)	2009	2,100
Labiche ¹⁷	Mountain	Canada (Yukon/Northwest Territories)	1993	450–700
Liard Plateau ¹⁷	Mountain	Canada (Yukon/British Columbia)	2011	150
Muskwa ¹⁸	Mountain	Canada (British Columbia)	2007	1,000
Pink Mountain ¹⁸	Mountain	Canada (British Columbia)	1993	1,725
Graham ¹⁸	Mountain	Canada (British Columbia)	2009	708
Torngat Mountains ¹⁹	Mountain	Canada (Quebec/Nunavut/Labrador)	2017	1,326
Iceland ²⁰	Mountain	Iceland	2015	5,000
Gwich'in, Inuvialuit, Sahtú, Wek'èezhii, southern NWT ²¹	Forest	Canada (Northwest Territories)	2012	6,500
Maxhamish, Calendar, Snake–Sahtahneh, Parker, Prophet ²¹	Forest	Canada (British Columbia)	2012	1,000
Chinchaga, Bistcho, Yates, Caribou Mountains ²¹	Forest	Canada (Alberta)	2012	1,100

POPULATION	ECOTYPE	JURISDICTION	MOST RECENT SURVEY YEAR	POPULATION ESTIMATE AND TREND
Spirit, Swan, Ozhiski, Missisa, James Bay, Kesagami ²²	Forest	Canada (Ontario)	2011	2,112
Quebec boreal caribou ²³	Forest	Canada (Quebec)	2012	6,740
Lac Joseph, Red Wine, Mealy Mountain ²¹	Forest	Canada (Labrador)	2012	2,983
Karelia and other Russian populations ²⁴	Forest	Russia	2015	12,800

¹Barten 2015, ²Crowley 2015a, ³Peterson 2015, ⁴Crowley 2015b, ⁵Ricca et al. 2014, ⁶ADFG 2017, ⁷Harvest Management Coalition 2019, ⁸COSEWIC 2016, ⁹COSEWIC 2017b, ¹⁰Cuyler et al. 2016, ¹¹CARMA 2020, ¹²COSEWIC 2017a, ¹³COSEWIC, 2015, ¹⁴Le Moullec et al. 2019, ¹⁵Mizin et al. 2018, ¹⁶Belikov and Kupriyanov 1985, ¹⁷Environment Yukon 2016, ¹⁸COSEWIC 2014, ¹⁹Couturier et al. 2018, ²⁰Pórisson 2018, ²¹Environment Canada 2012, ²²MNRF 2014a,b, ²³Équipe de Rétablissement du Caribou Forestier du Québec 2013, ²⁴Gunn 2016

**2010 and 2012 survey (Cuyler et al. 2011) results considered out of date; 2018 survey suggests decline in Kangerlussuaq–Sisimiut while 2019 survey suggests increase in Akia–Maniitsoq and Ameralik (Cuyler unpublished)



Figure 3-29. Trends and distribution of Rangifer populations based on Table 3-4.

Several smaller populations of caribou inhabit sub-Arctic portions of Alaska, including five populations along the Aleutian Archipelago and west coast. These populations are considered part of the migratory tundra ecotype based on genetics, although in some instances their ecology and habitat are similar to the mountain caribou ecotype found in western Canada. Population dynamics and trends for these populations are variable (Figure 3-29). They are managed by the Alaska Department of Fish and Game through hunting quotas.

In Canada, migratory tundra caribou belong to two sets of populations that share similar ecological characteristics but different genotypes—the barren-ground caribou inhabiting the mainland tundra and lower Arctic islands to the north and west of Hudson Bay and the eastern migratory populations along the south and eastern shores of Hudson Bay through to Labrador. Overall, numbers of migratory tundra caribou have declined (Figure 3-29) from approximately 3 to 1 million across 17 populations between 1989 and 2016 (COSEWIC 2016, 2017b). The average decline is estimated at 56% since 1989, and five populations declined by more than 80% from peak numbers. While natural fluctuations were common for these populations in the past, current demographic data and threats from changing climate and industrial development are without historical precedent. Barren-ground caribou are assessed as threatened by the Committee on the Status of Endangered Wildlife in Canada (COSEWIC 2016) and the eastern migratory population to be designated as endangered (COSEWIC 2017b). See also Box 3-4.

Although Greenland caribou are typically included with the migratory tundra populations, expanses of tundra similar to that of North America and Russia are absent in mountainous Greenland. Furthermore, Greenland caribou exhibit minimal seasonal movements, which are highly individualistic rather than the aggregations typical of the migratory tundra populations. As such, Greenland caribou ecology resembles a mixture of mountain and Arctic island populations (Cuyler & Linnell 2004, Cuyler et al. 2017). In Greenland, harvest management regulates 11 caribou populations of which 10 are likely a genetic mix of native caribou and feral semi-domestic reindeer. Monitoring is infrequent and typically only includes the four commercially important populations in southwest Greenland. These are the Kangerlussuaq–Sisimiut, Akia–Maniitsoq, Ameralik and Qeqertarsuaat populations. The four populations combined make up 96 to 97% of all caribou in Greenland. The Kangerlussuaq–Sisimiut and Akia–Maniitsoq populations are the two largest in Greenland and are CARMA reference populations. Although changes in census methods and surveyed areas obscure trends, Local Knowledge for southwest Greenland is unanimous that there was an increase in abundance in the 1970s and populations have remained high since. Between 2000 and 2012, the status of Greenland caribou appeared stable (Figure 3-29) at approximately

140,000. The 2018 and 2019 aerial surveys covered only the Kangerlussuaq–Sisimiut, Akia–Maniitsoq and Ameralik populations in southwest Greenland. The as yet unpublished preliminary results suggest decline in the Kangerlussuaq–Sisimiut population but growth in both Akia–Maniitsoq and Ameralik.

In Russia, the current status of migratory tundra reindeer is 510,000 individuals, with an overall declining trend (Figure 3-29). The largest population, the Taymyr population, declined from an estimated 1 million in 2000 to 370,000 in 2017. On the Yamal Peninsula, abundance has declined from 3,000 to 2,000 between 1991 and 2015. The North Yakutia populations (Yana–Indigurka and Sundrunskaya) peaked in the 1990s and then subsequently declined. In contrast, the Lena–Olenek population increased from 55,000 in 1985 to 95,000 in 2009 and the Chukotka population increased from 33,000 in 1991 to 93,700 by 2015. Evaluating trends is complicated in some instances due to the loss of semi-domestic reindeer to wild populations.

Arctic island populations of *Rangifer* are found in Canada, Norway (Svalbard) and Russia. The current population is estimated at approximately 62,000 (Table 3-4). Russia and Canada report long-term declines in abundance since the 1960s (Figure 3-29).

On the Russian Arctic islands, the Russian endemic subspecies *R. t. pearsoni* is restricted to Novaya Zemlya Island, where the population declined to about 5,000 individuals in 2015 from an estimated 15,000 in 1998 (Mizin et al. 2018). In addition to Novaya Zemlya, there is a stable population of 10,000 to 15,000 individuals on the New Siberian Islands. A small population also occurs on Severnaya Zemlya—300 individuals in the 1980s (Belikov & Kupriyanov 1985)—although no surveys have been conducted recently and current status is uncertain (Mizin et al. 2018).

In the Canadian Archipelago, Arctic island *Rangifer* consist of Peary caribou (*R. t. pearyi*) and Dolphin and Union caribou (*R. t. groenlandicus*). Peary caribou occur in four populations based on movement of individuals between groups of islands. Peary caribou have declined by about 75% from an estimated 22,000 individuals in 1987 to 5,400 individuals in the mid-1990s, partly due to a large die-off around that time related to severe icing events. In 2014, the total Peary caribou population was estimated at 14,000, mostly due to rebounds in the Banks–Victoria and the Western Queen Elizabeth populations; however, in the most recent surveys of the Prince of Wales–Somerset–Boothia population only six individuals were observed and there is no sign of recovery (COSEWIC 2015). Dolphin and Union caribou are unique for their sea-ice dependent migration between Victoria Island and the continental mainland. They have undergone several range contractions and expansions since the beginning of the 20th century, however in the past two decades they have declined

by 50 to 60% from about 34,000 individuals in 1997 to 18,400 in 2015. While fluctuations in the Dolphin and Union population have occurred naturally in the past, concerns remain that recovery from current declines may be hampered by multiple novel threats, including decreases in sea ice connectivity between winter and summer ranges due to increased icebreaker and commercial shipping traffic as well as climate change.

Arctic island *Rangifer* are also found in areas of the Svalbard Archipelago. Historic (pre-1925) overharvest nearly eradicated this endemic subspecies (*R. t. platyrhynchus*). Nevertheless, this has been followed by over half a century of total protection. Recently, strict harvest management has been permitted. Today, this population has recolonised almost all previous ranges. Current population estimate for the entire Archipelago is approximately 22,500 (Le Moullec et al. 2019).

Populations of *Rangifer* of the mountain ecotype occur within the CAFF boundary in Canada and Iceland (in Norway only south of the CAFF boundary). Generally, mountain *Rangifer* populations occur at lower densities than migratory tundra populations, however it is unclear whether this is due to the resource limitations of the mountainous terrain they inhabit or a longer history of habitat fragmentation and degradation in sub-Arctic regions with larger human populations and more resource development. Currently, within the CAFF boundary there are approximately 37,000 mountain *Rangifer* in at least 14 recognised populations in Arctic and sub-Arctic mountains (Table 3-4).

In Canada, the majority of mountain populations within the CAFF boundary are in the Mackenzie Mountains and northern Rocky Mountains of British Columbia, the Northwest Territories and Yukon. There is an additional population of mountain caribou in the Torngat Mountains of northeast Quebec, Labrador, and Nunavut. The western populations number 31,000 individuals. Many of the largest populations, such as Redstone and Bonnet Plume, are considered stable at 10,000 and 5,000 individuals respectively (COSEWIC 2014). The Torngat Mountain population, however, has been assessed by COSEWIC as endangered, with a decline from 5,000 individuals to 930 individuals between 1980 and 2014 (COSEWIC 2017), although the peak population size may have been overestimated (Couturier et al. 2018). A more recent aerial survey estimated the Torngat Mountains population at 1,326 individuals, although with only two rigorous aerial surveys the trend of this population is still uncertain (Couturier et al. 2018).

The *Rangifer* of Iceland are descended from 35 semi-domestic reindeer translocated in the late 1700s from Norway. Numbers were estimated at approximately 3,500 in 2002 and currently number around 10,000 individuals. The population is free from large predators and abundance is closely managed using hunter harvest.

The forest populations of *Rangifer* live in sub-Arctic boreal regions along the southern CAFF boundary. In general, these populations do not form large aggregations like those of migratory tundra *Rangifer* and migrate only short distances to nearby seasonal ranges. In Canada, forest *Rangifer* are known as boreal caribou. There are 20 recognised populations, whose ranges are primarily located within the CAFF boundary, numbering approximately 20,500 individuals in total (Environment and Climate Change Canada 2012). Boreal caribou are legally listed as threatened under the Species at Risk Act in Canada, largely due to the impacts of industrial development on habitat and predator-prey dynamics.

Several populations of forest *Rangifer* also occur in Russia (Gunn 2016), although not all populations are within the CAFF boundary. Determining the status of these populations is challenging due to partial range overlap with migratory tundra populations and the difficulty of distinguishing between the two during survey efforts. Forest *Rangifer* also occur in low numbers in the Kainuu Region of Finland (Gunn 2016); however, these populations are south of the CAFF boundary.

Monitoring data on demographic, health, genetic diversity, and phenology parameters for *Rangifer* are less available than abundance data. CARMA (2015) found that monitoring frequency, methods and target data used to assess *Rangifer* populations varied among surveys, limiting comparative analyses across populations. A synthesis of trends of the FEC attributes for *Rangifer* is not currently available. Data are available for some of the populations through CARMA (Gunn & Russell 2015).

Distribution is also important for the assessment of *Rangifer* populations. *Rangifer* are distributed across tundra and boreal forests. Changes in the distribution of continental tundra *Rangifer* from historic eras to contemporary times are poorly known. Syroechkovskiy (2000) reported that Russian *Rangifer* distribution has contracted to the North and West, and become fragmented over 85% of its former range. Likewise, and based on Indigenous Knowledge, the southern extent of the winter distribution of migratory tundra populations in the boreal forests of central Canada has declined since 1935.

CARMA recently (2017) compiled available collar data (unpublished) for North American populations and found overall distributions have declined for all seasons since 2010 with the most marked decline being calving grounds (22% decline) and winter range (18% decline). Conversely, the area change for summer range was a 2% decline.

BOX 3-4. DRAMATIC *RANGIFER* POPULATION AND DISTRIBUTION DECLINES: TWO CASE STUDIES FROM THE CANADIAN ARCTIC

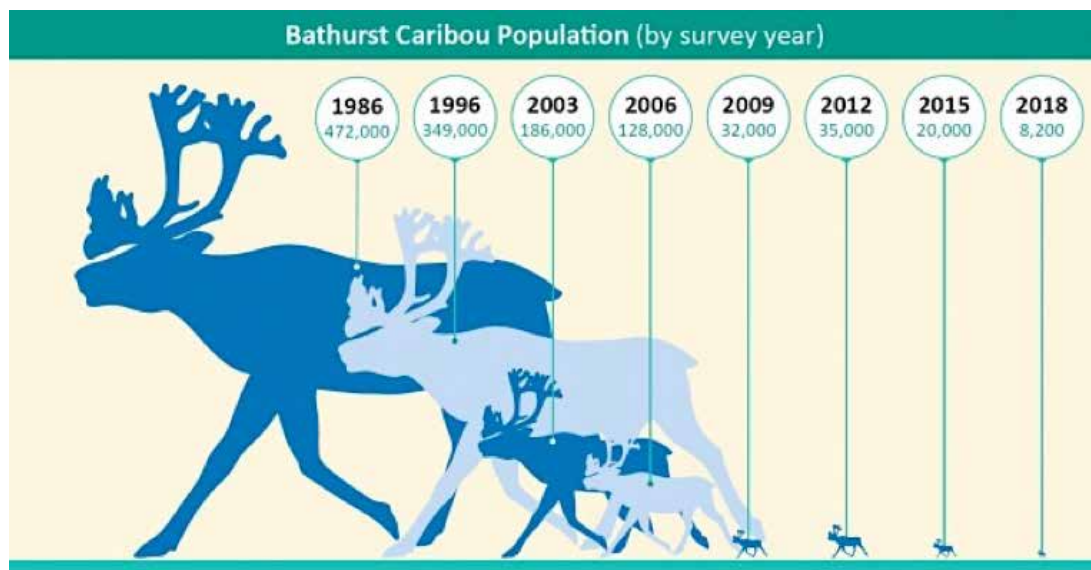
Migratory *Rangifer* populations have cyclical population dynamics and large fluctuations are well documented due to the cultural importance of Rangifer for Indigenous Peoples and the highly conspicuous phenomenon of long-distance seasonal migrations. However, while most historic accounts of declines in the early 20th century were followed by rebounds in population, current declines in migratory populations are more concerning due to unprecedented and sustained reductions in population size, and a novel set of obstacles to population recovery due to climate change and increased industrial development.

In the case of the George River population in northern Quebec and Labrador, at peak population size in the early 1990s it was considered the largest population of a migratory ungulate at nearly 1 million individuals, which was followed by a 99% reduction to less than 9,000 individuals in 2016 and an 85% reduction in range. The decline is thought to have been driven in part by density-dependence, as evidenced by overgrazed lichen habitats and poor body condition; however, other factors are thought to have contributed, such as industrial impacts on habitat, overharvesting, and changes in climate. While the exact mechanisms remain uncertain, the decline of the George River population prompted an assessment and classification by COSEWIC of endangered and threatened the food security and cultural wellbeing of the Indigenous Peoples of Labrador and northern Quebec who traditionally depend on the population. In addition to reaching the lowest population size since assessments began in the 1940s, the threats to recovery for this population include, further habitat change due to climate change, increasing industrial development within the population's range—including calving and migration routes—and amplified harvesting effects in the context of low populations levels. The Ungava Peninsula Caribou Aboriginal Round Table was assembled in 2017 and has brought together Indigenous governments to work together to conserve the George River population for future generations.



Ungava Peninsula Caribou Aboriginal Roundtable. Photo:Nadia Saganash, used with permission

Over a similar timeframe, the Bathurst migratory population in Northwest Territories declined by 98% between 1986 and 2015, from approximately 450,000 to 8,200. Simultaneously, the size of post-calving and autumn ranges declined based on Indigenous Knowledge and data from satellite telemetry of collared individuals. In addition to changes in spatial use, by 2017, the population also changed their use of habitat—previously they wintered in the boreal forest and presently they winter on the tundra. This change in wintering grounds reduced the extent of the spring migration by a straight line distance of approximately 500 kilometres, a 50% reduction from the spring migrations typical in the late 1990s. Indigenous communities, concerned by the decline and impact on harvest opportunities and cultural wellbeing over the short- and long-terms, requested the aid of the federal and territorial governments in the establishment of a Bathurst Caribou Advisory Committee and to co-develop a range plan to provide the herd with a resilient landscape to support the population through multi-decadal dynamics and manage cumulative impacts of landscape disturbance with harvest opportunities for Indigenous communities.



Graphic from Northwest Territories Department of Environment

Muskoxen

MOXNET identified 55 muskox populations (Table 3-5), including both native and translocated animals. The designated populations often reflect administrative or political regions rather than distinct muskox populations and their distribution within a region. Two subspecies of muskoxen, *O. m. wardi* and *O. m. moschatus*, are recognised. They are often referred to as ‘white-faced’ and ‘barren-ground’, respectively.

Table 3-5. Global overview of muskox populations, location, subspecies designation, origin, most recent survey year, population size and trend over the last 10 years.

Population trends (Increasing, Stable, Decreasing, or Unknown) are indicated by shading. Modified from Cuyler et al. 2020.

POPULATION	SUBSPECIES	ORIGIN	MOST RECENT SURVEY YEAR	POPULATION SIZE AND TREND
U.S. (Alaska)				
Nunivak Island	<i>wardi</i>	Translocated	2015	740
Nelson Island	<i>wardi</i>	Translocated	2018	444
Yukon Kuskokwim Delta	<i>wardi</i>	Translocated	2017	252
Seward Peninsula	<i>wardi</i>	Translocated	2017	2,353
Cape Thompson	<i>wardi</i>	Translocated	2017	227
North East	<i>wardi</i>	Translocated	2018	285
CANADA-mainland				
Yukon Yukon North Slope	<i>wardi</i>	Translocated	2018	344
Northwest Territories				
Inuvik	<i>moschatus</i>	Native	2009	2,855
Sahtu	<i>moschatus</i>	Native	1997	1,457
North Great Slave	<i>moschatus</i>	Native	2018	8,098
South Great Slave	<i>moschatus</i>	Native	2011	164
Nunavut				
MX-09	<i>moschatus</i>	Native	2018	539
MX-11	<i>moschatus</i>	Native	2013	13,592
Thelon, MX-12	<i>moschatus</i>	Native	1994	1,095
MX-13	<i>moschatus</i>	Native	2010	4,736
MX-10	<i>moschatus</i>	Native	2013	3,685
Boothia Peninsula MX-08	<i>wardi</i>	Native	2018	3,649
Quebec (Nunavik)				
Ungava Bay	<i>wardi</i>	Translocated	2019	3,000
Eastern Hudson Bay	<i>wardi</i>	Translocated	2016	1,000
CANADA-Arctic Archipelago				
Northwest Territories				
Banks Is.	<i>wardi</i>	Native	2014	14,021
NW. Victoria Is.	<i>wardi</i>	Native	2015	14,547
Melville Is. Complex	<i>wardi</i>	Native	2012	3,716
Nunavut				
E. Victoria Is. MX-07	<i>wardi</i>	Native	2014	10,026
Pr. Wales/Somerset Is. MX-06	<i>wardi</i>	Native	2016	3,052
Bathurst Is. Complex MX-05	<i>wardi</i>	Native	2013	1,888
Ringnes & Cornwall Is. MX-03	<i>wardi</i>	Native	2007	21
Axel Heiberg Is. MX-02	<i>wardi</i>	Native	2007	4,237
Ellesmere Is. MX-01	<i>wardi</i>	Native	2015	11,315
Devon Is. MX-04	<i>wardi</i>	Native	2016	1,963

POPULATION	SUBSPECIES	ORIGIN	MOST RECENT SURVEY YEAR	POPULATION SIZE AND TREND
GREENLAND				
Inglefield Land	<i>wardi</i>	Mixed	2000	273
Cape Atholl	<i>wardi</i>	Translocated	2017	212
Sigguk (Svartenhuk)	<i>wardi</i>	Translocated	2002	193
Naternaq	<i>wardi</i>	Translocated	2004	112
Sisimiut	<i>wardi</i>	Translocated	2018	2,622
Kangerlussuaq	<i>wardi</i>	Translocated	2018	20,334
Nuuk	<i>wardi</i>	Translocated	2016	14
Ivittuut	<i>wardi</i>	Translocated	2017	812
Nanortalik	<i>wardi</i>	Translocated	2018	32
Inner Kangerittivaq Fjord	<i>wardi</i>	Native	2004	562
Jameson Land	<i>wardi</i>	Native	2000	1,761
North East Greenland	<i>wardi</i>	Native	1992	12,500
SCANDINAVIA				
Norway: Dovre	<i>wardi</i>	Translocated	2018	244
Sweden: Rogen Nature Reserve	<i>wardi</i>	Translocated	2017	10
RUSSIA				
Yamal Peninsula	<i>wardi</i>	Translocated	2017	300
Taymyr Peninsula	<i>wardi</i>	Translocated	2017	12,100
Begicheva Island	<i>wardi</i>	Translocated	2017	230
Putorana Plateau	<i>wardi</i>	Translocated	2004	20
Anabarskay	<i>wardi</i>	Translocated	2017	1,040
Bulunskay	<i>wardi</i>	Translocated	2017	700
Indigirskay	<i>wardi</i>	Translocated	2017	350
Kolymskay	<i>wardi</i>	Translocated	2017	30
Magadan Oblast	<i>wardi</i>	Translocated	2015	16
Magadan Omulevka River	<i>wardi</i>	Translocated	2015	6
Chukotka	<i>wardi</i>	Translocated	2017	4
Wrangel Island	<i>wardi</i>	Translocated	2018	1,000
GLOBAL TOTAL MUSKOXEN				circa 168,778

The current circumpolar population size estimate is 170,000 individuals. This represents an increase from previous estimates of 134,000 to 137,000 in 2008, approximately 135,000 in 2013 and 111,000 to 135,000 in 2017, and represents the best approximation considering all data ambiguities. Of the total, 80% of wild muskoxen are *O. m. wardi* and 20% are *O. m. moschatus*—which occur primarily on mainland Canada. Translocations over the past century have resulted in the return to a circumpolar distribution. All reintroduced or translocated animals have been *O. m. wardi*. As evident in Table 3-5, 71% of muskox populations are native and 29% are translocated. Geographically, the majority of muskoxen are in Canada, followed by Greenland, Russia, Alaska, and Scandinavia. While some populations are in decline (historically some of the largest populations – most notably Banks Island), others have expanded their range or experienced increases typical of translocated populations (Figure 3-29). For two small populations in

Greenland, a stable or decreasing trend is the result of wildlife management interventions designed around specific goals.

Recent trends for 38 muskox populations/regions (Table 3-5) show 23 increasing (36.2% of present global abundance), 9 stable (13.1%) and 6 decreasing (15.5%). Conspicuously, in 2000, two of today's declining populations were then the largest native populations in the world, with a combined total of approximately 87,000 muskoxen. Today, they number about 24,000. Mortality events caused by infectious agents have been identified but are unlikely the sole cause of the decline. Recent trends are unknown for 17 populations (35.1% of present global abundance). Thus, interpreting the true impact of these declines relative to the total global population is difficult. Regardless, it is evident that population status can change quickly.

Information on muskox demographics is difficult to obtain and therefore not commonly collected or reported. Although circumpolar in extent, available data are typically only available for small areas or areas with high muskox densities. Demographic data are collected using ground-based surveys, which can be costly and logistically difficult to execute. Currently, our ability to compare sex and age across populations is limited. Adoption of standardised methodology would allow for interpretation of trends and population dynamics in the future.

Although the general distribution of muskoxen is well defined, detailed information on spatial structure is mostly not available. This species is widely dispersed and in many cases surveys are infrequent. Some populations of muskoxen have been observed to be relatively sedentary while others move between seasonal ranges. Muskoxen have also been observed vacating one region and moving to occupy new ranges. These factors make monitoring of spatial distribution challenging. Infrequent surveys also negatively impact our understanding of phenology in muskoxen.

Although in the past muskoxen have survived major shifts in climate, current genetic information reveals that they have gone through a number of bottlenecks and extirpation events resulting in low genetic variability. One of the consequences of this low variability is very low diversity in the major histocompatibility complex, which may lower their ability to respond to infectious diseases. In general, conservation of muskoxen could be enhanced with better understanding of muskox genetics.

Attention to disease in muskoxen is relatively new. Although infectious disease agents have been identified in declining populations in Alaska, Canada and Norway, documentation of occurrence and impacts of these pathogens could be improved. Attention could focus on overall muskox health, paired with demographic or abundance surveys. Cuyler et al. (2020) provide an up-to-date overview of pathogens and diseases described in muskoxen in their electronic supplementary materials.



Figure 3-30. Trends and distribution of muskoxen populations based on Table 3-5.

Modified from Cuyler et al. 2020.

3.4.1.2 Small Herbivores

Lemmings

Lemmings are currently being monitored at 38 sites. Their status and trends were determined based on data from these sites as well as recent data (since 2000) from an additional 11 previous monitoring sites (Figure 3-31). Of those sites monitored, Fennoscandia is overrepresented relative to the geographical area it covers, whereas Russia is underrepresented. Based on the skewed geographical coverage, more information is available for some species of lemmings than others, particularly the Norwegian lemming.

Methods for monitoring small mammals varied by site and ranged from live trapping with multiple sampling events in a given year (mark-recapture studies) to systematically recorded incidental observations and qualitative indices. Annual lemming abundances were recorded at all sites, but mostly in the form of relative abundance indices. Quantitative density estimates based on mark-recapture live trapping were available only for four high Arctic sites.

As noted in the *Arctic Biodiversity Assessment*, large variability in amplitude of lemming cycles is the norm, making trends difficult to identify without long-term, multi-cycle time-series data. Given that caveat, and the heterogeneity of available data types, there is no current

evidence that pan-Arctic lemming populations have been increasing or decreasing over the last 25 years. There are two exceptions—a negative trend detected for low Arctic populations sympatric with voles, and indications of a negative trend in Russia.

Abundance data for lemmings showed large amounts of heterogeneity across years, sites, and species. Patterns of fluctuations also varied. Norwegian lemmings exhibited regular outbreaks at three to six-year intervals, but sometimes much longer periods without outbreaks, and with large variation in amplitude. Vole peaks in Fennoscandia were often synchronous with lemming peaks, but not always. Outside of Fennoscandia, heterogeneity was also large. Regular cycles with a period of three to four years were observed at some sites, but this pattern varied considerably. In many cases, patterns were difficult to discern because of large differences in amplitude or changes in monitoring methodology. Change in species composition were noted at two low Arctic lemming monitoring sites: in 2010 in Churchill, Manitoba, meadow voles (*Microtus pennsylvanicus*) were recorded after having been absent during monitoring in the 1990s; and in 2013 and 2014, voles (*M. middendorffii*) were observed in south-eastern Taymyr for the first time despite years of monitoring.

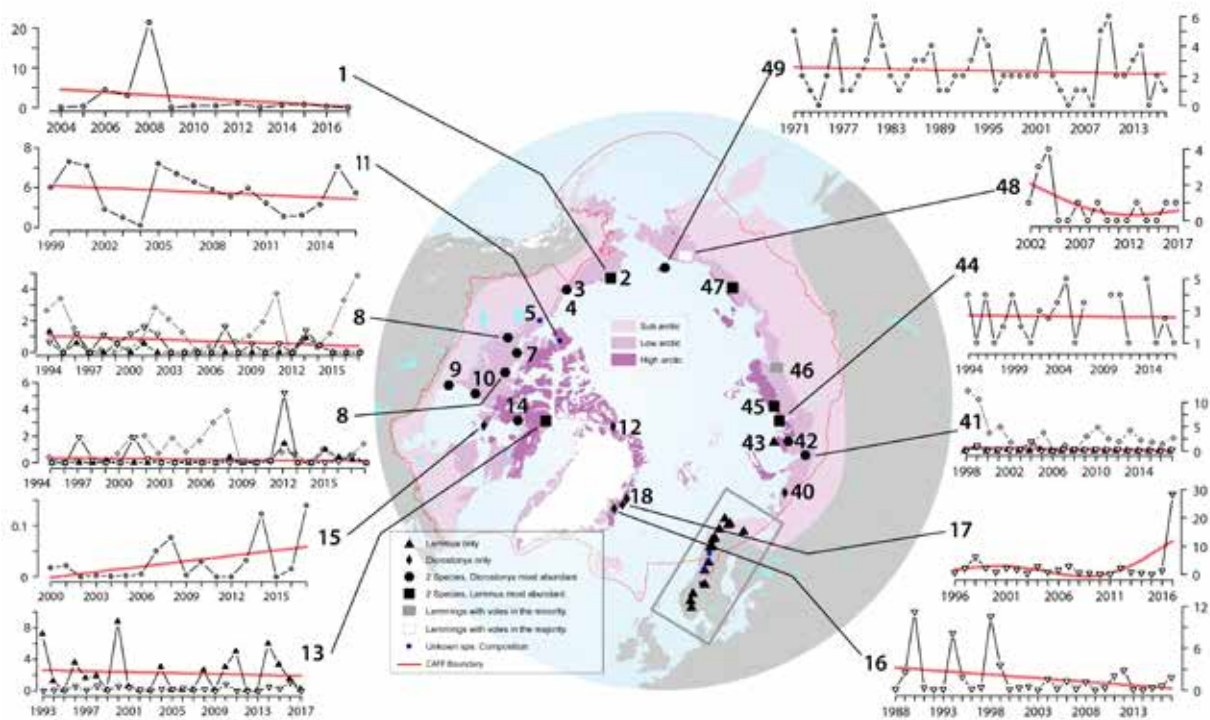


Figure 3-31. Location and trends of lemming populations at monitoring sites across the circumpolar region. Numbers refer to sites in Ehrich et al. 2020. Symbols indicate small rodent community composition. Modified from Ehrich et al. 2020.



Lemming. Photo: Frank Fichtmueller/Shutterstock.com

In addition to abundance, the CBMP–Terrestrial Plan considered two other attributes to be essential for monitoring lemmings—health and phenology. These, however, were seldom monitored. Diseases and parasites were only monitored systematically at a few sites and phenology was only regularly monitored on Wrangel Island (one of the discontinued monitoring programmes). Phenological information gathered at this site included first appearances on the snow, migration to summer habitat and observations of first juveniles.

The CBMP–Terrestrial Plan recommended monitoring demographics, spatial structure, and genetic diversity of small mammals. Approximately half of the sites regularly collected data on sex and age classes of captured individuals and occasionally on reproductive status. Spatial data is also available for a number of sites. Genetic diversity has been assessed in some cases but often only once at a given site. Other data sometimes collected in association with monitoring included diet, abundance and reproduction of lemming predators, availability of alternative prey, plant productivity and phenology, and abiotic factors.

3.4.1.3 Medium-sized Predators

Arctic Fox

Arctic foxes are currently monitored at 34 sites throughout the North, with most monitoring efforts concentrated in Fennoscandia (Figure 3-32). The duration of monitoring across all sites is variable at between 2 and 56 years and was ongoing at 27 of the 34 sites (79%) as of 2015. Monitoring projects cover almost equally the four climate zones of the species' distribution—high Arctic, low Arctic, sub-Arctic, and montane/alpine.

Fox dens are monitored because they are long-lasting reproductive structures used repeatedly by territorial individuals. Typically, data collected for Arctic foxes include, den density, number of active dens, number of breeding dens and litter size. Beyond that, monitoring programmes vary greatly with respect to other variables. Almost all sites monitor fox abundance, reproductive effort, and litter size. Additional variables for informing population status are less well represented. Additional metrics include, pup survival and genetic parameters monitored in more than 20 (59%) projects, contaminant levels monitored in 13 (38%) and disease exposure monitored in five (15%).

Arctic fox ecology was highly variable between sites with regards to long term population trends, annual and multi-annual fluctuations, diet composition and interaction with red foxes and humans. Densities of known dens varied 100-fold across monitoring sites, from 0.01 to 1 den per square kilometre (mean of 0.18 ± 0.25 dens per square kilometre). Minimum and maximum numbers of Arctic fox breeding pairs were available for most monitoring sites. Between-year variations can reflect multi-annual fluctuations, long term changes in fox abundance or variation in monitoring effort. Of the 34 monitoring sites, long term population trends were stable (17 populations, 50%) or increasing (nine populations, 26%), with only three populations (9%) decreasing. Trends were unclear in five (15%).

Most populations showed strong multi-annual fluctuations (22 populations, 64%) and the majority of

these fed primarily on lemmings (90%; 20 of 22). Nine showed no multi-annual fluctuations and these groups fed primarily on birds, marine food, or large mammal carcasses (89%; 8 of 9). Three showed weak or unclear fluctuations.

The circumpolar population of Arctic fox shows little genetic differentiation with the exception of the diverged Commander Islands populations. Monitoring data exist for phenology of pup emergence (19 sites) and phenology of moulting (17 sites), but no synthesis of these data is available. A full assessment of phenology is also challenging as projects typically concentrate fieldwork in summer. Samples have been collected to provide health data on levels of contamination (22 sites), parasites (18 sites) and disease exposure (6 sites), but samples were analysed only partially and again no data synthesis is available



Figure 3-32. Arctic fox monitoring study sites. Modified from Berteaux et al. 2017; Arctic fox distribution area modified from Angerbjörn & Tannerfeldt 2014.

3.4.2 EFFECT OF DRIVERS ON FECS AND THEIR ATTRIBUTES

Climate change is the primary driver influencing biodiversity, abundance, and ecological function for all CBMP focal mammal species; it is indeed the most important driver of change in terrestrial Arctic ecosystems (CAFF 2013a). In terrestrial environments, impacts from climate change on all FEC functional groups include a general warming trend and increased variability in the Arctic climate that can manifest as interannual variability as well as short- and long-term cyclical climatic fluctuations. Interannual variability in weather may include severe storms, extraordinarily warm or cold winters and summers, variable amounts of snow in all seasons, midwinter rain and thaw events, rainy summers, drought summers and strong winds. In autumn and spring, variability can include erratic timing of snowmelt and snow arrival.

For Arctic ungulates, annual variability in weather patterns affects calf productivity and survival. Deep snow and icing events—such as winter rain and melting temperatures that create ice cover on the ground or in the snowpack—make it difficult for large herbivores to access forage. This may lead to decreased calf recruitment and, in extreme cases, can cause die-offs. Meanwhile, summer drought can negatively affect vegetation that is essential winter forage for large herbivores. Temporal and spatial scale are important considerations when judging the impact of weather events. The impacts of increasing frequency, distribution, severity, and extent of stochastic weather events on population dynamics remain unknown.

For lemmings, autumn and winter rain and midwinter thaws lead to hard snow and icing at the bottom of the snowpack. These impenetrable layers impact movement and limit access to food plants, resulting in reduced reproduction and survival. Lemming populations appear to be more sensitive to this change in winter climate than northern voles, resulting in a fading out of lemming outbreaks in areas of lower abundance (documented in Fennoscandia). This loss of outbreaks may contribute to reduced amplitude and extend the time period between lemming cycles, however, to date, there is no detectable regional (Fennoscandia) or circumpolar trends of decreasing lemming populations. In addition, later onset of snow in autumn and earlier spring melt reduce the duration of snow cover and may impact lemming winter reproduction. Local/regional changes in lemming populations may cascade to predator populations through declines in prey availability, with particularly dramatic consequences for specialist species, such as snowy owls or Arctic foxes.

Impacts of warming temperatures on specific mammalian habitat is variable and depends on local conditions, including precipitation patterns, presence of

permafrost, soil moisture conditions and the presence of herbivore taxa. Warming temperatures may also result in range extensions of wildlife pathogens, particularly those from sub-Arctic regions, which may change the pattern of transmission and exposure of native host populations to new pathogens. Changes in the distribution and prevalence of pathogens are likely to play a role in future distribution and dynamics of Arctic mammal populations. For Rangifer and muskoxen, there is already evidence that increasing temperature influences development, distribution, and emergence of some pathogens.

Range extension of boreal mammalian species into Arctic tundra areas is also introducing new herbivore competitors and potential predators into true Arctic ecosystems. Examples of species with northward range extensions include red fox, moose (*Alces americanus*), Eurasian elk (*A. alces*), American beaver (*Castor canadensis*), snowshoe hare (*Lepus americanus*), Middendorff's vole (*Microtus middendorffii*) and meadow voles (*M. pennsylvanicus*). Populations of North American species introduced into Eurasia, such as muskrat (*Ondatra zibethicus*) and American mink (*Neovison vison*), are also moving into low Arctic areas (CARMA 2013a). For muskoxen, increased range overlap with grizzly bears in north-eastern Alaska (*Ursus arctos*) has resulted in new predator-prey dynamics (Reynolds et al. 2002).

Contaminants also pose a threat to Arctic mammals, particularly predators. Contaminants have the potential to impact the health and fecundity of Arctic wildlife, and there are concerns regarding food security and health in northern communities for whom harvest of *Rangifer* is a critical resource. Lack of data, however, makes it difficult to understand the extent and magnitude of the impacts.

Humans may also have more direct impacts on biodiversity/abundance of Arctic mammals. Impacts that directly affect habitat and populations include infrastructure (roads, structures associated with resource development), harvest, introduction or reintroduction of plants and animal species, disturbance from tourism, and greater human activity due in part to technological changes (modern boats, snow machines and all-terrain vehicles) that facilitate more frequent and widespread travel sometimes into formerly inaccessible habitats. These impacts may be direct, such as overharvest, or indirect, such as displacement from essential habitats (calving grounds, denning locations, pupping and feeding areas).

Conversely, overabundant semi-domestic reindeer may be problematic. Heavy grazing and trampling impact terrestrial Arctic habitats by reducing lichen cover and favouring graminoids (Bernes et al. 2015). High

abundance of semi-domestic reindeer, coupled with mortality through winter icing events, increases the number of reindeer carcasses available to predators. This appears to have propelled red fox population increases and range expansion, as well as benefited other boreal generalist predators such as corvids, while having detrimental effects on Arctic fox and many species of ground-breeding birds such as ptarmigan and waders.

Additional direct and indirect human impacts on Arctic fox include feeding (positive or negative), removal of competitors, killing and transmission of disease by pets. In Fennoscandia, Arctic foxes are considered critically endangered. They are currently benefiting from a comprehensive conservation programme including supplemental feeding, culling of red fox and release from captive breeding. This has resulted in increasing trends for several populations. At present, it is unclear whether these populations would maintain a positive trend without these supporting measures. The northward expansion of red fox, to the detriment of Arctic fox, has often been attributed to a warming climate but evidence suggests that direct and indirect food supplementation by humans may be the main causal factor.

3.4.3 COVERAGE AND GAPS IN KNOWLEDGE AND MONITORING

Large Herbivores—Rangifer and Muskoxen

In many areas, large herbivore surveys are infrequent, lack measures of variance (or exhibit large variability) and methodology and effort lack consistency. All these factors lead to uncertainties in the data and is a barrier to comparing among regions and states.

Abundance trends are difficult to ascertain for a number of populations from survey estimates alone. The implementation of standardised methods for improving *Rangifer* population estimates has been in place for the last 30 years and represent a significant advance, providing a useful template for muskoxen. Surveys for both *Rangifer* and muskoxen are hampered by the species' diffuse distribution and remote locations. Most abundance estimates do not differentiate sex and age classes. Demographics are difficult to obtain, due in part to the need for more intensive, and, for muskoxen, often ground-based surveys. Demographic data are critical for interpreting population trends, developing management strategies and allowing for comparisons across regions.

For both *Rangifer* and muskoxen, more information is needed on population specific vulnerability to the cumulative effects of climate change and other human impacts. Access to timely and accurate data is critical for identifying management actions that build adaptive capacity and resilience within populations, particularly those that have declined to historic lows that may be outside of the natural range of population

fluctuation. The only populations showing strong and stable numbers are in Greenland, Iceland, and Svalbard, and this may skew conclusions. Experts – scientific, indigenous, and local – play a critical role in reporting and integrating this information.

Little is known about the impacts of changing climate on the distribution and prevalence of disease. Recent mortality events in Alaska and Canada have illustrated our limited understanding of disease in *Rangifer* and muskoxen. There is widespread recognition of the need to develop standardised health assessment protocols capable of providing basic information on the prevalence, significance, and role of disease in large herbivore population dynamics.

For Arctic ungulates, there is a general lack of both reliable harvest data and effective models to determine sustainable harvesting levels. This is unexpected considering the high degree of regulation of present-day harvests. Hunting was presumed to be a contributing factor to the decline of muskoxen in North America in the early 1900s. Changes in overall harvest, as well as the sex and age composition of the harvest, can impact population composition, group dynamics and overall abundance. Accurate harvest data are needed to inform conservation efforts as well as provide insights into the economic benefits of commercial harvests.

Small Herbivores—Lemmings

While lemming abundance is monitored across all sites, methods as well as levels of precision vary. Quantitative density estimates (such as through mark-recapture analysis) are rare because they are often quite invasive, labour intensive and, consequently, typically limited to small spatial scales. Most small mammal monitoring programmes therefore rely on abundance indices. Fauteux et al. (2018) found good correlation of mark-recapture estimates with indices based on systematic incidental observations and snap trapping. Although simple to implement, incidental observations have a number of shortcomings, that is, the challenge of distinguishing between small mammal species. Snap trapping is the most common method for monitoring lemmings, but sampling designs vary.

The variety of methods used for monitoring small mammals may be a challenge when looking at large-scale patterns. While all quantitative methods allow comparisons of trends and relative dynamic patterns, it can be difficult to compare abundance among sites, which is critical for examining trophic interactions. Qualitative index series may exhibit more regular cycles than quantitative series, and in long qualitative time series, there can also be an effect of shifting baseline, making it difficult to identify long term trends. Standardisation of monitoring methods across sites would address many of these issues. Adoption of standardised methods in a number of disparate long-term monitoring programmes is difficult to implement without losing the value of the historic data. The old and

new protocols should be implemented simultaneously for a number of years to establish correction factors between time series. The end result, however, should be a number of comparable long-term time series.

Parasites and diseases of lemmings have been studied at a few monitoring sites but are not generally included in regular monitoring protocols. Likewise, genetic structure has not been investigated regularly. Progress could be made in monitoring of genetic structure, as well as health, through analysis of previously collected tissues and could provide a historical context. As previously noted, the majority of lemming monitoring efforts occur in the summer. Consequently, little information is available on annual or site-specific phenology.

Geographically, lemmings are most intensively monitored in Scandinavia. This geographical bias is particularly evident in the lack of representativeness of the Russian and Canadian Arctic's. In Russia for example, which encompasses the majority of the Eurasian Arctic, there are only four ongoing long-term monitoring projects with more than five years of data. The lack of lemming monitoring in some locations is also indicative of gaps in knowledge of other ecosystem attributes.

Lack of good spatial coverage in small mammal monitoring south of the Arctic outside of Scandinavia is also an information gap. The distribution of several lemming species extends south of the Arctic and lack of monitoring in these areas make it difficult to assess changes in distribution. Similarly, several vole species are extending their ranges northward. Lack of range distribution information for these species make it difficult to document and understand changes.

Temporally, small mammal monitoring typically occurs during snow-free periods. Monitoring is usually conducted during one or two periods in summer. Insights into winter abundance and activity is generally restricted to counts of winter nests after snowmelt. Winter abundance is likely critical to understand the impact of climate change in lemmings—an animal specialised for life under the snow. This knowledge gap is well known, but the challenges of studying lemmings in the winter, under the snow, in remote Arctic locations are difficult to overcome. New technology is poised to open up new possibilities through the development of camera tunnels for monitoring lemmings year-round.

The CBMP–Terrestrial Plan recommends an ecosystem-based approach to monitoring that is structured around explicit models. One of the reasons to monitor small mammals, as well as the other mammal FECs, is for insights they yield on ecosystem function, trophic interactions, and drivers of environmental change. Analysing changes in lemming abundance as a function of ecological drivers is only possible if drivers of change are also measured. Less than half of lemming monitoring sites gather data annually on abiotic conditions. This is a lost opportunity.

Medium-sized Predators—Arctic Fox

Similar to international monitoring efforts for *Rangifer* and muskoxen, a circumpolar network of Arctic fox biologists facilitates information exchange. Although circumpolar, over a third of monitoring sites are geographically concentrated in Norway, Sweden, and Finland. Arctic fox abundance, reproductive effort and litter size were assessed in almost all monitoring projects. Other variables indicative of population status were also monitored but these variables were not uniform in type or extent across projects. For example, pup survival and genetic parameters were monitored in many populations but not all. One challenge in assessing abundance is a measure of non-breeding adults. In some years, this may be the majority of adults in the population. Better harmonisation across monitoring projects can allow sharing of protocols and data for greater inference for this important variable.

Many projects monitored some variables indicative of ecosystem structure. The variables monitored and the techniques used, however, differed across projects, reflecting differences in effort, objectives, and ecosystem structure. In addition, less than 30% of projects monitored two or more variables indicative of ecosystem function.

Large and Small Predators and Medium-sized Herbivores

The CBMP–Terrestrial Plan identified large predators, small predators, and medium-sized herbivores FECs as part of the mammalian monitoring framework and recommended that these FECs and their attributes be monitored when feasible. Presently, monitoring of these FECs takes place sporadically and on a regional basis with limited scope tailored to specific regional issues and it is challenging to summarise the attributes for these FECs in the absence of consistent, widespread monitoring efforts throughout the circumpolar Arctic. Monitoring of these FECs would benefit from an organised international collaborative approach, much as CARMA, MOXNET and other networks that have facilitated the synthesis of data across geographical areas.

3.4.3.1 Recommended revisions to FECs and key attributes

The FEC attributes for mammals as defined in the CBMP–Terrestrial Plan are listed in Table 2-1. In many instances, monitoring of attributes considered essential is lacking. Based on experience obtained from producing the START, some revisions are recommended to future monitoring. Attributes considered essential or recommended are presented in Table 3-6.



Muskox. Photo: Longtaildog/Shutterstock.com

Table 3-6. Summary and recommended revisions of mammal FECs and key attributes.

Recommended revisions are shown in **bold italics** with the current category in brackets. “E” means essential attributes. “R” means recommended attributes.

FECs	EXAMPLES	FEC ATTRIBUTES						COMMENTS - REASONS FOR RECOMMENDED CHANGE
		ABUNDANCE	DEMOGRAPHY	PHENOLOGY	DIVERSITY	HEALTH	SPATIAL STRUCTURE	
Mammals								
Large herbivores	<i>Rangifer</i> , muskoxen, moose	E	E	E	E (R)	E	E	For <i>Rangifer</i> in particular, conservation efforts often focus on specific ecotypes or genetic types. Good examples include forest Rangifer in North America and specific populations of Arctic Island <i>Rangifer</i> .
Medium-sized herbivores	hares	E	E	E	R	E	R	No change
Small herbivores	lemmings, voles	E	R	E	E (R)	E	E (R)	Small mammal diversity is a good indicator of environment change. As an important prey resource for many Arctic predators, spatial structure is essential for understanding food web dynamics in Arctic ecosystems.
Large predators	brown bear, grey wolf	E	E	E	R	E	R	No change
Medium-sized predators	wolverine, lynxes, foxes	E	R	E	E (R)	E	E (R)	Climate and human impacts in some areas of the Arctic may lead to barriers in connectivity
Small predators	stoat/weasel/ermine	E	R	E	R	E	R	No change

3.4.4 CONCLUSIONS AND KEY FINDINGS

Trends in abundance varied for the mammal species addressed in this report. Globally, populations of *Rangifer* have mostly declined since the 1990s, some dramatically. There are, however, notable exceptions, which begs the question of why some populations are doing well and others are not. Overall, present abundance for muskoxen is largely unchanged with some areas experiencing increases while other populations have declined. Circumpolar lemming abundance is fluctuating but appears stable overall, however there are indications that lemmings are declining in the southern portions of their range where voles also occur. In general, Arctic fox populations are either stable or increasing with just a few monitoring sites indicating a decline in abundance.

Key findings

- ▶ Globally, populations of *Rangifer* have mostly declined since the 1990s, some dramatically; however, there are notable exceptions. In addition, there are changes in distribution, range, and fragmentation.
 - ▶ Conservation of *Rangifer* often focuses on ecotypes based on genetics and behaviour. Four ecotypes are widely accepted—migratory tundra, Arctic islands, mountain, and forest. The majority of migratory tundra and forest *Rangifer* herds have declined in population size. Trends for Arctic island and mountain *Rangifer* tend to be stable or unknown
 - ▶ *Rangifer* trends are confounded by infrequent monitoring, variable methods, as well as introductions, local management and in some cases, mixing of domestic, feral, and native populations.
 - ▶ Current circumpolar abundance estimate for muskoxen is higher than estimates from 2013 and 2017. Recent variations indicated that 23 muskox populations/regions were increasing, nine were stable, six were decreasing, while variation was unknown for 17. Of note, the two with steepest declines were, in 2000, the largest endemic populations in the world. Infrequent monitoring and variable methods confound comparisons.
 - ▶ Trend is not detectable in pan-Arctic lemming populations over the last 25 years.
 - ▶ Considering lemmings in different small mammal communities revealed a negative trend for low Arctic populations outside of Fennoscandia sympatric with voles. There were also indications of a negative trend in Russia, where several of the decreasing mixed community populations were located.
 - ▶ With one exception, all low Arctic lemming populations occurred in mixed small rodent communities including one or more species of voles.
- ▶ Change in species composition was noted at two low Arctic monitoring sites with vole species appearing in 2010 and 2013 in Churchill Manitoba and south-eastern Taymyr, respectively.
 - ▶ Although highly variable, Arctic fox abundance was either stable or increasing at the majority of monitoring sites with only a few in decline. Trend was unknown at a few of the sites.
 - ▶ Arctic fox abundance, reproductive effort and litter size was assessed in almost all populations. Better harmonization of protocols and data sharing would allow for greater understanding among sites, identify data gaps and direct future research.
 - ▶ Currently, international monitoring networks exist for only three of the six mammal FECs. Future monitoring efforts would benefit from the establishment or expansion of monitoring networks to collect data on the remaining three FECs.

Challenges exist for assessing the abundance of focal mammal species across the circumpolar Arctic. They include:

- ▶ reliability of abundance estimates—for example lack of precision;
- ▶ changing baselines—such as changes in species distribution, sampling methodology, changes in areas monitored;
- ▶ differences in frequency of monitoring by regions; and
- ▶ spatial extent of monitoring—expanding monitoring efforts in underrepresented areas would be beneficial to understanding circumpolar ecological changes.