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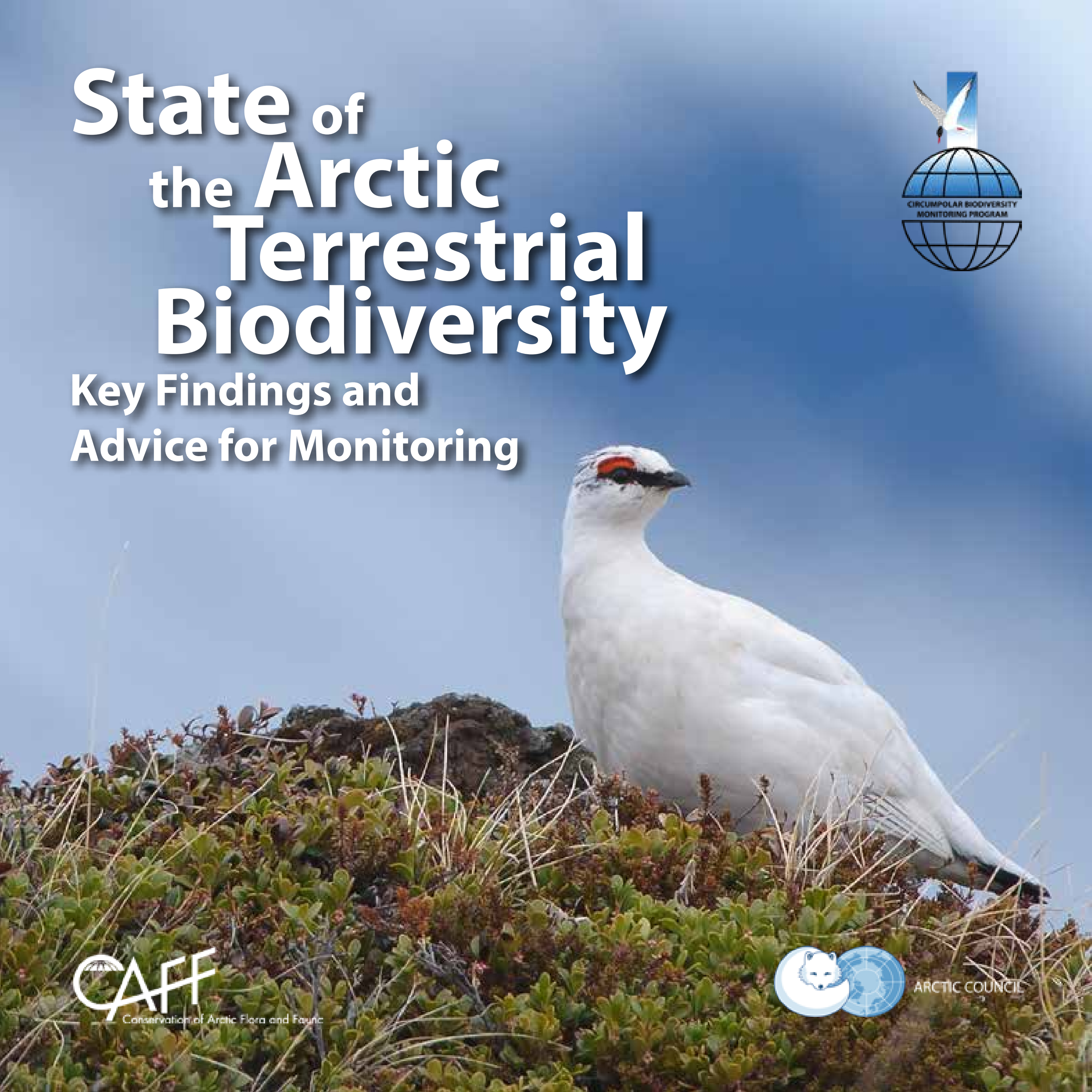
State of the Arctic Terrestrial Biodiversity

Key Findings and Advice for Monitoring



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State of the Arctic Terrestrial Biodiversity: Key Findings and Advice for Monitoring

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The report and associated materials can be downloaded for free at: www.arcticbiodiversity.is/terrestrial

Cover photo: Rock ptarmigan in Iceland. Photo: Einar Guðmann

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- Finnish Ministry of the Environment
- Ministry of Agriculture, Self-Sufficiency, Energy and Environment, Government of Greenland
- Icelandic Institute of Natural History
- Norwegian Environment Agency
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Autumn colours on the tundra.
Photo: Evgeniy Trufanov/Shutterstock.com

A researcher releases an adult peregrine falcon after it was tagged with a small geolocator, south Greenland. The device will reveal key insights on migration.
Photo: Knud Falk / Søren Møller

Introduction

The ***State of the Arctic Terrestrial Biodiversity Report*** (START) is a product of the ***Circumpolar Biodiversity Monitoring Program*** (CBMP) Terrestrial Group of the Arctic Council's ***Conservation of Arctic Flora and Fauna*** (CAFF) Working Group. The overall goal of the START is to assess the status and trends of terrestrial Focal Ecosystem Components (FECs)—including species of vegetation, arthropods, birds and mammals—across the Arctic, and identify gaps in monitoring coverage towards implementation of the CBMP's ***Arctic Terrestrial Biodiversity Monitoring Plan*** (CBMP Terrestrial Plan). This report is a summary of key findings and advice for monitoring based on the START.

Where data is available, the START:

- describes current and/or historical status of FECs;
- evaluates trends;
- considers how changes in biodiversity may be linked to potential drivers;
- describes the state of Arctic terrestrial biodiversity monitoring;
- identifies research priorities and knowledge gaps; and
- provides advice for future terrestrial biodiversity monitoring efforts.

The Arctic contains large terrestrial areas with diverse ecosystems that sustain important and unique biodiversity as well as Indigenous Peoples and Arctic residents who depend on healthy ecosystems. The terrestrial Arctic is approximately seven million square kilometers, of which less than half is vegetated and almost one third is covered by ice. The conditions that govern Arctic terrestrial ecosystems differ from most other terrestrial ecosystems due to extreme cold, strong winds, drought, and extended seasonal darkness and brightness with a short but productive growing season. Arctic ecosystems host highly specialized organisms that have adapted to survive in these conditions as well as migratory species that exploit rich Arctic resources during summer breeding periods.

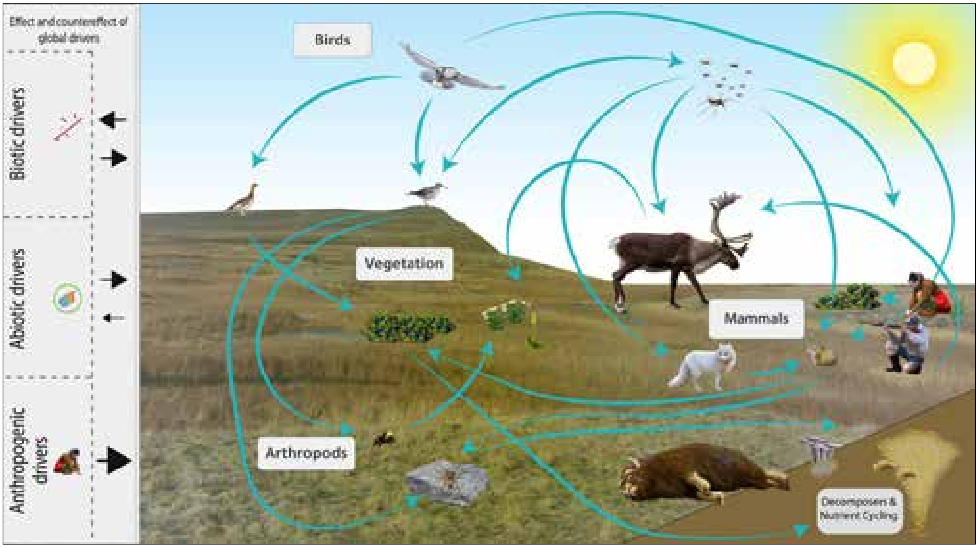
The ***Arctic Terrestrial Biodiversity Monitoring Plan*** (CBMP Terrestrial Plan) is an agreement by Arctic states and Permanent Participants (PPs) to compile, harmonize and compare results from Arctic terrestrial biodiversity monitoring efforts. This work is coordinated under the ***Circumpolar Biodiversity Monitoring Program*** (CBMP) of the Arctic Council's ***Conservation of Arctic Flora and Fauna*** (CAFF) Working Group. The CBMP is a network of scientists, Indigenous Knowledge and/or Local Knowledge holders, governmental bodies, Indigenous organizations, conservation groups, and practitioners, working to harmonize and integrate efforts to monitor the Arctic's living resources.

Key elements of the terrestrial ecosystem, called **Focal Ecosystem Components** (FECs), were identified as important to monitor because they may indicate changes in the overall terrestrial environment. FECs were identified within vegetation, arthropods, birds, and mammals. Furthermore, several **attributes** of FECs, such as abundance, demographics, diversity, or phenology, were identified and further classified as essential or recommended for monitoring. The START focuses its reporting on essential attributes, as these data are more often available.

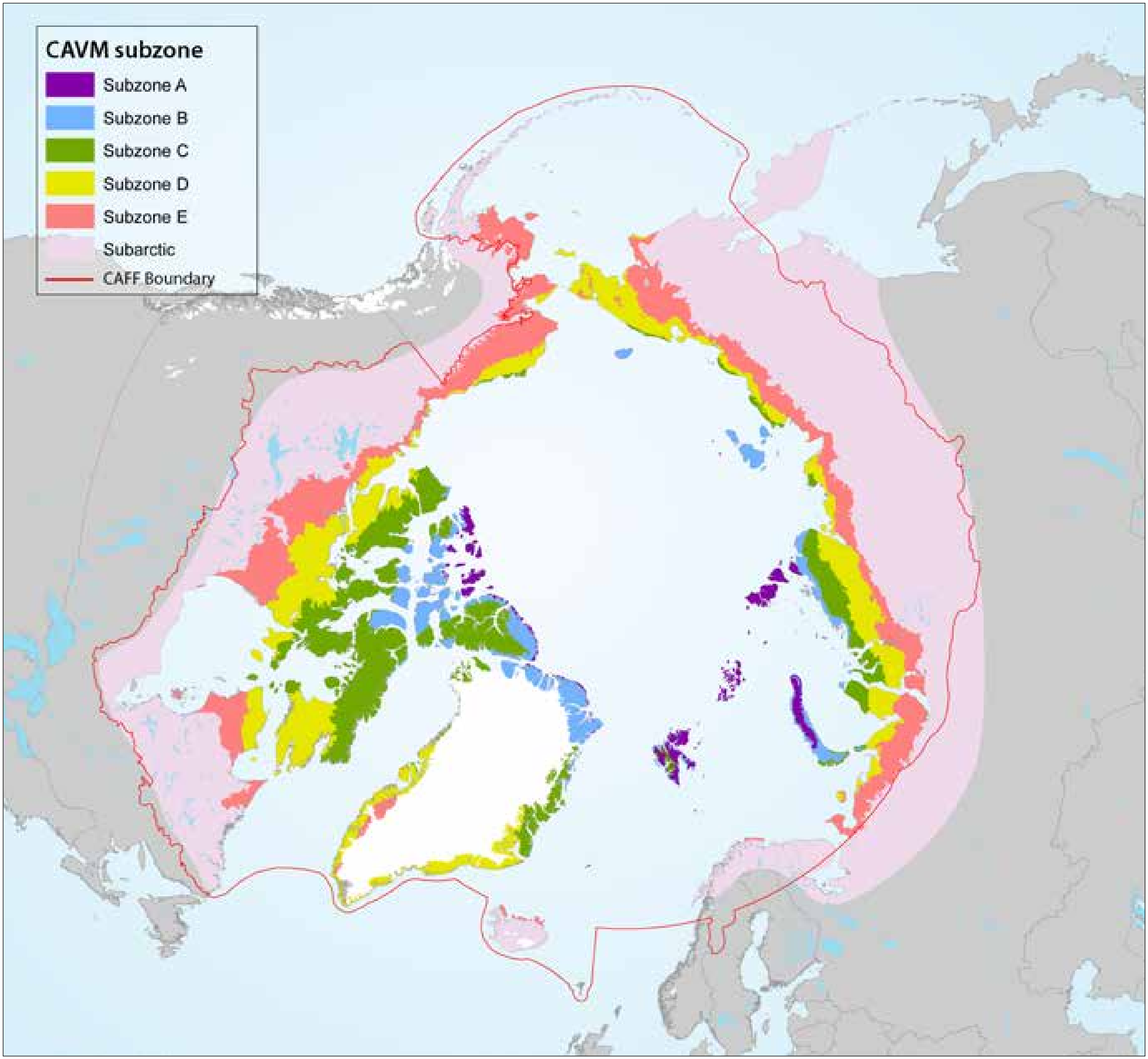
This report represents an important step in ongoing efforts to advance circumpolar terrestrial biodiversity monitoring and to understand the impact of changes on Arctic terrestrial ecosystems. The START builds on the CBMP Terrestrial Plan and associated processes of data compilation, analysis, and scientific publication led by the CBMP Terrestrial Group. Information from the START can be used to refine and adapt current and future biodiversity monitoring efforts in the Arctic, and allows the CBMP to better meet the needs of decision makers. Based on the available information, key findings include:

- Climate change is the overwhelming driver of change in terrestrial Arctic ecosystems, causing diverse, unpredictable, and significant impacts that are expected to intensify;
- Changing frequency, intensity, and timing of extreme and unusual weather events due to climate change are affecting some species, with unknown effects on populations;
- Although some trends have been observed, natural variability in Arctic terrestrial environments and large information gaps make it difficult to assess and summarize global trends for Arctic terrestrial biodiversity;
- Species from southern ecosystems are moving into the Arctic and are expected to push Arctic species northwards, create an “Arctic squeeze”, and change species’ interactions;
- Changes in culturally important food resources have implications on the food security and cultures of Indigenous Peoples and Arctic residents; and
- The range and complexity of drivers affecting Arctic terrestrial biodiversity signals the need for comprehensive, integrated, ecosystem-based monitoring programs, coupled with targeted research projects to help decipher causal patterns of change.

Advice for monitoring includes ecosystem-based monitoring and reporting, better coordination, standardization of methods, improved use of Indigenous Knowledge, Local Knowledge, and citizen science, and addressing knowledge gaps.



Conceptual model of the high Arctic terrestrial food web.



Geographic boundaries and ecosystems included in the START align, in most cases, with those of the Arctic Biodiversity Assessment and cover high Arctic (subzones A-C) and low Arctic (subzones D-E) regions consistent with the Circumpolar Arctic Vegetation Map (CAVM).

Key Findings

Climate change is the overwhelming driver of change in terrestrial Arctic ecosystems, causing diverse, unpredictable, and significant impacts that are expected to intensify.

- Increasing temperatures cause earlier onset, longer duration and increased plant growth, and changes in diversity, abundance, composition and structure of vegetation. Since 2001 there has been a significant increase in vegetation productivity across the Arctic, and an earlier start of the growing season in the sub and low Arctic.
- Different climate scenarios predict that up to 80% of high-Arctic breeding waders may lose much of their current breeding areas in 50 years, potentially changing species interactions and migration patterns.
- Higher spring temperatures and less snow cover increase nesting success for many geese.
- Increasing temperatures influence development, distribution, and emergence of some caribou/reindeer and muskoxen pathogens that may negatively impact health.
- Recovery from declines in some Arctic island populations of caribou/reindeer may be hampered by multiple threats, including decreases in sea ice connectivity between winter and summer ranges.
- Earlier springs disrupt the timing of ecological cues that some species use to start key life events. Although evidence varies, mismatches are considered among the leading potential stressors of climate change.
    - Earlier snow melt can lead to earlier arthropod emergence and peak activity, affecting key ecosystem services like pollination, and food availability for birds. Missing an advancing window of peak food abundance has reduced growth rates and body size of some wader species, while other species appear unaffected.
    - Changes in spring snow cover can influence the timing and success of breeding waders. Some species have advanced their breeding, while others are unable to keep pace, all with unknown effects at the population level.
    - Some caribou/reindeer populations have experienced reproductive failures associated with a mismatch in timing with their food.
- Natural population cycles of some species are fluctuating beyond historical levels, with potential effects on predator-prey dynamics and other species interactions.
    - Reduced snow cover can negatively impact lemming winter reproduction, and although no circumpolar trend has been detected, declining lemming populations reduce an important food source for many Arctic species and may increase the predation risk to ground-nesting birds.
    - In Scandinavia, the rough-legged buzzard population has declined by almost 50% since the 1970s and has been partly decoupled from rodent cycles, and snowy owls have very low productivity in areas and years with low lemming population.
    - Reductions in ptarmigan abundance reduce the breeding success of gyrfalcon in some areas.
    - Some caribou/reindeer populations have hit historic lows, in part from a warming climate and industrial development, including habitat fragmentation, degradation and disturbance.

Spring arrives on the tundra in Chukotka, Russian Federation.
Photo: Vladimir Yakovlev

Changing frequency, intensity and timing of extreme and unusual weather events due to climate change are affecting some species, with unknown effects on populations.

- Increasingly mild winters and ground-ice formation is causing damage to vegetation.
- Increases in surface icing may result in increased winter mortality of springtails, important for decomposition and nutrient cycling.
- Increased frequency of heavy rain events, and warm temperatures causing massive blackfly outbreaks, have killed Arctic peregrine falcon chicks.
- Winter rain and midwinter thaws lead to impenetrable layers of hard snow and icing, making it difficult for species to access forage, leading to reduced movement, reproduction, and survival of lemmings, decreased caribou/reindeer calf survival and, in extreme cases, caribou/reindeer die-offs.
- Summer drought can negatively affect vegetation that is essential forage for mammals.

Although some trends have been observed, natural variability in Arctic terrestrial environments and large information gaps make it difficult to assess and summarize global trends for Arctic terrestrial biodiversity.

- Data for most FECs was often deficient, with uneven geographic coverage and incomplete time series. Therefore, it was possible to report on only about half of FEC attributes identified as essential or recommended by the CBMP Terrestrial Plan, and some FECs went unreported.
- Changes in Arctic terrestrial environments are fundamentally diverse with some species' populations increasing in some areas and decreasing in others. Summarizing these changes at the circumpolar scale can hide dramatic changes at the local level.
- Given highly variable environments, drivers need to be investigated and interpreted in ecosystem or habitat specific contexts.

For species where time-series data existed, circumpolar population trends were variable for FECs:

- There has been increased growth and encroachment of shrubs and trees in parts of the low Arctic. Plant abundance remained mainly stable, but when changes occurred, shrubs, mosses and lichens were most affected.
- Among important pollinating flies, trend information exists for east Greenland (Zackenberg), where analysis shows dramatic decreases (80%) in abundance between 1996 and 2014.
- A major group of decomposer arthropods, the springtails (Collembola), showed overall increases in abundance but declines in diversity in some habitats in west Greenland (Kobbefjord), with some contrasting patterns in east Greenland.
- Of the 88 species of birds examined, 20% experienced declines in all populations, while well over half had at least one population in decline.
- More than half of all wader species are declining, but there is large variation across flyways with 88% of waders declining in the East Asian-Australasian Flyway, compared with 70% of wader populations stable or increasing in the African-Eurasian Flyway.
- Nearly half of all geese species are increasing.
- Populations of rock and willow ptarmigan showed both positive and negative trends.
- Arctic-breeding populations of gyrfalcons and peregrine falcons are relatively stable.
- Circumpolar populations of caribou/reindeer have declined since the 1990s, some dramatically, with notable exceptions. Most migratory tundra and forest caribou/reindeer populations have declined, while known trends for Arctic island and mountain caribou/reindeer tend to be stable.
- Current circumpolar abundance estimates for muskoxen is higher than estimates from 2013 and 2017. This may be due to increased abundance data, and a trend is not assumed.
- There have been no detectable trends in circumpolar lemming populations over the last 25 years.
- Arctic fox abundance was either stable or increasing in most monitoring sites.

Species from southern ecosystems are moving into the Arctic and are expected to push Arctic species northwards, create an "Arctic squeeze," and change species' interactions

- There has been increased growth and encroachment of shrubs and trees in parts of the low Arctic, expansion of woody plants into the tundra, and increased grass cover, while moss and lichen cover has decreased.
- Outbreaks of fast-moving defoliating insects are expected to increase as species shift northward. Some birds species are moving northwards, for example, snowy owls are breeding further north in western Siberia, peregrine falcons have possibly expanded their range in high Arctic Greenland and the short-eared owl has expanded into the eastern Canadian high Arctic. In 2017, Lapland longspurs were found breeding over 650 kilometres further north of their previous-known range in east Greenland. In sub-Arctic Scandinavia, some bird ranges advanced 21 kilometres northward between 1970-2000.
- Range extension of boreal mammals such as the red fox, moose, American beaver, snowshoe hare and voles into the Arctic introduces new competitors and predators with unclear effects on Arctic species.
- Increased range overlap between muskoxen and grizzly bears in northeastern Alaska has resulted in new predator-prey dynamics.
- Pathogens from southern latitudes are a concern for the health, distribution and dynamics of Arctic species.

The red knot, a high-Arctic-breeding wader species in decline. Waders comprise almost half of Arctic bird species examined in the State of the Arctic Terrestrial Biodiversity Report, many of which are in decline due to threats inside and outside the Arctic. Photo: Danita Delimont/Shutterstock.com

Changes in culturally important food resources have implications on the food security and cultures of Indigenous Peoples and Arctic residents.

- Indigenous Knowledge indicates increasing variability in year-to-year berry abundance, which may be particularly pronounced for plants with specialist pollinators.
- In recent years, unprecedented outbreaks of defoliating insects have caused severe declines in berry yields for some Indigenous communities.
- Most Arctic goose populations that stage or winter in North America and western Europe have increased but many goose populations that breed in the Russian Arctic and stage or winter in central and eastern Asia are declining. These changes are largely the result of influences outside the Arctic.
- Some caribou/reindeer populations of importance to Indigenous communities have dramatically declined, with some experiencing changes in distribution, range, and fragmentation. For example, the Bathurst population declined by 98% between 1986 and 2015, with post-calving and autumn range declines, and a change in winter habitat from the boreal forest to the tundra, which reduced spring migration distance by 50%.
- Lack of data makes it difficult to understand the extent and magnitude of change in many food resources.

Changes in pollinator activities have potential implications for Arctic food systems and culturally important species, such as berries. Photo: longtaildog/Shutterstock.com

Arctic fox in winter fur at Zackenberg Research Station, Northeast Greenland. The Arctic fox is the only medium-sized terrestrial mammalian predator that occurs throughout the circumpolar Arctic. Photo: Lars Holst Hansen

The range and complexity of drivers affecting Arctic terrestrial biodiversity signals the need for comprehensive, integrated, ecosystem-based monitoring programs, coupled with targeted research projects to help decipher causal patterns of change.

- Integrated monitoring of abiotic and biotic interactions is critical for the ability to understand changes in Arctic terrestrial biodiversity and must permeate current and future monitoring and reporting.
- Arctic biodiversity is under pressure from a variety of drivers acting alone and in combination. There is currently no scientific method or standardized approach for determining the cumulative effects of stressors, but various modelling frameworks look promising.
- Knowledge about causalities in the ecosystem, spatial data on important areas for species and ecosystems, and data on the distribution and intensity of human activities are essential to establish a more adaptive and ecosystem-based approach to management.
- Indigenous Knowledge encompasses entire annual cycles, extended time periods, evaluation processes, and methodologies. This long-term holistic perspective can provide important insights.

Advice for Monitoring

Ecosystem-based Monitoring and Reporting

Monitoring and reporting should encompass all key taxonomic groups and their likely relationships, linking responses to main biotic and abiotic drivers of change.

- Better coordinate between disciplines and knowledge systems both within and among Arctic states and Indigenous organizations, including experts in abiotic drivers of change (the Arctic Monitoring and Assessment Program) and other monitoring initiatives.
- Promote long-term integrated studies across biomes and taxonomic groups for examining trophic dynamics and other key interactions.
- Improve integration of factors that underpin changes in phenology, demography, and abundance.

Coordination

Improved coordination of monitoring is necessary to implement a comprehensive, integrated, ecosystem-based monitoring program envisioned by the CBMP. Coordination is necessary to help achieve additional advice for monitoring presented in the START.

- Design statistically rigorous sampling methodologies and protocols.
- Encourage states to implement the CBMP Terrestrial Plan to secure long-term funding for existing monitoring.
- CAFF, including the CBMP, should take a coordinating role to follow-up on advice from this report. Specific tasks are found in the CBMP Strategic Plan 2021-2025.

Methods

Increased attention to methodology facilitates more precise and comparable results, standardized data collection, and ability to link regional monitoring to circumpolar efforts.

- Standardize how data is collected, managed, and reported, including field and sampling protocols, data collection methods, terminology, database harmonization and management, tools for data archiving and specimen libraries, including identification and curation.
- Create a harmonized, accessible, and long-term taxonomic framework for Arctic monitoring.
- Complete baseline studies and structured inventories to improve circumpolar data across FECs.
- Promote multi-species studies and long-term time series data.

Biologists survey a vegetation plot using a plot intercept method.
Photo: Lawrence Hislop

Indigenous Knowledge

The CBMP Terrestrial Plan aims to utilize both Indigenous Knowledge and science. Despite efforts, Indigenous Knowledge has not been systematically included in the START. To obtain a full assessment of the status and trends, better understand relationships and changes, and fill key knowledge gaps, there must be improved engagement with Indigenous Knowledge holders, Indigenous governments, and Indigenous monitoring programs not only in development of assessments but in collaboratively building more comprehensive monitoring programs and initiatives.

- Improve understanding of the research and monitoring priorities of PPs and Indigenous governments, organizations, and Peoples.
- Develop long-term partnerships between scientists and Indigenous Knowledge holders to co-develop mutually relevant research and monitoring priorities and programs with equitable participation in all stages of monitoring, beginning with research design, and continuing through implementation, analysis, interpretation, and communication of results.
- Seek guidance on how institutional resources can align with and support existing Indigenous-led monitoring efforts, the development of new Indigenous-led monitoring programs, and Indigenous models of land stewardship that include monitoring components.
- Consider and articulate the ways in which programs and findings can support Indigenous land stewardship.
- Support Indigenous-led monitoring capacity through investments in northern-based research, learning and digital infrastructure and by supporting education, employment, and leadership opportunities for Indigenous Peoples.
- Ensure monitoring agreements detail mechanisms for the protection and responsible use of data and Indigenous Knowledge, including basic principles of data sovereignty.
- Increase engagement of Indigenous Peoples within CBMP.
- Work with PPs to develop strategies to more effectively recognize and reflect Indigenous Knowledge in the CBMP.

An ornithologist discusses bird nesting locations with a Chukchi reindeer herder, Chukotka, Russian Federation. Photo: Julia Darkova

Crane fly on the tundra, Nunavut, Canada. Arthropods are a diverse group of animals including insects, spiders, and mites. They are an important food source for other species and fundamental to a number of key ecosystem services, such as soil nutrient cycling, decomposition, and pollination. Photo: Fiona Paton

Local Knowledge and Citizen Science

Local Knowledge exists on a spectrum from long-term, place-based experiential knowledge held by local residents, including harvesters, to knowledge of more recent residents. As such, monitoring efforts to work with Local Knowledge must interact with a wide range of diverse knowledge holders.

- Dedicate more time to collaboration with Local Knowledge holders in monitoring design, analysis and interpretation.
- Encourage and support citizen science platforms that engage Arctic residents, as well as visitors. Platforms should reflect strong scientific goals, have transparent methods for evaluating data quality, build communities of observers, engage a strong volunteer base, and devote consistent efforts to communicating results.
- Identify and collaborate across existing platforms to increase awareness and participation in citizen science and consider new approaches to address knowledge gaps.
- Invest in digital infrastructure as a prerequisite for fully accessible platforms to inform biodiversity monitoring.

Knowledge Gaps

Currently, there is some monitoring for all FECs, but it varies in coverage, duration, frequency and access to institutional support and resources.

- Expand and coordinate long-term *in situ* time series across regions and across FECs.
- Implement ecosystem-based approaches that better monitor and link biological attributes to environmental drivers.
- Increase partnerships with Indigenous Knowledge holders and organizations.
- Increase and support contributions from Local Knowledge holders and citizen science.
- Work with Arctic Council Observer states to collect and compile knowledge on Arctic biodiversity.
- Improve data collection on rare species and species of concern.

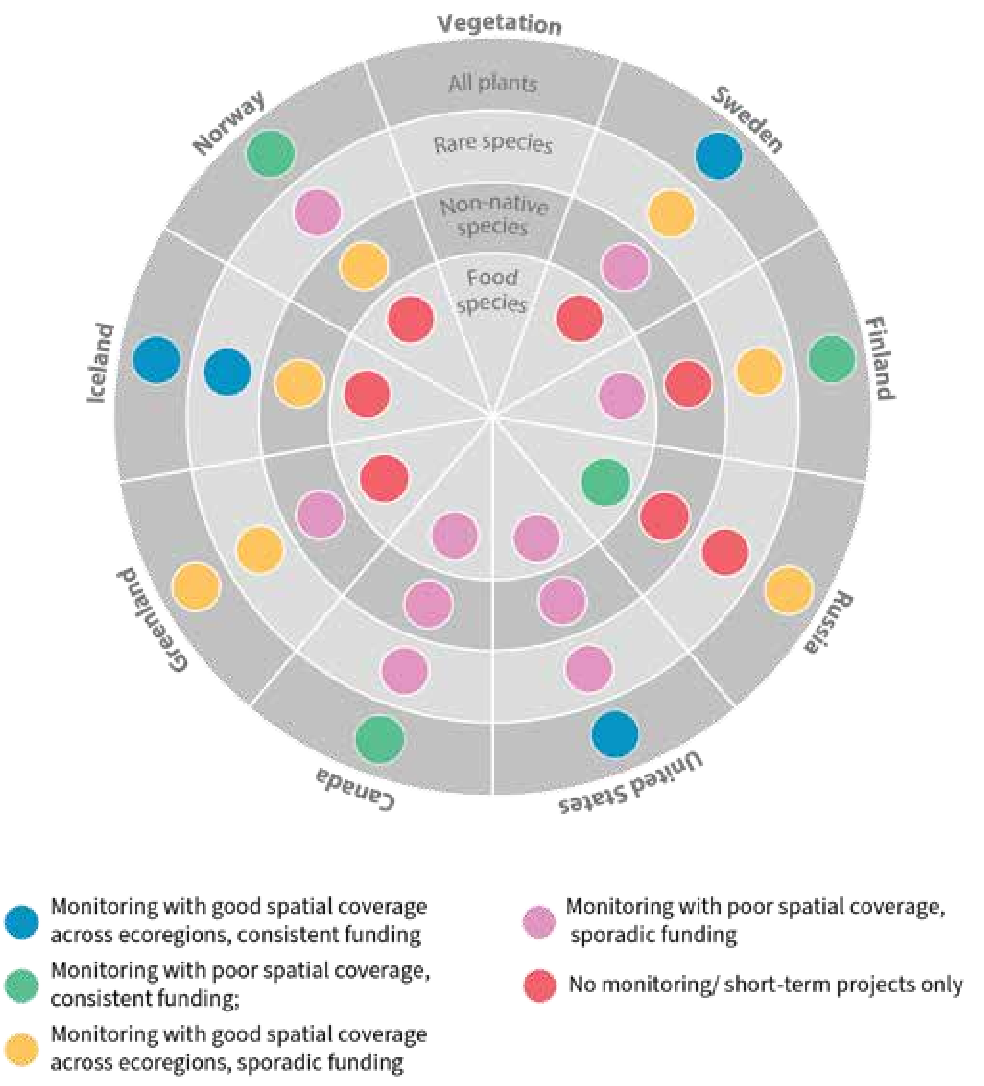
Vegetation

Monitoring of vegetation is inconsistent, with large gaps in geographical cover. Of the four FECs for monitoring vegetation, the START was able to report on all plants, species of concern, and invasive alien species. Food species were not included as data were too disparate.

- Investigate causality in vegetation change in the context of ecosystem components, including habitat-specific drivers, particularly climate, and emphasize ecosystem-based approaches.
- Continue and expand *in situ* time series.
- Utilize plot-based vegetation surveys to provide insight into vegetation changes and improve the ability to predict environmental change impacts on tundra ecosystems.
- Better consider the expected impacts of biotic and abiotic drivers on vegetation change when developing monitoring programs and conceptual models.
- Use regional and global remote-sensing products with higher spatial and temporal resolution.
- Increase monitoring efforts for all FECs, and target efforts to address data gaps, such as for food species.

Moss campion in the foreground as biologists survey vegetation in the distance, Svalbard, Norway. Photo: Lawrence Hislop

Vegetation



Status of monitoring of essential and recommended attributes for vegetation in Arctic terrestrial environments.

Arthropods

Arthropods are highly diverse and under-studied. They serve as important connections between trophic levels and several are important indicators of changing environments. The START reports on six FECs: pollinators, decomposers, herbivores, prey for vertebrates, blood-feeding insects, and predators and parasitoids. Only a few localized trends are provided due to high variability and lack of monitoring.

- Implement long-term sampling programs at strategic sites with rigorous standardized trapping protocols.
- Collect baseline data, including structured inventories, using standardized protocols for FECs and key attributes.
- Work with Indigenous Knowledge holders, Local Knowledge holders, and/or citizen science to identify regionally important species to monitor, and key locations for long-term monitoring activities.
- Focus monitoring efforts on taxa that: (a) are well-studied with existing data; (b) respond to, or are vulnerable to, change; and/or (c) have possible range shifts.
- Monitor dominant habitats at a variety of sites at both small and large geographic scales.
- Monitor relevant microhabitat environmental parameters, in addition to climatological variables, and connect to biological trends at relevant scale.
- Focus on critical FEC attributes, including ecosystem processes such as pollination, decomposition, and herbivory.
- Continue specimen sorting, identification and reporting and construct a complete trait database.
- Complete molecular sequence libraries, increase international collaboration to collate, analyze, archive, and make data accessible.

Flies, such as this Diptera *on an Arctic alpine fleabane, provide valuable pollination services, Nunavut, Canada. Photo: Fiona Paton*

Arthropods

Status of monitoring of essential and recommended attributes for arthropods in Arctic terrestrial environments.

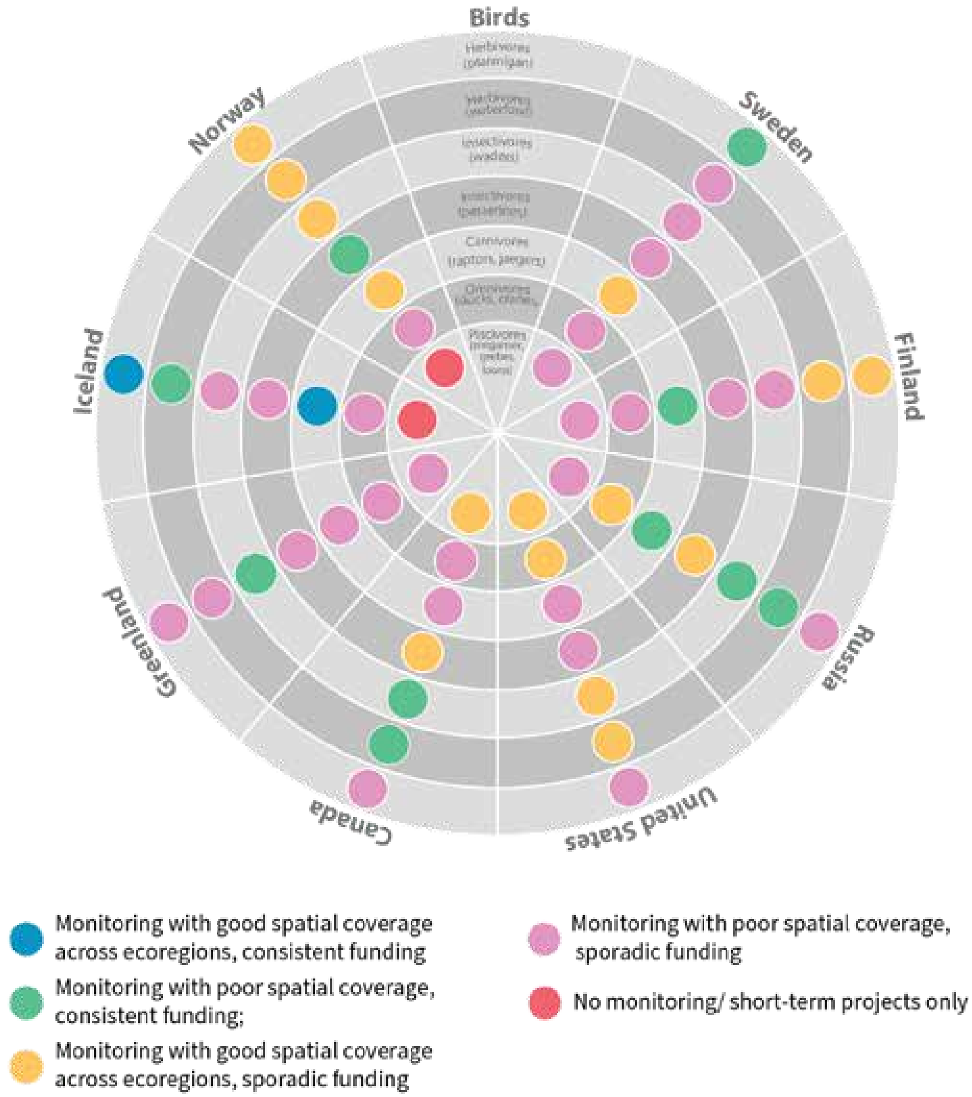
Birds

Most bird species are difficult to monitor and attribute change due to the large spatial extent of their breeding habitats and multiple threats throughout flyways. Current monitoring is uneven and inadequate. The START reports on herbivores, insectivores, carnivores, and omnivores.

- Sustaining long-term monitoring projects is the best opportunity to track changes in FECs and drivers of those changes.
- Expand monitoring of species and populations with unknown or uncertain trends such as waders in the Central Asian Flyway and East Asian–Australasian Flyway (under the Arctic Migratory Birds Initiative).
- Improve monitoring coverage of the high Arctic and other areas with poor spatial coverage (i.e., Canadian Arctic Archipelago, Greenland, and eastern Russia), including staging and wintering areas within and outside the Arctic.
- Adopt new and emerging monitoring technologies, including various tagging devices (for the study of distribution and migration, and identification of critical stopover and wintering sites), bioacoustics (for abundance and diversity sampling), and satellite data (for colony monitoring).
- Enhance coordination within and among Arctic and non-Arctic states to improve data collection on migratory species and critical site identification across species' ranges.
- Harmonize long-term studies to improve the reliability of status and trends assessments, ability to report on FEC attributes (e.g., phenology), and possible effects of environmental change, including risks of phenological mismatch.
- Use research stations as platforms to increase data coordination, sampling, and analyses, of FECs and drivers, and ensure standardized bird monitoring is part of station mandates where lacking.
- Strengthen linkages with AMAP to improve contaminant monitoring at different trophic levels and facilitate cooperation on isotope and genetic studies.

Snowy owls feed a grey-sided vole to their chicks, Norway. Photo: K.O. Jacobsen

Birds



Status of monitoring of essential and recommended attributes for birds in Arctic terrestrial environments.

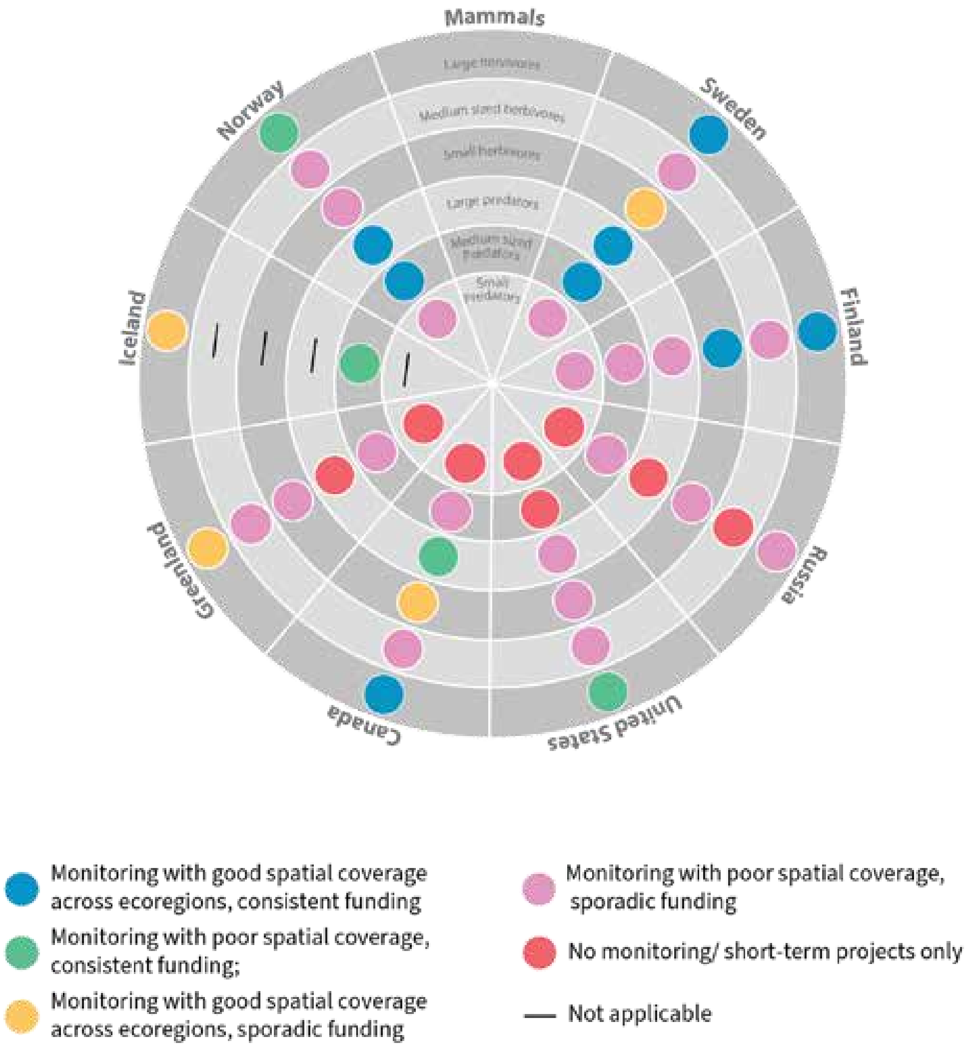
Mammals

The START reports on half of mammal FECs including large herbivores (caribou/reindeer, muskoxen), small herbivores (lemming), and medium-sized predators (Arctic fox). Data deficiencies prohibited reporting on medium-sized herbivores, and large and small predators.

- Develop synchronized protocols that include more attributes and reduce geographical knowledge gaps.
- Establish or expand international monitoring networks for medium-sized herbivores and large and small carnivores.
- Emphasize spatial structure and diversity in monitoring efforts due to the northward advance of southern competitors and vegetation changes.
- For large herbivore, small herbivore, and medium-sized predator FECs:
    - Agree on priorities and harmonize data collection across sites and programs;
    - Share and standardize protocols, in cooperation with relevant partners including Indigenous Peoples and organizations, to include abundance, demographics, spatial structure, health, phenology and, for harvested species, harvest rates; and
    - Ensure monitoring programs employ existing methods with new harmonized methods to allow data comparisons.
- Monitor health as an attribute and develop standardized health assessment protocols due to the anticipated impact of climate change on distribution and prevalence of disease.
- Monitor abiotic factors and drivers of change, across greater spatial distributions to assess the cumulative impacts of climate and other anthropogenic change on populations across their ranges.
- Conduct research on the vulnerabilities of populations to climate change and human impacts, and on genetic diversity and spatial structure of FECs.
- Increase collaboration using interdisciplinary and multi-knowledge approaches to share site- and population-specific information. This can improve monitoring and lead to better models to assess the vulnerabilities and resilience of specific populations.
- Address challenges in assessing abundance of FECs across the Arctic, including:
    - reliability of abundance estimates, such as lack of precision and accuracy;
    - changing baselines, such as changes in species distribution, sampling methodology, and areas monitored; and
    - differences in frequency and spatial extent of monitoring.

Muskoxen at Zackenberg Research Station, Northeast Greenland. Photo: Lars Holst Hansen

Mammals



Status of monitoring of essential and recommended attributes for mammals in Arctic terrestrial environments.

A reindeer walks past a vegetation monitoring site, Svalbard, Norway. Photo: Lawrence Hislop

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