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Conservation of Arctic Flora and Fauna

CBMP

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# Terrestrial Expert Monitoring Group

Background Paper of the Circumpolar Biodiversity Monitoring Programme´s
Terrestrial Expert Monitoring Group

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- Environment Canada, Ottawa, Canada
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- Icelandic Institute of Natural History, Reykjavik, Iceland
- The Ministry of Domestic Affairs, Nature and Environment, Government of Greenland
- Russian Federation Ministry of Natural Resources, Moscow, Russia
- Swedish Environmental Protection Agency, Stockholm, Sweden
- United States Department of the Interior, Fish and Wildlife Service, Anchorage, Alaska

***CAFF Permanent Participant Organizations:***

- Aleut International Association (AIA)
- Arctic Athabaskan Council (AAC)
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Contents

# 1. Foreword

United States and Greenland/Denmark agreed in 2010 to act as lead countries for the initial development of the Terrestrial Expert Monitoring Group (TEMG) of CAFF's Circumpolar Biodiversity Monitoring Program (CBMP).

Prior to the first meeting of the Terrestrial Expert Monitoring Group (TEMG) in April 2011, the two lead countries developed the Draft Terms of Reference (App. 1) and an outline for the Terrestrial Expert Monitoring Group – Background Paper. Before summer 2011, the TEMG had members from all eight Arctic countries.

The overall goal of the TEMG is to develop a multi-disciplinary, integrated, pan-Arctic, long-term terrestrial biodiversity monitoring plan. In addition to the monitoring plan, the Arctic Council has asked the CBMP and thus the TEMG to develop an implementation plan for the monitoring plan that identifies timelines, costs, organizational structure and partners.

This document provides an overview of the development of the monitoring and implementation plan and is produced by the TEMG with assistance from a number of experts in various countries. This background document also served as a basis for the first international workshop of the TEMG that was held in Hvalsø, Denmark on October 11 - 13, 2011, and has provided important guidance for the activities and discussions of the TEMG.

Members of the the Terrestrial Expert Monitoring Group at their inaugural workshop in Denmark October, 2011.
Photo: Melinda Ballard

## 2. Introduction

Arctic ecosystems host unique assemblages of organisms. The size and nature of Arctic ecosystems make them critically important to the biological, chemical, and physical balance of the globe. Documented environmental changes include significant loss of multi-year sea ice, declining integrity of permafrost, increased coastal erosion, and changes in water balance and availability, all of which have (or are predicted to have) impacts to biological and physical processes of the Arctic. Healthy Arctic ecosystems are of fundamental economic, cultural and spiritual importance to Arctic residents.

In response to the global importance of the Arctic and its biodiversity, the increasing pressures on Arctic biodiversity and human communities, and the limited capacity to monitor and understand these changes, the Arctic Climate Impact Assessment (ACIA) recommended that long-term Arctic biodiversity monitoring be expanded and enhanced. In its acceptance of ACIA's recommendations, the Arctic Council directed the Conservation of Arctic Flora and Fauna (CAFF) Working Group to further examine those findings related to biodiversity conservation and to develop follow up programs and activities to address key projections for the future of the Arctic. A primary response has been the implementation of the Circumpolar Biodiversity Monitoring Program (CBMP).

The CBMP serves as an international forum of local resource users, scientists, and conservation experts from all eight Arctic countries, the six international indigenous organizations of the Arctic Council, and various global conservation organizations. The CBMP is strategically linked to other international conservation programs and initiatives such as the Arctic Monitoring and Assessment Program (AMAP), International Arctic Science Committee (IASC), Sustaining Arctic Observing Networks Initiative (SAON), International Polar Year (IPY), the Arctic Biodiversity Assessment (ABA), the Global Earth Observation – Biodiversity Observation Network (GEO-BON) and the Convention on Biological Diversity (CBD), thereby ensuring effective coordination and integration with related Arctic and global initiatives.

The CBMP's results will be developed via the Arctic Council into effective conservation, mitigation, and adaptation policies that promote the sustainability of the Arctic's living resources. To develop effective policies, information is needed on the status of and trends in Arctic biodiversity at the circumpolar level, and also on the natural and anthropogenic stressors driving trends in Arctic biodiversity at all geographic scales. Understanding how and why biodiversity is changing at various scales will enable local communities and decision making bodies to develop informed policies and responses focused on adaptation, mitigation, and conservation. CBMP seeks to provide this information in a timely fashion using diverse formats.

Svalbard reindeer /Photo: Mark Marrissink

Towards this end, the CBMP is establishing four Expert Monitoring Groups representing major Arctic themes (Marine, Coastal, Freshwater, and Terrestrial). Each group, representing a diversity of disciplines, is tasked with developing pan-Arctic integrated biodiversity monitoring plans for these Arctic biomes.

## 2.1 Purpose and need

Svalbard /Photo: Mark Marrissink

The CBMP is a mechanism for coordinating and enhancing long-term biodiversity monitoring efforts throughout the Arctic in order to improve our ability to detect and report on trends and stressors. The programme developed a five year strategy to implement an integrated and sustained Arctic biodiversity monitoring network, which includes the establishment of the four Expert Monitoring Groups to develop pan-Arctic, integrated monitoring plans.

The Terrestrial Expert Monitoring Group (TEMG) is responsible for developing a pan-Arctic, integrated, terrestrial biodiversity monitoring plan that serves as an umbrella monitoring framework. The purpose is to ensure better coordination between existing terrestrial biodiversity monitoring initiatives and networks and more efficient and effective synthesis and delivery of the results of this monitoring to decision makers, stakeholders and the general public.

The need to measure change in Arctic biodiversity is increasing given the emerging evidence that Arctic ecosystems are already rapidly responding, in some cases quite dramatically, to climatic changes. Substantial shifts in the Arctic environment are predicted for the near future (e.g., encroachment of more southerly species and ecosystems) and recent changes in physical processes such as sea ice loss have outpaced predicted changes. Limited functional redundancy in Arctic ecosystems poses a particular risk as the loss of a single species could have dramatic and cascading effects on an ecosystem's state and function. A common single-species approach to monitoring, especially with a bias toward charismatic (versus functional) species, limits the ability to detect and understand potentially critical changes in Arctic ecosystems. A broader and more integrated approach that monitors more functional species and ecosystem aspects will result in a better understanding of how the Arctic systems are responding to changes, and how these changes compare with global biodiversity trends. The use of a broader and more integrated approach to biodiversity monitoring is essential in order to develop effective conservation and adaptation strategies.

Climate change is placing increased pressure on the resiliency and sustainability of Arctic biodiversity. However, as described in Chapter 3, it is not the only stressor. Others include: habitat fragmentation; regional development such as oil, gas and mineral exploration and production, hydroelectric projects, environmental contaminants, urbanization, increased agriculture, air traffic, invasive species, etc. Oil and gas development is expected to play a particularly role in shaping the Arctic of the future, as the Arctic is estimated to contain a quarter of the world's remaining oil and gas reserves. Currently, the United States Geological Survey estimates that 10% of the world's oil and 25% of the world's natural gas is produced in the Arctic, with the majority coming from Arctic and sub-Arctic regions within the Russian Federation.

Information on Arctic biodiversity, human stressors, and natural changes is currently available in a piecemeal fashion and on an irregular basis. An integrated picture of the status of and trends in key species, habitats, processes, services, and ecosystem integrity in the Arctic and along related migration routes is not fully developed. At the same time, numerous monitoring efforts are currently underway, although without general coordination, long-term commitment, integration and involvement of local people. These deficiencies have resulted in weak linkages between monitoring results and decision making and a corresponding frequent inability to detect and understand change in many instances. An

integrated, interdisciplinary, and collaborative Arctic biodiversity monitoring program that enhances our ability to detect important trends on a timely basis, attribute these trends to causal factors, and disseminate this information in both the public and policy arena is urgently needed.

## 2.2. Integrated ecosystem-based approach to Arctic biodiversity monitoring

The CBMP has adopted an integrated, ecosystem-based approach to monitoring in its program design, organization, and operation (Fig. 1).

The ecosystem-based approach integrates information from land, water, and living resources, and lends itself to simultaneously monitoring many aspects of an ecosystem and developing an inter-relational understanding of the system's elements. This approach considers the integrity of an entire ecosystem and its interaction with other ecosystems. It also identifies important relationships bridging ecosystems, habitats, and species, and the impacts of stressors on ecological functions. The resulting information provides a basis for adaptive management, enabling effective conservation, mitigation, and adaptation actions appropriate to the Arctic.

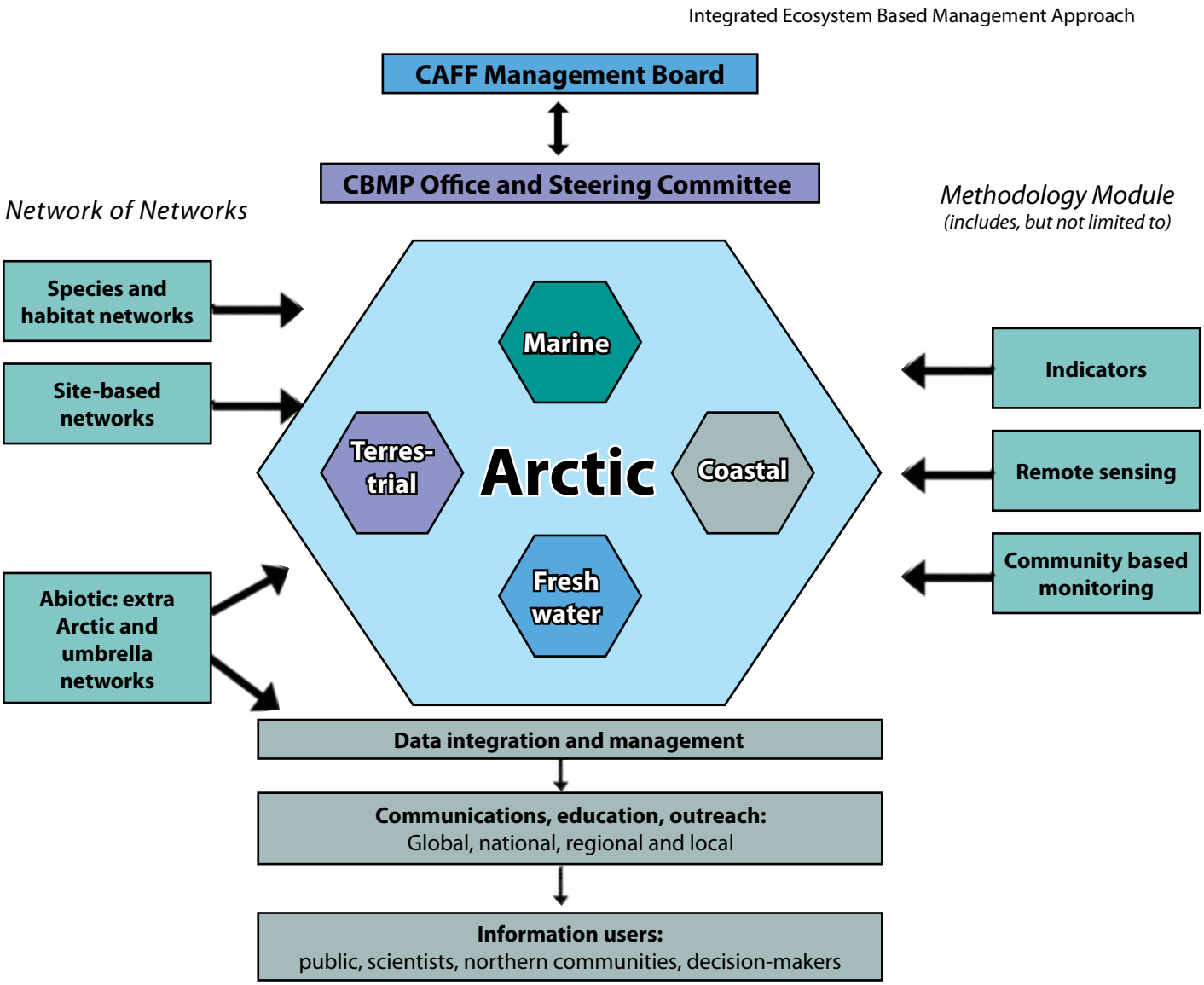



**Figure 1.** Relationship of Expert Monitoring Groups to the Circumpolar Biodiversity Monitoring Program of the Conservation of Arctic Flora and Fauna. Outputs of a coordinated monitoring approach for Arctic terrestrial ecosystems will serve a number of mandates at various scales, and build on a network of networks.

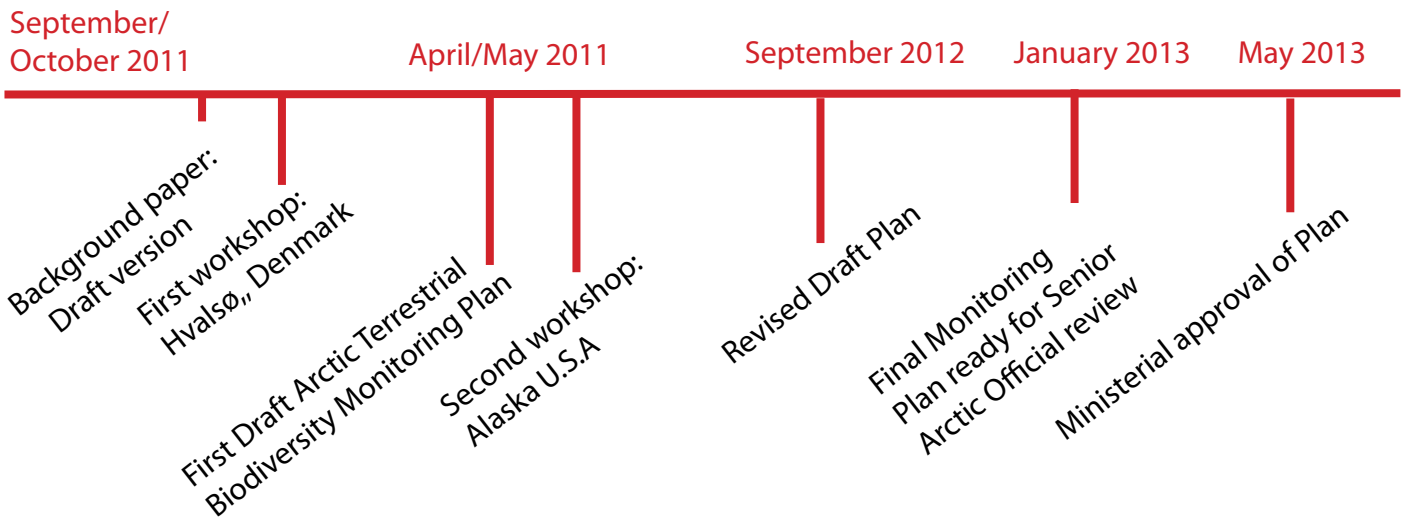
## 2.3 Terrestrial Expert Monitoring Group goals and objectives

The TEMG's goal is to promote, facilitate, coordinate and harmonize terrestrial biodiversity monitoring activities among circumpolar countries, and to improve ongoing communication amongst and between scientists, community experts, managers and disciplines both inside and outside the Arctic. The net result of this approach will be the ability to detect, understand and report on the causes of long-term change in the composition, structure, and function of Arctic ecosystems and the biodiversity they support.

The primary objective of the TEMG is to develop a multidisciplinary, integrated, pan-Arctic long-term terrestrial ecosystem-based biodiversity monitoring plan that:

- Achieves more efficient, effective, and coordinated Arctic terrestrial biodiversity monitoring through improved data accessibility and harmonization of methods;
- Identifies, rescues, aggregates and analyzes existing data to generate statistical baselines;
- Identifies gaps in existing monitoring and proposes new monitoring efforts where necessary;
- Improves data management;
- Provides information for regular assessment and reporting of pan-Arctic monitoring activities and results;
- Supports international biodiversity convention goals, particularly the Convention on Biological Diversity.

## 2.4 Process timeline




## 2.5 Early decisions including linkage to the Arctic Biodiversity Assessment

Information on Arctic biodiversity is sparse and many untested assumptions provide the only operational paradigms and context for long-term monitoring. While individual programs and efforts do exist, current programs focused on terrestrial biodiversity lack ecosystem level integration. Consequently, the 'bigger picture´ is being missed, making it difficult to assess the impacts of known stressors to the Arctic, such as climate change and industrial development, and their consequences to humans. Recent assessments and reports (the Arctic Climate Impact Assessment, the overview from the International Conference on Arctic Research Planning II, Intergovernmental Panel on Climate Change Fourth Assessment Report, Arctic Biodiversity Trends 2010) underscore that the Arctic region will be affected most profoundly by climate change. The Arctic Climate Impact Assessment further recommended that long-term Arctic biodiversity monitoring be expanded and enhanced. The CAFF Working Group responded to this recommendation with the implementation of the Circumpolar Biodiversity Monitoring Program.

Planning for the TEMG has been ongoing since 2006. Three international CBMP workshops held in Anchorage (November 2006), Washington, DC (March 2008), and Vancouver (September 2008) helped establish the concept and development of a number of Expert Monitoring Groups (terrestrial, coastal, marine, freshwater). The decisions and thoughts from these workshops are described in the CBMP Framework Document and Five Year Implementation Plan, both endorsed by the Arctic Council Senior Arctic Officials (SAO´s) and Ministers.

The CBMP's mandate is to coordinate Arctic biodiversity monitoring, data management and reporting. In keeping with this overarching goal, the CBMP is to be based on existing monitoring activities that are already implemented, and wherever possible, circumpolar in scope. Further the TEMG should assess existing Arctic biodiversity monitoring capacity and identify what – if any – critical gaps exist and how best to address them in the future monitoring of Arctic biodiversity. Where possible, the plan should be coordinated with existing or planned regional, national or bilateral projects that could contribute to a circumpolar understanding of biodiversity trends.

Following the establishment of the CBMP, the CAFF Working Group agreed that it was necessary to provide policy makers and conservation managers with a synthesis of the best available scientific and traditional ecological knowledge on Arctic biodiversity. As a result, the Arctic Biodiversity Assessment (ABA, www.caff.is/aba), was endorsed by the Arctic Council in 2006. The aims of the ABA are to provide a much needed description of the current state of the Arctic's ecosystems and biodiversity, create a baseline for use in global and regional assessments of biodiversity, and provide a basis to inform and guide future Arctic Council work. In addition, the ABA will provide up-to-date scientific and traditional ecological knowledge, identify gaps in the data record, and identify key mechanisms driving change, and produce policy recommendations regarding Arctic biodiversity. This assessment is scheduled to be finished in 2013.

In line with Arctic Council decisions, the TEMG will, in the widest extent, use the ABA as a platform for design and selection of key ecosystem elements (i.e., "indicators" as defined in Arctic Biodiversity Trends 2010) to monitor. The resulting outputs from the CBMP Arctic Terrestrial Biodiversity Monitoring Plan will inform future assessments to which the ABA will be considered the baseline.

Spatially, the focus of the TEMG should be on the tundra and polar desert ecosystems (north of the treeline), but inclusive of those sub-Arctic and alpine regions from where species are expected to migrate into Arctic regions (see Chapter 5.1). Specifically, this spatial definition does not include those areas defined in the U.S. Arctic Policy outside of the CAFF Circumpolar Arctic Vegetation Map.

Future monitoring work will need to identify sites where continuous data collections will be possible. New studies also often tend to lack linkages to previously collected archival data. This needs to be improved by accessing historic information (e.g., reports of past studies, photographs) and revisiting and resampling orphaned monitoring sites, in some cases, to which the current status can be compared (inspired by the International Polar Year (IPY) project 'Back to the Future').

# 3 Considerations for monitoring Arctic terrestrial biodiversity

## 3.1 Heterogeneity of Arctic terrestrial ecosystems

Although Arctic biodiversity is low compared to other regions of the world, the Arctic hosts a unique array of specialized species and ecosystems. Given this, and the large geographic extent of the circumpolar Arctic, the climatic, geological and geophysical variability involved, it is not realistic to fully represent all Arctic terrestrial ecosystems in a biodiversity monitoring program. A major task for the design phase of a monitoring program will be to define the key ecosystems to be included, from plot scale to landscape scale, within each of the regions in the Arctic proper (see Chapter 5.1). Trade offs

are required between a scientifically ideal design, scarce fiscal and human resources, and political and cultural interests. However, using remote sensing techniques, we can look beyond the site level and use remotely sensed information to better integrate both intensive and extensive monitoring.

## 3.2 Stressors

Mining machinery Photo: Lawrence Hislop

The Arctic is currently undergoing rapid changes: cultural, political and socioeconomic changes resulting in exploitation of natural and non-renewable resources, as well as physical development, changes in climate, and changes in pollution, both local and transboundary. These changes are going to interact and accelerate in the future, and in various ways, putting an increased pressure on biodiversity within the Arctic.

The composition of Arctic biodiversity is highly related to temperature, directly in the form of freezing tolerance or productivity, but also indirectly through temperature effects of thawing of permafrost, snowmelt, drought, fires, changes in phenology and cascading effects on trophic interactions, encroachment of invasive species, pest outbreaks and disease transmissions. Therefore, it is expected that future warming will have a widespread and complex impact on biodiversity throughout the Arctic. For some species currently limited by the short Arctic summer, longer growing seasons may be an advantage in terms of reproduction and growth; however, for specialized Arctic flora and fauna, the combined change will mainly have negative effects.

Effects may be successional changes, such as the northward movement of the treeline which will affect not only Arctic biodiversity through shifting habitats and species, but also reduce albedo (surface reflectivity), further enhancing warming of the atmosphere. Similarly, the composition and distribution of plant communities is likely to change throughout the Arctic. Generally, there is an increase in productivity over much of the Arctic, as well as an increase in the length of the growing season. While the number of plant species inhabiting the current Arctic may actually increase over the long-term, there is a risk of losing cold-adapted species, thus reducing the global diversity (e.g., high Arctic mosses and lichens are expected to suffer). Retreat of permafrost and changing soil moisture conditions will also affect plant communities. For example, mires, an important habitat, are at risk of drying out with consequent losses of associated arthropod and bird communities. For lowland flora and fauna, sea level rise may cause substantial habitat loss.

Effects may also be abrupt and thus more difficult to predict. Increased risk of extreme events, such as icing, and cascading effects will contribute to more unstable and unpredictable conditions. An example is the dampening of rodent cycles due to unstable winter conditions which has a cascading effect on the guild of mammalian and avian predators depending on the rodents. Migratory Arctic species constitute a special case since they will not only be affected by changing conditions on their Arctic breeding grounds but also by global change effects operating on their staging and wintering grounds outside the Arctic. Arctic breeding shorebirds are at particular risk from pressures on their intertidal habitats in their staging and wintering areas.

Human use of living resources in terms of harvesting, reindeer husbandry and, in the low Arctic, small scale farming and berry collection, affect certain species and ecosystems. Patterns and intensity of use will change with ongoing cultural and technological changes and warmer climate.

With increasing global demands for resources, the Arctic is becoming a focal area for hydrocarbon and mineral development. Increasing industrial development to extract hydrocarbon, mineral and hydropower resources in the Arctic may locally affect distribution and abundances of flora and fauna, directly due to physical development of infrastructures, disturbance via associated human activities, onsite and downstream pollution and/or, indirectly, by opening up access to adjacent, previously remote areas. In addition to climate change, reindeer herding in Fennoscandia is threatened by increased resource development, and in Russia, hydrocarbon development is actually considered a greater threat to the most productive herding areas than climate change.

Tourism is increasing throughout the Arctic. On–shore activities from cruise ship tourists and individual-based hiking are placing increased disturbance pressure on terrestrial flora and fauna in some places.

## 3.3 Monitoring based on conceptual models

An integrated monitoring approach needs to reach across programs, jurisdictions, stakeholders, and agencies to manage for ecosystem sustainability (i.e., capacity). One way to achieve this goal is to identify management questions, and key ecosystem elements and associated attributes, leading to the selection of potential monitoring parameters and methods. Of primary importance here is that final parameter selection is based on key ecological functions or essential species demonstrated within common, accepted conceptual ecological models. Conceptual ecological models for the Arctic based on science and other expert input, can provide a common language that addresses ecosystem sustainability, and provides a basis for resource decisions predicated on maintaining or restoring ecosystem capacities through monitoring key ecosystem elements and functions and their associated parameters.

To facilitate effective and consistent reporting, the CBMP will choose a suite of key ecosystem elements and related attributes that provide a comprehensive picture of the state of Arctic biodiversity—from species, to habitats, to ecosystem processes, to ecological services. The key elements will be chosen to represent key ecological species or functions, and will be identified via ecological modelling and through an expert opinion consultation process.

The following steps (adapted from Mulder et al. 1999[1]) describe the sequence of events the TEMG will follow to identify monitoring key elements for consideration:

- Review and finalize Arctic, terrestrial biodiversity monitoring goals and objectives, and management questions to be answered;
- Develop a high-level conceptual ecological model for the Arctic to identify key terrestrial ecosystem types, stressors, and/or regionally significant species essential to properly functioning and sustainable Arctic ecosystems, and consider for monitoring;
- Develop a conceptual ecological model(s) for each of the key terrestrial ecosystems/ecoregions identifying key ecosystem elements and related attributes, and relationships and processes between elements, attributes, and stressors; and,
- Identify a suite of key ecosystem elements, attributes, and parameters to report on status and change across Arctic terrestrial ecosystem attributes.

## 3.4 Key ecosystem elements, attributes and parameters

The monitoring programme outlined here is based on a three-level hierarchical approach: Key ecosystem elements (also known as indicators), attributes, and parameters, as exemplified in Table 1

1 Mulder, B.S., Noon, B.R., Spies, T.A., Raphael, M.G., Palmer, C.J., Olsen, A.R., Reeves, G.H. & Welsh, H. H. Jr. 1999. The strategy and design of the effectiveness monitoring program for the Northwest Forest Plan. Gen. Tech. Rep. PNW-GTR-437. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station. 138 p. http://www.treesearch.fs.fed.us/pubs/3002

below. "Key elements" are ecosystem components which are critical to the functioning and resiliency of Arctic ecosystems and/or reflect the vital importance to the subsistence and economies of northern communities. The TEMG will identify key elements on the basis of (a) conceptual ecological models that clarify the ecological theory supporting their selection, and (b) the information needs of communities and managers/decision makers. Key element selection will follow the guidelines developed by CBMP (Five year implementation plan, strategy for developing indices and indicators, etc.) and which, as much as possible, can be scaled.

Each key element then has a number of attributes, which describes various aspects or characteristics of the key element. Lastly, each attribute has a number of potential parameters that are the actual entities measured in the field (Table 1). Working in concert, the hierarchical components (key elements, attributes, and parameters) build on one another; that is, individual parameters inform the status of the attributes, and in turn, the attributes collectively inform the status of the key elements.

Parameters for consideration by the TEMG will be SMART (specific, measurable, achievable, results oriented, and temporally defined). The TEMG will use the following criteria to evaluate and select the attributes and parameters:

- sensitivity to natural or anthropogenic drivers;
- scientific validity;
- ecological relevance;
- relevance to and resonance with diverse audiences (e.g., local communities, decision makers, global public);
- availability and sustainability of monitoring capacity and expertise;
- subjection to targets and thresholds; and
- practicality.

The TEMG key elements will further be chosen so they, to the greatest extent possible, can contribute to the Convention on Biodiversity, Aichi Biodiversity Targets and to the CBD UNEP/CBD/COP-/DEC/X/13 decision, considering CBMP as an important input to the work.

**Table 1. Structure of the monitoring program, here exemplified with caribou**

| Key Element | Attribute | Parameter |
|---|---|---|
| Caribou | Abundance | Number |
| | Demographics | Calf percentage<br>Age composition<br>Winter mortality<br>..... |
| | Health | Prevalence<br>..... |

## 3.5 Linkage to stressors

Increasing pressures induced by, for instance, climate change and human activities are all contributing to severe changes in natural ecosystems in the Arctic and elsewhere. A strong motivation of the TEMG is therefore to develop a platform to assess the effects of multiple stressors. Hence, it is necessary to include monitoring of natural and anthropogenic stressors, or indices thereof, in the terrestrial monitoring program. An appropriate balance between monitoring of ecosystem key elements and stressors must be developed to not only document change, but also to establish the causal relationships between changes in biodiversity and these pressures.

### 3.6 Community Based Monitoring

The peoples inhabiting the various regions of the Arctic spend vast amounts of time on the land and at sea. Drawing on personal experience, information shared with others, and knowledge handed down through the generations, residents of the Arctic are able to recognize subtle environmental changes and offer insights into their causes. They are community-based monitors by virtue of their day to day activities.

In addition to their inherent capacity in community based monitoring (CBM), Arctic residents have the ability to employ standard scientific monitoring procedures in the practice of citizen science, thereby extending the reach and effectiveness of programs which tend to rely solely on a limited number of trained scientists to carry out monitoring.

Indigenous and other Arctic peoples wish to impart their environmental understanding to scientific discourse, not only because they have a great deal to offer but also because this exchange represents an important step towards full participation in resource management activities.

The CBMP believes that CBM has significant contributions to make to circumpolar monitoring efforts. The Arctic Council's Permanent Participants and other Indigenous and local organizations desire a strong CBM element within the CBMP. The communities of the Arctic region will directly benefit from the powerful information gathering and dissemination approach that the CBMP offers. Maximizing the contributions of circumpolar peoples to the CBMP will help ensure that the program is relevant and responsive to local concerns.

The use of community members in research collection leads to greater investment in the research itself and a greater understanding of the results.

Means of incorporation and research needs:

- Create a platform to acquire TEK data in a standardised manner – the CBMP handbook is developed and should be integrated
- Determine what community based monitoring projects are currently active in the Arctic (development of a CBM Registry)
- Determine how existing community monitoring efforts work into our ecosystem-based approach (based on attributes and parameters chosen, determine which ones are best monitored using community-based approaches)
- Identify community priority ecosystem components to help select monitoring parameters and reporting status of key elements.

## 4. Monitoring Approach and Methods

The CBMP TEMG will pursue a terrestrial biodiversity monitoring program following an ecosystem-based approach. Information related to multiple interacting parameters at various scales will be collected and integrated to identify ecosystem status and trends and to diagnose potential drivers, processes at play, and implications of those trends. The ecosystem approach generates a comprehensive picture of biodiversity processes and trends which will better inform decision-making related to the conservation and management of Arctic terrestrial biodiversity.

The monitoring strategy will be designed to satisfy the needs for Arctic terrestrial biodiversity information and to detect changes in terrestrial biodiversity which may occur in the future as much as possible.

To this end, the strategy must balance specific inquiry-based monitoring with broader ambient monitoring. Clearly articulated monitoring questions are essential to shape the selection of the

monitoring key ecosystem elements and associated parameters, and the TEMG monitoring scheme will, thus, be adaptive, whilst still maintaining core monitoring efforts. The strategy will build from existing monitoring networks and local capacity as much as possible to maximize the efficiency and likelihood of success. However, while much can be accomplished through existing networks, the monitoring strategy will identify needs which are not addressed through current capacity. Hence, the TEMG monitoring scheme aims to use both existing and new monitoring efforts at different scales (from plot, over species and populations, to remote sensing) and integrate these through modelling. The latter in particular requires a statistically sound design that allows for the temporal and spatial upscaling of collected data.

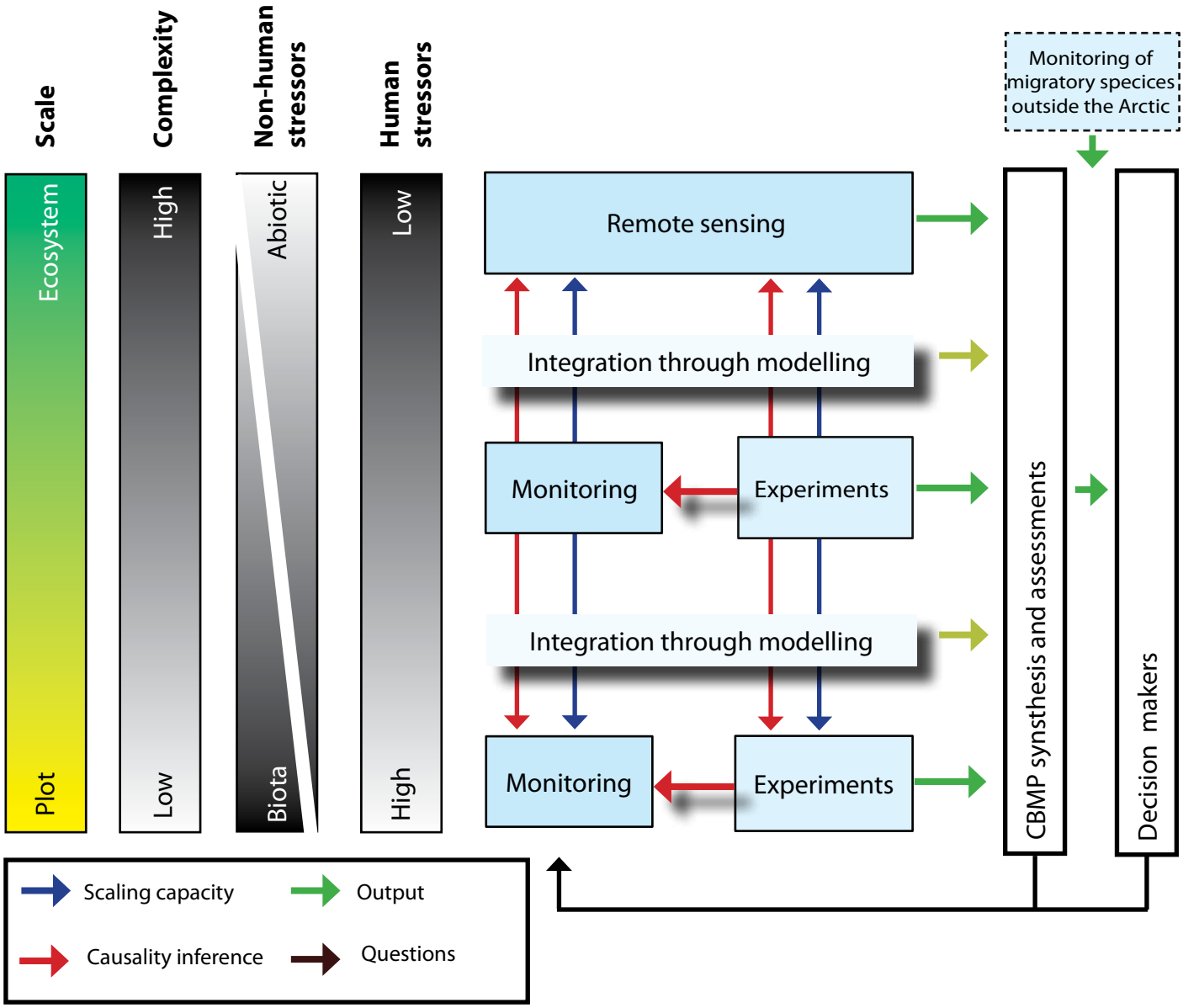



**Figure 2.** Conceptual visualisation of the TEMG monitoring scheme. Monitoring efforts at the various levels (unbroken frames) are integrated through modelling (blue arrows), and complemented with experimental research and monitoring efforts conducted outside the TEMG monitoring scheme (broken frames). Causal linkages (red arrows) can be established through experimental work, and on the larger scale inferred from detailed data on the smaller scale. Monitoring outputs (green arrows) can be extracted on all levels, and feed into the assessment and decision-making processes, ultimately also feeding back into the TEMG monitoring scheme (black arrows).

## 4.1 Methods

Methods to detect change at scales from local to landscape and provide complementary information are essential. The various approaches can be layered and combined during data collection or analysis. Such integration between and among the approaches will increase the probability of detecting change, will support up- and down-scaling of identified effects and create a more effective monitoring scheme. Several key methods currently in use to track terrestrial biodiversity, which may be applicable to the Arctic, are summarized below.

### 4.1.1 Plot/site based monitoring

Plot or site monitoring involves repeated visits to a designated geographic location for routine sampling. These plots and sites can form the structure onto which monitoring of a number of biological entities can be layered to facilitate an integrated, place-based assessment of change. Further, through harmonization of monitoring parameters and collection methods across geographical locations, data generated can be rolled up for broader scale assessments and reporting of change.

Allocation of resources to plot/site-based monitoring requires trade offs between geographical coverage and intensity of monitoring effort. Plot monitoring can be done intensively with detailed measurements of many parameters, and more frequent observations at fewer sites. This narrow-but-deep "intensive" plot monitoring can help to identify drivers of biological trends and a better understanding of the ecological processes in play. Plot monitoring can also be applied extensively with less frequent visits, or fewer monitored parameters, but at more sites. This shallow-but-wide "extensive" approach to detecting change is valuable over a broader geographic area, but there is a higher risk that unique changes will not be detected. The TEMG monitoring strategy will seek a balance of intensive and extensive sampling necessary to described key ecological processes as defined in the conceptual models.

Special emphasis will be placed on revisiting sites which have been investigated in the past, e.g., as part of the International Biological Programme (1964-1974) or equivalent studies. The IPY project 'Back to the Future' has demonstrated the value of these multi-decadal comparisons of abiotic and biotic changes in tundra ecosystems for which few long time series exist. Thereby, knowledge was passed from old to new generations of researchers, sites were mapped with GPS and data stored in modern electronic databases. More sites can easily be added to the list, and CBMP is an obvious host for the continuation of the project and archiving of data.

### 4.1.2 Species based monitoring

Species-based monitoring can focus on populations of single species, multiple species, assemblages of multiple species, or communities. Within an ecosystem-based approach, monitoring efforts generally focus on identifying:

- keystone species because these play a critical role in ecosystem function;
- umbrella/key elements/ indicator species for which correlations between the patterns of a target variable and a proxy variable are anticipated;
- rare species, for example based on red lists;
- species which are important as a resource to local communities
- or invasive species.

While there are many possible key elements in an ecosystem, species-based monitoring often focuses on population size and distribution. There are many direct methods used to perform species-based monitoring including point count surveys, transect surveys, aerial surveys, traps, active or passive samplers, etc. Species monitoring can also be indirect and focus on evidence of the population or their activity through monitoring dens or nests, tracks or runways, scat, hair, or other methods. Species or community behaviour, condition, productivity, phenology, seed dispersal and viability, reproductive

success, body condition, and/or other biological parameters may also be monitored. Easily recognised species or species used for local consumption are suitable for community-based monitoring. Species-based monitoring will be promoted within the TEMG monitoring strategy for those key species that are essential to ecosystem functioning as defined in the conceptual models.

### 4.1.3 Remote sensing

Remote sensing is attractive for Arctic monitoring because it allows for measurement of changes over vast, remote, and difficult to access areas which would otherwise be impossible to track. Additionally remote sensing data which includes both satellite and air and ground based photography can be used as a "time machine" to support the above mentioned "Back to the Future" studies as well as establish historical baseline conditions to observe changes in both land cover and habitat. Advancements in processing techniques and satellite image quantity and quality in recent years have greatly improved our ability to conduct terrestrial biodiversity monitoring via remote sensing. This increased availability of good quality remote sensing data will continue into the future.

Remote sensing can be used to track biological entities directly (via land cover classification and change detection methods, and species movement and distribution with global positioning system and/or radar technologies). Remote sensing has also been used indirectly via methods which measure and map variables that are believed to influence biodiversity, such as hydrology, active layer of the permafrost, coastal erosion, sea ice, and surface temperature, topography, and snow cover. Remote sensing derived time series of vegetation indices have been widely and successfully used to study Arctic regions and have been linked to ground studies at plot, transect, and landscape scales. Remote sensing has also been used to measure changes in Arctic terrestrial phenology, habitat or land cover extent, disturbance, and productivity, among other measures.

Choosing a remote sensing application necessarily involves trade offs between spatial resolution, geographic coverage, revisit time and sensor type. Sensor types include electro-optical (EO) and microwave. EO sensors are limited by cloud cover and solar illumination constraints while microwave sensors image through clouds throughout the year but are less useful in mapping land cover. EO satellite data with high spatial coverage and revisit times, such as the Advanced Very High Resolution Radiometer (AVHRR) and Moderate Resolution Imaging Spectrometer (MODIS) are readily available for free or at a nominal cost, but have a relatively low spatial resolution (1 km). Moderate spatial resolution (10-30 meters) EO imagery such as Landsat, SPOT, and IRS can be accessed, but at a slightly increased cost and with lower temporal frequency (Note: Landsat data is now free of charge). Commercial EO satellite data such as Rapid Eye, Quickbird, GeoEye, and IKONOS with spatial resolutions of approximately 2-5 meters is also available for parts of the Arctic. It is expensive but has proven useful to support studies of a limited geographic area that requires fine resolution. The moderate and high resolution EO imagery can be usefully applied to track finer scale changes in representative areas or areas of or particular interest or concern, such as caribou calving grounds. Microwave satellite data such as SAR which has imaged the arctic region continuously since 1998 has been shown useful in mapping frozen versus non-frozen lakes in the North Slope, as well as providing information on measuring the active layer of the permafrost. Additionally, the SAR data which is available for free in respect to the ESA products provides other information that influences biodiversity such as coastal erosion and sea ice extent. The ability of SAR to map land dynamics in the Arctic has not been tested but a pilot program to evaluate whether this is possible is underway.

There are challenges related to the temporal frequency of satellite imaging, difficulty in obtaining clear EO images, because of the high probability of cloud cover in the Arctic, solar illumination constraints and logistical problems and cost associated with groundtruthing. It can be difficult to detect the subtle changes associated with Arctic landscapes and communities using remote methods, therefore it is essential that management questions and monitoring objectives are explicitly linked to appropriate and capable remote sensing applications. Nonetheless, satellite based earth observation will be a critical

component of Arctic terrestrial biodiversity monitoring.

The TEMG monitoring strategy supports an optimized integration of field and remote sensing based sampling, but intends to promote the use of remote sensing and other geospatial technologies to the maximum extent possible.

#### 4.1.4 Modelling

Modelling can be used to integrate and upscale and downscale identified trends, and by combining status and trend site-information with the geographic extrapolation abilities of remote sensing, modelling can serve to fill in gaps in our understanding where information is lacking. Models are also useful to predict and test potential future scenarios and will further elucidate possible changes and inform adaptive management.

### 4.2 Standardization and harmonization

The TEMG supports standardization of biodiversity monitoring methods, where appropriate (e.g., for new measures and for existing measures that are already close to standardized in their application). In cases where standardization is not possible or practical, harmonization of monitoring methodologies will facilitate integration of data across regions and scales. The adoption of robust monitoring protocols will ensure the validity and consistency of the data and demonstrate to end users that results are reliable. Such protocols must be scientifically sound and include clear standard operating procedures. These should be crafted to be as simple, inexpensive and repeatable as possible in order to promote their wide adoption. These operating procedures should include all elements of the monitoring program from sample design to field procedures to data processing and management, sharing and archiving. When being considered for integration into the TEMG monitoring strategy, priority will be given to monitoring programs following standardized protocols and those that can be "crosswalked" between efforts to provide the most comprehensive coverage possible. In some cases, possibility to standardize monitoring protocols will be limited due to natural heterogeneity of desired monitored parameters among regions. In these cases, special efforts should be put into developing modelling approaches and tools for integration and analyses of such diverse data through harmonization.

### 4.3 Sampling design

Monitoring based on statistically sound design is essential for defensible decision making; and both consistent data collection methods and consistent probability-based sample design are required to ensure that data can be integrated and applied to future, and unanticipated, questions. Ideally therefore, a sampling design for monitoring-data collection should be based on an unbiased, random probability (all locations have some, but potentially unequal, probability of being sampled), stratified, and scalable methodology, and should be targeted at specific questions of interest with careful consideration of how the data will be analyzed and used. Final sample design will follow several fundamental steps, including[2]:

1) determine final study area and sampling strata required to address questions and associated objectives;
2) generate sample locations (and backup points) via an unbiased, random probability, stratified, scalable sampling methodology;
3) define/document decision rules for when sample points will not be included (e.g., dangerous to access) and how to replace abandoned locations with another sample point; and

2 Adapted from: Toevs, G.R., Karl, J.W., Taylor, J.J., Spurrier, C.S., Karl, M., Bobo, M.R. & Herrick, J.E. 2011. Consistent Indicators and Methods and a Scalable Sample Design to Meet Assessment, Inventory and Monitoring Information Needs Across Scales. Rangelands 33(4), 14-20.

4) determine an optimized collection approach to specify which of the samples will be collected via "field" versus "image" (i.e., remote sensing) visits.

When being considered for integration into the TEMG monitoring strategy, priority will be given to monitoring programs following a well thought out and statistically valid sampling design. Desired detectable change, precision, and certainty in results must be described. The proposed sampling design will be relevant to the key element in question and may vary among the selected key elements.

## 4.4 Implementation

The TEMG monitoring strategy will build from existing monitoring networks (some described below) and local capacities as much as possible to maximize the efficiency of the monitoring effort and likelihood of success. While much can be accomplished through existing networks, the monitoring strategy may identify needs which cannot be addressed through existing capacity. For unaddressed needs, the TEMG will seek opportunities to fill these gaps.

Site based networks: Several plot based pan-Arctic monitoring networks relevant to terrestrial biodiversity that are currently in operation will be critical partners in the delivery of a terrestrial biodiversity monitoring strategy. These include the international SCANNET network, INTERACT, the International Tundra Experiment (ITEX), as well as many national networks.

Species based networks. The TEMG will build on and enhance the efforts of ongoing species networks such as the Circum Arctic Rangifer Monitoring and Assessment (CARMA) Network, Arctic Bird Breeding Conditions Survey as well as networks monitoring Arctic bird species when they are outside the Arctic, e.g., the Goose Specialist Group of Wetlands International and the Wader Study Group. New networks may be initiated to fill in gaps where required.

Research community: Arctic researchers can be an engaged, valuable resource for collecting monitoring information and to help clarify processes affecting biodiversity trends. In turn, the researchers can benefit from access to a broad set of timely, relevant monitoring data. Such collaboration is an efficient method to improve monitoring capacity.

Traditional Ecological Knowledge: Arctic indigenous people hold invaluable ecological knowledge that has been passed down through generations. Integrating this knowledge into the monitoring approach may allow for a deeper understanding of observed changes.

Community Based Monitoring: Local Arctic residents are the eyes and ears on the ground. Through a well thought out monitoring design, including clear protocols and data platforms, and with training and support, locals can be engaged to provide firsthand high quality, scientific biodiversity data to complement professional monitoring efforts, in particular with regard to species monitoring.

Other networks: While TEMG efforts are focused on tracking biodiversity in the terrestrial sphere, we are cognizant of the linkages between biodiversity and ecosystem functions and processes across biomes (e.g., marine, freshwater) and media (e.g., air, water, soil). Coordination with networks in these areas can greatly enhance the ability to detect and understand the observed changes in terrestrial Arctic biodiversity in an efficient and cost effective manner.

## 4.5 Data analysis and reporting

Data cleaning and validation (i.e., quality assurance), analysis, integration, and reporting are essential steps in the monitoring strategy. These steps should be considered at the design stage of the monitoring program and should be appropriate to the selected key element and associated parameters.

Methods for consideration may include assessments of trends and relationships, maps demonstrating distribution shifts or other changes, development of indices, multivariate ordination, and the creation of mathematical models, temporal as well as spatial.

## 5. TEMG focal areas: Geographic boundaries and definitions

The TEMG closely follows the geographic boundaries, species and ecosystem coverage as defined by the CAFF Arctic Biodiversity Assessment (Fig. 3), from where the below definitions have been extracted.

Spatial integration is necessary to deliver meaningful information for the terrestrial monitoring program. The CBMP's mandate is to measure biodiversity on an ecosystem level.

In order to have the terrestrial monitoring program achieve relevant spatial coverage, a definition of region is necessary. 'Region' can be defined in several ways including political borders (territorial or settlements), socioeconomic categories, geologic regions, watersheds, or biogeography. Different regions will be affected by different stressors to differing degrees—in some cases, a given region could even serve as reference for another (e.g., a remote site could be used as reference site for one to be impacted by development). Monitoring should be performed in a way that allows comparisons among regions, and needs to be extended to suit a given region's specific issues or interests.


**Figure 3.** Boundaries of the geographic area covered by the Arctic Biodiversity Assessment and the terrestrial CBMP, defined by the division between high Arctic, low Arctic and sub Arctic according to the Circumpolar Arctic Vegetation Map. In principal, only high and low Arctic is covered; however, with the inclusion of alpine sub Arctic regions in proximity of the Arctic proper.

## 5.1 Geographic boundaries and definitions

Arctic proper: From a geophysical point of view, the terrestrial Arctic may be defined as the land north of the Arctic Circle, where there is midnight sun in the summer and winter darkness. But from an ecological point of view, it is more meaningful to use the name for the land north of the tree line, which generally has a mean temperature below 10-12 °C for the warmest month. With this definition, the Arctic land area comprises about 7.5 million km$^2$, or some 5.5% of the land surface on Earth. The Arctic may be divided into a number of subzones based on floristic types, i.e., subzones A-E on the Circumpolar Arctic Vegetation Map (CAVM, CAFF 2003, see http://data.arcticatlas.org/). Here, the division between the high Arctic and the low Arctic is most relevant, and we use the separation between subzones C and D on the CAVM.

High Arctic: The high Arctic comprises the Arctic land masses in the far north where mean July temperatures vary from 6°C in the south to only approximately 2°C in the north. Precipitation in the north is less than 50 mm per year and falls mainly as snow. The high Arctic consists of polar semi-desert vegetation in the south (cryptogam–herb, cushion plant-cryptogam, and mire communities which do not cover all of the ground) and polar desert (herb-cryptogam communities which cover only approximately 5% of the ground) in the far north.

Low Arctic: The low Arctic is characterised by mean July temperatures between 6-12°C, more precipitation more evenly distributed during the year, both in form of snow and rain. The Low Arctic tundra has much more lush vegetation than the high Arctic, with shrub tundra's, mires with sedges and, in the northern end, dwarf shrub–herb communities.

Sub Arctic: This is the ecotone between the Arctic and the taiga, i.e., the area between the timberline and the tree line. Hence, the sub Arctic is not part of the Arctic. However, the sub Arctic comprises low alpine and high alpine zones in mountainous areas closely connected to the Arctic, oceanic tundra (e.g., the Aleutian Islands) and the forest tundra (e.g., the sub Arctic). The sub Arctic is addressed because it comprises species of significance to the Arctic tundra region, it has an influence on the Arctic tundra region and it provides a potential for species movement into the current Arctic tundra region, e.g. due to global change.

## 5.2 Species and ecosystems to be included

Biodiversity is defined by the Convention on Biological Diversity as "the variability among living organisms from all sources, including terrestrial, marine and other aquatic ecosystems and the ecological complexes of which they are part, this includes diversity within species, between species and of ecosystems." More simply, biodiversity is the variety of the world's organisms, including their genetic makeup and the communities they form. Biodiversity is dynamic: the genetic composition of species changes over time in response to natural and human-induced selection pressures; the occurrence and relative abundance of species in ecological communities changes as a result of ecological and physical factors

In the context of Arctic biodiversity, the CAFF-CBMP recognizes the influence of natural- and human-processes in Arctic ecosystems. Arctic biodiversity depends, to a large extent, on systems extending far beyond the boundary of the Arctic, for example global migration of species.

Humans and their cultural norms are components of ecosystems, and therefore, potentially influence Arctic biodiversity. To a level beyond most flora and fauna, humans both influence and benefit from essential goods and services provided by Arctic biodiversity.

Monitoring an array of ecosystem elements, including species, habitats, structure, processes, functions, and stressors, is necessary to gain a meaningful understanding of Arctic biodiversity issue and concerns.

Since there is no strict definition of an Arctic species, we include all species that reproduce in the Arctic proper and/or have genuine populations in the Arctic proper, i.e. excluding species with accidental or clearly insignificant appearance within the Arctic. Sub Arctic species and ecosystems are dealt with as outlined above. For vascular plants the Panarctic Flora checklist[3] could be used as a guideline as it is limited to the Arctic proper.

Ecosystems are similarly included, if they have a genuine representation within the Arctic proper (e.g., the Circumpolar Arctic Vegetation Map). Regarding the distinction between marine, freshwater and terrestrial: marine (/coastal) includes everything up to the high water mark (i.e. including the intertidal zone), fens and marshes are considered terrestrial, whereas tarns, ponds, lakes and rivers are considered freshwater ecosystems.

## 6. Expert Workshops

In a series of two workshops, experts with broad expertise (both scientific and community-based) on various aspects of Arctic terrestrial ecosystems and monitoring will be brought together to design a monitoring plan that will identify;

- trends in biodiversity; and
- possible causal links to stressors.

These two workshops will contribute towards the design of the integrated Arctic Terrestrial Biodiversity Monitoring Plan and to identify the networks to be involved.

### 6.1 First workshop (Denmark, October 2011)

The first workshop will initiate the design of a framework for an integrated monitoring strategy for the Arctic Terrestrial Biodiversity Monitoring Plan using the TEMG background paper as a platform. The first outcomes would include identifying what to monitor (key elements/indicators), when (over what time period and how often) and where (geographic locations). It will be necessary to address the following overarching questions:

- What kind of questions can we expect the main users (administrators, politicians, local communities etc.) to ask, and what issues will they need information on in the future?
- In the light of the questions by the main users, how should the monitoring plan be designed to be able to detect trends in terrestrial biodiversity in the Arctic? What trends may the plan be unable to detect?
- Can causal links between such trends and stressors be identified? What criteria should be used to choose common and standardized / harmonized parameters of key elements and monitoring sites?
- What existing and ongoing monitoring activities/programs can be used to build the integrated monitoring plan?
- What are the major gaps in current monitoring? What new and existing data and/or projects could be developed to fill these gaps?
- What organizations and networks are responsible for the monitoring activities?
- How can we benefit from ongoing work and existing networks, and how can we work collaboratively with IASC and INTERACT for mutual benefit?
- How can we best build on results from the ongoing Arctic Biodiversity Assessment (www.caff.is/aba) that is expected to be finished in 2013, but will be available in a draft form in 2012?

### 6.2 Second Workshop (United States, May 2012)

3 Elven, R. (Ed) (2007 onwards). Checklist of the Panarctic Flora (PAF) Vascular Plants. Version: May 2007. http://www.binran.ru/infsys/paflist/index.htm

The second workshop in this process is scheduled for May 2012. A more precise description of this workshop will be developed after the first workshop. However, the overall purpose will be to finalise the production of a draft Arctic Terrestrial Biodiversity Monitoring Plan. The following questions should tentatively be the main issues for the second workshop:

- Which key ecosystem elements, attributes, parameters and stressors shall be monitored and how can this be accomplished with the existing monitoring networks?
- What critical gaps remain, and what approaches should be considered to fill these?
- What organizational structure (e.g., network, or network of networks) will be necessary to organise the relevant monitoring programs and activities to form and implement an integrated plan?
- What resources will be required to develop and implement the plan, recognizing that some elements may be dependent on the continuation of programs that are the responsibility of single countries?

## 7. Data Management

A key objective of the Circumpolar Biodiversity Monitoring Program is to create a publicly accessible, efficient, and transparent platform for collecting and disseminating information on the status of and trends in Arctic biodiversity. This objective will be instrumental in achieving the Program's mandate to report on trends in a timely and compelling manner so as to enable effective policy responses. The CAFF's CBMP data management objectives are focused on the art of the possible—developing data management systems that facilitate improved access to existing biodiversity data and integration of these data between disciplines, while maintaining the data holders' ownership and control of the data. It is expected that each country would still be responsible for supporting data management (e.g. quality assurance and control and compilation of existing national datasets) and contributions from their individual monitoring networks (i.e., the data holders), whereas the CBMP will focus its efforts on building the mechanisms to access and integrate this data across countries and networks, as well as promoting a common, standardized data management approach among the countries. For this approach to be successful, it is imperative that national datasets are made available.

Data sources, formats, and subjects vary widely across the Arctic biodiversity research and monitoring community. One challenge is to access, aggregate, and depicts the immense, widely distributed, and diverse amount of Arctic terrestrial biodiversity data from the multitude of contributors involved in this monitoring plan. A related challenge is to integrate and correlate this information with other relevant data (e.g., physical, chemical, etc.) to better understand the possible causes driving biodiversity trends at various scales (regional to global) and thereby facilitate management responses and research. Furthermore, it is critical to deliver this information in effective and flexible reporting formats to facilitate decision making at a variety of scales from local to international. Meeting these challenges will significantly improve policy and management decisions through better and timelier access to current, accurate, and integrated information on biodiversity trends and their underlying causes at multiple scales.

In some cases, especially for the higher trophic levels, biodiversity data and relevant abiotic data layers are already available and can be integrated into the CBMP's Data Portal system. However, the task of aggregating, managing, and integrating data for the lower trophic levels is arduous, and it may be some time before such information can be accessed readily via the CBMP Data Portal. The establishment of Terrestrial Expert Networks, as well as support from each nation and from the CAFF Data Manager, will facilitate this process through the adoption of common data and metadata standards and the development of common database structures.

The following sections provide an overview of the data management framework to be used for managing the outputs of the Arctic Biodiversity Monitoring Plan. Such a framework is essential to ensure effective,

consistent, and long-term management of the data resulting from coordinated monitoring activities.

## 7.1 Purpose of data management

Effective and efficient data management is fundamental to the success of the CBMP and this monitoring plan. A key measure of success will be the ability to effectively connect individual partners, networks, and development of key element/ indicator efforts into a coordinated data management effort that facilitates data access and effectively communicates Arctic biodiversity status and trends to a wide range of audiences and stakeholders. Executed correctly, data management can fulfil the following functions:

Quality assurance: ensures that the source data sets and the collection methodologies of key element parameters are optimal and that data integrity is maintained throughout processing.

Consistency across parameters and networks: encourages the use of common standards and consistent reference frames and base data sets.

Efficiency: reduces duplicate efforts by sharing data, methodologies, analysis, and experience.

Sustainability: ensures archiving capability and supports ongoing measurement and reporting.

Enhanced communications: produces and distributes information through integrated and open web-based services, making key element/indicator methodologies and data accessible and providing source metadata.

Improved linkages: ensures complementarities between various networks and partnerships and with other related international initiatives, other key element/indicator processes (national, regional, and global), and global assessment processes (e.g., the Global Biodiversity Outlook and Millennium Ecosystem Assessment).

Enhanced credibility: provides transparency with respect to methodologies, data sets, and processes.

Implementation of the Arctic Terrestrial Biodiversity Monitoring Plan will rely on participation from many partners. An efficient and user-friendly metadata and data management system will facilitate this collaboration, providing multiple benefits as outlined above. It will offer unique opportunities for monitoring networks to exchange data, draw comparisons between data sets, and correlate biodiversity data with data derived from other networks, using a common, web-based platform. A roadmap for data management, the CBMP Data Management Strategy (Zöckler 2010 unpublished) has been developed to guide the management and access of metadata and data amongst and between the CBMP networks.

Further details on data management issues are provided in Appendix 3.

# Appendix 1
# Terrestrial Expert Monitoring Group: Terms of Reference

Approved by TEMG 6 July 2011

## I. Introduction

Arctic biodiversity is under growing pressure from both climate change and resource development, requiring both managers and users to have access to more timely and complete biodiversity status and trend data. Yet existing monitoring programs remain largely uncoordinated, lacking the ability to effectively monitor, understand and respond to biodiversity trends at the circumpolar scale. The maintenance of healthy Arctic ecosystems is a global imperative as the Arctic plays a critical role in the Earth's physical, chemical and biological balance. Maintaining the health of Arctic ecosystems is also of fundamental economic, cultural and spiritual importance to Arctic residents, many of whom maintain close ties to the land and sea.

To meet these challenges, the Circumpolar Biodiversity Monitoring Program (CBMP) is working with partners to harmonize and enhance long-term Arctic biodiversity monitoring efforts in order to facilitate more rapid detection, communication and response to significant trends and pressures. The Arctic's size and complexity represents a significant challenge towards detecting and attributing important biodiversity trends. This demands an integrated, pan-Arctic, ecosystem-based approach that not only identifies trends in biodiversity, but also identifies underlying causes. It is critical that this information be made available to generate effective strategies for adapting to changes now taking place in the Arctic - a process that ultimately depends on rigorous, integrated, and efficient monitoring programs that have the power to detect change within a 'management' time frame.

Towards this end, the CBMP is facilitating an integrated, ecosystem-based approach to monitoring through the development of four Expert Monitoring Groups (EMG) representing major Arctic themes (Marine, Coastal, Freshwater, Terrestrial). Each group will function as a forum for scientists, community experts and managers to promote, facilitate, share, and coordinate research and monitoring activities to faciliate improved and cost effective monitoring that has a greater ability to detect and understand significant trends in Arctic biodiversity. The focus of each EMG is to develop an integrated, pan-Arctic biodiversity monitoring plan that coordinates existing monitoring capacity to increase our power to detect and understand important biodiversity trends and report these trends using effective and timely formats. Such a coordinated effort will be more cost effective than multiple, uncoordinated monitoring efforts.

## II. Goals and objectives

### A. Goal

To promote, facilitate, coordinate and harmonize terrestrial biodiversity monitoring activities among circumpolar countries, and to improve ongoing communication amongst and between scientists, community experts, managers and disciplines both inside and outside the Arctic.

### B. Objectives

The Terrestrial EMG will:

- Develop a multidisciplinary, integrated, pan-Arctic, long-term biodiversity monitoring plan that:
- Respond to identified science questions and user needs;
- Identify and align with specific monitoring and management objectives;
- Identify a suite of focal ecosystem components to focus monitoring on and a suite of priority parameters for each focal ecosystem component;
- Identify a small suite of terrestrial ecosystem indicators (derived from the parameters) that can be

used to report on the state and quality of terrestrial arctic ecosystems;
- Identify optimal sampling schemes for the chosen parameters;
- Make use of existing monitoring capacity and information (scientific, community-based, and Traditional Knowledge);
- Identify key abiotic parameters relevant to terrestrial biodiversity that need continual monitoring; and,
- Identify and, where possible, addresses current gaps in coverage (both elemental, spatial and temporal).
- Develop an implementation plan for the monitoring plan that identifies timelines, costs, organizational structure and partners.

## III. Administration

### A. Membership

Members of the Terrestrial Expert Monitoring Group (TEMG) will develop, consult and work with national teams of terrestrial biodiversity experts representing existing, relevant terrestrial research and monitoring networks (e.g. site-based networks such as INTERACT; Theme or species based networks such as CARMA, etc.) in their country. The membership will ensure strong and ongoing connections to existing national and international terrestrial research and monitoring networks to ensure the development of the plan is well consulted on and is readily implemented upon completion.

The Terrestrial Expert Monitoring Group will be comprised of up to a maximum of 15 members representing the relevant terrestrial Arctic countries and Arctic Council programs and Indigenous Peoples organizations. Each member on this group will act as a focal point drawing from and consulting with a diversity of experts within their own nations.

Each CAFF National Representative and Permanent Participant can appoint one member (with the exception of the Kingdom of Denmark who can also ensure membership representation from Greenland and the Faroe Islands). CAFF observer countries and observer organizations will be invited to take part in the EMG workshops. The two workshops will provide a key opportunity for experts to develop elements of the monitoring plan. The ongoing development of the plan will also involve many opportunities for expert input through consultations with the TEMG members and through peer review of the draft monitoring plan. The members will be expected to serve a term of two and a half years allowing for the completion of the Terrestrial Biodiversity Monitoring Plan. The membership can be modified to add new members if deemed appropriate by the existing Terrestrial Expert Monitoring Group and sanctioned by the CAFF Management Board.

Terrestrial EMG members are expected to attend the two planning workshops together with a range of experts representing organizations and geographic areas important to Arctic terrestrial biodiversity research and monitoring. Also, a subset of non-member experts representing organizations responsible for the collection and management of relevant abiotic data and representing biodiversity themes will be invited to attend the workshops (e.g. climate, permafrost, etc.). The TEMG members will also be expected to attend monthly conference calls and work between calls to solicit and gather required national information to facilitate the development of the monitoring plan.

Upon completion of the integrated monitoring plans, CBMP will work with the TEMG to establish an 'implementation structure/ group' that will be responsible for facilitating and tracking the implementation of the long-term monitoring plan and for providing ongoing communication and coordination of monitoring activities. It is possible that some of the TEMG members will be part of a future implementation structure/ group'.

### B. Leadership

The Terrestrial EMG will be directed by two co-leads (United States and the Kingdom of Denmark)

The co-leads will be responsible for:

I. overseeing the development of a background paper
II. organizing and facilitating the integrated monitoring planning workshops,
III. organizing and participating in regular planning meetings and conference calls (with at least one week notice for such planned meetings and calls),
IV. ensuring at least one membership conference call per quarter,
V. communicating regularly with the CBMP office,
VI. preparing and distributing materials prior to meetings
VII. completing appropriate records of meetings and results of workshops,
VIII. leading the development of the integrated monitoring plan.
IX. ensuring that materials and records are provided to the CAFF Secretariat, CBMP office, and all attendees within 60 days of completed meetings.
X. ensuring that meeting agendas are developed in consultation with other members. The Lead and/or Co-lead also coordinates the work of the Terrestrial EMG between meetings.

## C. Coordination

The CBMP office will be responsible for ensuring coordination (connectivity and compatibility) between the Terrestrial Expert Monitoring Group and the other Expert Monitoring Groups. This will be accomplished through participation on scheduled Terrestrial EMG conference calls and, as needed, conference calls or meetings between the CBMP Office and EMG leads.

Where possible, a designated member of each EMG will participate in the other EMG workshops to ensure consistency and integration and prevent overlap between the developing monitoring plans.

The CBMP Office and CAFF Secretariat will, in cooperation with the EMGs, provide state-of-the-art data management, assessment, outreach and communication services.

## D. Workplan

Years 1 and 2: Over the course of a two to two and half year period, the Terrestrial EMG will develop a background paper and hold two integrated monitoring planning workshops focusing on the development of a pan-Arctic integrated terrestrial biodiversity monitoring plan. Generally, these workshops will be held in the country or countries that are sponsoring the Terrestrial EMG. Representatives from the host countries will be responsible for coordinating logistical arrangements. Each nation will also be responsible for providing travel support, if necessary, for their own experts to attend the workshops.

Years 3 onwards: Upon completion of the Terrestrial Biodiversity Monitoring Plan, a new organizational structure as suitable will track and promote implementation of the monitoring plans and provide an ongoing forum for promoting, facilitating and coordinating terrestrial biodiversity research and monitoring.

## E. Decision making

Decision making within the Terrestrial EMG is by consensus of the designated official representatives (members).

## F. Expenses

Unless there is prior agreement, Terrestrial EMG members are responsible for their work time and travel coordination and expenses as well as securing support for participation (including travel expenses) of their own national experts to engage in the process of developing the monitoring plan

# Appendix 2:
# TEMG members and associates

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# Appendix 3: Data management issues

Appendix 3 should be regarded in conjunction with Chapter 7.

## 1. Coordinated data management and access: the CBMP web-based Data Portal

Arctic biodiversity research and monitoring involves a multitude of networks producing information in diverse formats with minimal integration. While much information is produced by these networks, much of it is inaccessible, not reported, or in user-unfriendly formats. New, webbased data management tools and new computational techniques have provided an opportunity for innovative approaches to data management, critical for a complex, international initiative such as the CBMP.

CAFF's CBMP has developed a state-of-the-art Data Portal (www.cbmp.is): a simple, web-based and georeferenced information network that accesses and displays information on a common platform to encourage data sharing and display. The data portal represents a distributed data management structure where data holders and publishers retain ownership, control, and responsibility for their data. Such a system provides access to immediate and remotely distributed information on the location of Arctic biological resources, population sizes, trends, and other indicators, including relevant abiotic information. As well as providing a point for Arctic biodiversity information, the Data Portal provides a simple approach for experts to share information through the web and allows for the integration and analysis of multiple data sets.

The CBMP's Data Portal requires the establishment of a series of data nodes, with each data node representing a data type or discipline (e.g., caribou, shorebirds). Each data node will be established and supported nationally. The CAFF Data Manager will interact with the national nodes to ensure interoperability and data aggregation and will provide overall maintenance and management of the resulting pan-Arctic aggregated data. Where appropriate, the CBMP will establish web based data entry interface systems (web services) tailored to each data node/discipline, allowing researchers in each country to enter their data on an annual or semi-annual basis (depending on the frequency of data collection) via the Internet. This information will be aggregated, automatically populating a database established at an organization of the Expert Network's choosing. The Terrestrial Expert Network leads will have overall administrative privileges (password controlled) to view, maintain, and edit the database. Each expert within a discipline group will have access (via a password) to enter and maintain their own data. Each Terrestrial Expert Network will be responsible for defining and implementing the analytical approaches to generating the key elements/ indicators. The CBMP will work with each Terrestrial Expert Network to establish analytical outputs, via the Data Portal, tailor made for the data collected and housed at the data node. Priority data on key elements will be managed via the web portal whereas other dataset compilations can be directly archived at the CAFF Secretariat or through an agreement with an existing data centre.

Users (e.g., scientists, decision makers, and the public) will have password controlled access to the data outputs via the CBMP Data Portal. Users will be able to perform set analyses (defined by the Expert Networks) on the Portal, which will immediately access the most current data at the data node (using XML Internet language) and display the output of the queried analysis (see app.). Much of the initial work in the implementation phase of the Arctic Terrestrial Biodiversity Monitoring Plan will involve aggregating existing data sets to create pan-Arctic data layers. The life cycle of the data, from collection to presentation, is shown in Fig. App. 8.2.

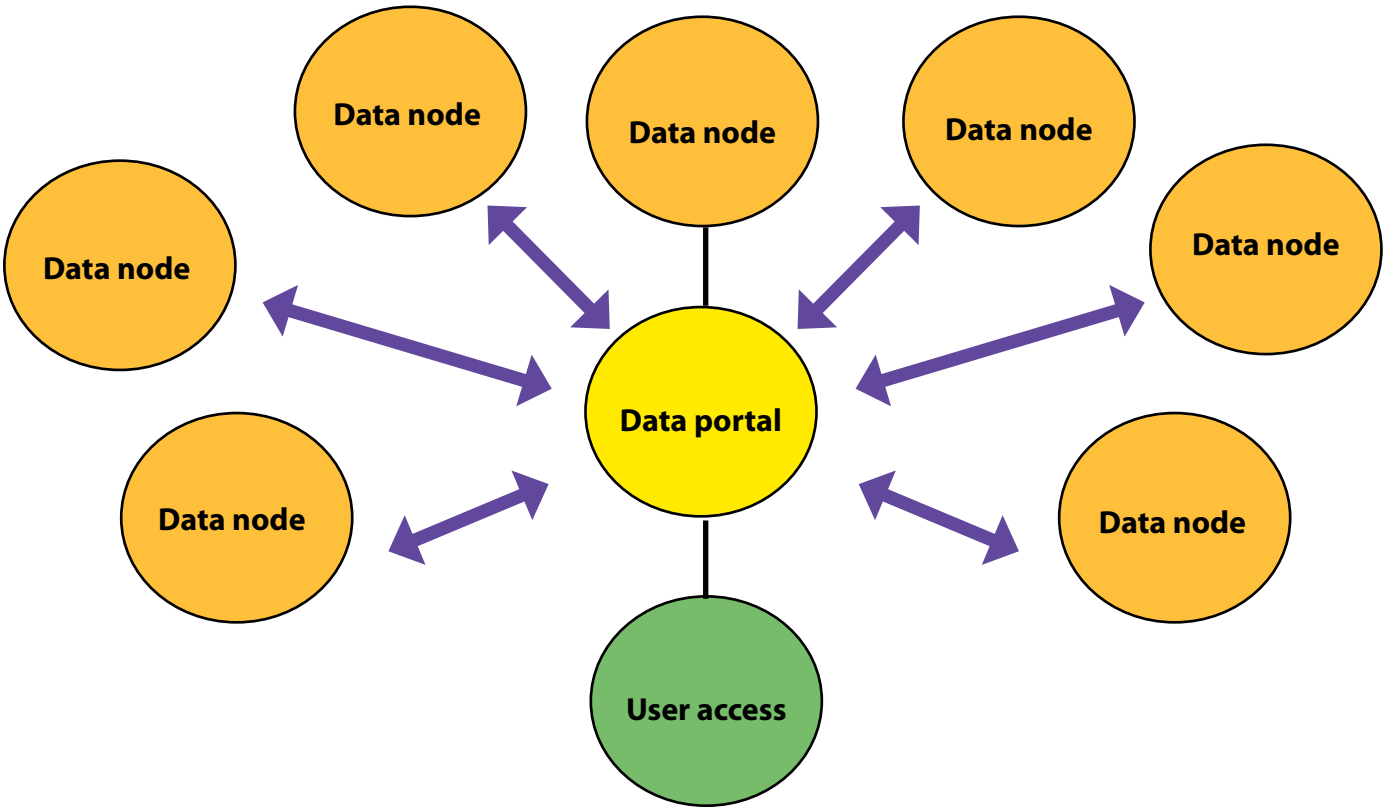


**Figure App. 8.1** Illustration of the CBMP network of data nodes and their integration via a common platform, the CBMP Webbased Data Portal.

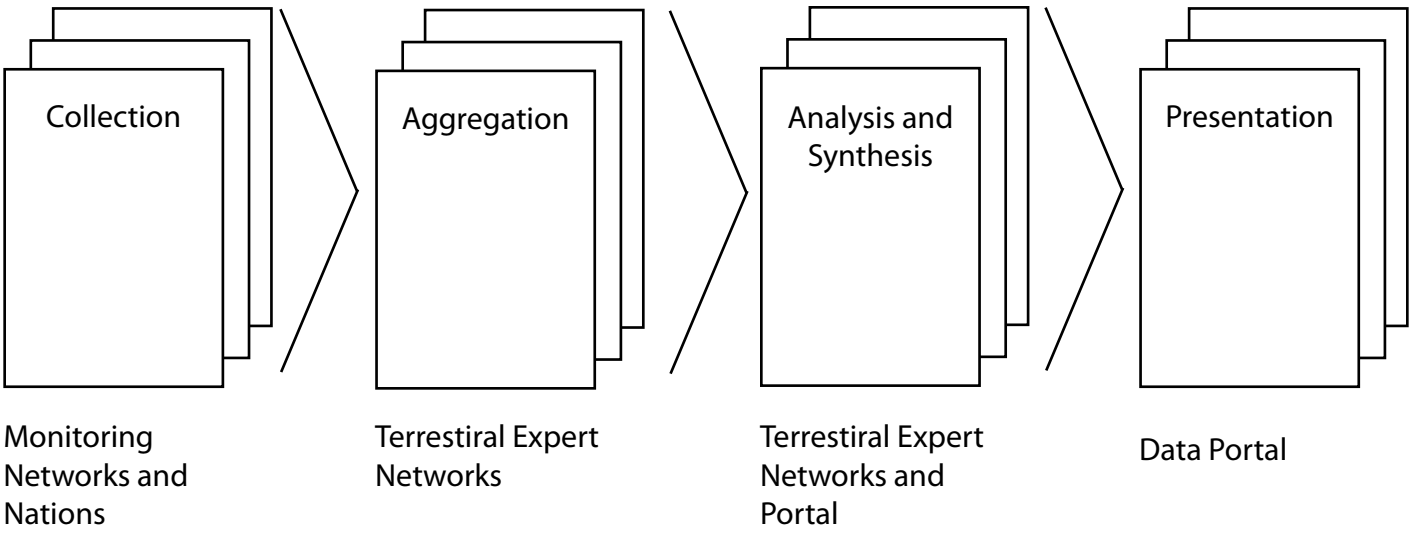


**Figure App. 8-2A** simplified overview of the steps involved in accessing, integrating, analyzing, and presenting biodiversity information via an interoperable web based data portal and an indication of the responsibilities at each step.

The CBMP Data Portal will be flexible, password driven, and customizable to serve a diversity of clients (Fig. App. 8.3). The general public will have access to information on key elements/ broad indicators and general information on Arctic biodiversity data trends. National and sub national governments as well as the Expert Networks will have the opportunity to customize the Portal for their own purposes (e.g., display only the geographic scope of relevance to them, etc.). Both governments and Expert Networks will have the option of choosing the data layers they are willing to have publicly available while having their own password controlled domain to allow the inclusion of other data layers that they may not want to go public (e.g., unpublished data, data on threatened species) but that they would like to use for their own analyses.

This model of operation allows for user involvement at a variety of stages and can accommodate a large number of participants. The aim is to facilitate complete access to the collective knowledge, analysis, and presentation tools available from the many participants and stakeholders both within and outside the Arctic community.

Web based portals provide a convenient common entry point that allows for a broad spectrum of users worldwide (e.g., scientists, decision makers, and the public) controlled access to data outputs.


**Figure App. 8.3** Illustration depicting the Data Portal concept and how clients can utilize the system to meet their specific needs.

The web based portal will serve two purposes for the CBMP. First, it will provide access to georeferenced information from within partner networks, as well as providing a common platform with multiple entry points for controlled data access, integration, harmonization, and delivery. Secondly, it will enable a wide range of user groups to explore trends, synthesize data, and produce reports with relative ease.

Development of this distributed system will necessitate the adoption and use of existing and widely accepted standards for data storage and query protocols, along with high quality and standardized metadata and web servers (spatial and tabular). The metadata will be housed on an existing meta-database system (Polar Data Catalogue) allowing for simple and efficient access to a large and constantly updated, web based, searchable, georeferenced metadata system. The Arctic terrestrial biodiversity monitoring programs identified as core to the implementation of the monitoring plan will be input into this meta-database.

The web based data portal will generate indicators/ key elements representing status and trend analyses, which in turn will be reported by the CBMP through a variety of means. These could include turnkey webbased reports and status and trends reports at multi-year intervals.

Georeferencing will be critical to the successful integration of disparate data sets. Resolving the different spatial recording schemes used between the various data nodes and data holders—as well as the ranges of data volumes and bandwidth —will be key challenges to overcome. Techniques will be devised to convert data into a standard format for integration. These technical issues will be addressed during the implementation phase.

## 2. Data storage

A decentralized data storage system is proposed for the CBMP web portal since it offers a solution to concerns over data ownership and copyright. Data policies such as the Conservation Commons and the IPY Data Policy address these issues in general terms. Decentralized approaches to data storage are already successfully applied in the Global Biological Information Facility (GBIF), Ornithological Information System (ORNIS), and other data networks worldwide. Although the data are decentralized, access to and depiction of the data is unified, allowing for multiple integrations for the user. Other compiled datasets may, with appropriate permissions, be archived also at the CAFF Secretariat. Options for mirrored archiving of data generated by the CBMP-Terrestrial Plan will be considered such as working with existing data centres.

For all indicators/ key elements developed under the CBMP, a database of the time series of reviewed and published indicators/ key elements will be maintained via the data node hosts. All relevant metadata and the timeseries data will be consistently available, along with information about the associated methodology, quality, and interpretation. The CBMP Meta-Data Archive will be linked to other clearing house mechanisms for access and dissemination. Specific data sets will be contributed by partners to the monitoring plans as they are developed and published.

## 3. Data policy

### 3.1 Ownership and custodianship

A data node host may act as custodian for individual data collectors, holders and publishers, but this does not automatically confer any rights to those data. The responsibility and own-ership of the data will always remain with the data collector, publisher and/or holder who bear responsibility for any changes or amendments to the data.

Data collectors could transfer their rights to a data archive, or maintain their rights and store their data with a data archive or any other data holder who uses their data. It is also possible to release data conditionally (e.g., based on requested input and acknowledgement). This flexible model embraces all options from free public data to strict data control and is a feature that will likely prove popular with web portal users and contributors.

### 3.2 Intellectual property rights

Unless requested otherwise, the data collector will be acknowledged as owner of the intellectual property of the data (or the representative of the organization that is the property owner). This model follows global policies such as Conservation Commons and the IPY Data Policy.

Conservation Commons

The Conservation Commons is characterized by an underlying set of principles that supports open access to and fair use of data and information related to the conservation of biodiversity. The purpose of the Conservation Commons Principles is to allow the distribution of and access to biodiversity data among the many databases housed by large organizations. The principles are as follows:

Open access: The Conservation Commons promotes free and open access to data, information, and knowledge for all conservation purposes.
Mutual benefit: The Conservation Commons welcomes and encourages participants both to use and to contribute data, information, and knowledge.
Rights and responsibilities: Contributors to the Conservation Commons have the right to be acknowledged for any use of their data, information, and knowledge, as well as the right to ensure that the integrity of their contribution to the Commons is preserved. Users of the Conservation Commons are expected to comply, in good faith, with terms of use specified by contributors.

**International Polar Year Data Policy**

The IPY Data Policy considers data a global resource and promotes free and open access to raw data online in order to stimulate academic progress. IPY's policy adheres to the most up-to-date scientific principles, with requirements for data to be documented with standardized metadata [e.g., Federal Geographic Data Committee (FGDC) and National Biological Information Infrastructure (NBII)]. Online posting of well-documented and interpreted versions of the data is also encouraged. The purpose of this policy is to encourage the widest possible exchange of relevant data. This policy is endorsed by the funding agencies of polar nations and viewed as a template by many other countries.

### 3.3 Data sharing and access

The data collected by the CBMP will be available continually at a fixed entry point operated by CAFF on the Internet. This point could be mirrored at a data collector/holder's site, at the web portal site of a data host, or both (e.g., by linking to both websites). The web portal will allow for organized and restricted access to data where necessary.

CAFF's CBMP encourages data providers to comply with the Conservation Commons and IPY Data Policy on the delivery of free biodiversity data to the public. Compliance with accepted data policies and provision of data to the CBMP Data Portal system will result in password access being provided to the data layers found on the Data Portal. This incentive-driven approach should encourage scientists and others to contribute their data to the Portal as it will result in their access to other data layers relevant to them. Arctic Council countries are also encouraged to make their publicly funded datasets available for use in the CBMP Data Portal system.

A condition of project funding or support through CAFF/CBMP should be the guaranteed availability of any resulting data for use by the CBMP. Additional uses are encouraged and should also be specified. This should provide maximum opportunity for synergies that inevitably follow the presentation and availability of new data.

### 3.4 Data release code

All CBMP participants will agree to their data being utilized, within specified terms, in broader analyses and collections by identified users within CAFF and the CBMP. All products, including value-added products (e.g., GIS layers, reports, analyses) identified and released under the management of CAFF and the CBMP, will have appropriate acknowledgement secured. This can be achieved by registration of the data user and through a request to sign or agree with basic conditions of use. These protocols should not pose a constraint to free data release to the public.

The CBMP will create a safe and reliable data network, making high quality digital data available to global users online. Restricted data would be flagged accordingly (e.g., in the metadata) and only released for specific usage or by specific users with password access. The technical setup implemented will allow achievement of this goal and protection to the data holder. Data collectors, holders, and providers will have full freedom to specify the level of detail that they wish to make available.

### 3.5 Data use restrictions

Ultimately, the CBMP wants to optimize the flow of information pertaining to Arctic biodiversity. While the CBMP will strive to provide unrestricted access to data, there are some exceptions that should be considered and accommodated in order to maximize the utilization of data. For example, unpublished data may require either temporary restrictions and/or partial access (i.e., only advanced analytical results available instead of raw data) in order for the data collector/holder to retain publishing rights. As well, data on some endangered or threatened species may require certain levels of protection to prevent destruction of and/or disturbance to these populations.

The IPY Data Policy prescribes a six-month delay before information is released to the public. Depending on the project and publication circumstances, the CBMP suggests a delay of two to four years, according to data type and project history. Funding agencies in several countries already have a two-year data release policy in place. Details will depend on specific situations, but overall the CBMP will strive for timely release of data in order to promote scientific progress and discovery.

Following is a list of access classifications:

- Unrestricted access: Freely available to all participants to incorporate within any product and project.
- Permission based access: Specific acknowledgements/permission statements must be incorporated within the product. The data management structure will account for these restrictions by creating a process for obtaining permissions to use the data. The system will be efficient and simple to navigate. This will be achieved by using metadata to point to data and describe them, and then by controlled access to actual download of these data once the data user agrees with terms of use.
- Password restricted access: Access to the data set is restricted to those participants who have been given specific access via a password/key. This can be important for raw data management within a network.
- Copyright restrictions: Available for use only by the data collector/holder. This class is likely to apply to dynamic data sets in a state of flux and receiving constant updates. Even with this level of restriction, there might still be opportunities for the data to contribute generic analyses. An example would be the use of simple data summaries to determine if populations are stable, increasing, or decreasing. The copyright issue needs to be clearly identified. (A pilot project is currently underway to test operability for restricted access of generic seabird data.)
- Publication delay: These data are being published by the data collector and owner and will be released, ideally, within a six month period. In some cases, the release could be delayed for up to four years. The exact release date will be specified and negotiated with the provider.
- Protection of endangered species, human rights, and/or national security: These data are not released because release could threaten endangered species, violate human rights, or pose a risk to national security. Examples include personalized interview information and sensitive human DNA data. Unless the pertinent threat is resolved or clarified, these data will either be unavailable or available only in a coarse or delayed fashion.

### 3.6 Acknowledgements

The database structure and the web based portal will ensure that the source of every single data set is properly acknowledged. Full acknowledgement requires that each data set carry a unique name and reference. The reference can take any number of forms: publications, organizations' databases, libraries, data archives with multiple entry providers, networks, etc. The precise wording of the acknowledgement will be provided by the data holder/collector, and it is the responsibility of the data provider to ensure the originality of the source.

## 4. Data and metadata standards

In order for the various networks involved in implementing the Arctic Terrestrial Biodiversity Monitoring to collaborate, input, and share data and metadata, common data and metadata standards need to be chosen.

CAFF's CBMP has chosen the Federal Geographic Data Committee (FGDC) standard to ensure compatibility with the Global Earth Observation System of Systems (GEOSS) program, along with many other global and regional programs that have adopted this standard (e.g., OBIS, GCMD, and GBIF). The FGDC standard is widely embraced by IPY and can be stored and linked with all relevant biodiversity and other data sources. Freely available software allows users to apply these metadata conveniently and post them online with the clearinghouses (e.g., Polar Data Catalogue). Because data that lack metadata can be virtually unusable, both are crucial requirements and thus requested by funding agencies and the data initiatives cited here.

# Appendix 4
# Existing monitoring capacity by country

| Country | Study site | Program title | Objectives | Abstract | Zonation | Time coverage |
|---|---|---|---|---|---|---|
| Canada | Alexandria Fiord | Alexandria Fiord ITEX Site | | | | - |
| Canada | Northern Yukon, NWT and Alaska | Arctic Borderlands Ecological Knowledge Coop | To monitor and assess ecosystem changes in the range of the Porcupine Caribou Herd and adjacent coastal and marine areas; To encourage use of both science-based studies and studies based on local and traditional knowledge in ecological monitoring and ecosystem management; To improve communications and understanding among governments, aboriginal and non-aboriginal communities and scientists with regard to ecosystem knowledge and management; and To foster capacity-building and training opportunities in northern communities in the context of the above listed goals. | Community researchers conduct interviews with local experts each year. Observations about fish, berries, caribou, unusual animal sightings, weather conditions, and other aspects of the environment and communities, are pulled together. | Low arctic | 1994- |
| Canada | Queen Maud Gulf Bird Sanctuary | Arctic Ecosystems Monitoring | To detect changes in population trajectories, and identify factors driving change related to waterfowl, waterbirds and arctic fox. | Survival and reproductive rates of waterfowl, waterbirds, and arctic fox are used to understand the relationships between population health and disease, harvest rates, and climatic conditions. | High arctic | 1990- |
| Canada | Eastern and central Canadian Arctic | Arctic Goose population monitoring program | To provide long-term, regular monitoring of arctic nesting goose populations, including snow geese designated as overabundant. Information used for harvest regulations in CAN and US. | The Arctic Goose population monitoring program tracks goose population trends and survival and determines if population reduction measures are effective. | High arctic | 1993- |
| Canada | Aulavik National Park | Aulavik Ecological Integrity Monitoring Program | Data from the park EI monitoring and reporting program is analyzed and assessed every 5 years, and published in a State of the Park Report. | Multiple measures of species and processes are monitored. Peary caribou, Lemmings, raptor productivity, Muskox, Active layer, soils, landcover change , plant productivity/green up (NDVI), Breeding Bird Survey | High arctic | - |

| Country | Study site | Program title | Objectives | Abstract | Zonation | Time coverage |
|---|---|---|---|---|---|---|
| Canada | Auyuittuuq National Park | Auyuittuuq National Park Ecological Integrity Monitoring Program | Data from the park EI monitoring and reporting program is analyzed and assessed every 5 years, and published in a State of the Park Report. | Multiple measures of species and processes are monitored. Lemming Abundance, Vegetation Communities, Plant Phenology, Active Layer Monitoring, Land Cover Change, Primary Productivity. | High arctic | - |
| Canada | Baker Lake, Nunavut | Baker Lake | | Monitored measures include vegetation composition and percent cover as part of the ITEX network, NWT/NU Bird Checklist Survey, Water Quantity/Quality Monitoring, Baker Lake Snow Fence Project and Permafrost Monitoring, Climate Monitoring, Upper Air Monitoring Program and NWT Small Animal Survey. | | - |
| Canada | Canada | Canadian Peregrine Falcon Survey | To monitor recovery of peregrine falcon across Canada with a view to monitoring long-term population trends. | The Canadian Peregrine Falcon Survey is designed to determine productivity and number of occupied sites; to assess the recovery status of this threatened species | Low arctic | 1970- |
| Canada | Canadian Permafrost Region | Canadian Permafrost Monitoring Network | The Canadian Permafrost Monitoring Network provides long-term field observations of permafrost thermal state and active layer thickness. | Information is provided on permafrost thermal state (ground temperatures) and active layer thickness for several sites across the Canadian permafrost region. Individual site metadata/descriptions are provided on the monitoring network web sites (gtnp.org; canpfnetwork.com). Permafrost thermal state is determined through measurement of ground temperatures at several depths. Measurements are obtained by lowering a calibrated thermostat into a borehole, or from multi-sensor cables permanently installed in the borehole. Measurements may be recorded manually or by data loggers. Borehole depth varies from less than 10 m to greater than 50 m. Ideally (although not always feasible at all sites), temperatures at shallow depths (upper 10 to 20 m) should be collected at monthly or more frequent intervals. Summary data, including the range in temperature at each depth (where available) are provided on network web sites. Active layer thickness is determined through mechanical probing annually, frost tubes, and interpolation of soil temperatures (Protocols at http://www.udel.edu/Geography/calm/). Active layer data are posted on the network web site. | Low arctic | 1978- |

| Country | Study site | Program title | Objectives | Abstract | Zonation | Time coverage |
|---|---|---|---|---|---|---|
| Canada | North America | Christmas Bird Count | To determine the abundance and distribution of wintering populations of all bird species. | In 1900, American ornithologist Frank Chapman asked birders across North America to head out on Christmas Day to count the birds in their home towns and submit the results as the first "Christmas Bird Census." The Christmas Bird Count, as it is now called, is conducted in over 2000 localities across Canada, the United States, Latin America, and the Caribbean. These bird observations have been amassed into a huge database that reflects the distribution and numbers of winter birds over time. Christmas Bird Counts are conducted on any one day between December 14 and January 5 inclusive. They are carried out within a 24 km diameter circle that stays the same from year to year. Christmas counts are generally group efforts, though single observer counts can and do happen. They are organized at the local level, usually by a birding club or naturalists organization. | Low arctic | 1900- |
| Canada | Northwest Territories | CIMP Community based environmental monitoring in the NWT | The long-term goal of this program is to establish and maintain a network of sites to characterize regional environmental variability and serve as a baseline, against which to measure changes resulting from the cumulative impacts of multiple perturbations. To date our efforts have focused on several terrain types in the Mackenzie Delta Region. In 2011, we will revisit and establish new sites in the Delta region, but we will also set up new sites in the Gwich'in Settlement Area and Yellowknife Area. Our objective is to test our sampling protocol at a wider range of sites and ultimately finalize and publish a guidebook so that this protocol that can be implemented by communities across the NWT. As in past years, the selection of sampling sites will be based on discussions with the Mackenzie Delta CIMP steering committee and HTC members. Areas identified by the HTCs as priorities will also be the focus of hypothesis driven field investigations conducted by researchers at the University of Victoria | At all sites in the network we measure vegetation structure, plant community composition, tree density, the productivity of edible berries, active layer depth, and near surface ground temperatures. At core sites we also maintain meteorological stations, frost tubes, and deep ground temperature cables. Revisiting baseline sites every five years will allow us to determine if vegetation and permafrost conditions are responding to increased air temperatures or altered natural disturbance regimes. This monitoring network will also act as a basis to determine if the environmental impacts of future development exceed thresholds defined by baseline variability. | Low arctic | 2009- |

| Country | Study site | Program title | Objectives | Abstract | Zonation | Time coverage |
|---|---|---|---|---|---|---|
| Canada | CircumArctic | CircumArctic Rangifer Monitoring and Assessment Network (CARMA) network | To determine caribou population trends - assessing mechanisms of population change based on monitoring of health and body condition, demographic parameters and habitat conditions from herds throughout the Arctic. | CARMA is a network of researchers, managers and community people who share information on the status of the world's wild Rangifer (reindeer and caribou) populations, and how they are affected by global changes, such as climate change and industrial development. | High arctic | 2004- |
| Canada | Canada | e-Bird Canada | To provide year round distribution and abundance information on all bird species in Canada, the US and Mexico. eBird's goal is to maximize the utility and accessibility of the vast numbers of bird observations made each year by recreational and professional bird watchers. | Checklist of all bird species. Allows for participation of citizen scientists at any location at any time. | Low arctic | - |
| Canada | Bylot Island, Nunavut | Ecological Studies & Environmental Monitoring at Bylot Island Srmilik National Park | The objectives of this long-term project are to (1) study the trophic dynamic of high-arctic ecosystem, and in particular the plant-herbivore and predator-prey interactions; (2) monitor the abundance and reproductive activity of a large number of wildlife species, the annual production and phenology of plants and the local climate; (3) study the impact of climate warming on the trophic dynamic, selected wildlife species and their habitat; (4) conduct intensive demographic studies of key species (snow geese, arctic fox, long-tailed jaeger, lemmings). | The following species are closely monitored. Greater Snow Goose, Arctic Fox, Lemmings, Snowy Owl, Long-tailed jaeger, Glaucous Gull, Rough-legged hawk, Shorebirds, Lapland Longspur, Ermine, Terrestrial Arthropods and vegetation. Incidental monitoring of other terrestrial bird/mammal species | High arctic | 1988- |
| Canada | Anderson River bird sanctuary | Factors causing declining numbers of lesser snow geese and brant at Anderson River bird sanctuary | Monitor number and locations of migrating, staging, nesting and non-breeding snow geese and brant. Determine predator use and impacts on goose productivity with focus on grizzly bear. Quantify and identify areas of habitat loss. | Tracking snow geese and brant geese migration, staging, and nesting. Plots are used. Percent cover of habitat types. Delta flooding chronology maps. LANDSAT imagery. Inter annual variations of habitat determined by NDVI | | - |

| Country | Study site | Program title | Objectives | Abstract | Zonation | Time coverage |
|---|---|---|---|---|---|---|
| Canada | Herschel Island | Fox population monitoring on Herschel Island | Long term monitoring of the abundance and reproductive success of fox populations | We are monitoring the reproductive activity of Arctic and Red Foxes. We find dens through systematic searches throughout our study site. All dens found are positioned with a GPS and revisited several times to identify the species, minimum litter size and collect prey remains and scats to determine the diet. The study was expanded in 2008 to investigate hypotheses concerning the competitive interactions of the two species. | Low arctic | 2007- |
| Canada | Inuvialuit Region (Inuvik Region), NWT | Government of the Northwest Territories, Inuvik Region, Terrestrial Mammal and Raptors monitoring programs | Wildlife Management | Caribou (Harvest Data, Post-calving Photo Survey – Tuktoyaktuk Peninsula, Cape Bathurst and Bluenose-West Herds, Caribou Recruitment Surveys (Cape Bathurst and Bluenose-West Herds), Caribou Body Condition and Health, Boreal Woodland Caribou - Habitat and Productivity monitoring, Caribou - Peary - Population Estimate, Muskox Harvest, Grizzly Bear Problem Bear Program, Grizzly Bear Population Study, Grizzly Bear Harvest Monitoring, Polar Bear Harvest Monitoring, Polar Bear Traditional Knowledge Project, Polar Bear Population Assessments, Polar bear movement patterns and habitat use, Wolf Harvest Monitoring, Wolverine Carcass Collection, Inuvik Region, Wildlife Observations (WMIS), NWT Small Mammal and Hare survey (Inuvik site), Peregrine Falcon Surveys, Raptor Nesting Sites (Observations), NWT Virtual Herbarium | | 1990- |

| Country | Study site | Program title | Objectives | Abstract | Zonation | Time coverage |
|---|---|---|---|---|---|---|
| Canada | Kangiqsualujjuaq, Nunavik | Impact of climatic variability on berries productivity in Nunavik: Kangiqsualujjuaq | In northern Canada, productivity of berry shrubs in response to a warming climate is poorly known. We are investigating the response of berry producing shrubs to natural variation and simulated environmental changes for four species commonly used by Inuit communities. The four studied species include bilberries (Vaccinium uliginosum), cranberries (Vaccinium vitisidaea), crowberries (Empetrum nigrum), and cloudberries (Rubus chamaemorus). | We are collecting data on soil temperature, nutrient and humidity, on vegetative growth and sexual reproduction (weight and number of berries) under experimental warming conditions (open-top chambers, OTCs) vs. control. For experimental plots we use standard ITEX open top chambers (Molau and Molgaard, 1996) in a bloc design experiment (3 replications per bloc; n = 4 blocs per study site). The point intercept method was used to characterize the plant communities within 70 x 70cm quadrates. In addition, to evaluate natural variation under a range of light availability, plots under trees, erect shrub species and in open areas were sampled for growth and productivity of berry shrubs. The selection of these plots was based on previous analysis of vegetation change from aerial photographs by Benoît Tremblay, UQTR. Microclimatic conditions, including soil surface temperature, nutrient, light intensity and moisture availability were recorded throughout the 2009 growing season and plant cover estimated with cover abundance scale. For series of sites (warming experiment and shading gradient), basic flower phenology (first flower, first fruit) and berry productivity (fruit number and weight) are noted for each species. Aborion rates are estimated by the difference between flower and fruit counts and vegetative growth by measuring the annual shoot elongation. Chemical analyses are used to estimate phenolic compounds and antioxidant capacity. Similar project going on in Kangirsujuaq. | | 2007- |
| Canada | Quebec, Ontario, Manitoba. In Arctic, coastal lowlands. 3 survey plots/year | Interior Canada Goose banding and productivity survey | To monitor distribution, nesting effort, survival, population size, productivity and harvest rate of sub-arctic nesting Canada geese. | Tracking Canada Geese through banding and area searches. | Low arctic | 1977- |
| Canada | Inuvialuit Settlement Region | Inuvialuit Harvest Study | To monitor trends in aboriginal waterfowl hunting, particulary for declining or overabundant species. | The Inuvialuit Harvest Study studies trends in aboriginal waterfowl hunting, particulary for declining or overabundant species. Six surveys are administered at 3 communities per year. | Low arctic | 1989- |
| Canada | Quebec, specifically Nunavik | Inventaire de la Bernache du Canada population de l'Atlantique | Inventaire des couples nicheurs de Bernache du Canada (population de l'Atlantique) et des autres espèces de sauvagine. | Inventory of Arctic Goose populations and other species of wildfowl. | Low arctic | 1993- |

| Country | Study site | Program title | Objectives | Abstract | Zonation | Time coverage |
|---|---|---|---|---|---|---|
| Canada | Ivvavik National Park | Ivvavik National Park Ecological Integrity Monitoring Program | Data from the park EI monitoring and reporting program is analyzed and assessed every 5 years, and published in a State of the Park Report. | Multiple measures of species and processes are monitored. Breeding Bird Surveys, Winter track surveys, Insect community, vegetation structure, soil moisture, active layer depth, landcover change, plant productivity/green up (NDVI), Porcupine caribou population, lemmings, Breeding Bird Survey, soils | Low arctic | - |
| Canada | East Bay, Nunavut | Long-term monitoring of shorebirds and seabirds at East Bay | Track demographic parameters; identify impacts of disease and predation on population declines; examine migration routes | Survival and reproductive rates and other measurements of shorebirds and seabirds, and coastal waterbirds are used to understand the relationships between population health and contaminants (such as methyl mercury), disease, regional weather conditions, and climate. | High arctic | 1999- |
| Canada | Bathurst Caribou habitat | Migratory barren ground caribou habitat indicators using remote sensing | To define and develop habitat indicators for the calving ground, summer range and winter range of Bathurst caribou herd using field measurements, satellite earth observations, and climate records | Key indicators include foliage biomass, lichen coverage, snow cover, annual maximum snow depth, and mean ice content in snow | Low arctic | 1985- |
| Canada | Canada | National Harvest Survey | To quantify the sport harvest of all migratory game birds in Canada. | The National Harvest Survey is the joint name for two surveys sent annually to a sample of purchasers of the Migratory Game Bird Hunting Permit (MGBHP), introduced by the federal government in 1966. These two surveys are the Harvest Questionnaire Survey (HQS) and the Species Composition Survey (SCS). Data from these and other CWS surveys are used to assess the status of migratory game bird populations in Canada, their productivity, survival rates, and amount of harvest they can sustain. | Low arctic | 1969- |
| Canada | Canada | National Scale Land Surface Characterization | To provide a national time series of baseline information that is being used to characterize and monitor land surface changes. These multi-sensor datasets underpin a number of numbers of national and international reporting activities, contribute to scientific understanding of environmental processes, and support regional ecological assessments and natural resource management. | Long Term Satellite Data Records<br>Parameters derived from the LTSDRs include forest disturbances, land cover change, groundwater discharge, water volume estimates for hydro management and vegetation health/productivity.<br>For other parameters see Cryosphere Monitoring | Low arctic | 1985- |

| Country | Study site | Program title | Objectives | Abstract | Zonation | Time coverage |
|---|---|---|---|---|---|---|
| Canada | North America | North American Breeding Bird Survey | To monitor status and trends in land bird populations throughout North America | The BBS is a long-term, large-scale, international avian monitoring program initiated in 1966 to track the status and trends of North American bird populations through the contributions of citizen scientists. The USGS Patuxent Wildlife Research Center and Environment Canada, Canadian Wildlife Service jointly coordinates the BBS program. | Low arctic | 1966- |
| Canada | Yukon, NWT, Nunavut, Nunavik, Nunatsiavut | Northern Contaminants Program (NCP) | to reduce and, wherever possible, eliminate contaminants in traditionally harvested foods, while providing information that assists informed decision making by individuals and communities in their food use. | This initiative supports cross-disciplinary studies that advance general contaminants-related knowledge, including projects that address climate change - contaminant interactions, and encourages researchers to seek opportunities to combine NCP activities with those funded by other programs to explore these cross disciplinary questions. Activities funded by NCP fall under 5 subprograms: human health; environmental monitoring and research; community-based monitoring and research; communications, capacity and outreach; and national/ regional/ international coordination and Aboriginal partnerships. Study of heavy metals in tissues; Persistent Organic Pollutants (POP) in tissues. Priority species are ringed seal, beluga, narwhal, walrus, polar bear, sea birds (thick-billed murre and northern fulmar), and sea-run Arctic char. Temporal trends - the goal of temporal trend monitoring is to be able to detect a 10% annual change in contaminant concentration over a period of 10-15 years with a power of 80% and confidence level of 95%. Based on the typical standard deviation of 30-50% displayed in the current biomonitoring dataset, the annual collection of at least 10 samples per indicator species and location should be sufficient to achieve this goal. Recommended sampling locations have been selected to build on existing datasets and sample archives, and to provide wide geographic coverage. | Low arctic | 1991- |
| Canada | Northwest Territories | Northwest Territories Cumulative Impact Monitoring Program (CIMP) | To encourage community-based monitoring and community capacity-building; to provide the enabling data infrastructure which will facilitate the gathering, collection synthesis and analysis of environmental information in the NWT to make the information available and accessible to decision makers? This initiative will contribute to the establishment of baseline information and allow for trend analysis. | A multi-stakeholder initiative that sponsors community-based monitoring projects related to priority Valued Ecosystem Components. Tracked Valued Ecosystem Components are caribou, moose, land mammals, birds, vegetation, water and sediment quality, water quantity, snow, ground ice and permafrost, fish habitat, populations, and harvest, fish Quality, marine life, human health and wellness, climate and air quality. | Low arctic | 2009- |

| Country | Study site | Program title | Objectives | Abstract | Zonation | Time coverage |
|---|---|---|---|---|---|---|
| Canada | Nunavut | Nunavut General Monitoring Plan (NGMP) | To provide the enabling data infrastructure which will facilitate the gathering, collection synthesis and analysis of environmental information in the NWT to make the information available and accessible to decision makers? This initiative will contribute to the establishment of baseline information and allow for trend analysis. | A multi-stakeholder initiative that sponsors community-based monitoring projects related to priority Valued Ecosystem Components. This initiative will provide the enabling data infrastructure which will facilitate the gathering, collection synthesis and analysis of environmental information in the NWT to make the information available and accessible to decision makers. This initiative will contribute to the establishment of baseline information and allow for trend analysis. | High arctic | - |
| Canada | Northwest Territories/Nunavut | NWT/NU Bird Checklist Survey | To better understand status and distribution of species in NWT and NU. | The Northwest Territories / Nunavut Bird Checklist Survey are a bird monitoring program that relies on the observation and reports of volunteers. It was initiated to collect much needed information on the distribution, abundance and breeding status of birds in the Northwest Territories and Nunavut. It was initiated by Environment Canada's Canadian Wildlife Service in 1995 as a response to needs identified in the Canadian Land birds Monitoring Strategy. | Low arctic | 1995- |
| Canada | Wapusk National Park, Ivvavik National Park, Torngat Mountenous National Park, Sirmilik National Park | ParkSPACE: Towards an Operational Satellite - based System for Monitoring Ecological Integrity of Arctic National Parks | To develop an operational EO-based system for ecological integrity (EI) monitoring and reporting in Canada's northern national parks, so that EO-based measures of changes in key ecological characteristics of arctic national parks are incorporated by PCA for monitoring, reporting, and protecting Canada's national parks' EI on a routine basis. | Key EI measures include changes in shrub richness (fractional land cover), plant growth (seasonal profiles of vascular foliage biomass, peak foliage biomass and seasonal integrated foliage biomass x day), seasonality (leaf on, leaf off, and growing seasonal length), permafrost active layer, and lakes and wetland extent | Low arctic | 1985- |
| Canada | Canada | PlantWatch | To track the biological responses of key plant species to climactic and other ecosystem changes in order to better predict and manage the impacts of such changes on natural systems and people. | The PlantWatch program engages citizen scientists in monitoring the timing of bloom events of indicator plant species over a period of several years and to educate them about ecological issues related to climate change and plants. PlantWatch North is a subset of the national PlantWatch program. | Low arctic | 2002- |
| Canada | Quebec | Quebec Aboriginal Subsistence Harvest Survey | Updates from 1970's our knowledge of the subsistence harvest levels for geese and ducks by Quebec's Cree and Inuit communities | Survey of Aboriginal harvest for geese and ducks | Low arctic | 2005- |

| Country | Study site | Program title | Objectives | Abstract | Zonation | Time coverage |
|---|---|---|---|---|---|---|
| Canada | Quebec | Quebec Bird Population Surveys (EPOQ) | Diffuser les connaissances acquises sur la répartition, la reproduction, le comportement et les habitats des oiseaux du Québec. Favoriser la protection des oiseaux et la préservation de leurs habitats. Diffuser les connaissances acquises sur l'ornithologie amateur au Québec. | EPOQ records bird observations submitted mainly by volunteer birders in Québec. | Low arctic | 1975- |
| Canada | Quebec | Québec Breeding Bird Atlas | To map the distribution of each bird species nesting in Québec and to map the relative abundance of certain of these. | Citizen scientists ccollect data to map the presence, relative abundance and distribution of breeding birds. | Low arctic | 1984- |
| Canada | Quttinirpaaq National Park | Quttinirpaaq National Park Ecological Integrity Monitoring Program | Data from the park EI monitoring and reporting program is analyzed and assessed every 5 years, and published in a State of the Park Report. | Multiple measures of species and processes are monitored. Peary Caribou, vegetation communities, plant phenology, soils, land cover change, primary productivity. | High arctic | - |
| Canada | Polar | RADARSAT Science Polar Datatset | | Marine surveillance, ice monitoring, disaster management, environmental monitoring, resource management and mapping in Canada and around the world using RADARSAT imagery. | | 1995- |
| Canada | Resolute, Nunavut | Resolute | | Terrestrial biological measures monitored include NWT/NU Bird Checklist Survey, Browne Island Seabird Colony/Calibration of the Sea Wifs Satellite, Arctic Insects, Global Change and the ITEX Program, and Ecohydrology of Vegetation Bands Associated with Latelying Snowbeds. | | - |
| Canada | Sirmilik National Park | Sirmilik National Park Ecological Integrity Monitoring Program | Data from the park EI monitoring and reporting program is analyzed and assessed every 5 years, and published in a State of the Park Report. | Multiple measures monitored. Lemming Abundance, Avian Biodiversity, Arctic/Red Fox Occurrence, Arthropod Biodiversity/Phenology, Vegetation Communities, Plant Phenology, Active Layer Depth, Land Cover Change, and Primary Productivity. | High arctic | - |

| Country | Study site | Program title | Objectives | Abstract | Zonation | Time coverage |
|---|---|---|---|---|---|---|
| Canada | Walker Bay, Kent Peninsula, Nunavut | Small mammal monitoring at Walker Bay | Long term monitoring of small mammal abundance and reproductive activity | We monitor lemming abundance using two methods. (1) Capture-marking-recapture by live trapping animals using Longworth traps on twelve 0.36 grids (25 live-trap stations) and one 9-ha grid (100 live traps) in mixed heath/wetland habitats. The 12 small grids have been sampled in 1996, 1997, 1999, 2004, 2007 and 2009. The large grid was sampled in 2004 and 2007. Trapping sessions last for 3 days and occur only once during the summer in June/July. We identify all animals to species and age class and also determine the reproductive condition of all captured animals. (2) Survey of lemming winter nests after snow-melt in our live-trapping grids in mid-June (2007 and 2009). | High arctic | 1996- |
| Canada | Herschel Island and Komakuk Beach | Small mammal monitoring on Herschel Island and Komakuk Beach | Long term monitoring of small mammal abundance and reproductive activity | We monitor lemming abundance using three methods. (1) Absolute abundance estimation by capture-mark-recapture. This involves live trapping animals using Longworth traps on three, 2 to 9 ha grids (50 to 256 traps/grid) in wetland and mesic habitats; trapping sessions last for 2-3 days and are repeated up to three times during the summer from early-June to mid-September. We also determine the reproductive condition of all captured animals. (2) Full counts and mapping of lemming winter nests after snow-melt (early June) on our absolute abundance live-trapping grids. (3) Relative abundance estimation by live-trapping (Longworth traps) on four 300 m long transects with 3 traps at stations 15 m apart along each transect. Transects are run for approximately 48 hours, in each of two seasons – spring (early to mid June) and fall (late August or Sept). We also investigate the role of snow cover and depth in habitat selection by lemmings using snow fencing to enhance snow depths on an experimental trapping grid. Snow fencing (1 m high) is erected in parallel lines c. 40 m apart and perpendicular to the prevailing wind, and traps a great deal of extra snow. The intensity of lemming habitat use is measured through the density of lemming winter nests as mapped on the experimental and a control grid just after snow melt in spring. | Low arctic | 2007- |
| Canada | Quebec | SOS-POP Suivi de l'occupation des stations de nidification Population d'oiseaux en péril du Québec | Identifier les sites de nidification des espèces d'oiseaux en péril au Québec, assurer un suivi fréquent pour en vérifier l'occupation, dénombre les oiseaux présents, documenter les perturbations anthropiques. | | Low arctic | 1994- |

| Country | Study site | Program title | Objectives | Abstract | Zonation | Time coverage |
|---|---|---|---|---|---|---|
| Canada | Bylot and Ellesmere Islands | Suivi de la démographie de la Grande Oie des neiges et de l'habitat dans l'Arctique (Greater Snow Goose) | Dynamique des populations Grande Oie des neiges et suivi de ses habitats. | This monitoirng program tracks the long-term impact of overabundant Greater Snow Geese on Arctic Habitats. | High arctic | 1989- |
| Canada | Various loctions. In BCR 3 there are 4 locations. | Suivi télémétrique de la Grande Oie de Neiges | Amélioration de l'estimation de la population de la GON au printemps et sSuivi de la migration de la Grande Oie des neiges | Monitoring Greater Snow Goose populations in the spring and following their migration. | High arctic | 2006-2011 |
| Canada | Inuvialuit Settlement Region | Surveys of geese and swans in the Inuvialuit Settlement Region | To determine the numbers, distribution and productivity of geese and swans in the Inuvialuit Settlement Region | Surveys of geese and swans in the Inuvialuit Settlement Region. | Low arctic | 1989- |
| Canada | Torngat Mountains National Park | Torngat National Park Ecological Integrity Monitoring Program | Data from the park EI monitoring and reporting program is analyzed and assessed every 5 years, and published in a State of the Park Report. | Multiple measures of species and processes are monitored. Permafrost (core temperature), Tundra Vegetation change, land cover change, plant growth and seasonality (NDVI), Bluenose West caribou population | Low arctic | - |
| Canada | Tuktuk Nogait National Park | Tuktuk Nogait National Park Ecological Integrity Monitoring Program | Data from the park EI monitoring and reporting program is analyzed and assessed every 5 years, and published in a State of the Park Report. | Multiple measures of species and processes are monitored. Bluenose West caribou population, lemmings, breeding bird survey, raptor productivity, grizzly bear habitat use, active layer depth, permafrost, landcover change, plant productivity/green up (NDVI). | Low arctic | - |
| Canada | Daring Lake, NWT | Tundra Ecosystem Research Station | Environmental and wildlife monitoring Control site to compare with effects of mining on the Central Barrens | Identified priority research and monitoring areas are The International Tundra Experiment , Breeding bird surveys at Daring Lake, Small mammal monitoring – population trends, Raptor monitoring, Interaction of biting insects and forage availability for caribou of the Bathurst herd, Denning ecology of tundra wolves, Abundance and population trends of wolverines. Next programs delivered in association with Universities: Carbon flux, nutrient cycling and respiration of arctic plants, Snow depth and CO2 flux in hummock tundra, Nitrogen cycling in the arctic tundra, Effects of caribou grazing on low arctic tundra, Variation in $CO^2$ exchange on the tundra. | Low arctic | 1994- |

| Country | Study site | Program title | Objectives | Abstract | Zonation | Time coverage |
|---|---|---|---|---|---|---|
| Canada | Vuntut National Park | Vuntut National Park Ecological Integrity Monitoring Program | Data from the park EI monitoring and reporting program is analyzed and assessed every 5 years, and published in a State of the Park Report. | Multiple measures of species and processes are monitored. Vegetation productivity, Porcupine Caribou Herd, Vegetation composition, Tundra cover, White-winged, black and surf scoters and Peregrine falcons. | Low arctic | - |
| Canada | Wapusk National Park | Wapusk National Park Ecological Integrity Monitoring Program | Data from the park EI monitoring and reporting program is analyzed and assessed every 5 years, and published in a State of the Park Report. | Multiple measures of species and processes are monitored. Caribou (population dynamics), snowpack, microclimate (weather station), landcover change, vegetation disturbance- trails, helicopter over flights, tundra vehicle use, fuel cache management and barrel cleanup, Canada geese abundance and nest success, lesser snow geese abundance and nest success, anuran survey, permafrost temp, primary productivity (NDVI), snow geese impacts on wetland vegetation, hunting and furbearer records, over snow vehicle use. | Low arctic | - |
| Canada | Central and Western Arctic | Waterfowl breeding population survey for central and western arctic Canada. | To determine population status of waterfowl in the central and western Arctic of Canada. | This aerial transect survey is intended to replace traditional helicopter transect surveys that have been done by CWS intermittently since the early 1990's throughout western and central arctic Canada. | | 2009- |
| Canada | Herschel Island | Weasel population monitoring on Herschel Island | Long term monitoring of weasel population abundance | We have attempted to quantify weasel abundance on Herschel Island by live capture-mark-recapture. This approach was not successful in 2007, as capture success on a trapping grid of 100 m x 500 m (total area ca. 4 square km) was too low. Most weasels (all least weasels) are caught in lemming live-traps on lemming trapping grids (9 ha), but these are too small to encompass many weasel home ranges. No new work was accomplished in 2008. In 2009 an intermediate sized live-trapping grid was used for weasels. | Low arctic | 2007- |
| Canada | Ward Hunt Island | | | Research on structure and functioning of lake and river ecosystems at high latitudes; dynamics of northern ice shelves; cyanobacteria ecology; impacts of UV radiation and climate change on aquatic ecosystems. | | - |
| Canada | Canadian Arctic | Program for Regional and International Shorebird Monitoring (PRISM)- Tier 2 | provide long-term, periodic monitoring of arctic breeding shorebird species, habitats, and phenology | Area search - double sampling. 15-60 sites per year. | | 1999- |

| Country | Study site | Program title | Objectives | Abstract | Zonation | Time coverage |
|---|---|---|---|---|---|---|
| Faroe Islands | Central and northern Faroe Isands | GLORIA (Global Observation Research Initiative in Alpine Environments) | The purpose of Gloria is to establish and maintain a long-term observation network for the comparative study of the effects of climate change on mountain biota. | In the Faroe Islands the vegetation on four mountain summits ranging in altitude from 380 to 750 m a.s.l. is monitored, and permanent plots are established. | Selected alpine | 2009- |
| Faroe Islands | Sornfelli | ITEX (International Tundra Experiment) | Is to monitor changes in the vegetation and flowering phenology in Open Top Chambers. | The ITEX site in the Faroe Islands is alpine at an altitude of 600 m a.s.l. The vegetation and the flowering phenology of Silene acaulis has been monitored since 2001 in OTC, grazed and not grazed control plots. | Selected alpine | 2001- |
| Finland | Kevo Research Station, University of Turku | Population fluctuation of hole nesting passerine birds 1982- | Population fluctuation of hole nesting passerine birds 1982- | | Selected alpine | 1982- |
| Finland | Kevo Research Station, University of Turku | Aerobiological pollen monitoring 1976- | Aerobiological pollen monitoring 1976- | | Selected alpine | 1976- |
| Finland | national | Arctic fox (Alopex lagopus) population monitoring | Arctic fox (Alopex lagopus) population monitoring. Coverage national (present only in Sub-Arctic area). Over 80 % of the known territories monitored yearly. | Arctic fox (Alopex lagopus) population monitoring | Selected alpine | 1956- |
| Finland | Kevo Research Station, University of Turku | Berry production of ericaceous shrubs 2009- | Berry production of ericaceous shrubs 2009- | | Selected alpine | 2009- |

| Country | Study site | Program title | Objectives | Abstract | Zonation | Time coverage |
|---|---|---|---|---|---|---|
| Finland | national | Breeding land-bird line transect censuses | The bird atlas survey (2006-2010) can be viewed as a tool to monitor biodiversity. The main aim of the third atlas was to examine the present distribution of Finnish birds, and to investigate changes in distribution together with other environmental data. In particular, the first bird atlas 1974–79 (Hyytiä et al. 1983) and the second bird atlas 1986–89 (Väisänen et al. 1998) are important reference materials. The data of the atlas were also used in the evaluation of the Red Listed species in Finland 2010. | The Third Finnish Breeding Bird Atlas survey was conducted in 2006–2010. The first two atlases were carried out in 1974–79 and 1986–1989. The aim of the third atlas was to examine present distributions of birds and compare them with those published in the previous atlases. The atlas data can be utilized together with other long-term bird monitoring and other environmental data to investigate changes in biodiversity. Distribution data was collected from 10 x 10 km grids (KKJ Uniform Coordinate System). When the third bird atlas project was initiated, a specific network of standardized line transect censuses was also established. The aim is to get data on numbers of birds and their population changes. When put together, the atlas data and constant line transect data form a good overall picture of the numbers and distribution of Finnish bird populations. The population estimates shown in web page are mostly based on data from line transects. | Selected alpine | - |
| Finland | Migration routes from arctic breeding areas through Finland | Census of the migration of arctic birds | The aim is to monitor annual and long-term changes in migrating populations of arctic breeding offshore and water birds, geese and skuas. | Number of individuals and species of arctic breeding water birds is monitored by the bird stations of Rönnskär, Jurmo and Hanko in the southern coast of Finland. Comparison between spring and autumn migrations gives an estimation of the breeding success. Twice a year (spring and autumn migrations). | Selected alpine | Since 1950s- |
| Finland | Kevo Research Station, University of Turku | Flowering date (277 species) 1975- | Flowering date (277 species) 1975- | | Selected alpine | 1975- |
| Finland | Kevo Research Station, University of Turku | Fruiting bodies of mushrooms | Fruiting bodies of mushrooms | | Selected alpine | - |
| Finland | national | Golden eagle (Aquila chrysaetos) population monitoring | Golden eagle (Aquila chrysaetos) population monitoring. Coverage national. 100 % of the known territories monitored yearly in the Sub-Arctic area / reindeer herding area. Information collected: nest locations, occupancy, breeding results. Standard: Nordic countries | Golden eagle (Aquila chrysaetos) population monitoring | Selected alpine | 1981- |

| Country | Study site | Program title | Objectives | Abstract | Zonation | Time coverage |
|---|---|---|---|---|---|---|
| Finland | national | Gyrfalcon (Falco rusticolus) population monitoring | Gyrfalcon (Falco rusticolus) population monitoring. Coverage national (present only in Sub-Arctic area). About 90 % of the known territories monitored yearly. Information collected: nest locations, occupancy, breeding results. Standard: National, adapted from Golden eagle monitoring. | Gyrfalcon (Falco rusticolus) population monitoring | Selected alpine | 2000- |
| Finland | Kevo Research Station, University of Turku | Lepidopteran population fluctuation and species composition 1972- | Lepidopteran population fluctuation and species composition 1972- | | Selected alpine | 1972- |
| Finland | national | Lesser White-fronted Goose (Anser erythropus) population monitoring | Lesser White-fronted Goose (Anser erythropus) population monitoring. Coverage national (breeding only in Sub-Arctic area). No breeding observed since 1995. Information collected: nest locations, occupancy, breeding results. Standard: National | Lesser White-fronted Goose (Anser erythropus) population monitoring | Selected alpine | - |
| Finland | Kevo Research Station, University of Turku | Long-term environmental monitoring and manipulative experiments addressing cause-effect relationships of anthropogenic environmental changes. | Long-term environmental monitoring and manipulative experiments addressing cause-effect relationships of anthropogenic environmental changes. Monitoring programs in next columns. | The Kevo research station is situated by Lake Kevojärvi, in the commune of Utsjoki, the northernmost municipality in Finnish Lapland. The site lies about 60 km north of the continous pine forest line and belongs to the subarctic of forest tundra zone, a birch subzone of the boreal coniferous forest. The research area as a whole comprises mainly the biological province of Inari Lapland, an area of ca. 20 000 $km^2$, including the large Lake Inari. There are experimental areas for simulated acid deposition (started 1985), effects of sulphuric deposition and heavy metals (1991) , treeline gardens ranging from 90 m to 270 m a.s.l., (1970's) and from the borderline of continuous pine forests to the birch forest line. Besides circumpolar conifer provenances (11 species) progenies of both Betula pendula and B. pubescens (mainly ssp. czerepanowii). The station also maintains long-term environmental monitoring (weather since 1962), catchment monitoring terrestrial and aquatic data (Economic Commission for Europe monitoring program) (1989), Air quality monitoring – national background reference station (Finnish Meteorological Institute). | Selected alpine | 1954- |

| Country | Study site | Program title | Objectives | Abstract | Zonation | Time coverage |
|---|---|---|---|---|---|---|
| Finland | Kilpisjärvi Biological Station, University of Helsinki | Long-term follow-up studies | Widely respected, long-term follow-up studies form the core of the scientific activities at the station. The most long-lasting series of observations concerns the fluctuations of the small rodent densities over a 50-year period. Furthermore, the population dynamics of passerines have been monitored since 1957. Long-term research projects also include the periodicity in the quality and quantity of vegetation in the mountain region. Recent research activities have extended from animal and botanical ecology into hydrobiological and paleolimnological geography and geophysics has been conducted at the station. Seismic station of the Institute of Seismology is situated at the station. Monitoring programs in next columns. | The Kilpisjärvi Biological Station was founded in 1964. The principal aim of the station is to promote biological and geographical research in the north, and to provide students of biology and geography with information about natural phenomena in northern lands. The station is open to researchers of all nationalities. Kilpisjärvi Biological Station is situated in the mountain birch forest zone near the 70th parallel of northern latitude in the north-westerenmost part of Finland. Station belongs to University of Helsinki, the Faculty of Biological and Environmental sciences. | Selected alpine | 1957- |
| Finland | national | Monitoring birds of prey | The nationwide monitoring study on birds of prey, conducted in unison with the Ringing Centre and the Ministry of the Environment, started in 1982. Populations of birds of prey are studied at 10 km x 10 km raptor grid squares based on the National Grid and spread over the country. The aim is to find all nests - or at least all occupied territories of the birds of prey in the squares. | | Selected alpine | 1982- |
| Finland | national | Monitoring of large carnivores | The Finnish Game and Fisheries Research Institute estimate large carnivore populations primarily on the basis of observations recorded by the volunteer carnivore network. The network has been working since 1978, and consists of about 2,000 hunters who are experts in recognizing the tracks and faeces of large carnivores. FGFRI research projects provide additional information for the estimation. | Monitoring large carnivore brown bear (Ursus arctos), wolf (Canis lupus), wolverine (Gulo gulo) and lynx (Lynx lynx) populations | Selected alpine | 1978- |

| Country | Study site | Program title | Objectives | Abstract | Zonation | Time coverage |
|---|---|---|---|---|---|---|
| Finland | Sub-Arctic | Monitoring of threatened and/or EU habitat directive's vascular plants | Metsähallitus has the national responsibility of promoting conservation and organizing monitoring of certain threatened species, or species which are mentioned in the Habitats Directive. In Sub-Arctic three vascular plant species are monitored regularly: Hairy stonecrop (Sedum villosum), Wall hawk's-beard (Crepis tectorum ssp. Nigrescens), Fragrant shield fern (Dryopteris fragrans) | Hairy stonecrop (Sedum villosum), Wall hawk's-beard (Crepis tectorum ssp. Nigrescens), Fragrant shield fern (Dryopteris fragrans) monitoring | Selected alpine | 1996- |
| Finland | Enontekiö, Kilpisjärvi | Monitoring scheme for subarctic butterflies and moths | The goal is to monitor the occurrence of the subarctic species and abundance of mainly diurnal species | Occurrence and abundance of the subarctic butterflies and moths. | Selected alpine | 2008- |
| Finland | national | Moth monitoring scheme | Moth monitoring is a long-term monitoring scheme which aims at collecting information on changes in moth populations and their habitats over a long time period. | Material is collected from the sample container of the light traps once a week during the summer > number of species and individuals per week per trap >> abundance, the beginning and end of flight, mass occurrence, climate change, etc. All night flying Macrolepidoptera | Selected alpine | 1993- |
| Finland | national | National Butterfly Recording Scheme (NAFI) | In general, butterflies are regarded as one of the most endangered insect groups in Finland. Several factors have been implicated in the decline of butterflies, but the prime factor has been the alteration or complete destruction of the habitat. | Field data in NAFI are based on observations of butterflies made by voluntary amateur and professional lepidopterists all over the country, marked on the form designed for the scheme. | Selected alpine | 1991- |
| Finland | national | National forest inventory (VMI) | The National Forest Inventory is a monitoring system that produces information concerning national and regional forest resources (volume, growth and quality of growing stock), land use structure and forest ownership, forest health, biodiversity of forests and forest carbon stocks and their changes. Also in Sub-Arctic area. | | Selected alpine | 2003- |

| Country | Study site | Program title | Objectives | Abstract | Zonation | Time coverage |
|---|---|---|---|---|---|---|
| Finland | national | Peregrine falcon (Falco peregrinus) population monitoring | Peregrine falcon (Falco peregrinus) population monitoring. Coverage national. About 90 % of the known territories monitored yearly. Information collected: territory locations, occupancy, breeding results. Standard: National, adapted from Golden eagle monitoring | Peregrine falcon (Falco peregrinus) population monitoring | Selected alpine | 1980- |
| Finland | Kilpisjärvi Biological Station, University of Helsinki | Phenological phenomena, yearly variation in production and seed crop of selected alpine plants | Phenological phenomena, yearly variation in production and seed crop of selected alpine plants, such as the Mountain Birch (Betula pubescens ssp. czerepanovii), the Bilberry (Vaccinum myrtilus), the Glacier Buttercup (Ranunclus glacialis), the Globeflower (Trollius europaeus) and the Mountain Avens (Dryas octopetala) have been monitored since 1960s. These long-term studies are still maintained. | | Selected alpine | 1964- |
| Finland | Kevo Research Station, University of Turku | Phenology monitoring (24 species) 1977- | Phenology monitoring (24 species) 1977- | | Selected alpine | 1977- |
| Finland | Kevo Research Station, University of Turku | Pollen deposit monitoring 1982- | Pollen deposit  monitoring 1982- | | Selected alpine | 1982- |
| Finland | Kilpisjärvi Biological Station, University of Helsinki | Population dynamics of hole-nesting passerne birds 1957- | Population dynamics of hole-nesting passerine birds 1957- | | Selected alpine | 1957- |
| Finland | Kevo Research Station, University of Turku | Population fluctuation and breeding success of the birds of prey 1982-2005 | Population fluctuation and breeding success of the birds of prey 1982-2005 | | Selected alpine | 1982-2005 |
| Finland | Kevo Research Station, University of Turku | Population fluctuation birch eating insect herbivores 1986- | Population fluctuation birch eating insect herbivores 1986- | | Selected alpine | 1986- |

| Country | Study site | Program title | Objectives | Abstract | Zonation | Time coverage |
|---|---|---|---|---|---|---|
| Finland | Kevo Research Station, University of Turku | Rodent populations (birch forest and tundra) 1981- | Rodent populations (birch forest and tundra) 1981- | | Selected alpine | 1981- |
| Finland | Kilpisjärvi Biological Station, University of Helsinki | Small rodents 1946- | Small rodents 1946- | | Selected alpine | 1946- |
| Finland | Northernmost reindeer herding districts of Finland (all districts north from about 67ºN) | The reindeer pasture inventory | The changes on pastures, whether they are caused by grazing, other land use, or by climate and weather, are usually reflected in reindeer herding. | Inventory: lichen biomass in the field sites, structure of the pastures and land use with remote sensing. Survey of 1) amount and quality of pastures, 2) productivity of pastures, 3) changes on pastures and possible reasons, 4) effects of reindeer herding | Selected alpine | 1995- |
| Finland | national | White-tailed eagle (Haliaeetus albicilla) population monitoring | White-tailed eagle (Haliaeetus albicilla) population monitoring. Coverage regional (Sub-Arctic area totally) | White-tailed eagle (Haliaeetus albicilla) population monitoring | Selected alpine | - |
| Finland | national | Wildlife triangle counts (game species) | Sustainable harvesting of game populations and the corresponding determination of hunting quotas require reliable information on the size and development of game populations. Continuous monitoring of game populations is an important task of the Finnish Game and Fisheries Research Institute. Reliable information on game abundance and the annual game bag benefits both hunting and scientific research. More than 30 game species are monitored. | More than 30 game species are monitored | Selected alpine | 1989- |
| Greenland | Kobbefjord, SW Greenland | BioBasis Nuuk | The overall aim of Nuuk Basic is to examine 1) how climate change affects the dynamics and processes in a high arctic ecosystem, and 2) how arctic ecosystems feed back to the atmosphere. | The goal of BioBasis is to monitor the dynamics of a large variety of organisms and biological processes in the local ecosystem. The programme includes 27 elements of terrestrial plant, arthropod and bird dynamics in Kobbefjord and monitoring of phyto- and zooplankton in two lakes. Emphasis is on populations, phenology, and reproduction. | Low arctic | 2007- |

| Country | Study site | Program title | Objectives | Abstract | Zonation | Time coverage |
|---|---|---|---|---|---|---|
| Greenland | Zackenberg, NE Greenland | BioBasis Zackenberg | The overall aim of Zackenberg Basic is to examine 1) how climate change affects the dynamics and processes in a high arctic ecosystem, and 2) how arctic ecosystems feed back to the atmosphere. | The goal of BioBasis is to monitor the dynamics of a large variety of organisms and biological processes in the local ecosystem. The programme includes 35 elements of terrestrial plant, arthropod, bird and mammal dynamics in Zackenbergdalen and adjacent valleys besides monitoring of phyto- and zooplankton in two lakes. Emphasis is on populations, phenology, reproduction and predation. | High arctic | 1996- |
| Greenland | CW Greenland | Body Health & Condition of Caribou Populations | The overall aim is to assess the vulnerability of Greenland herds to global changes. This is achieved through an initial standardized 'snapshot' of body health and condition allowing crossherd comparisons. With extensive retrospective databases for some herds, and links to global changes, several relevant questions are examined. The goal is a time series of 'snapshots' allowing temporal comparisons on the same herd. | Caribou collections done about once a decade, using standardized protocols, make possible cross-herd comparisons across the circumarctic, and enable us to track changes in the same herd over time. Links to climate change are made. Relating the results to known caribou demographics may explain some of the mechanisms behind observed population changes or stability over the past decade. The results may be used by policy makers to fine tune caribou management. | Low arctic | 1996- |
| Greenland | Kangerlussuaq, W Greenland | Community structure and dynamics in relation to species interactions and climate change. | How are trophic interactions among predators and herbivores, and among herbivores and plants, influenced by climatic variation and change? How do abiotic conditions and species interactions shape plant community composition and primary productivity? To answer these questions, my colleagues and I have conducted extensive analyses of long-term data and simulation modeling. | Beginning in 2002, I adopted an empirical approach to investigating these questions by initiating a large-scale, long-term field experiment in West Greenland involving the use of multiple herbivore exclosures and passive warming devices. My students, assistants, and I erected 6, 800m$^2$ permanent exclosures designed to eliminate herbivory by caribou and muskoxen in order to quantify the impact of these herbivores on productivity and species composition of arctic plant communities. | low arctic | 2002- |
| Greenland | South Greenland | Investigations of the Peregrine Falcon in South Greenland | Monitoring of a terrestrial migrant predator: reproduction, timing of breeding and environmental pollutant loads and effects | Monitoring of Peregrine Falcon (Falco peregrinus tundrius) breeding success, timing of breeding (shifting with climate change), trends loads and effects of "classical" pesticides as well as "new" contaminants (e.g. flame retardents) | low arctic | 1981- |
| Greenland | Traill Island | Karupevl Valley Project | To document the fluctuating collared lemming populations and its effects on the predator guild | The project registers annually all lemming winter nests, including stoat depredated nests, and the reproductive activity of the various predatory mammals in the valley. | High arctic | 1988- |

| Country | Study site | Program title | Objectives | Abstract | Zonation | Time coverage |
|---|---|---|---|---|---|---|
| Greenland | Greenland | Monitoring the Caribou & Muskox Harvest | Detailed hunter harvest reporting is to provide biological data, specific to each caribou or muskox population. | General harvest reporting provides total numbers harvested in the entire country for all species. Harvest reports specific to caribou and muskox, however, contain information about each animal's location, age, sex, presence of calf-at-heel, and rump fat depth. Monitoring the annual demographics of animals harvested is used to access the impact of the human harvesting on the populations. Monitoring changes in biological parameters is used to access trends in population health and reproduction. | Low arctic | 1995- |
| Greenland | CW Greenland | Satellite tracking of two Caribou Populations | The overall aim is to delineate movement patterns, seasonal ranges and critical habitat prior to development. | In 1997-98 fifteen caribou cows (8 in the Kangerlussuaq-Sisimiut population and 7 in the Akia-Maniitsoq) received satellite collars in West Greenland and were tracked for three years. In 2008 forty caribou cows received GPS satellite collars and were followed for two years. Movement, critical habitat and migration information was obtained. | Low arctic | 1997-2010 |
| Greenland | CW Greenland | Status of Caribou Populations | The overall aims of the aerial surveys are to estimate and monitor trends in the abundance and herd structure of the three largest caribou populations in CW Greenland. | The goal of the surveys is is to monitor the dynamics and demographics of the one most culturally important terrestrial mammal in West CW Greenland. The data sampled collected includes information on number, group size, sex, age and distribution of Rangifer. The surveys occur about every five years in late winter (March/April). Results can be obtained from the Greenland Institute of Natural Resources Website www.natur.gl under publications/technical reports. | Low arctic | 2000- |
| Greenland | Kangerlussuaq - Sisimiut, CW Greenland | Status of Muskox Population | The overall aim of the minimum count ground surveys is to estimate the abundance provide an index of abundance and herd structure of the largest Muskox population in CW Greenland. | The goal of the surveys is to monitor trends in abundance and dynamics of the biggest Muskox population in CW Greenland. The results are used by policy makers for harvest management. Data sampled includes number, group size, sex, age, distribution and density. | Low arctic | 2000- |
| Greenland | Svartenhuk, Naternaq, Ivittuut, Ittoqqortoormiut | Status of Small Muskox Populations | Minimum counts ground surveys provide an index of abundance and herd structure. They also promote scientist-hunter collaboration owing to a foundation on local involvement, which includes not just the planning stages, but also execution and reporting. | The goal of these ground surveys is to monitor trends in abundance and dynamics so that harvest quota regulation is possible for even these small or remote populations of muskox. Data sampled includes number, group size, sex, age, distribution and density. | Low arctic | 2002- |

| Country | Study site | Program title | Objectives | Abstract | Zonation | Time coverage |
|---|---|---|---|---|---|---|
| Greenland | Nuuk, SW Greenland & Narsarssuaq, S Greenland | Vegetation Monitoring | The overall aim of the vegetation monitoring is to examine how climate changes and herbivory affects the biodiversity and plant dynamics in a low arctic ecosystem | The goal of the monitoring is to estimate the effect of herbivory in relation to climate on the biodiversity of plant species inside and outside exclosures that has been in place for 5 to 25 years. | Low arctic | 1990- |
| Greenland | Pituffik Peninsula, Northwest Greenland | | The Welker lab is dedicated to understanding the ecophysiological processes governing the functional and structural traits of Arctic/Alpine tundra, boreal forests and temperate grasslands under current and future conditions. Welker's research program centers on four main themes: 1) experimental and observational studies that examine how carbon and nitrogen cycling in Low and High Arctic ecosystems respond to deeper snow in winter and warmer temperatures in summer; 2) continental-scale processes and patterns of the isotope geochemistry of precipitation as a means to understand the ecohydrology of landscapes and the recording of climate records in proxies such as ice cores, tree rings and speleothems; 3) the food web and migratory ecology of ecosystems in Alaska involving gray wolves, moose, salmon, caribou, polar bears, white-fronted geese, and seabirds; and 4) climate-plant-animal interactions in Arctic and temperate landscapes using experimental and observational studies. | | high arctic | 2000- |
| Iceland | Öxnadalur, Eyjafjörður, N-Iceland | GLORIA Iceland | Monitoring of changes of vegetation on 4 peaks ranging in altitude from 520 m.a.s.l. to 1100 m.a.s.l. | The GLORIA network has been ongoing for more than 10 years and is distributed worldwide. The purpose of the network is to monitor vegetation changes due to climate change. | Low arctic | 2008- |
| Iceland | Þingeyjarsýslur, NE Iceland | Monitoring of moorland birds in NE Iceland | To monitor the density, distribution and population development of breeding moorland birds in NE Iceland. | The goal is to monitor the population dynamics of moorland birds in relation with abiotic environmental factors. The breeding numbers and density of different species is estimated annually from point counts. Abiotic factors are monitored at fixed weather stations in the area by the Icelandic Meteorological Office. | Low arctic | 2009- |

| Country | Study site | Program title | Objectives | Abstract | Zonation | Time coverage |
|---|---|---|---|---|---|---|
| Iceland | Þingeyjarsýslur, NE Iceland | Moth monitoring in NE Iceland | To monitor the distribution and population change of moths in Iceland. | The goal is to monitor the distribution and population dynamics of moths in Iceland in relation with abiotic environmental factors. Moths are collected in light-trap annually from week 16 to week 40. Abiotic factors are monitored at fixed weather stations in the area by the Icelandic Meteorological Office. | Low arctic | 2007- |
| Iceland | Flatey, Breiðafjörður, A-Barð, Iceland | Monitoring bird-life on Flatey | Changes in breeding birds, species composition and populations size. | Monitoring of an island breeding bird community of around 20 species. The oldest monitoring regional program for breeding bird fauna in Iceland. | low arctic | 1974- |
| Iceland | Flatey, Breiðafjörður, A-Barð, Iceland | Population study on Snipe | Population dynamics and modeling study. | Changes in population size, breeding distribution, changes throughout summer, production, recruitment, and modeling population | low arctic | 1998- |
| Iceland | Eyjafjarðará delta area, Eyf, Iceland | Eyjafjarðará Delta Monitoring Program | Changes in breeding birds, species composition and population size. | Monitoring changes of a delta breeding bird community of around 30 species. | low arctic | 1988- |
| Iceland | Eyjafjörður, Eyf, Iceland | Black-headed Gull & Common Gull Monitoring Program | Changes in population numbers. | Population numbers and distribution of colonies or nesting sites are monitored in the entire Eyjafjörður region, from Ólafsfjörður on the west end to Grenivík on the eastern side. | low arctic | 1980- |
| Iceland | Eyjafjörður, Eyf, Iceland | Krossanesborgir Monitoring Program | Changes in breeding birds, species composition and population size. | Monitoring changes of a moorland and wetland breeding bird community of nearly 30 species. | low arctic | 1998- |
| Iceland | Eyjafjörður, Eyf, Iceland | Hundatjörn Monitoring Program | Changes in breeding birds, species composition and population size. | Monitoring changes of a wetland breeding bird community of around 10 species. | low arctic | 2008- |
| Iceland | Lowlands and highlands in Iceland | Iceland Pasture Project | To monitor vegetation composition and range conditions of pastures on common grazing lands and home ranges in the lowlands and highlands of Iceland in relation to changes in grazing pressure and climate. | The project was started in 1997-1998 by setting up 100 permanent plots in rangelands and pastures. Sampling included vascular plant composition and cover, biomass, soil pH, total C and N, range condition, photographing. Second sampling was carried out in 2005, when a survey of heath land birds was also carried out in the southern lowlands. Data has been made available through the ITEX project. | low arctic | 1997- |
| Iceland | Esjufjöll, Bræðrasker, Kárasker and Maríusker nunataks | Monitoring of plant succession of nunataks in Vatnajökull glacier, SE-Iceland | Follow the succession of plants and lichens on nunataks of known age. | In 1965 Eythor Einarsson did put up permanent plots in Kárasker (appeared in 1940) and Braedrasker (appeared in 1961) which have been monitored regularly since. In 2000 Mariusker appeared and permenent plots where put up there in 2005 and in 2006 permenent plots where put up in Esjufjöll. | low arctic | 1965- |

| Country | Study site | Program title | Objectives | Abstract | Zonation | Time coverage |
|---|---|---|---|---|---|---|
| Norway | Varanger Peninsula | COAT - Climate Ecological Observatory for Arctic Tundra | Monitoring the plant based food web in low arctic tundra (including the tundra-birch forest ecotone) with respect to impacts of climate change. Some data sets runs back to 2001. But the full monitoring system, following the principles of adaptive monitoring, is due to be established in 2012. | The low arctic tundra harbors endemic biodiversity as well as many ecosystem services that are likely to be impacted by climate warming of the Arctic. COAT follows a protocol based on principles of adaptive monitoring as to monitore modules of the plant based food web in low arctic tundra. The food web modules are centered on critical functions and ecosystem services that can be expected to respond strongly to climate change. A comprehensive science plan for COAT is presently drafted and the observatory is due to be established in 2012. | Low arctic | 2001- |
| Norway | Pasvik, Finnmark | Environmental monitoring and assessment system in the joint Finnish, Norwegian and Russian border area | Identify possible effects of air pollution from The Nikel melter on the terrestrial ecosystem in the joint Finnish, Norwegian and Russian border area | | Selected alpine | 1993- |
| Norway | Finnmark | Golden Eagle monitoring in Finnmark | | | Selected alpine | - |
| Norway | Svalbard | Microtus rossiaemeridionalis dynamics in Svalbard (1991-) | | | High arctic | - |
| Norway | Finnmark | Monitoring of Bean Goose in Finnmark (2002- ) | Monitor population development in spring staging, and moulting areas in Finnmark. Combined with satellite tracking and neck-banding. | | | - |
| Norway | Finnmark | Monitoring of Lesser White-fronted Goose in Norway (1991-) | | | Selected alpine | - |
| Norway | Finnmark; northern Troms | Monitoring of palsa peatlands | | | Selected alpine | - |

| Country | Study site | Program title | Objectives | Abstract | Zonation | Time coverage |
|---|---|---|---|---|---|---|
| Norway | Finnmark | Monitoring of Rough-legged Buzzard in Porsanger (2005 - | Monitoring of numbers of breeding pairs along a standard track in Porsanger municipality. Combined with satellite tracking. | | | 2005- |
| Norway | Finnmark | Monitoring of Ruff and Bar-tailed Godvit in Stabbursnes (1991- | Monitor population development during spring and autumn staging in the inner parts of the Porsangen Fjord. For Ruff also numbers at the biggest lekking site in Porsanger is daily monitored throughout the breeding period. Combined with satellite tracking and data-loggers. | | | 1991- |
| Norway | Finnmark | Monitoring of Slovenian Grebe in Porsanger (2000 - | Annual monitoring of breeding pairs in Porsanger where most of the breeding pairs in Finnmark are located. | | | 2000- |
| Norway | Finnmark | Monitoring of Snowy Owl (2002 - ) | Monitoring of occurrence of Snowy Owls, breeding distribution and breeding success. Combined with satellite tracking. | | | 2002- |
| Norway | Finnmark | Monitoring of Steller's Eider (2008 - | Monitoring of wintering numbers, flock size and distribution of birds during late wintering (March-April). | | | 2008- |
| Norway | Finnmark | Moose migration across the Norwegian/Russian border– BioForsk (1981-) | | | Selected alpine | - |
| Norway | Finnmark | Muskrat in the Pasvik river (1994-) | | | Selected alpine | - |
| Norway | Northern Norway/Finnmark | National Monitoring Program for Large Carnivores (1990-) | | | Selected alpine | - |

| Country | Study site | Program title | Objectives | Abstract | Zonation | Time coverage |
|---|---|---|---|---|---|---|
| Norway | Troms | Outbreaking geometrid moth populations in subarctic birch forest | Population dynamics of geometrid moth in subarctic birch forest | Geometrid moth are keystone species in subarctic birch forest that influence forest dynamics and arctic-alpine treelines. The species are highly climate sensitive and some of them have recently invaded into the subarctic with massive ecosystem impacts. | Selected alpine | 1999- |
| Norway | Northern Norway | Polar fox monitoring (1990-/2003-) | | | Selected alpine | - |
| Norway | Svalbard; Brøggerhalvøya, Adventdalen, Sassendalen | Population monitoring of Arctic Fox in Svalbard (1982-) | Objectives: To accomplish a long term monitoring and assessment program for the arctic fox in order to detect early population changes and long term trends. The arctic fox is listed as an indicator species for monitoring of terrestrial biodiversity in Svalbard (MOSJ). The arctic fox is monitored because: 1) they are top predators that have significant impacts on both terrestrial and marine ecosystems, 2) they are hunted annually and 3) they are important vectors for zoonosis (rabies and parasites as Echinococcus multilocularis) | | High arctic | 1982- |
| Norway | Svalbard; Hanaskogdalen m. sidedaler, Adventdalen m. sidedaler, Helvetia og DeGeerdalen, Eskerdalen, Sassendalen | Population Monitoring of Svalbard Rock Ptarmigan (2000-) | Main Objective: To develop, establish and accomplish a long term monitoring and assessment program for the Svalbard rock ptarmigan in order to detect early population changes and long term trends. The Svalbard rock ptarmigan is the only land inhabiting bird which resides in Svalbard throughout the year. It is listed as an indicator species for monitoring of terrestrial biodiversity in Svalbard (MOSJ). The Svalbard rock ptarmigan is monitored because: 1) it is an endemic sub-species which imparts special management responsibilities for Norway, 2) it is the most important small game species for hunting, and 3) current ecological knowledge is limited | | High arctic | 2000- |

| Country | Study site | Program title | Objectives | Abstract | Zonation | Time coverage |
|---|---|---|---|---|---|---|
| Norway | Pasvik, Finnmark | Small rodents in Pasvik (1985-) | | | Selected alpine | - |
| Norway | Svalbard, Brøgger peninsula | Svalbard caribou in Brøgger Peninsula (1978-) | | | High arctic | - |
| Norway | Svalbard, Adventdalen | Svalbard caribou: population monitoring in Adventdalen (1979-) | | | High arctic | - |
| Norway | Dividalen, Finnmark | Terrestrial Monitoring Program (TOV) | provide basis for assessing long-term changes in nature; document trends and geographical differences; early discovery of effects of human influences in ecosystems and species diversity; distinguish anthropogenic changes from natural dynamics | Results from TOV document changes that may be related to changes in climate and pollution loads. In several southern sites of birch or spruce forest, large mosses have increased, reflecting a milder climate and longer growing season. Increases for somewhat thermophilous epiphytic species and decreases for cold-tolerant species also indicate effects of a milder climate. In some southern monitoring sites, a limited increase for nitrophilous species may be related to long-term deposition of nitrogen. Pied flycatcher breeding season follows the mean May temperatures rather closely. There were no apparent effects of pollution on birds or small rodents. Changes in land use may affect the ground vegetation in some sites. No alien, invasive species have been observed at the monitoring sites. A few threatened or vulnerable species, mainly birds, have been observed at the sites. | Selected alpine | 1993- |
| Norway | Svalbard; Endalen | Terrestrial Monitoring Program (TOV) | Identify possible effects of climatic change and air pollution on the floristic composition of arctic vegetation on Svalbard | | High arctic | 2009- |
| Norway | Finnmark; northern Troms (and all Norway) | TOV-E; Norwegian Breeding Bird Census (1995-) | | | Selected alpine | - |
| Russia | Laplandsky State Reserve | Archives of nature | The overall aim of the "Archives of nature" program of the nature reserve is to study natural processes and to reveal interactions between various parts of natural systems | | Selected alpine | 2001- |

| Country | Study site | Program title | Objectives | Abstract | Zonation | Time coverage |
|---|---|---|---|---|---|---|
| Russia | Ary-Mas, Taimyr Peninsula | Archives of nature | "Archives of nature" program of the State Nature Reserve "Taimyrsky" aims to study natural processes and to reveal interactions between various parts of natural systems | | Low arctic | 1993- |
| Russia | Tundrovaya River valley, Wrangel Island | Archives of nature | The overall aim of the "Archives of nature" program of the nature reserve is to study natural processes and to reveal interactions between various parts of natural systems. At this site monitoring of a Snow Geese colony is carried out | | High arctic | 1989- |
| Russia | Neizvestnaya River upper reaches, Wrangel Island | Archives of nature | The overall aim of the "Archives of nature" program of the nature reserve is to study natural processes and to reveal interactions between various parts of natural systems. At this site monitoring of Snowy Owls, skuas, Arctic Foxes and rodents is carried out. | | High arctic | 1999- |
| Russia | W.Barents station, Medusa Bay, Taimyr Peninsula | Biological monitoring at W.Barents station | | | High arctic | 1993-2007 |
| Russia | Chaun-Palyavaam river delta, Chukotka | Biology of Spectacled Eider in the Chaun-Palyavaam river delta | Biology of Spectacled Eider in the Chaun-Palyavaam river delta | | Low arctic | 2001- |
| Russia | Erkatayakha and Payutayakha rivers, Yamal Peninsula | Long-term monitoring of bird and rodent populations on the south-western Yamal | | | Low arctic | 2002- |
| Russia | Djukagirskoe Lake, "Kytalyk" reserve, Indigirka River basin | Monitoring of Siberian White Crane and Sandhill Crane | Monitoring of Siberian White Crane and Sandhill Crane | | Low arctic | 2000- |

| Country | Study site | Program title | Objectives | Abstract | Zonation | Time coverage |
|---|---|---|---|---|---|---|
| Russia | Meinypylgyno settlement vicinity, Chukotka | Monitoring of Spoon-billed Sandpiper | Monitoring of a population of the Spoon-billed Sandpiper, a species facing extinction | | Low arctic | 2003- |
| Russia | Belyaka Spit, Chukotka | Monitoring of Spoon-billed Sandpiper | Monitoring of a population of the Spoon-billed Sandpiper, a species facing extinction | | Low arctic | 1986- |
| Russia | Kolokolkova Guba coast, Tobseda settlement | Studies of Barnacle Goose ecology on coastal marshes | The program aims to study ecology of Barnacle Geese in a growing colony | | Low arctic | 2002- |
| Russia | Schuchya River, middle reaches, Yamal Peninsula | Studies of birds of prey on southern Yamal Peninsula | The program aims to study ecology of birds of prey | | Low arctic | 1991- |
| Russia | Bludnaya River mouth, Taimyr Peninsula | Wader Monitoring Project on Taimyr | Monitoring activities in the lower Khatanga River area on south-eastern Taimyr are aimed at revealing patterns of adaptations of waders to the Arctic environment and its long-term changes | | Low arctic | 1994- |
| Sweden | Sweden | NILS | NILS is a nationwide environmental programme that monitors landscape conditions and changes in all terrestrial habitats in Sweden. | NILS follows the biological diversity by monitoring the landscape with random sampling in 631 permanent sample plots, systematically distributed in Sweden. The sampling unit consists of 5x5 km plots where data is collected by manual interpretation of infrared aerial images, and by field collection in plots and along sampling transects. Data is collected on land cover, land use, vegetation parameters, tree cover, and abundance of functional plant categories as well as a selected list of vascular plant species, mosses, and lichens. | selected alpine | 2003- |
| Sweden | Sweden | LIFE+ MOTH | MOTH is a nationwide programme that monitors terrestrial habitat types listed in the Habitats Directive Annex I | The aim of the programme is to demonstrate a cost effective national monitoring system adapted for northern European conditions that will directly be applicable to use in the implementation of the Habitats Directive to the European Commission. Auxiliary information will be used in connection with random sampling to improve the accuracy of the habitat assessments also for sparse habitats. Methodologically, we are developing a two phase design for habitat assessment that combines interpretation of aerial photos with assessments in the field. | selected alpine | 2010-2014 |

| Country | Study site | Program title | Objectives | Abstract | Zonation | Time coverage |
|---|---|---|---|---|---|---|
| Sweden | Ammarnäs, Sweden | Lund University Vindel River Expedition (LUVRE) | The LUVRE-project (Lund University Vindel River Expedition) has studied the breeding bird and insect fauna in the Ammarnäs area, Vindelfjällen Nature Reserve, annually since 1963. | Research and monitoring are mainly focussing on biodiversity, conservation and population ecology. Vindelfjällen Nature Reserve is one of the largest protected areas in Europe, covering 550 000 ha. | selected alpine | 1963- |
| Sweden | Ammarnäs, Sweden | post-LUVRE | Moult and fuel deposition of passerines is studied in subalpine birch forest near Ammarnäs in Swedish Lapland. The work forms a part of the LUVRE-project (Lund University Vindel River Expedition) that has studied the breeding bird fauna in the area since 1963. | The main project within Post-LUVRE is the standardized netting carried out from 15 July to 20 August between 07.00 and 13.00 each day. Since the start of Post-LUVRE we have ringed more than 26 000 birds of 61 species. Using standardized ringing data we can monitor both long-term trends and yearly variation in size and reproductive success of breeding populations | low arctic | 1983- |
| Sweden | Sweden | Svensk Dagfjärilsövervakning | To monitor the Swedish butterfly fauna using standardized fixed route walks and point counts and to analyze these data in relation to factors such as habitat features and climatic variables. | The Swedish Butterfly Monitoring Scheme is a national monitoring programme coordinated by Lund University for the Swedish Environmental Protection Agency. The monitoring scheme is volunteer-based and runs from April 15th to September 15th annually. Sites are visited 3-7 times per season and are surveyed using a standardized, common methodology. | selected alpine | 2010- |
| Sweden | Sweden | Svensk Fågelstaxering | We monitor the common birds of Sweden since more than 35 years. Birds are counted in summer and winter at hundreds of different sites. Since the counts are carried out in the same way each year, we can detect which species that increase or decrease in numbers. | Svensk fågeltaxering is carried out at the Department of Biology Lund University, as a part of a national environmental monitoring project run by The Swedish Environmental Protection Agency. The bird counts are mainly carried out by volunteers, many of them members of the Swedish Ornithological Society | | 1975- |
| Sweden | Sweden | Monitoring of Swedish Lepidopterans within the habitat directive | To monitor a representative sample of the Swedish populations of butterfly and moth species covered by the EU habitat directive. | This monitoring programme is under development and is scheduled to be launched 2012-2013. A detailed plan is available: Harris, S., Ottvall, R. & Pettersson L. (2010) Biogeografisk uppföljning - förslag till variabler, indikatorer och data-insamling för delsystem fjärilar. – Rapport, Biologiska institutionen, Lunds universitet. As a preparation for the monitoring programme, pilot surveys have been carried out during 2011. | | 2012-13- |
| Sweden | 3 alpine areas of Sweden | Birds of the mountain heaths (Fjällhedens fåglar) | To monitor birds in an lowalpine area to follow long term fluctuations by transects | | selected alpine | - |

| Country | Study site | Program title | Objectives | Abstract | Zona-tion | Time cover-age |
|---|---|---|---|---|---|---|
| Sweden | Abisko area (in Sweden) | The eye of Abisko (Abiskoögat) | Measuring air temperature partly just to get today's weather but also to get a record of the air temperature in order to investigate climate variations and long-term changes. | | selected alpine | 1913- |
| Sweden | Abisko area (in Sweden) | The eye of Abisko (Abiskoögat) | Measuring precipitation partly just to get today's weather but also to get a record of the precipitation in order to investigate climate variations and long-term changes. | | selected alpine | 1913- |
| Sweden | | The eye of Abisko (Abiskoögat) | The main purposes of recording the date of total ice cover on the lake, the ice thick-ness during the ice cover period, date of lake ice melting and the duration of the lake ice are twofold. One purpose is to better understand the climatic processes involved as well as the climate itself. The other main purpose is to investigate how the climate affects the lake itself (biologi-cally, physically and chemically). | | selected alpine | 1915- |
| Sweden | | The eye of Abisko (Abiskoögat) | Measurements of soil temperatures and permafrost say something about today's climate, but are also very useful variables to predict future climate scenarios as well as understanding the past. | | selected alpine | 1988- |
| Sweden | Abisko and Latnjajaure (Sweden) | The eye of Abisko (Abiskoögat) | Date of arrival and departure of selected migratory birds are recorded and the birds are ring marked all in order to better understand i.e. how, when and where they migrate and how old they get. | | selected alpine | 1967- |

| Country | Study site | Program title | Objectives | Abstract | Zonation | Time coverage |
|---|---|---|---|---|---|---|
| Sweden | Abisko | The eye of Abisko (Abiskoögat) | To study changes of tree and forest lines in order to record the changes and to help interpreter treeline changes in the past and predict future changes. Additionally changes of forest areas of mountain birch have been studies. In order to get a more complete picture of treeline dynamics factors such as insect attacks, fungi attacks, grazing, management, and forest fires have also been added. | | selected alpine | - |
| Sweden | Abisko | The eye of Abisko (Abiskoögat) | Phenology studies as one indicator for climate change. | | selected alpine | - |
| Sweden | Sweden | Small mammals (in the mountains) | Capturing small mammals in order to better understand small mammal dynamics mainly in alpine and subalpine areas. | | selected alpine | 1971- |
| Sweden | Latnjajaure (Sweden) | International tundra experiment (ITEX) | | | selected alpine | 1994- |
| Sweden | Sweden | Flora guardians | NGO based monitoring system for most thretened vascular plants in Sweden according to Swedish Redlist | | selected alpine | 1987- |
| Sweden | Sweden | Svenska fenologiätverket (Swedish phenology network, blmmar.nu | Follow the phenology of many species in order to increase data and better understand different species phenology. One important aspect is also to detect changes in phenology given the ongoing climate change. | | selected alpine | 2008- |

| Country | Study site | Program title | Objectives | Abstract | Zonation | Time coverage |
|---|---|---|---|---|---|---|
| USA | Alaska-North Slope | North Slope Land Cover | Water: evaluates potential changes to fresh water availability across a large region; Wildlife: can be used to evaluate effects of climate induced changes to vegetation and model wildlife habitat for future adaptation scenarios; Vegetation: evaluates changes in vegetation composition related to changes in the climate and feeds predicative models for vegetation changes across a large region; Sea level and shore line erosion: used to evaluate rapid changes in shore line caused by increased storm surges and raising sea level; Feeds into models on permafrost changes in the Arctic | The North Slope Science Initiative (NSSI) is working to bring North Slope land cover maps into the digital age. There are approximately 55 different land cover products that have been completed across the North Slope over the past three decades. Many of these supported localized research projects; some are more regional in scope using field data for validation; and others are computer generated maps with no field validation. All of these have one common element: none actually used a standardized protocol that could combine all the efforts into a single highly accurate slope-wide map. Portions of the North Slope are also thought to have changed dramatically since most of these efforts were initiated. As such, no common up-to-date land cover protocol or database exists across the North Slope. A consistent and accurate land cover database is needed to provide a strong baseline for any geographic information system (GIS). Dependable land cover information is critical to interpreting landscape integrity, fire risk models, and current and future wildlife habitat availability, and can even be used in permafrost and active layer models and to help parameterize habitat-based models of carbon sequestration. The NSSI/BLM has developed land cover protocols that are consistent in approach and have been accepted by numerous stakeholders. Completion of this important project would provide the first comprehensive, field validated digital data for the majority of the U.S. Arctic, including the 23+ million acre National Petroleum Reserve Alaska, necessary as resource managers are challenged with a rapidly changing Arctic. | Low arctic | 1992-2011 |

| Country | Study site | Program title | Objectives | Abstract | Zonation | Time coverage |
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| USA | Alaska | Ecosystem Performance in the Yukon River Basin and North Slope | Central Alaska is ecologically sensitive and experiencing stress in response to regional warming. Quantitative measures are needed to monitor the response of ecosystems to climate change, fire, insect damage, and management policies and to predict responses to future climate scenarios. The methodology quantifies the state and trends of ecosystem changes, and separates the influences of climate and local site conditions from the influences of disturbances and land management. | USGS EROS acquires, processes, archives, and distributes large amounts of remotely sensed data from a variety of sensors. The USGS EROS and other agencies support the science expertise to develop process models based on the time series of biophysical information in the archive and with incoming information. This project develops a quantitative understanding and modeling of ecosystem processes at the pixel scale. This emerging quantitative capability integrates ground based spatial data with remotely sensed information providing powerful capabilities to develop ecosystem process models. Detailed data from cooperators with site-specific flux towers are integrated to create models a land cover type, e.g., grassland, which is then simulated across the region. Tasks describe these exchanges of GPP and NEE in the Northern Great Plains and other regions. This modeling, our rich archival resources, and our special ability to combine near real time remotely sensed data with other large spatial data sets also allows us to evaluate, map, and dynamically monitor the performance of ecosystems. This emerging capability is leading to a national plan to dynamically monitor ecosystems and to detect anomalous annual performance and trends. | selected alpine | 2009- |
| USA | Alaska | eMODIS | eMODIS Alaska responds to a community-specific need for alternatively packaged MODIS data. Vegetation monitoring benefits from the NASA MODIS orbit cycle (vs. Landsat) and spatial resolution (vs. AVHRR), but is challenged with making the standard products directly useful because of their map projection, file format, composite interval, and production time | The eMODIS Alaska product suite includes 250-m, 500-m, and 1,000-m surface reflectance and NDVI composited in 7-day intervals over Alaska and that part of Canada including the Yukon River Basin. The products are delivered on an Albers Equal Area mapping grid as GeoTIFFs. NASA's Moderate Resolution Spectroradiometer (MODIS) Terra level-1B source data are processed with a combination of MODIS standard algorithms and recycled USGS EROS Direct Broadcast System software to generate an historical record (2000-present) of the Alaskan growing season (February-October) | selected alpline | 2005- |
| USA | Alaska-North Slope | Coastal Erosion on Alaska's North Slope | Present modern erosion rate measurements for a 100 km segment of the Beaufort Sea coastline based upon vertical aerial photography captured since 1955 to the present including ground based video. | Incorporation of historic and modern observations allows the detection of loss of cultural/historic sites as well as modern infrastructure. U.S. Geological Survey topographic maps reveal a number of known cultural/historical sites and modern infrastructure that date to at least the 1950's that were lost due to coastal erosion by the early 2000's. We identify sites that are currently being threatened by an encroaching coastline. Our modern erosion rate measurements can potentially be used to predict when a site or infrastructure will be impacted if such erosion rates persist. | Low arctic | 1995- |

| Country | Study site | Program title | Objectives | Abstract | Zonation | Time coverage |
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| USA | Alaska-North Slope | Permafrost and Climate Monitoring Network | The network was established to provide high quality real-time environmental data to aid in land management decision making. The information is also used extensively in logistics and aircraft operations | This real time network is a subset of a larger U.S. Geological Survey permafrost and climate monitoring research network. Many of the stations are colocated with deep boreholes, thus forming the basis for comprehensive permafrost monitoring observatories. The objectives of the larger network include climate change detection, monitoring how permafrost and vegetation respond to climate change, and acquiring improved data for current permafrost characterization and impact assessment models | Low arctic | mid 1970s- |
| USA | Alaska-North Slope | | The TLO focuses on three primary, tightly coupled objectives to provide the relevant information that land and wildlife resource managers will need to make informed decisions. (1) We are conducting a retrospective analysis on changes in lake temperature, water level, sedimentation rates, water chemistry, watershed hydrology, confining permafrost degradation, and human disturbance over the historic period. (2) We are collecting baseline data on water quality and quantity in Teshekpuk Lake and its surrounding watershed, permafrost and active layer dynamics in the catchment, climatological observations, phenological information, fish and invertebrate surveys, and potential human disturbance. (3) We plan to develop a predictive model that will forecast potential changes in lake water temperature, changes in freeze up and breakup dates, fluctuations in lake water level, increases in permafrost degradation, increases or decreases in runoff contribution from the watershed, impacts of sea level rise and inundation with salt water, and potential impacts from oil and gas activity in the region through the beginning of the next century. | This is a multi-year, multi-cooperator, and multidisciplinary effort that focuses on Teshekpuk Lake and its surrounding watershed in order to assess the past, present, and future response to climate change and human pressure. The Teshekpuk Lake region is considered one of the most productive, diverse, and sensitive wetland ecosystems in the entire Arctic due to the presence of a large number of migratory waterfowl, a resident caribou herd, and several freshwater and anadromous fish species. Teshekpuk Lake is also the largest lake on the North Slope of Alaska, contains the largest watershed of any lake in the region, provides the most extensive overwintering fish habitat in the region, and is the third largest lake in the state. Our efforts began in 2007 and have continued through 2011 and during this time period we have established the Teshekpuk Lake Observatory. | | - |

| Country | Study site | Program title | Objectives | Abstract | Zonation | Time coverage |
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| USA | Alaska | Alaska Boreal Forest and Arctic Shrub Mapping | The purpose of this program is to provide continuous field maps of percent shrub cover (for Arctic Alaska) and percent forest cover and forest height (for Interior Alaska) at 250 m spatial resolution or better. Initial effort is focusing on developing techniques and creating a baseline map. Future efforts will (assuming continued funding) be directed towards monitoring efforts (e.g. 5 year updated products). | Alaska's arctic tundra and boreal forest ecosystems are undergoing rapid changes as a result of changes in climate, with shrub cover increasing in the Arctic and changes in fire frequency, permafrost, and other factors affecting the structure and composition of Alaska's boreal forest. This project aims to develop remote sensing techniques for creating a baseline map as well as regularly updated inventories of percent shrub cover in the Arctic and percent forest cover and forest height in the Interior. | selected alpine | 2008- |
| USA | Alaska | National Park Service Alaska Region Inventory & Monitoring Program | Natural resources inventories and monitoring for National Parks in Alaska | The Inventory and Monitoring Program (I&M) is built on the premise that understanding the condition of the natural resources is vital to accomplishing the NPS mission of protecting park resources unimpaired for future generations. The goal of the I&M program is to develop scientifically sound information on the current condition and long-term trends in park ecosystems and to determine how well management practices are sustaining those ecosystems. The goal remains relevant today, particularly in the little studied remote areas that comprise Alaska parks. | Low arctic | Mid 1990s- |
| USA | North Slope - Alaska | Seasonality of circumpolar tundra - ocean and atmosphere controls and effects on energy and carbon budgets | Characterize the seasonal linkages between land surface greenness and a suite of land, atmosphere and ocean measures in the context of Arctic tundra vegetation | Updated our findings based on 1982-2008 from the Bhatt et al. (2010, Earth Interactions) paper with analysis for the period 1982-2010. 1) Fine tuned the analysis of regional trends and variability on a seasonal time scale in sea ice concentration, surface temperature and updated NDVI data. These results appeared in our Earth Interactions paper and continue to hold for the 1982-2010 period. 2) Analyzed weekly climatology, variance and trends for sea ice concentration and surface temperature for the 19 Arctic regions (regions were revised in January 2011). The same analysis was conducted for biweekly NDVI. We have analyzed decadal average seasonal curves for open water, biweekly NDVI and weekly land temperatures | Low arctic | 2009- |

| Country | Study site | Program title | Objectives | Abstract | Zonation | Time coverage |
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| USA | North Slope - Alaska | Vegetation of zonal patterned-ground ecosystems along the North America Arctic bioclimate gradient | Interactions between the physical environment and biotic properties of vegetation influence the formation of small patterned-ground features along the Arctic bioclimate gradient | Characterizing the composition and structure of small-scale plant communities growing on distinctive microhabitats within patterned ground complexes was necessary to understand the biological and physical controls of vegetation on patterned-ground morphology. Coarser-scale vegetation units, referred to here as 'zonal patterned-ground vegetation complexes' (groups of patterned-ground plant communities within zonal landscapes), were useful for landscape and regional-level comparisons and for extrapolation of information collected at plot scales to larger regions. Vegetation maps of the representative landscapes in each subzone were needed for extrapolation. Different growth characteristics of plants growing in northern and southern parts of the gradient have an important effect in stabilizing highly frost-active soils. A conceptual diagram summarizes the interactions between vegetation and patterned-ground morphology along the Arctic climate gradient. | Low arctic | 2011- |

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