Arctic Ecozone^{+} highlights and key findings summary.

Canadian Biodiversity: Ecosystem Status and Trends 2010

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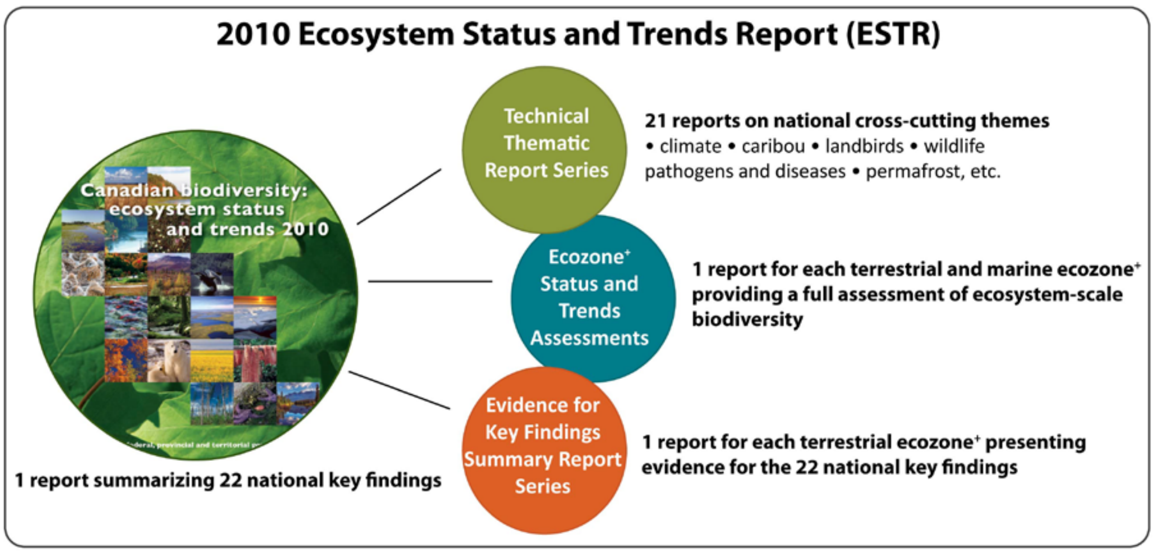
PREFACE

The Canadian Councils of Resource Ministers developed a Biodiversity Outcomes Framework[4] in 2006 to focus conservation and restoration actions under the *Canadian Biodiversity Strategy*.[7] *Canadian Biodiversity: Ecosystem Status and Trends 2010*[8] was the first report under this framework. It presents 22 key findings that emerged from synthesis and analysis of background technical reports prepared on the status and trends for many cross-cutting national themes (the Technical Thematic Report Series) and for individual terrestrial and marine ecozones$^+$ of Canada (the ecozone$^+$ Status and Trends Assessments). More than 500 experts participated in data analysis, writing, and review of these foundation documents. Summary reports were also prepared for each terrestrial ecozone$^+$ to present the ecozone$^+$-specific evidence related to each of the 22 national key findings (the Evidence for Key Findings Summary Report Series). Together, the full complement of these products constitutes the 2010 Ecosystem Status and Trends Report (ESTR).

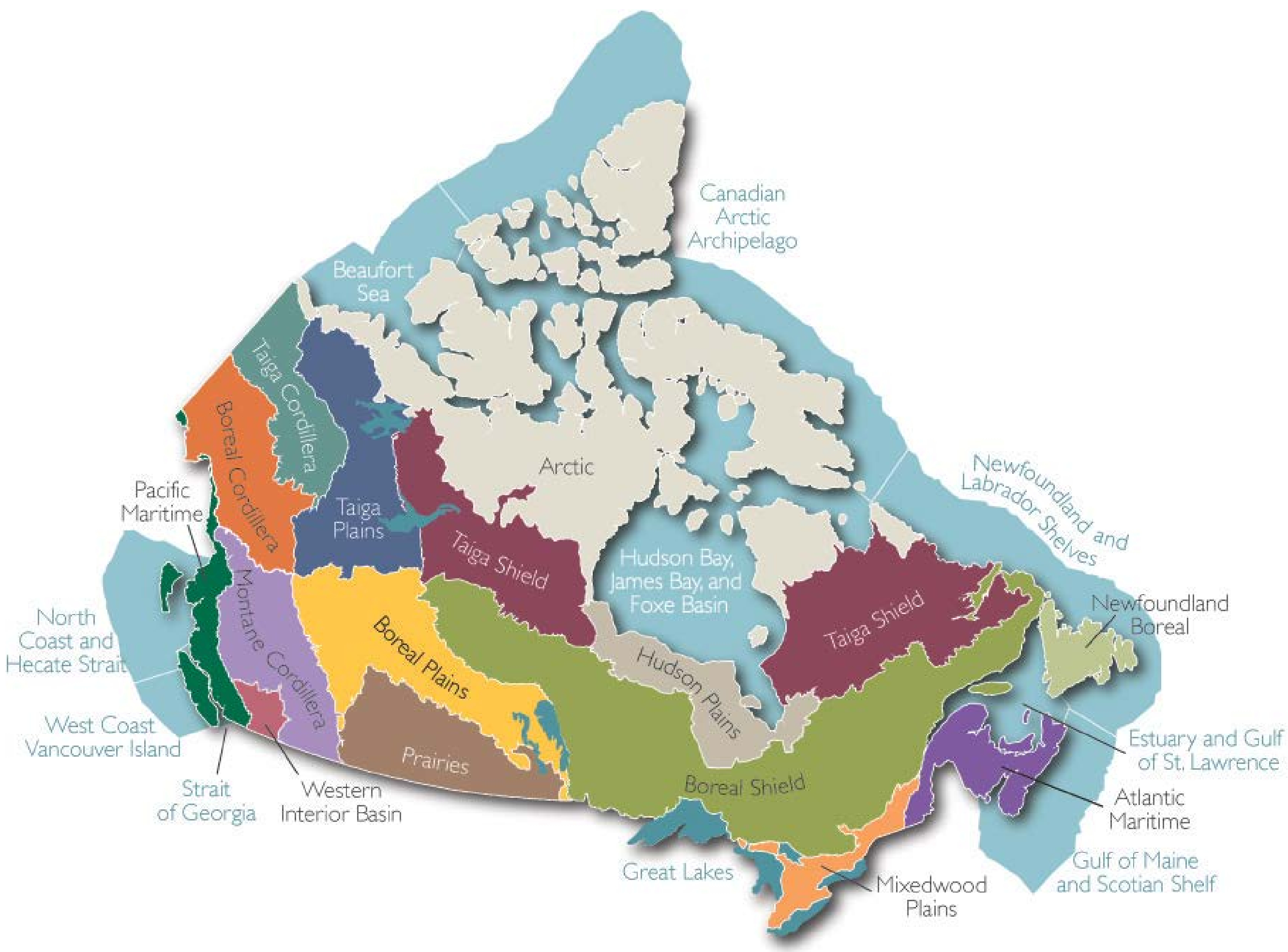


This report, *Arctic Ecozone$^+$ Highlights and Key Findings Summary*, differs from the other summaries. It consists of two parts. The first part presents highlights from the full Arctic Ecozone+ status and trends assessment, providing an overview of the ESTR findings for the Arctic and providing a foundation for further work on ecological indicators and ecological assessment. The second part presents a table that summarizes the evidence from the Arctic Ecozone$^+$ related to the 22 national key findings. The full technical assessment for the Arctic should be consulted for further information and discussion of ecological context, and for source references. Note that the technical report was updated from a 2010 draft, and it is based partly on the national thematic trend analyses. The time span of all trends presented is specified; in some cases more recent data may be available.

The Arctic component of ESTR covers Canada's terrestrial and freshwater Arctic ecosystems, essentially the landmass north of treeline (referred to as the Arctic Ecozone+). Jurisdictions within the Arctic Ecozone$^+$ are all of Nunavut and northern Northwest Territories, Yukon, Quebec, and Newfoundland and Labrador. This is the homeland of Canadian Inuit.

Ecological classification system – ecozones⁺

A slightly modified version of the Terrestrial Ecozones of Canada, described in the *National Ecological Framework for Canada*[9], provided the ecosystem-based units for all reports related to this project. Modifications from the original framework include: adjustments to terrestrial boundaries to reflect improvements from ground-truthing exercises; the combination of three Arctic ecozones into one; the use of two ecoprovinces – Western Interior Basin and Newfoundland Boreal; the addition of nine marine ecosystem-based units; and the addition of the Great Lakes as a unit. This modified classification system is referred to as "ecozones⁺" throughout these reports to avoid confusion with the more familiar "ecozones" of the original framework.[10]



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Arctic Ecozone+ Status and Trends Assessment acknowledgements

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Review conducted by scientists and renewable resource and wildlife managers from relevant territorial and federal government agencies through a review process recommended by the ESTR Steering Committee. Additional reviews of specific sections conducted by university researchers in their field of expertise at the request of the authors. Peer review of the final draft coordinated by the Canadian *Society* for *Ecology* and Evolution. The report was greatly improved by the reviews of D. Berteaux, P. Hale, and one anonymous reviewer.

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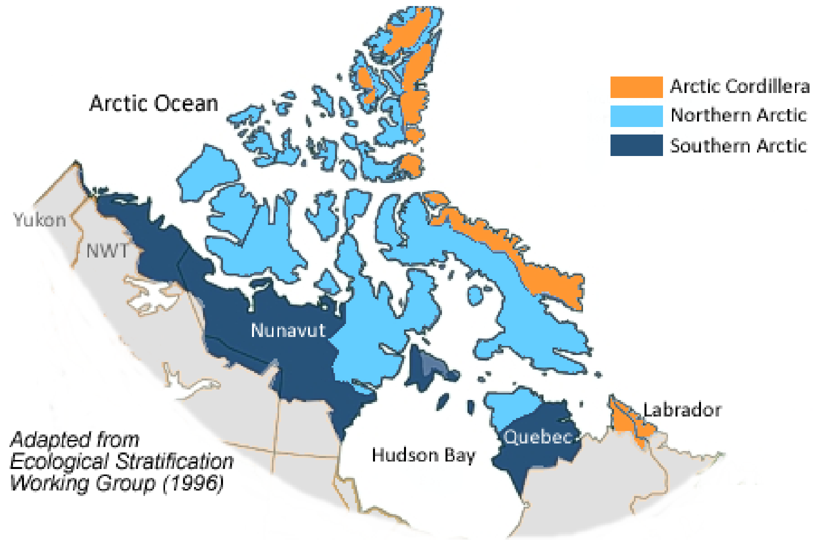
PART 1: ARCTIC ECOZONE+ STATUS AND TRENDS ASSESSMENT HIGHLIGHTS

1. Ecozone+ overview

- **Land area.** 3,148,000 km^2.
- **Area of lakes, ponds, and rivers.** 80,000 km^2.
- **Length of coastline.** 179,950 km (3/4 of Canada's coastline).
- Three **major regions**: Arctic Cordillera, Northern Arctic, and Southern Arctic. Distinct enough to be ecozones in the Canadian classification system, but are combined here for reporting purposes.
- **Rivers** draining the ecozone+ flow either to Hudson Bay, Ungava Bay, or directly to the Arctic Ocean.



- **Topography and soils.** Southern Arctic: mainly discontinuous glacial deposits underlain by granitic bedrock; Northern Arctic: west is lowland plains with outcrops of sedimentary bedrock and cover of glacial moraine and marine deposits, while east is dominated by granite bedrock with very deep permafrost; Arctic Cordillera: rugged mountains, nunataks, valleys and fiords; 75% ice or bare rock; remainder is mainly colluvial and morainal debris.
- **Permafrost** is continuous, may be several hundred metres thick, and has temperatures colder than -5°C.
- **Inuit** form the majority of residents. The ecozone+ encompasses most of four regions established through Canadian comprehensive land claim agreements: 1) Inuvialuit Settlement Region (parts of Yukon and NWT); 2) Nunavut; 3) Nunavik (part of Quebec); and, 4) Nunatsiavut (part of Newfoundland and Labrador).
- **Co-management** regimes for wildlife and habitat through boards or councils with input from Aboriginal regional and local governance bodies, as well as federal and territorial governments, are central to all aspects of ecological management, monitoring, and research.

↑ **Human population** tripled from 12,000 in 1971 to over 36,000 in 2006.

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2. Abiotic drivers

- **Climate change** has particularly affected the Arctic, with warming at about twice the rate of the global average. This high latitude amplification of climate change is projected to continue, augmented by feedback mechanisms. Example: temperatures rise when less heat is reflected from land and sea surfaces because there is less ice and snow.
- **Seasonal climate trends** from 1950 to 2007 show broad patterns of change with considerable regional variation. Some parameters show greater change or greater variability in the past 20 years. Trends averaged across the ecozone+:

↑	**Temperature**: increased in spring and fall. Many individual stations with increasing trends and across all seasons. No cooling trend at any station in any season.
↑	**Precipitation**: increased in all seasons, especially winter. Greatest relative increases of all ecozones+ in Canada.

- **Climate oscillations** strongly influence Arctic climate trends and variability, especially the Pacific Decadal and Arctic oscillations, but these cannot account for the pattern of recent pan-Arctic warming.

High Arctic tundra and muskoxen. Photo: Paul Loewen, iStock.com

3. Ecosystem functions and processes

- **Rapid shrinking of all aspects of the cryosphere** has been a dominant trend in Arctic ecosystems that began over 30 years ago and is particularly evident over the past decade. Changes in ice and snow are linked with ecosystem disturbance and other ecosystem processes such as hydrology and primary productivity.
- **Permafrost** has warmed and the active layer has increased in thickness—with major implications, including: changes in vegetation, alteration of carbon balance, changes in wetlands, nutrient cycling, and habitat features such as tussock tundra and sites suitable for denning mammals. Greater changes in the past two decades have occurred in permafrost in the Arctic than in taiga and boreal ecozones because there is less insulation from vegetation and snow.

↑	West	**Permafrost temperatures** increased since the early 1990s (Tuktoyaktuk Peninsula, Mackenzie Delta tundra uplands, Herschel Island)
↑	Central-southern	General increase in **thaw depth** (Baker Lake)
↑	High Arctic	**Permafrost temperatures** increased since mid-1990s with more rapid increase from 2005 to 2011, related to warm winters (Alert)
↑	East	**Permafrost** warmed since mid-1990s, following a cooling period in early 1990s; active layer depth increased (Iqaluit, Northern Quebec sites)

Melting pingo wedge ice near Tuktoyaktuk. Photo: Emma Pike, Wikimedia

- **Snow** has decreased, both in duration of snow cover and in maximum depth of the snowpack—despite an increase in snowfall. This is related to warmer temperatures. Around the circumpolar Arctic, snow cover in June has declined precipitously, especially since 2000, marking a major, broad-scale ecological change. Ecological consequences of reduced duration of snow cover include reduced albedo that increases climate warming and changes to other ecosystem processes, notably permafrost, streamflow, and timing and extent of primary production. Changes in snowpack affect vegetation and animals.

↓	**Snow cover duration** shorter on average by 9 days in fall and 8.5 days in spring from 1950 to 2007
↓	**Snow depth** (maximum) – reduced by an average of 13 cm, with high variability from site to site (and with very few monitoring sites)

- **Sea ice.** A major shift in the state of Arctic ecosystems has been the reduction in extent of sea ice in the past 30 years, with accelerated melting and loss of multi-year ice in the last few years. Terrestrial, as well as marine, ecosystems are affected, including changes in coastal climate conditions and features, and loss of critical habitat for animals that spend parts of their lifecycles on or at the edge of sea ice.

↓	**Extent of sea ice** in September (annual minimum) severely declined since first satellite measurement in 1979. The 2012 extent, the lowest on record, was 48% below the 1979-2000 average.
↓	**Loss of multi-year ice**: percentage of ice aged four or more years decreased from 26% in 1988 to 7% in 2012.

- **Glaciers.** Over half of the 300,000 km^2 of glaciers and ice caps (excluding the Greenland Ice Sheet) draining to the Arctic Ocean are in the Canadian Arctic Archipelago. The rate of loss of this land ice, from melting and ice-berg calving, has increased since the late 1980s. Meltwater from Canadian Arctic glaciers contributed an estimated 0.71 mm per year to global sea level rise from 2003 to 2009 (29% of observed sea level rise in this period). As ice masses melt, land available for development of tundra ecosystems will increase.

↓	**Arctic Island glaciers** have been losing mass since the late 19^{th} century, with the trend slowing for a period in mid-20^{th} century, and with accelerated loss in the past 25 years (four glaciers on Queen Elizabeth Island). Longest of these records (Agassiz Ice Field) shows the recent melt rate was the highest in at least 4,200 years. Small ice caps on Baffin Island have declined or disappeared.

- **River and lake ice** timing and duration. Trend information is indirect, as long-term, ground-based monitoring is lacking. Evidence from lake sediments suggests annual ice duration has decreased since about 1850 with greater change in recent decades. A study based on remote sensing of lake ice concluded that the ice-free period increased across Canada, but change was more pronounced in the Arctic. Increased ice-free season is linked to warmer water and alterations in water mixing regimes and distribution of nutrients and oxygen. These are linked to observed increases in lake productivity and to changes in algal communities.

↑	Based on one remote sensing study, **lake ice-free season** increased by 1.75 days per year in six Arctic lakes, 1985-2004, with both earlier break-up and later freeze-up

- **River flow** monitoring is sparse in the Arctic Ecozone[+] and status and trends are not known for most of the smaller rivers. Trends for large Canadian rivers draining to the Arctic Ocean and surrounding seas and straits are better known, but observed changes are driven mainly by conditions in southern ecozones[+]. Large river discharge trends vary among analyses, being dependent on the subset of stations and the time period looked at. Long-term trends are also related to decadal-scale climate oscillations. Analyses of hydrometric data also reveal recent (since about 1990) shifts in seasonal timing of streamflow, as well as increases in variability.

↓ →	**Annual river flows** decreased from 1960s to about 2000, especially for rivers discharging to Hudson Bay and Labrador Sea—but no overall flow change in rivers directly entering the Arctic Ocean (3 analyses varying in time period and sites included).
↑	**Annual river flows** increased since 1989, detected in analyses that include data into the first decade of the 2000s; includes a reversal of earlier declines in discharge to Hudson Bay and Labrador Sea.

- **Wetland, pond, and lake area** trends varied and there is no systematic monitoring. Recent short-term trends were detected through remote sensing. Ecosystem changes have occurred at the landscape scale, altering amounts and quality of freshwater and wetland ecosystems and affecting tundra carbon balance.

↑	P**ond and lake extent** increased in some Southern Arctic areas from melting permafrost and greater precipitation (including over 3% gain, 2000-2009, in the Mackenzie Delta)
↓	**Pond and lake extent** decreased, including ponds drying up, in drier Northern Arctic and Arctic Cordilleran areas from warmer summers and earlier ice melt. Some Ellesmere Island ponds that had been permanent water bodies for millennia dried up in 2005 and 2006.

- **Extreme weather events**—especially heavy snow in critical periods in spring or fall, and rain-on-snow events that create ice layers in the snow—have been documented to cause population crashes in several animal groups, including Peary caribou, muskoxen and small mammals, especially in the High Arctic.
- **Fire** is not currently a major disturbance in tundra ecosystems but there is evidence that it may become more widespread with warmer summers.
- **Permafrost disturbance**, in the form of slope failures and thermokarst ponding due to high temperatures melting permafrost, is increasingly observed in areas with ice-rich permafrost in fine sediment. Slumping of land due to permafrost thawing strips areas of vegetation cover and reduces productivity of nearby surface waters. In the Southern Arctic slumping can expose stores of frozen organic matter, turning tundra sites from carbon sinks to sources.

Retrogressive thaw slumps (slope failures) increased in Mackenzie Delta region since 1970s. Increases also recorded on Ellesmere and Melville islands.

- **Community and population dynamics** are strongly influenced by climatic variables and oscillations, especially in the High Arctic. Food chains are short and a few animals dominate. Ecosystems are nutrient limited. Cyclic population fluctuations of small mammals often drive populations of predators. Populations of other grazers are indirectly linked to small mammal cycles through changes in vegetation or because they are alternate prey species. Caribou, the main large tundra grazer, fluctuate in numbers over periods of decades and their foraging ranges expand and contract, affecting vegetation over broad areas.

Small mammals (lemmings, voles, and shrews) showed no clear long-term trends in abundance, though trend detection was made difficult by cyclic and year-to-year variation in abundance and generally short monitoring records (19 NWT-Nunavut Small Mammal Survey sites, various periods 1990-2012)

Tundra vole. Photo: Wikimedia

- **Wildlife disease.** The main wildlife disease of concern is brucellosis in caribou, infecting 20 to 50% of barren-ground caribou (2011 estimate), which may be an increase in prevalence since the 1960s. Brucellosis is considered to be responsible at least in part for the recent decline of the Southampton Island caribou herd. The disease is not in the woodland caribou of northern Quebec (George and Leaf River herds).
- **Wildlife host-parasite** systems are susceptible to climate change as free-living parasite life stages are temperature and moisture sensitive. Temperatures have warmed enough for a lungworm that parasitizes muskoxen to expand its range and develop to the infective stage in one season instead of two, but it is not clear to what extent these changes have occurred.

INDICATION OF ECOSYSTEM CHANGE	The protozoan ungulate **parasite** *Besnoitia tarandi* recently emerged as a disease-causing agent in caribou in northern Quebec and Labrador (hunter observations; veterinary studies) and may be a cause of increased lesions reported for caribou in 2005 discussions with hunters in the Western Arctic.

- **Phenology.** The start and the length of the growing season are largely determined by snow cover. The trends from 1950 to 2007 were towards earlier snowmelt and longer snow-free seasons (see point on snow above). Broader ecological consequences of earlier and longer growing seasons are expected to include changes in insect pollination and seed production, but there is little information on these consequences for the Canadian Arctic.

EARLIER	Thirty-year trend for tundra plants to **earlier flowering and earlier leafing-out**, corresponding with warming and earlier snowmelt over the same period (2013 synthesis of International Tundra Experiment (ITEX) results, based on plant plots, circumpolar scale including Canadian sites).

- **Nutrient cycling.** Because tundra ecosystems are nutrient limited due to low rates of productivity, decomposition and mineralization, changes in nutrient cycling can have major consequences to tundra vegetation. Research in northern Alaska indicated that increased nutrient uptake has been important in the widespread conversion of tundra areas to shrub that has occurred there in recent decades. Soil microbial communities, important in nutrient cycling, changed in composition in some experimentally warmed plots, especially in wet sedge tundra (based on research around the circumpolar Arctic).

	Research on the effects on climate change on **nutrient cycling in tundra** has shown that availability of inorganic and organic nitrogen can increase in experimentally warmed plots (analysis of studies around the circumpolar Arctic, including Canadian sites)
INDICATION OF ECOSYSTEM CHANGE	Experimental warming of Canadian High Arctic tundra plots led to changes in **mycorrhizal fungi** communities associated with birch and willow shrub roots. These fungi-root associations are important in nutrient uptake. Broader ecological consequences are not known.

- **Carbon storage and release.** Tundra ecosystems have been carbon sinks for tens of thousands of years due to low decomposition rates and permafrost processes. Warming brings potential for a change from carbon sink to carbon source, but there are few studies on carbon flux in Canadian tundra. In addition, examination of circumpolar studies indicated a greater potential for increasing loss of carbon from Low Arctic ecosystems than from High Arctic ecosystems. Canadian Arctic tundra ecosystems contain about 76 Gt of soil organic carbon in the upper metre (2008 estimate). This is carbon that might react to near-term climate change. Release of carbon is a positive feedback, increasing atmospheric greenhouse gas concentrations and contributing to climate change.

INDICATION OF ECOSYSTEM CHANGE	Circumpolar studies using experimental warming of tundra plots (including those on Ellesmere Island) indicated that wet tundra systems may remain carbon sinks when warmed but dry tundra systems may become carbon sources.

Arctic tundra wetlands. Photo: G. Burba, iStock

- **Pollination.** There has been little study on pollination relationships in the Canadian Arctic and little is known about current status and trends related to climate change. While many tundra plants are self-pollinated or pollinated by the wind, insect pollination is important for setting seeds and maintaining genetic diversity. Flies, bumblebees and butterflies are important pollinators.
- **Primary production in lakes and ponds** increased in the 20th century, based on analysis of sediment cores. The best explanation for this change in freshwater algae is climate warming leading to longer ice-free seasons and associated changes in lake ecosystems. Changes are most pronounced in the High Arctic.

↑	A pronounced 20th century increase in **freshwater primary production** in six Baffin Island lakes appears to be synchronized with the record of recent climate trends (based on analysis of sediment core that extend back in time over 5,000 years).

- **Primary production on land.** Several measures of primary productivity show marked and widespread increases.

Photosynthetic capacity of plant cover increased throughout the Arctic Ecozone[+] from 1985 to 2006, based on the Normalized-Difference Vegetation Index (NDVI), which is calculated from space-based (satellite) observations. Areas with particularly strong trends included the Labrador Peninsula, the area northwest of Hudson Bay, and southern Ungava Peninsula. (Based on a study done for this report.)

Tundra biomass (net primary production) for both wet and dry tundra types increased over the past 20-plus years on Ellesmere Island. Snow-bed heath biomass increased from 33 g/m^2 in 1981 to 87 g/m^2 in 2008. (Based on long-term studies at Alexandra Fiord.)

Annual above-ground production of wetland grasses almost doubled from 1990 to 2010 on Bylot Island, due to increases in summer temperature. (Based on long-term studies on Bylot Island.)

Lichens and bearberry on dry tundra. Photo: urbanraven, iStock

- **Human stressors on ecosystem functions and processes.** Climate change, due to anthropogenic increases in greenhouse gases, is the major stressor across the ecozone[+]. Roads and other human disturbances are important locally.

The Arctic is warming at about twice the rate of the global average, with some of the most marked changes in the Canadian Arctic (As reported in Intergovernmental Panel on Climate Change and Arctic Council assessments.)

Atmospheric **carbon dioxide started to increase rapidly** in the late 19th century, based on ice core samples from Antarctica. Carbon dioxide measured in the atmosphere above Alert, Nunavut steadily increased from about 335 to 390 ppm from 1975 to 2010.

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4. Ecosystem structure

- **Reduction of the tundra biome.** Evidence for the trend towards loss of tundra comes from remote sensing, climate records and ground-based studies. The trend is linked with increasing primary productivity and changes in tundra plant communities. The strongest changes have occurred in northwestern Canada.

INDICATION OF ECOSYSTEM CHANGE	**Increase in shrub cover** has been confirmed in a range of locations, including Herschel Island, northern Alaska, the Mackenzie Delta, and the region east of Ungava Bay. Greater shrub cover means reduced lichen and a possible change in community structure. Shrub cover also increases ground-level absorption of solar radiation, leading to greater heating of the atmosphere, a positive feedback mechanism of growing importance.

- **Shifts in algal and invertebrate species assemblages in lakes and ponds.** Evidence for this trend comes from analysis of lake sediment cores and is linked with increases in primary productivity, as well as with changes in the duration of lake ice cover. The trends are widespread across the ecozone+ and are evident in other parts of the circumpolar Arctic where recent warming has occurred.

INDICATION OF ECOSYSTEM CHANGE	**Species assemblages in Arctic lakes and ponds** have changed, beginning in the mid-19th century. After centuries or millennia of relative stability, diatom communities have changed radically, and there is evidence that the changes are working their way up through higher trophic levels. (Based on studies of lake core sediments at several locations in the Canadian Arctic.)

- **Tundra plant communities.** Tundra plant communities are showing changes around the circumpolar Arctic that are consistent with responses to warming (based on experimental and plot resampling studies through the International Tundra Experiment). However, trends in localized plant communities are hard to predict because they are subject to local conditions, including soil moisture, topography, permafrost, and precipitation.

↑	For a study of plant communities around the circumpolar Arctic, including Canadian sites, plant plots at 46 ITEX sites were re-sampled between 1980 and 2010. Overall there was an **increase in canopy height** and in the height of most vascular plants, and an increase in shrubs and plant litter. Experimental warming of tundra plots for one to six years led to increased growth of shrubs and grasses and decreased growth of lichens and mosses (based on 61 ITEX sites, 5 of which are in Canada).
↓	In the same studies, **mosses, lichens** and **bare ground cover** decreased.

- **Major human stressor on ecosystem structure.** Climate change is the major human-induced stressor on ecosystem structure in the Arctic.
- **Fragmentation and human disturbance.** Overall, the degree of human-induced fragmentation in the Arctic is extremely low. However, fragmentation is a concern at the regional level and likely to become more widespread as human population and industrial development increase. Human infrastructure, such as roads and airstrips, can change the spatial distribution of **predator foraging areas**, affecting the reproductive success of some prey species and the nesting distribution of raptors. Planning can mitigate these impacts.

↑ Food supplementation from human garbage is likely associated with the **expansion of the red fox** into the Arctic in the mid-20th century. Red fox out-compete Arctic fox, so the red fox expansion can result in loss of Arctic foxes from ecosystems.

Arctic fox by her den, near Cambridge Bay. Photo: DR Ferry, iStock.com

5. Ecosystem composition

The report does not cover all Arctic terrestrial species; it presents information on species of conservation concern (those considered at risk of extinction) and species of special interest due to their ecological importance and/or importance to humans.

- **Sensitivity to change.** Relatively low species diversity and generally simple food webs may limit the ability of Arctic ecosystems to resist perturbation and to recover when damaged.

Selected species of conservation concern

- **Caribou.** The caribou of the islands and mainland of the High Arctic: Peary caribou and the Dolphin and Union population of barren-ground caribou are listed under Canada's Species at Risk Act (SARA) as being of conservation concern (Endangered and Special Concern, respectively).

↓	**Peary caribou** have declined from about 44,000 to about 11,000 to 12,000 over the past 50 years. Their overall distribution has also declined, by about 15% between 1980 and 2006, with the apparent disappearance of two geographic populations.
↓ ?	The **Dolphin and Union caribou** of Victoria Island had been recovering slowly from a sharp decline through the 19th and early 20th centuries. However, hunting pressure and low cow survival suggest likelihood of a decline.

Peary caribou. Photo: Paul Loewen, iStock

- **Polar bear.** In 2013, the Canadian population of polar bears was estimated at approximately 16,200. Although the total size of the global population is unknown, it is likely that well over half of the world's polar bears live in Canada. They are adapted to hunting seals from sea ice, so rapidly declining sea ice due to climate change poses the most serious threat to the species. Polar bears are listed under SARA as being of conservation concern (Special Concern).

Of Canada's **polar bears**, as of 2013, 2 sub-populations are considered to be increasing or likely increasing, 6 are stable, and 4 are declining or likely declining. Data are insufficient to provide a trend for 1 sub-population (based on assessment of data available in 2013.)

- **Grizzly bear.** About a quarter of Canada's grizzly bear population lives in the Northwest Territories and Nunavut. They are vulnerable to human disturbance and to declines in caribou, an important seasonal food source. Population trends are poorly known. Barren-ground grizzly bears are expanding northward in some areas of the northwestern Arctic. The western population of grizzly bears has been assessed by the Committee on the Status of Endangered Wildlife in Canada (COSEWIC) as of Special Concern, but it is not listed under SARA.
- **Wolverine.** The western population was assessed by COSEWIC as of Special Concern (2003). A new wolverine assessment will be completed in 2014. Wolverine have low reproductive rates and are vulnerable to food shortages in the winter, when, on the tundra, they feed mainly on caribou.

Wolverine are considered (based on the 2003 COSEWIC assessment) to be at moderate to low densities, with stable populations in the NWT and Nunavut, and sensitive to changes due to harvest. Wolverine have been reduced to unconfirmed sightings in Quebec (since 1978) and Labrador (since 1950s), due to trapping, hunting, and declines in caribou.

Wolverine. Photo: R. Gau, nwtspeciesatrisk.ca

Selected species and species groups of special interest

- **Migratory tundra caribou**, a category that includes three subspecies (barren-ground, Grant's, and migratory woodland caribou), along with Peary and Dolphin and Union caribou (presented above as species of conservation concern) are the dominant large herbivore of the Arctic. Wintering ranges of many migratory herds extend south to the taiga. Populations typically rise and fall over decades, although human stressors, especially climate change and expansion of human population and development, may affect recovery of some herds.

↓	**Arctic mainland caribou herds** increased in numbers in the 1970s and 1980s and have generally declined in the past decade or more, with high variability in the rates of decline.

Beverley herd of barren-ground caribou, Thelon River, Nunavut, 1978.
Photo: Cameron Haye, Wikimedia

- **Muskoxen.** Canada has about three-quarters of the world's muskoxen, most of them on the Arctic islands. Muskoxen were reduced to a few isolated herds by 1916, partly through commercial harvest. Populations have rebuilt through introductions and range extensions.

↑	Muskox had been nearly extirpated in Canada, through commercial harvest, by the early 20th century. Since then numbers have built up through natural recovery and range expansion, aided by hunting bans and some reintroductions. Most (85%) of the estimated Canadian muskox population of 114,300 (three-quarters of the world's muskox population) are on Arctic islands.

- **Large carnivores** of North America, including wolves, grizzly bears and wolverines, have lost much of the southern parts of their ranges to expansion of human populations. As a consequence, northern ranges are increasingly important. **Wolf populations** are not monitored regularly and overall trends are not known. They can reproduce rapidly, making them resilient to disturbance. Their numbers tend to rise and fall in accordance with fluctuations in chief prey populations – including caribou, muskoxen and Arctic hares.

- **Birds**. The Arctic Ecozone+ is of global significance for the many bird species that breed wholly or chiefly in Arctic regions. Arctic-breeding migratory birds can be affected in other parts of their ranges as well, and trends may often be related to conditions on wintering or staging grounds.

Some **waterfowl** populations show mixed trends – such as common eiders, which appear to be declining in some parts of the ecozone+ and remaining relatively stable in other places. Some distinct species trends:

↓ **King eiders:** the western population declined from about 900,000 in 1960 to between 200,000 and 260,000 in the early 1990s; remain at about this level (based on the most recent survey during migration, 2003). The eastern population is also declining, although this decline may be related to a shift in distribution linked to human disturbance (based on data from Greenland).

↑ **Greater snow geese:** increased dramatically from a few thousand in the 1930s to an estimated million birds in 2012. The increase is related to changes in agricultural practices in the U.S. wintering grounds and has led to overgrazing on staging and breeding areas in Canada. **Lesser snow geese** also show population growth. (Based on annual counts on the wintering grounds.)

→ The eastern population of **tundra swans**, which nests from Alaska to Baffin Island, has remained stable at around 90,000 to 100,000 birds from 1982 to 2012. (Based on annual counts on the wintering grounds.)

↓ **Arctic-breeding shorebirds** are declining globally by 1.9% per year, with the rate of decline increasing for several species. The causes of these widespread declines are not clear. Sixty percent of North American shorebirds breed in the Arctic, many primarily in Canada.

↓ There are relatively few **landbird** species in the Arctic and few data on their population trends. Arctic-breeding landbirds known to be declining, based on counts on wintering grounds, include: hoary redpoll, American tree sparrow and Harris's sparrow, and snowy owl

American tree sparrow. Photo: P. Chouinard, iStock

- **Major range shifts of species native to Canada.** Arctic residents have reported changes in animal behaviour and distribution, and these observations have been documented in several studies. Among the observations are the presence of new insect and bird species and the northward movement of existing Arctic and boreal species, such as ravens, cougars and grizzly bears.

Moose have been expanding their range northwards in recent decades in much of the Arctic. Moose provide another prey source for predators, such as wolves, as well as an alternate food source for subsistence economies. They can also indirectly affect other ungulates – for example, if the availability of moose keeps the wolf population high through the summer on caribou wintering grounds, the caribou will face increased predation when they return.

- **Human stressors on ecosystem composition.** Climate change is a human-induced stressor for some species. Human settlements and infrastructure affect ecosystem composition through habitat change, disturbance, and harvest. Contaminants and pollution, from local sources and from long-range atmospheric transport, affect both terrestrial and aquatic ecosystems. Increased transportation and development in the Arctic is likely to increase the level of and impacts from human stressors.

Barrels abandoned on the tundra, Nunavut. Photo: Ryerson Clark, iStock

6. Ecosystem Goods and Services

- **Living space.** Modern Inuit and Inuvialuit use huge tracts of land as they travel to neighbouring communities to visit and conduct business and to remote camp sites to hunt, fish, and trap. Ice and snow form an important part of this living space. River, lake, and sea ice provides access to the land for hunting and fishing and for transport during much of the year.

In the Arctic, **permafrost** supports building structures, often on land that would be unusable if it were not frozen. Climate-change-induced reduction in extent of permafrost and increase in depth of annual thawing are current risk factors and future threats. Loss and reduction of ice cover negatively affects travel on land and over rivers, lakes and along coastal areas.

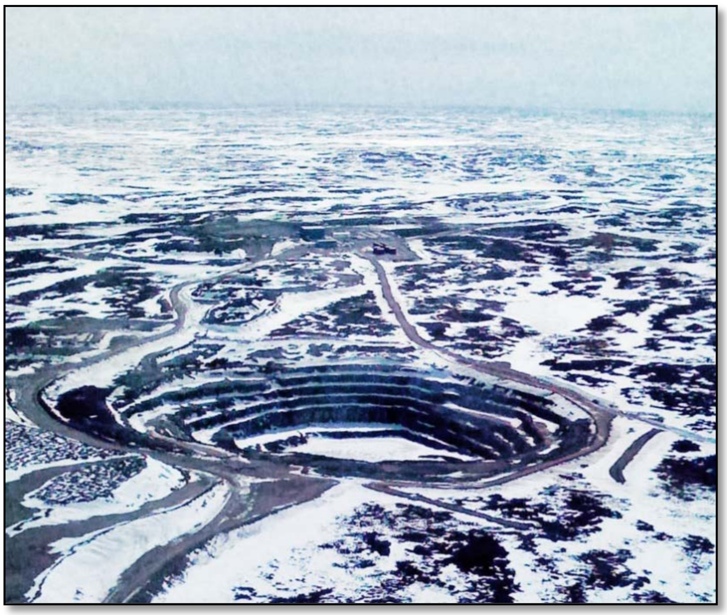
- **Food.** Harvest of country foods is not just a matter of calories and nutrients, but a central feature of Inuit and Inuvialuit cultural identity. Caribou are particularly important. For example, the annual combined harvest for the Northwest Territories and Nunavut is about 1.6 million kg of caribou – or, based on beef replacement value, about $35 million for meat alone. In addition, there is the value of hides, commercial harvesting, and the cultural value to Arctic peoples and communities.

Studies from the early 1970s to recent years show that Inuit and Inuvialuit across the ecozone[+] continue to rely heavily on traditional (or country) foods. Participation rates for fishing were about 70% in all regions, and about 50 to 60% for hunting caribou, moose or sheep, based on a comprehensive study conducted in 2001.

Fishing in the Burnside River, Nunavut. Photo: C. Farish, iStock.

7. Human Influences

- **Stressors and cumulative impacts.** The dominant human-linked stressor on Arctic systems is climate change and, based on climate model projections, that will continue to be true for the foreseeable future. Other widespread stressors include contaminants from long-range atmospheric transport. At the local or regional level, stressors include habitat fragmentation and disturbance, overharvest, and localized contamination. These stressors interact, often in complex and unpredictable ways.



Jericho Diamond Mine pit, Nunavut (operated 2006-2008).
Photo: Tom Churchill, Wikimedia

- **Main threats to caribou.** Stressors from human activities can interact with and exacerbate natural stressors, such as predation, parasites, and disease. This interaction can be particularly problematic during low periods in the caribou herds' population cycles when the herds are most vulnerable.

↑	The human population of the Arctic and neighbouring taiga ecozones[+] almost doubled between 1971 and 2006. The increased population, combined with new hunting technologies that make hunting more efficient, are likely to lead to **increased harvest pressure**.
↑	**Increased development** – mineral and hydrocarbon exploration and development, power lines, shipping, road construction, etc. – places pressures on caribou, particularly the migratory herds.
↑ ?	**Climate change** will affect the movements and distribution of the herds, as well as the ability of hunters to get on the land. The particular impacts will vary from herd to herd, depending on their traditional ranges and movement patterns and on how the stressors from climate change interact with other stressors, both natural and anthropogenic.

- **Stewardship and conservation.** A major human stressor for the Arctic is climate change. This stressor cannot be overcome through stewardship and conservation measures within the Arctic. It is a global problem, and the most significant measure that can be taken to conserve Arctic ecosystems is to reduce greenhouse gas emissions worldwide.

↑ Canada's annual **greenhouse gas emissions** rose from below 600 megatonnes CO_2 equivalent in 1990 to 746 megatonnes in 2007, then declined to 702 megatonnes in 2011. The Copenhagen target is 612 megatonnes by 2020 (17% below emissions for 2005).

- **Protected areas.** As plant and animal ranges shift and ecosystem function and processes are affected by climate change and by increasing development pressures, it becomes even more important to focus on conservation of important lands and waters, such as breeding areas for migratory birds and caribou.

↑ The total area protected in the Arctic Ecozone$^+$ increased from less than 50,000 km^2 in the 1950s to close to 300 km^2 by 2009. Overall, 11.3% of land is protected, with the highest proportion (24%) in the Arctic Archipelago and the lowest in the Northern Arctic (6.7%). (Based on analysis of Conservation Areas Reporting and Tracking System data current to May, 2009)

- **Environmental governance.** Resource management boards, established pursuant to land claims settlements, have become the dominant forces in management of land and natural resources in the Canadian Arctic. The networks of resource management boards, councils, and local hunters' and trappers' associations function as bottom-up, co-operative systems that are mandated to make use of science and Aboriginal traditional knowledge in making decisions about management of the land and natural resources of the Arctic.

Co-management meeting about the Yukon North Slope, Aklavik, NWT, Dec. 2007.
Photo: Wildlife Management Advisory Council (North Slope).

PART 2: ARCTIC ECOZONE+ KEY FINDINGS SUMMARY TABLE

Key findings at a glance: national and ecozone+ level

This table presents the national key findings from *Canadian Biodiversity: Ecosystem Status and Trends 2010*[1] together with a summary of the corresponding trends in the Arctic Ecozone+. Topic numbers refer to the national key findings in *Canadian Biodiversity: Ecosystem Status and Trends 2010*. Topics that are greyed out were identified as key findings at a national level but were either not relevant or not assessed for this ecozone+. All material for trends in the Arctic Ecozone+ was drawn directly from the *Arctic Ecozone+ Status and Trends Assessment*[2] except where additional references are included as footnotes.

Themes and topics	Key findings: NATIONAL	Key findings: ARCTIC ECOZONE+
THEME: BIOMES		
1. Forests	At a national level, the extent of forests has changed little since 1990; at a regional level, loss of forest extent is significant in some places. The structure of some Canadian forests, including species composition, age classes, and size of intact patches of forest, has changed over longer time frames.	As the southern boundary of the Arctic Ecozone+ is the tree line, forest cover is restricted to the forest-tundra transition zone. The northern boundary of tree distribution is often temperature limited, and it is anticipated that the overall trend will be northward expansion of forest under a warming climate. Current trends are variable, with, for example, treeline expanding northward in coastal areas of northern Quebec and Labrador, but not in the interior. A combination of increased growth and cover by shrubs and infilling by tree species may replace tundra at its southern margins in the forest-tundra zone.
2. Grasslands	Native grasslands have been reduced to a fraction of their original extent. Although at a slower pace, declines continue in some areas. The health of many existing grasslands has also been compromised by a variety of stressors.	Not relevant

Themes and topics	Key findings: NATIONAL	Key findings: ARCTIC ECOZONE+
3. Wetlands	High loss of wetlands has occurred in southern Canada; loss and degradation continue due to a wide range of stressors. Some wetlands have been or are being restored.	Wetlands cover approximately 10% of the Arctic Ecozone+. They are more common in the Southern Arctic. A high proportion of Arctic wetlands are wet sedge, grass, and moss wetlands. In moist regions of the ecozone+, thaw lakes and ponds have increased in amount and extent, evidently as a result of permafrost melting and precipitation increasing. However, in drier regions of the Northern Arctic and Arctic Cordillera, ponds have been reduced in extent and some have disappeared. Some ponds on Ellesmere Island that had been permanent water bodies for millennia dried up completely in the warm summers of 2005 and 2006. Surrounding moss and grass wetlands also dried, with the loss of seasonal standing water. More permanent ponds, as well as seasonal ponds and wetlands, can be expected to be lost through desiccation as the climate warms further. Ephemeral ponds and wetlands in the Arctic are important stopover sites for migratory birds and important nesting sites for shorebirds and geese on the coastal plain.
4. Lakes and rivers	Trends over the past 40 years influencing biodiversity in lakes and rivers include seasonal changes in magnitude of stream flows, increases in river and lake temperatures, decreases in lake levels, and habitat loss and fragmentation.	About three-quarters of Canada is drained by rivers discharging through the Arctic Ecozone+ to Arctic marine waters, accounting for almost half (48%) of the total discharge of Canadian rivers. Flow regimes and ecosystem conditions for major rivers crossing briefly through the ecozone+ at the far northern end of their courses are influenced strongly by climatic conditions, terrain, and stressors to the south. With few hydrometric stations with long-term datasets, information on trends in **river discharge** is limited. Total annual discharge from the ecozone+ to Arctic marine waters decreased from the mid-1960s to the early 2000s, but with strong regional variation: there was a strong decline in discharge to Hudson Bay and the Labrador Sea, but no significant trend for rivers draining directly to the Arctic Ocean. Analyses that include more recent data show a

Themes and topics	Key findings: NATIONAL	Key findings: ARCTIC ECOZONE+
		reversal of the earlier decline, including in Hudson Bay, with a significant increase in annual average flows since 1989. Based on remote sensing, total ecozone+ **lake area** declined from 2000 to 2009, likely related to the longer ice-free periods leading to increased evapotranspiration. In contrast, lake area increased over the same period in areas where melting permafrost led to increased land flooding—with, for example, an increase of 3% in the Mackenzie Delta. The impacts of climate change on **ecological processes** in lakes and rivers are complex and include shorter periods of ice cover, warmer water, changing lake mixing regimes, and changes in the distribution of nutrients and oxygen. Climate warming has been linked to shifts in algal and invertebrate species assemblages, food availability for fish, and overall freshwater ecosystem productivity.
5. Coastal	Coastal ecosystems, such as estuaries, salt marshes, and mud flats, are believed to be healthy in less-developed coastal areas, although there are exceptions. In developed areas, extent and quality of coastal ecosystems are declining as a result of habitat modification, erosion, and sea-level rise.	Coastal biomes are assessed in the ESTR marine ecozone+ reports.
6. Marine	Observed changes in marine biodiversity over the past 50 years have been driven by a combination of physical factors and human activities, such as oceanographic and climate variability and overexploitation. While certain marine mammals have recovered from past overharvesting, many commercial fisheries have not.	Marine ecozones+ are assessed in other ESTR reports.

Themes and topics	Key findings: NATIONAL	Key findings: ARCTIC ECOZONE+
Tundra[1]	Ecozone+-specific key finding	Polar barrens (less than 50% vegetation) and polar tundra (over 50% tundra vegetation) together cover 80% of the ecozone+. Reflecting the widespread warming trend across the ecozone+, the area of land with climatic conditions known to support tundra over the long term declined 20% since 1982. Tundra plant communities are changing across the biome in ways that are consistent with responses to experimental warming. Data from 1980 to 2010 for Canadian study sites were combined for analysis with results from other ground-based tundra monitoring sites across the circumpolar Arctic. Main trends include increases in average height of vegetation, more shrubs, and less bare ground. Experimental tundra plots (warmed 1 to 2°C by small, open greenhouses) provide an indication of the response of tundra to continued climate change. These responses include increases in shrubs, loss of species diversity, increased height of most vascular plants, and decreases in mosses, lichens, and bare ground cover.

[1] This key finding is not numbered because it does not correspond to a key finding in the national report.[1]

Themes and topics	Key findings: NATIONAL	Key findings: ARCTIC ECOZONE+
7. Ice across biomes	Declining extent and thickness of sea ice, warming and thawing of permafrost, accelerating loss of glacier mass, and shortening of lake-ice seasons are detected across Canada's biomes. Impacts, apparent now in some areas and likely to spread, include effects on species and food webs.	All forms of ice in Arctic biomes have shown rapid decline over the past 30 years, particularly over the past decade. **Permafrost** is warming and the depth of ground that thaws annually is increasing at monitoring sites across the ecozone+ (measured over varying periods, extending back to the 1980s). Loss of permafrost is leading to broad-scale changes, including changes in vegetation structure and communities, as well as positive feedbacks that increase rates of warming (such as reduced albedo affecting regional air temperatures, and changes in the carbon balance of the Arctic landscape contributing to the greenhouse effect and thereby accelerating global climate warming). **Sea ice** extent throughout the year decreased significantly from 1979 to 2013, as measured by remote sensing. Increased summer ice melting has led to a loss of multi-year ice and ice is melting earlier in the spring. These changes in sea ice affect not only marine ecosystems and ice-dependent species such as polar bears, they also affect coastal regional climate and vegetation, and some species of terrestrial wildlife. There has been a general melting trend for Canadian Arctic Island **glaciers and ice caps** since the late 19th century, with the trend slowing down for a period in the mid-20th century, and with accelerated ice loss in the past 25 years. The glacier mass loss for Arctic Canada from 2003 to 2009 was about 28% of the global glacier mass loss, excluding Antarctica and Greenland, and it accounted for about 29% of global sea level rise over this period. Increasing amounts of land are exposed as the glaciers melt, and this will lead to some increase in the area of tundra vegetation coverage. There is little information on trends in **lake ice**. Based on remote sensing data, the length of the annual ice-free period for seven lakes in the Arctic increased significantly from 1985 to 2004.

Themes and topics	Key findings: NATIONAL	Key findings: ARCTIC ECOZONE+
THEME: HUMAN/ECOSYSTEM INTERACTIONS		
8. Protected areas	Both the extent and representativeness of the protected areas network have increased in recent years. In many places, the area protected is well above the United Nations 10% target. It is below the target in highly developed areas and the oceans.	In 2009, almost 11.3% of the Arctic Ecozone+ was protected, an increase from just over 7.4% in 1992. Almost all of this land was protected as IUCN categories I–III. As of May 2009, the Arctic Archipelago had the highest proportion of protected areas, at 24.0% in 10 protected areas, followed by the Southern Arctic with 15.9% protected through 21 protected areas. The Northern Arctic had 6.7% of its land protected through 22 protected areas. Much of the growth of protected areas in the Arctic has been related to the settlement of land claims.
9. Stewardship	Stewardship activity in Canada is increasing, both in number and types of initiatives and in participation rates. The overall effectiveness of these activities in conserving and improving biodiversity and ecosystem health has not been fully assessed.	Stewardship activity related to conserving ecosystems in the Arctic Ecozone+ is important at community, regional, circumpolar, and global scales. Within the ecozone+, stewardship initiatives are often carried out within the framework of natural resource management systems that have strong community-level involvement. Fish, wildlife, and habitat are co-managed or managed with strong participation of the Inuit through resource management boards established pursuant to land claims agreements. These boards make use of both science and Aboriginal traditional knowledge to inform decision-making and are supported by hunters' and trappers' associations and other community-level organizations. At the circumpolar scale, the Arctic Council, an intergovernmental organization of the eight circumpolar nations, provides a forum for collaboration and oversight of many international initiatives related to ecological science, conservation of ecosystems, and sustainable development in the Arctic. International Arctic indigenous organizations are Permanent Participants in the Council. Responsibility for one of the most important stewardship activities for the Arctic—reduction in the rate of greenhouse gas emissions—is shared globally.

Themes and topics	Key findings: NATIONAL	Key findings: ARCTIC ECOZONE+
10. Invasive non-native species	Invasive non-native species are a significant stressor on ecosystem functions, processes, and structure in terrestrial, freshwater, and marine environments. This impact is increasing as numbers of invasive non-native species continue to rise and their distributions continue to expand.	Few invasive species are known from the Arctic compared to other ecozones+ but the impacts of these to biodiversity can still be severe, given that most native plant species have specialized northern niches.[3] Risk of introduction of invasive plants will increase with climate warming and changes in patterns of human use, particularly increased shipping, energy development, mineral exploration, and associated shore-based developments, such as ports, roads, and pipelines.[4]
11. Contaminants	Concentrations of legacy contaminants in terrestrial, freshwater, and marine systems have generally declined over the past 10 to 40 years. Concentrations of many emerging contaminants are increasing in wildlife; mercury is increasing in some wildlife in some areas.	Contamination of Arctic wildlife has been a concern since the 1970s, especially in relation to potential health effects for Arctic indigenous peoples. Three classes of contaminants of particular concern in the Arctic are: legacy contaminants (persistent organic pollutants such as DDT, PCBs, and toxaphene), newer toxic contaminants, such as brominated flame retardants, and mercury. Trends in the Arctic are consistent with the national key finding trends. Contaminant levels in Arctic fish and wildlife are considered to be below levels that would result in widespread effects on the health of fish and wildlife, with some possible exceptions, including for some polar bear populations.
12. Nutrient loading and algal blooms	Inputs of nutrients to both freshwater and marine systems, particularly in urban and agriculture-dominated landscapes, have led to algal blooms that may be a nuisance and/or may be harmful. Nutrient inputs have been increasing in some places and decreasing in others.	Not relevant

Themes and topics	Key findings: NATIONAL	Key findings: ARCTIC ECOZONE+
13. Acid deposition	Thresholds related to ecological impact of acid deposition, including acid rain, are exceeded in some areas, acidifying emissions are increasing in some areas, and biological recovery has not kept pace with emission reductions in other areas.	Despite the presence of potential acidifying pollutants in the atmosphere, there is little indication of soil or surface water acidification in the Arctic Ecozone+ to date.[5, 6] Most Arctic soils have low sensitivity to acid deposition, with the exception of some areas of the Northwest Territories, Yukon Territory, and Baffin Island, where soils and bedrock have low potential to reduce the acidity of atmospheric deposition.[7] Of lakes sampled in Arctic Canada, the only extremely acid-sensitive lakes found so far occur on Baffin Island and the central mainland straddling the border of Nunavut and the Northwest Territories.[6]
14. Climate change	Rising temperatures across Canada, along with changes in other climatic variables over the past 50 years, have had both direct and indirect impacts on biodiversity in terrestrial, freshwater, and marine systems.	Summer and fall temperatures increased significantly across the ecozone+ over the past 50 years, with increases at all seasons recorded for many climate stations. There were no significant cooling trends at any station in any season. Annual precipitation increased across the ecozone+, with the most significant change being in winter and with little to no change in summer. Across the ecozone+, snow cover duration decreased both in the fall and in the spring over the 50 year period. Annual maximum snow depth also decreased. In Canada, as at the global scale, the climate is warming faster in the Arctic than at lower latitudes. With this amplification of climate change, the direct and indirect impacts on ecosystems are of particular prominence in this ecozone+. Rapid loss of snow and ice across biomes, in particular, is leading to major changes in ecosystem structure and function.

Themes and topics	Key findings: NATIONAL	Key findings: ARCTIC ECOZONE[+]
15. Ecosystem services	Canada is well endowed with a natural environment that provides ecosystem services upon which our quality of life depends. In some areas where stressors have impaired ecosystem function, the cost of maintaining ecosystem services is high and deterioration in quantity, quality, and access to ecosystem services is evident.	Arctic ecosystems provide important provisioning, cultural, and regulating services. They produce food, fuel, and fibre essential to traditional Arctic cultures and economies, as well as commercial hunting, gathering, and small-scale fishing industries. Arctic fish and wildlife further support recreational and sport fishing and hunting. Cultural services include the significance of fish and wildlife to Inuit culture and tourism. Regulating services include carbon sequestration and climate regulation, increasingly impaired by climate warming and positive feedbacks caused by changes in albedo from diminished snow and ice cover. Studies since the 1970s show the continuing reliance of Inuit and Inuvialuit on traditional (country) foods as a significant source of calories and nutrients and as a central cultural feature. A snapshot of subsistence use is provided by an extensive 2001 survey from Labrador to the Western Arctic: over 60% of Inuit and Inuvialuit are active fishers, while about 50% hunt caribou, moose or sheep (with caribou being particularly important). Trapping participation rates were much lower, at or below 10 to 20% depending on region. Participation rates in subsistence activities were higher for people outside of major population centres.
THEME: HABITAT, WILDLIFE, AND ECOSYSTEM PROCESSES		
16. Agricultural landscapes as habitat	The potential capacity of agricultural landscapes to support wildlife in Canada has declined over the past 20 years, largely due to the intensification of agriculture and the loss of natural and semi-natural land cover.	Not relevant
17. Species of special economic, cultural, or ecological interest	Many species of amphibians, fish, birds, and large mammals are of special economic, cultural, or ecological interest to Canadians. Some of these are declining in number and distribution, some are stable, and others are healthy or recovering.	**Polar bears**: In 2013, the Canadian population of polar bears was estimated at approximately 16,200 individuals. Although the total size of the global population is unknown, it is likely over half of the world's polar bears live in Canada. Status and trends vary among subpopulations. As of 2013,

Themes and topics	Key findings: NATIONAL	Key findings: ARCTIC ECOZONE+
		two sub-populations were considered to be increasing or likely increasing, 6 were stable, and 4 were declining or likely declining. Data was insufficient to provide a trend for one sub-population. Polar bears, adapted to hunting seals from the ice, cannot persist without seasonal sea ice and rapidly declining sea ice poses the most serious threat to the species. Earlier sea-ice break-up around western Hudson Bay has led to poorer physical condition and poorer reproductive performance of polar bears. Other threats include overharvest, disturbance and loss of habitat due to increased human activity, and contaminants, including mercury and persistent organic pollutants. **Caribou:** Over the last 50 years, Peary caribou have declined from about 44,000 to 11,000 to 12,000. Trend analyses are limited by the infrequency of surveys and lack of older surveys. Factors influencing caribou abundance include weather, harvest, and predation. Periodic severe winters trigger large-scale mortality and reduction in productivity. Based on surveys of herds, migratory tundra (barren-ground) caribou numbers across the Arctic generally increased from low abundance around 1975 to peak abundance around 1995, followed by a decline with some indication of a recent levelling off or reversal of the decline. However, status and trends for individual herds vary. Current trends are likely a reflection of natural cycles in caribou abundance accentuated by the cumulative effects of increasing human presence on the caribou ranges, possibly interacting with climate change impacts. **Muskoxen**: As of 2012, Canada had about 115,000 muskoxen, which is about three-quarters of the world total. Muskoxen were hunted to near extinction on the Arctic mainland and on some Arctic islands by the early 1900s.

Themes and topics	Key findings: NATIONAL	Key findings: ARCTIC ECOZONE[+]
		They have since recovered through natural population increases and range extension, aided by a period of no harvesting from 1924 to 1969, followed by regulated harvest as populations expanded. **Birds**: Data on Arctic birds are lacking or sparse for many species, and it is often difficult to determine the causes of trends where data are available. Many Arctic-nesting shorebird and landbird species are declining on a continental basis, as are some sea ducks (e.g., king eiders, common eiders). Other Arctic bird groups, such as geese and swans, have mainly stable populations or have increased (due to changes in agricultural practices on their southern wintering grounds) over the past few decades. Arctic-nesting birds winter in many parts of the world where they may be vulnerable to stressors including loss of food supplies and habitat, pollution, disturbance, and overharvesting during winter and during migration. In the Arctic, they are vulnerable to changes in their habitat and food supplies and, in some cases, to overharvest.
18. Primary productivity	Primary productivity has increased on more than 20% of the vegetated land area of Canada over the past 20 years, as well as in some freshwater systems. The magnitude and timing of primary productivity are changing throughout the marine system.	Primary productivity is low in the Arctic compared with other ecozones[+]. Evidence is accumulating that the Arctic is getting greener and that the productivity of Arctic ecosystems is increasing. From 1985 to 2006, primary productivity, as measured by the Normalized Difference Vegetation Index (NDVI), increased over 12.2% of Arctic Ecozone[+] land area and decreased over only 0.1% of area. Areas with strong increases in NDVI were all in the tundra landcover class (over 50% cover of tundra vegetation), including areas located on Banks Island, Melville Island, Bowman Bay on Baffin Island, the northwestern Hudson Bay shore, and on the northern Labrador Peninsula, particularly in the lower elevations bordering Ungava Bay. The proportion of lands with increasing NDVI trends was highest in the Southern Arctic.

Themes and topics	Key findings: NATIONAL	Key findings: ARCTIC ECOZONE+
		Increases in plant productivity are due to increases in peak productivity and in growing season length. Long-term studies on Ellesmere and Bylot islands show that there have been large increases in biomass (net production) in Canadian High Arctic tundra over the past 20-plus years in response to climate change. Based on lake sediment core data, primary production has also increased rapidly in six Baffin Island lakes since the late 19th century, following a period of stable levels of primary production for millennia, leading to changes in algal species assemblages. Similar results have been found in other Canadian Arctic lake sediment studies.
19. Natural disturbance	The dynamics of natural disturbance regimes, such as fire and native insect outbreaks, are changing and this is reshaping the landscape. The direction and degree of change vary.	**Permafrost disturbance** and thawing due to higher temperatures has increased the frequency and magnitude of slope failures and converted areas of tundra to thermokarst ponds. In addition to changing the nature of the landscape for vegetation and wildlife, slope failures can expose previously frozen carbon to oxidation and alter biogeochemistry in lakes, leading to shifts in nutrient, light, and phytoplankton relationships. **Fire** is not a significant natural disturbance. Between 1960 and 2007, only five large fires (over 2 km^2) were documented for Arctic tundra. When they occur, tundra fires remove vegetation cover, deepen the active layer, and can release large amounts of carbon into the atmosphere. Increases in tundra fires will likely the trend to warmer summers, and the temperature-related increases in shrub vegetation, as has occurred in recent years in northern Alaska. **Severe weather events** that influence the timing, amount, or quality of snow can have major ecological impacts on ungulates, small mammals, and vegetation. Heavy snow and icing, for example, is known to reduce forage availability for ungulates and small mammals, increasing the risk of mortality or reproductive failure. Trends in severe weather events are not known.

Themes and topics	Key findings: NATIONAL	Key findings: ARCTIC ECOZONE+
20. Food webs	Fundamental changes in relationships among species have been observed in marine, freshwater, and terrestrial environments. The loss or reduction of important components of food webs has greatly altered some ecosystems.	Arctic food webs are relatively intact, with a diverse group of predators, including foxes, wolves, and grizzly bears, wolverines, weasels, and raptors. Predator-prey dynamics depend on heavily in most areas on lemmings and other small rodents, with alternative prey, such as geese and shorebirds, utilized by some predators in low abundance years. Compared with boreal ecosystems, large predators are not abundant in the Arctic tundra and predation impacts on ungulates are usually low unless the ungulates are at low densities. Wolves and tundra grizzly bears depend on caribou as prey, although the regulatory role of predation for caribou population dynamics is uncertain.
THEME: SCIENCE/POLICY INTERFACE		
21. Biodiversity monitoring, research, information management, and reporting	Long-term, standardized, spatially complete, and readily accessible monitoring information, complemented by ecosystem research, provides the most useful findings for policy-relevant assessments of status and trends. The lack of this type of information in many areas has hindered development of this assessment.	The Arctic ecozone+ covers a vast, sparsely populated area, made up of three distinct ecozones under the Canadian classification system, making adequate and representative monitoring, research, and provision of information challenging. Monitoring programs that were of particular value in assessing ecosystem status and trends in the Arctic Ecozone+ include those that integrate monitoring and research at sites (notably Bylot Island) and monitoring through networks that use consistent monitoring protocols and take an ecosystem approach through integrating monitoring and research of specific ecosystem features with monitoring and research into drivers, processes, and stressors (notably the networks monitoring tundra vegetation and caribou). However, these ecologically framed sites and networks are rare. Much of status and trends reporting needs to be patched together from specific, often short-term monitoring programs undertaken for purposes such as harvest regulation, assessment of development impacts, or as part of short-term academic research projects. Monitoring stations for parameters essential to tracking and

Themes and topics	Key findings: NATIONAL	Key findings: ARCTIC ECOZONE+
		understanding trends in drivers and processes, including climate, permafrost, and river flows, are limited and often grouped in few locations and with short and interrupted or discontinued records. Nonetheless, there are good monitoring data sets within the ecozone+, augmented by large-scale views from remote sensing. Canadian implementation of biome monitoring plans developed through the Arctic Council's Circumpolar Biodiversity Monitoring Program will lead to major benefits to future status and trend assessment.
22. Rapid change and thresholds	Growing understanding of rapid and unexpected changes, interactions, and thresholds, especially in relation to climate change, points to a need for policy that responds and adapts quickly to signals of environmental change in order to avert major and irreversible biodiversity losses.	For the Arctic Ecozone+, climate change is of primary concern in relation to interactions and rapid changes and thresholds. Rapid changes observed and projected to continue in ice and snow in particular lead to rapid ecological change. For example, reduction in duration and extent of sea ice leads to rapid loss of essential habitat for polar bears, currently detected as loss of body condition in some populations. Permafrost is undergoing a widespread warming—when shallow permafrost temperatures cross the melting point threshold, rapid, landscape-scale changes occur, including thaw slumps and flooding, with consequent impacts on land cover and aquatic habitats. When warm summers increase the rate of evaporation from shallow ponds and lakes beyond a threshold, these productive water bodies are lost, as is observed in the High Arctic. Rapid changes to wildlife population health and abundance result from changes in winter conditions—for example, increased number of freeze-thaw events leads to ice layers that can result in starvation or reproductive failure. Other unexpected changes for which there are some warning signs appearing in the ecozone+ include mismatches in timing of environmental conditions and species needs when, for example, spring comes earlier and hatching dates of birds are no longer synchronous with

Themes and topics	Key findings: NATIONAL	Key findings: ARCTIC ECOZONE[+]
		times of abundant food for the nestlings. These types of often poorly understood cascading ecological changes are likely to become of increasing importance as climate change progresses in the Canadian Arctic—pointing to the need for detection mechanisms and capacity for rapid response.

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