Taiga Shield Ecozone+ evidence for key findings summary

Canadian Biodiversity: Ecosystem Status and Trends 2010

Evidence for Key Findings Summary Report No. 9

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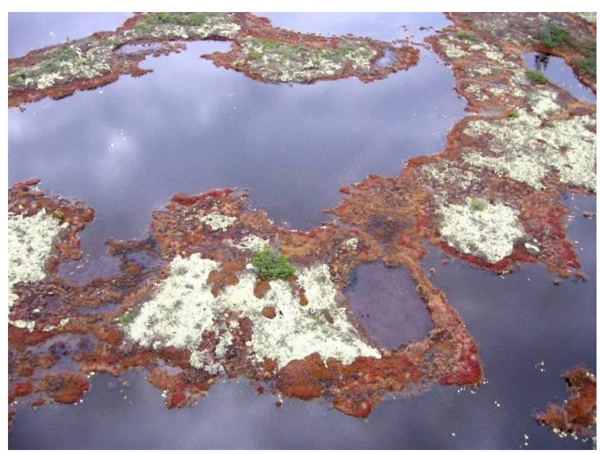

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Cover photos: Tree line, Singing Lake, NWT, © C. O'Brien; Lichen and shrub-covered palsas surrounded by a pond resulting from melting permafrost in a bog near the village of Radisson, QC, Serge Payette

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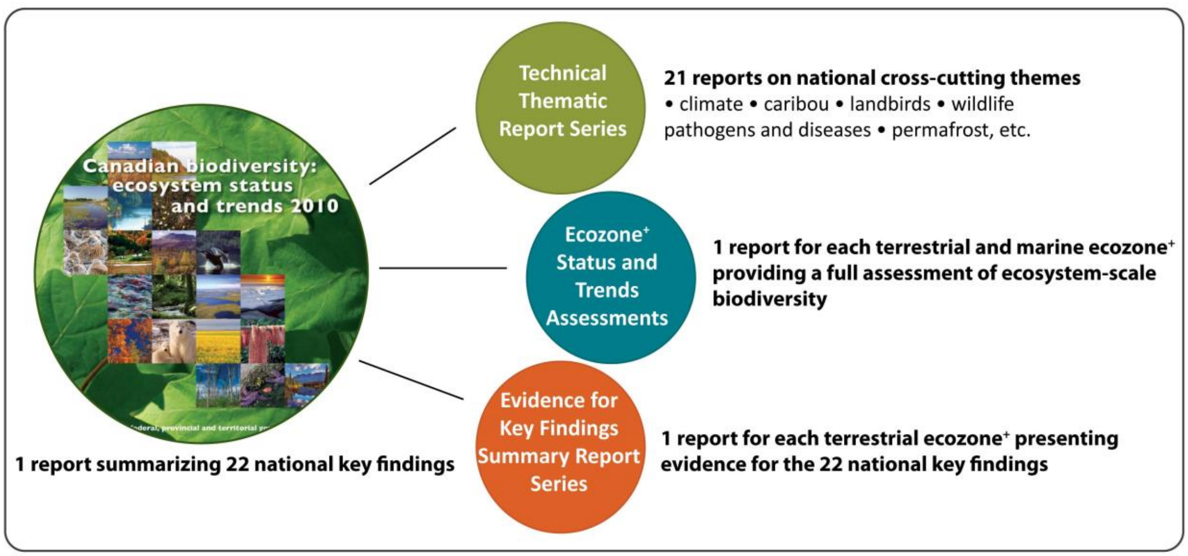
PREFACE

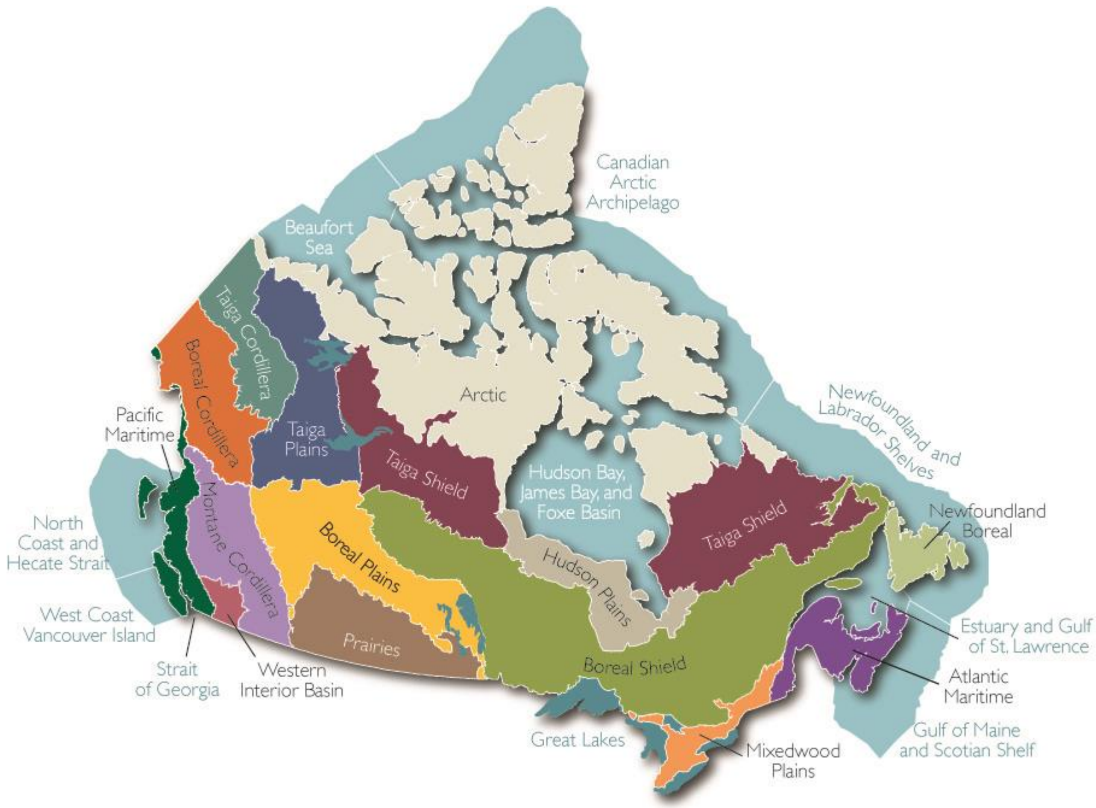
The Canadian Councils of Resource Ministers developed a Biodiversity Outcomes Framework[1] in 2006 to focus conservation and restoration actions under the *Canadian Biodiversity Strategy*.[2] *Canadian Biodiversity: Ecosystem Status and Trends 2010*[3] was the first report under this framework. It presents 22 key findings that emerged from synthesis and analysis of reports prepared as part of this project. These technical reports present status and trends information and analyses for many cross-cutting national themes (the Technical Thematic Report Series) and for Canada's terrestrial and marine ecozones⁺ (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, *Taiga Shield Ecozone⁺ Evidence for Key Findings Summary*, presents evidence related to the 22 national key findings and is therefore not a comprehensive assessment of all ecosystem-related information. The level of detail presented on each key finding varies and important issues or datasets may have been missed. As in all ESTR products, the time frames over which trends are assessed vary – both because time frames that are meaningful for these diverse aspects of ecosystems vary and because the assessment is based on the best available information, which is over a range of time periods.

Ecological classification system – ecozones+

A slightly modified version of the Terrestrial Ecozones of Canada, described in the *National Ecological Framework for Canada*,[4] 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.[5] The northern boundary of the western section of the Taiga Shield ecozone was adjusted based on ground-truthing of the original boundaries.



Acknowledgements

This summary report is based on the draft Taiga Shield Ecozone+ Status and Trends Assessment that was prepared by Anne Gunn and Joan Eamer. Additional reviews of this summary report were provided by scientists and resource managers from relevant provincial and federal government agencies, as well as two external expert reviewers. Further information about this ecozone+ can be found in the associated supplementary material for the Taiga Shield Ecozone+.

Contributions to the draft Status and Trends Assessment are listed below.

Taiga Shield Ecozone+ Draft Status and Trends Assessment acknowledgements

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- Aboriginal communities of the Taiga Shield: A. Penn
- La Grande hydro complex, fish and mercury sections (Hydro-Québec): R. Verdon, R. Schetagne and R. Lussier

Authors of ESTR Thematic Technical Reports from which material is drawn

- Large-scale climate oscillations influencing Canada, 1900-2008: B. Bonsal and A. Shabbar[6]
- Canadian climate trends, 1950-2007: X. Zhang, R. Brown, L. Vincent, W. Skinner, Y. Feng and E. Mekis[7]
- Trends in large fires in Canada, 1959-2007: C.C. Krezek-Hanes, F. Ahern, A. Cantin and M.D. Flannigan[8]
- Wildlife pathogens and diseases in Canada: F.A. Leighton[9]
- Trends in breeding waterfowl in Canada: M. Fast, B. Collins and M. Gendron[10]
- Trends in permafrost conditions and ecology in northern Canada: S. Smith[11]
- Northern caribou population trends in Canada: A. Gunn, D. Russell and J. Eamer[12]
- Woodland caribou, boreal population, trends in Canada: C. Callaghan, S. Virc and J. Duffe[13]
- Landbird trends in Canada, 1968-2006: C. Downes, P. Blancher and B. Collins[14]
- Trends in Canadian shorebirds: C. Gratto-Trevor, R.I.G. Morrison, B. Collins, J. Rausch and V. Johnston[15]
- Monitoring ecosystems remotely: a selection of trends measured from satellite observations of Canada: F. Ahern, J. Frisk, R. Latifovic and D. Pouliot[16]
- Biodiversity in Canadian lakes and rivers: W.A. Monk and D.J. Baird[17]

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 were conducted by university researchers in their field of expertise at the request of the authors.

Direction provided by the ESTR Steering Committee composed of representatives of federal, provincial and territorial agencies.

Editing, synthesis, technical contributions, maps and graphics, and report production by the ESTR Secretariat.

Aboriginal Traditional Knowledge compiled from publicly available sources by D.D. Hurlburt.

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Figure 1: Overview map of the Taiga Shield Ecozone+

ECOZONE+ BASICS

The Taiga Shield extends from the Northwest Territories to Labrador on both sides of Hudson Bay. It is a lightly-populated expanse of open forest, shrubland, tundra, and wetlands overlying the Precambrian Shield. The major localized stressor is hydroelectric development, principally on the eastern side of Hudson Bay, though there is also mining exploration and development across the ecozone+. Climate change affects the entire ecozone+. An overview of the ecozone+ is presented in Table 1.

Table 1: Taiga Shield Ecozone+ overview

Area	1,346,430 km^2 (14% of Canada)
Topography	Open forest dominated by small conifers, thinning to shrubland and tundra as latitude increases (Figure 2) About 13% covered by wetlands[18]
Climate	The climate is very different east and west of Hudson Bay, with the west being colder and drier:[19] • West: -8°C annual mean temperature with 200-500 mm of precipitation • East: 0°C annual mean temperature with 500-800 mm of precipitation
River basins	West of Hudson Bay, drains to: • Arctic Ocean via the Coppermine basin and the Mackenzie River basin • Hudson Bay via the Thelon, Dubawnt and other systems East of Hudson Bay drains to: • James and Hudson bays via the La Grande River and other systems • Ungava Bay • Atlantic Ocean
Geology	Underlain by Precambrian Shield, with 75% of land surface covered by glacial till Most of the ecozone+ is 100-600 m above sea level
Permafrost	Regions of continuous and discontinuous permafrost west of Hudson Bay Sporadic permafrost through most of the Taiga Shield east of Hudson Bay
Settlement	Sparsely populated (42,000 in 2006), with a number of small communities (Figure 3) The largest community is Yellowknife, NT (20,000 in 2006) About 60% of population is Aboriginal
Economy	Wildlife, fishing, and fur trade are important to the wage and non-wage economies of many small communities Mining, mineral exploration, hydroelectric development, and transportation, along with provision of government services, are mainstays of the wage economy
Development	Active mining exploration and development for base metals, gold, diamonds Hydroelectric projects, current and projected, especially east of Hudson Bay

Jurisdictions: The Taiga Shield Ecozone+ extends across the northern parts of five provinces (Newfoundland and Labrador, Quebec, Manitoba, Saskatchewan, and the northeast corner of Alberta) and two territories (southern Nunavut and a substantial part of the Northwest

Territories). About 60% of the population is Aboriginal: Algonquin-based Aboriginal peoples in the east (James Bay Cree, Cree, Innu, and the Labrador Inuit), and Athapaskan-based groups (Inuit, Sahtu Dene, Akaitcho, and Tlicho) and Métis in the west. Aboriginal government structures and powers vary widely across the region, depending on the status of land claims settlements.

East-west split: The Taiga Shield Ecozone⁺ is divided into eastern and western sections by Hudson Bay. While both parts share many characteristics, the wide geographic separation, combined with differing climatic and jurisdictional influences, means they must often be discussed separately.

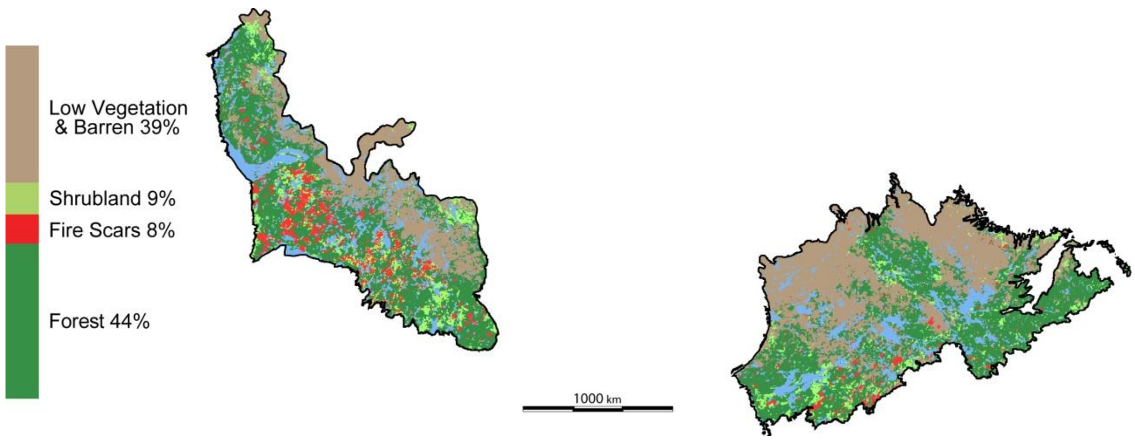


Figure 2: Major land cover classes in the Taiga Shield Ecozone⁺, 2005.
Land areas in urban, agricultural and snow/ice/glacier categories are very small (<0.01%) and there is no grassland.
The red, "disturbed" areas are recent burn scars.
Source: Ahern et al., 2011[16]

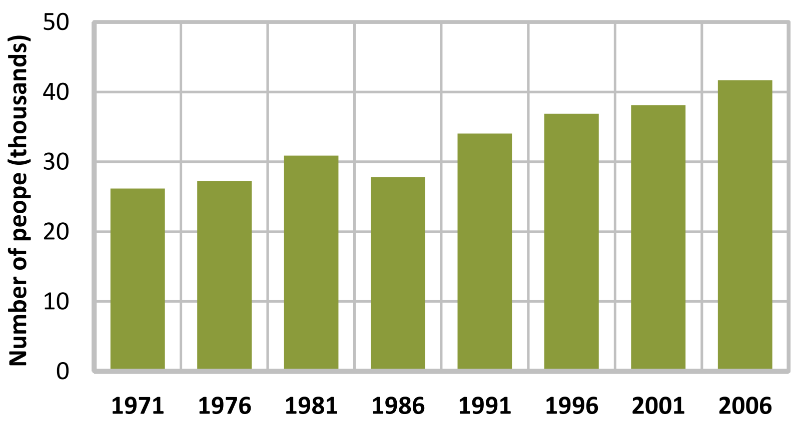


Figure 3: Human population of the Taiga Shield Ecozone⁺, 1971 to 2006.
Source: Environment Canada, 2009[20]

KEY FINDINGS AT A GLANCE: NATIONAL AND ECOZONE+ LEVEL

Table 2 presents the national key findings from *Canadian Biodiversity: Ecosystem Status and Trends 2010*[3] together with a summary of the corresponding trends in the Taiga Shield Ecozone+. Topic numbers in this section refer to the national key findings in *Canadian Biodiversity: Ecosystem Status and Trends 2010.*[3] 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+ and do not appear in the body of this document. Evidence for the statements that appear in this table is found in the subsequent text organized by key finding. See the Preface on page i.

Table 2. Key findings overview

Themes and topics	Key findings: NATIONAL	Key findings: TAIGA SHIELD 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.	While there is some evidence of expansion of forests northward and up slopes in the eastern Taiga Shield, most changes observed are in structure and species composition of vegetation within 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
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.	No overall trend information. Ponds are increasing in parts of Quebec and Manitoba due to melting of frozen peatlands.

Themes and topics	Key findings: NATIONAL	Key findings: TAIGA SHIELD ECOZONE+
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.	Changes in hydrology on unmanaged streams within the ecozone+ vary. The streams to the west of the ecozone+ are part of the Mackenzie River Basin, which has, overall, experienced climate-related increases in streamflow, (1970-2000) while much of the drainage to the east is to Hudson and James bays, which have experienced no net change in total freshwater input (1964-2010). Major changes in the seasonal flow patterns of several rivers, especially those draining to James Bay, have resulted from dams and diversions, starting in 1973.
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.	Coastlines are along James and Hudson bays, Ungava Bay, and the Atlantic Ocean. Little information on status and trends in coastal ecosystems was found for this report. The Hudson Bay region is undergoing a high rate of isostatic rebound, meaning that new soil and vegetation zones are forming. Eelgrass beds, formerly extensive along the James Bay coast, declined rapidly in the late 1990s, recovering somewhat to 2011.
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.	Not relevant
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.	Frozen peatlands, in the zones of sporadic and discontinuous permafrost in Quebec and Manitoba, are melting fast, with the southern boundary of permafrost landscape features in Quebec having moved north by 130 km in the past approximately 50 years.

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, 7% of the ecozone+ was protected, almost all through provincial and territorial reserves and parks.
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.	Aboriginal peoples make up about 60% of the population of the Taiga Shield, and many follow traditional approaches to stewardship. These approaches vary across cultures and regions but have in common systems based on respect for animals and intimate knowledge of the land.
Ecosystem conversion*	Ecosystem conversion was initially identified as a nationally recurring key finding and information was subsequently compiled and assessed for the Taiga Shield Ecozone+. In the final version of the national report,[3] information related to ecosystem conversion was incorporated into other key findings. This information is maintained as a separate key finding for the Taiga Shield Ecozone+.	The largest land conversion in the Taiga Shield Ecozone+ has been the flooding of land for hydroelectric development in northern Quebec. For the La Grande development, since the 1970s, about 2,000 km^2 of lake area and about 11,000 km^2 of land were converted to reservoir. About 6,000 km^2 of forest was lost due to conversion to reservoir or to land supporting infrastructure. The reservoirs underwent changes in water chemistry, plankton and fish populations, stabilizing after about 10 years. Further land conversion for hydro development is planned.
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.	Limited road access and long, severe winters have kept most invasive species out of the Taiga Shield so far. A few species of birds and plants have been found, mainly near Yellowknife.

* This key finding is not numbered because it does not correspond to a key finding in the national report.[3]

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.	Legacy contaminants in fish in Great Slave Lake are stable or declining, although mercury has increased (1993-2008). Mercury in fish increased 3 to 8-fold following reservoir creation in the La Grande complex, peaking after 5 to 13 years and returning to background levels 10 to 35 years after flooding.
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.	The main anthropogenic source of nutrient addition to freshwater systems has been hydroelectric development, through flooding and reservoir creation.
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.	Not considered to be a concern for this ecozone^{+}
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.	Coverage and distribution of climate trend data are poor for this ecozone^{+}. Temperatures showed increasing trends while precipitation trends were variable; snow cover duration decreased at the 3 stations with measurements. Most obvious ecological impacts are from changes in permafrost in the south and east of the ecozone^{+}, and changes in hydrology. There are indications of other impacts, for example caribou may be affected by the increase in ice content in snow.
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.	Provisioning services are important to cash and non-cash economies in the Taiga Shield and to cultures, nutrition and overall well-being. There are instances of deterioration of provisioning services from severe declines in caribou populations, from environmental changes affecting access to fishing and hunting, from contamination of fish by mercury, and from changes in behaviour of wildlife.

THEME: HABITAT, WILDLIFE, AND ECOSYSTEM PROCESSES		
Intact landscapes and waterscapes[*]	Intact landscapes and waterscapes was initially identified as a nationally recurring key finding and information was subsequently compiled and assessed for the Taiga Shield Ecozone[+]. In the final version of the national report,[3] information related to intact landscapes and waterscapes was incorporated into other key findings. This information is maintained as a separate key finding for the Taiga Shield Ecozone[+].	The Taiga Shield Ecozone[+] is a largely intact system. At the current rate of human activity, habitat changes are site-specific and local. However, their cumulative footprint is increasing.
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.	Most migratory tundra caribou herds are in decline and one herd (Bathurst) has declined severely in the last few years. Three local populations of boreal caribou in Labrador are declining. Other herds and local populations in the ecozone[+] have stable or unknown trends. Some species of waterfowl are in decline in the western Taiga Shield, especially scaup (63% decline since 1970s) and American wigeon, while trends are more stable in the eastern part of the ecozone[+]. There have been northward range shifts in the western Taiga Shield of several species, including white-tailed deer, coyote and wood bison.
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.	Remote sensing shows increased greening, with 36% of the land area showing a significant increase from 1986 to 2006 in NDVI, an index of primary productivity.

[*] This key finding is not numbered because it does not correspond to a key finding in the national report.[3]

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.	The area burned increased from the 1960s until the 1990s and declined in the 2000s. Decadal changes in area burned may be related to large-scale atmospheric oscillations. There is some indication of earlier fire seasons: an increase in May fires from none in the 1960s to 2.4% of fires in the 1990s. Little information was found on insect outbreaks, which are a less significant forest disturbance than fire in this 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.	Population cycles are a strong component of the system. Many species are migratory or at the edges of their ranges, making them vulnerable to pressures in other, more disturbed regions. There is insufficient monitoring to determine trends and to track effects of changes in one group of species on other ecosystem components.
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.	There is little on-the-ground or long-term monitoring of physical systems in the Taiga Shield. The status of a few keystone species (for example, barren ground caribou) is monitored, but little is known about status and trends for most animal and plant species and little is known about resilience to stressors and how many aspects of the ecosystems react to change. Some specific strengths and gaps are identified.
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.	Two instances of rapid change are identified: the precipitous decline in at least one population of migratory tundra caribou and the rapid breakdown of permafrost in peatlands of the eastern Taiga Shield.

THEME: BIOMES

Key finding 1 **Theme** Biomes

Forests

National key finding

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.

Forest-tundra zone

The northern boundary of the Taiga Shield is defined by the treeline – which is not a sharp line where trees end, but rather a zone of transition from increasingly sparse trees to tundra. The emerging picture for this forest-tundra zone is one of change, but not a uniform expansion of treeline.

West of Hudson Bay

The forest-tundra zone averages 145 km in width in the western Taiga Shield.[21] The presence or absence of trees at points within this transition zone depends on microclimate and topography,[22] as well as on past climatic conditions.[23] An analysis of the treeline zone for Canada west of Hudson Bay (including the treeline zone in the Taiga Plains and Taiga Cordillera ecozones+) shows no net increase in conifers, but significant changes in other land cover types (see box below).

East of Hudson Bay

In the Quebec part of the eastern Taiga Shield, trees in the forest-tundra zone have grown faster and taller since the 1970s[24] but distribution of trees has not changed greatly,[25] although white spruce has recently (over the past 50 years) expanded along the east coast of Hudson Bay.[26] In Labrador, treelines have expanded northward and up slopes over the past 50 years along the coast, but not inland.[27]

The forest-tundra zone west of Hudson Bay

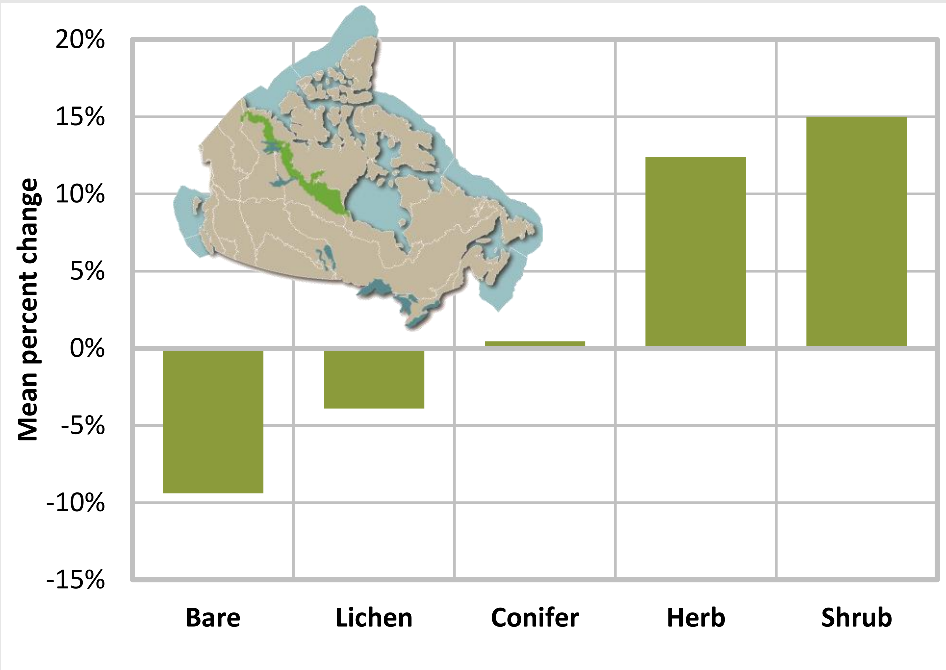


Figure 4: Vegetation changes in the treeline zone, west of Hudson Bay 1985-2006. Mean change over 22 years based on analysis of early spring and summer satellite images. The inset map, adapted from Olthof and Pouliot, 2010,[28] shows the area analysed. Source: data from Olthof and Pouliot, 2010[28]

A study using satellite imagery to look at recent trends along the treeline zone west of Hudson Bay found only a small net increase in tree cover, but major changes in vegetation cover (Figure 4).[28] Tree cover increased in the northern half of the zone, but this was mainly offset by decreases in the southern half. The changes were more pronounced to the west of the Taiga Shield, especially west of the Mackenzie Delta, likely related to drier conditions due to the marked warming trends in these regions.[29] The biggest changes were an increase in shrubs and, in the northwest of the treeline zone, a replacement of lichen cover and bare land with small, non-woody plants (herbs).

Key finding 3 **Theme** Biomes

Wetlands

National key finding

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 roughly 13% of the surface area of the Taiga Shield,[18] and trends in the total wetlands area are unknown. Ponds are increasing in parts of Quebec and Manitoba, and probably elsewhere in the ecozone+ due to melting of frozen peatlands (see Permafrost trends on page 17). This wetland expansion is related to changes in temperature and precipitation patterns. Some reduction of wetlands area has resulted from hydroelectric developments in northern Quebec (see Ecosystem Conversion on page 23).

Among the documented changes associated with hydroelectricity development east of James Bay is a reduction in the area of string bogs (narrow, low ridges with wet depressions or pools) in Quebec's Lake Plateau area. These wetlands provide habitat for shorebirds and bald eagles.[30] Both the James Bay (Quebec)[31] and Churchill River (Newfoundland and Labrador)[32] hydro projects will be expanded in the next few years—including development of two substantial reservoirs and diversion of half the flow of the Rupert River—which is likely to have a further impact on wetlands in the eastern Taiga Shield.

Key finding 4 **Theme** Biomes

Lakes and rivers

National key finding

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.

Changes in hydrology on unmanaged streams within the ecozone+ vary. The streams to the west of the ecozone+ are part of the Mackenzie River Basin, which has, overall, experienced climate-related increases in streamflow, (1970-2000) while much of the drainage to the east is to Hudson and James bays, which have experienced no net change in total freshwater input (1964-2010). Major changes in the seasonal flow patterns of several rivers, especially those draining to James Bay, have resulted from dams and diversions, starting in 1973.

Regional trends

Large-scale trends relevant to the Taiga Shield Ecozone+ are:

Mackenzie River Basin: increase in annual winter flows and in annual minimum flows from 1970 to 2000, and earlier spring peak flows. Flows in early summer and late fall, as well as the annual mean flow, decreased slightly. The trends correlate with warmer winters and springs, less winter snow, and more spring rain.[33]

Hudson Bay watershed: discharge declined from the mid-1960s to the mid-1980s, followed by a period of relatively high flows and an upward trend (Figure 5). It is unclear to what degree these trends are related to climate change and/or decadal climate oscillations.[34] While there was no trend in total discharge over the entire period, streamflow increased in the winter and decreased in the summer from 1964 to 2008. This seasonal shift is attributed to the strong influence of increasing flow regulation in this watershed: water stored in spring and summer is released in the winter for power generation.[34]

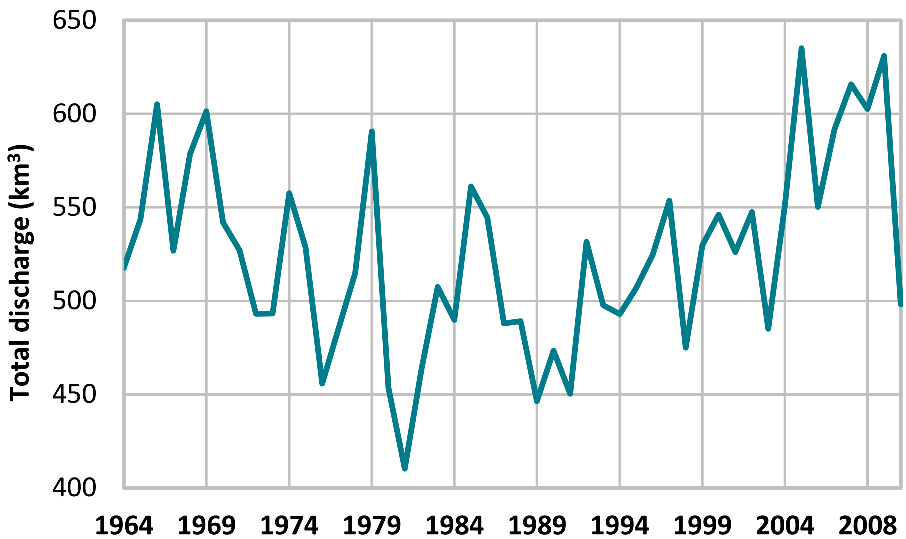


Figure 5: Total annual discharge into Hudson and James bays, 1964-2010.
Total discharge is estimated based on records from 23 rivers, including the regulated La Grande Rivière.
Source: Déry et al., 2011[34] with 2009 and 2010 data provided by S.J. Déry

Trends within the ecozone+: streams with natural flow regimes

This section is based on Canada-wide analyses performed by Cannon et al. 2011[35] for the 2010 Ecosystem Status and Trends Report.

Within both eastern and western parts of the Taiga Shield, hydrometric records are sparse and often too short to detect trends. Only two stations (Camsell River, NWT, and Seal River, Manitoba) – both in the western Taiga Shield – have adequate stream discharge and climate records (1961-2003) to examine trends over the annual cycle.[35] Both of these streams showed significant streamflow increases throughout the year, with the exception of spring (streamflow for Camsell River is shown in Figure 6). These changes could be due to a combination of the increased precipitation coupled with the warmer winters and springs recorded in the vicinity of the streams.[35]

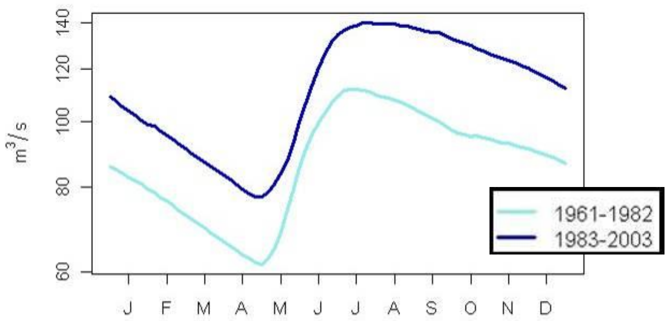


Figure 6: Streamflow change at Camsell River, 1961-1982 compared with 1983-2003. Streamflow was analyzed in 5-day periods, comparing 73 periods over the annual cycle. Source: Cannon et al., 2011[35]

Trends within the ecozone+: streams with managed flow regimes

Several major hydroelectricity developments, mainly in the eastern part of the ecozone+, have altered flow regimes since the 1970s. The La Grande (James Bay) hydroelectric development in Quebec has resulted in dramatic changes to some rivers in the eastern Taiga Shield. The complex was constructed in two phases, the first one during 1973-1985 and the second one during 1987-1996. Three main rivers were diverted into La Grande River: the Eastmain, Opinaca, and Caniapiscau. As a result of these diversions, the mean annual flow of La Grande River at its mouth doubled and its mean winter flow increased more than tenfold.[30]

Main impacts from these diversions include changes to estuarine, coastal and marine systems from the increased under-ice freshwater plume of La Grande River[36] (see Coastal on page 15).

Fishing yields fluctuated after diversions were put in place, but, overall, yields stabilized at levels above or close to those found under natural conditions.[37] In general, fish species composition and growth rates in the reduced-flow rivers were similar before and after the flow reductions.

Changes to fish populations in rivers with altered flow include:

- La Grande River: displacement of species that are not tolerant of cold water – walleye (*Sander viterus*) and cisco (*Coregonus* sp.) – by cold-water tolerant species – round whitefish (*Prosopium cylindraceum*) and brook trout (*Salvelinus fontinalis*).[37] Mean maximum summer water temperatures in the river were lowered from 16°C to 8°C following development.[37]
- Eastmain River: lake sturgeon (*Acipenser fulvescens*) numbers declined, related to flow reduction and habitat fragmentation by weirs.[37, 38] Fishing pressure may also have been a factor in this decline.[37] The James Bay population of lake sturgeon was assessed as being of Special Concern by COSEWIC in 2005, confirmed in 2006,[38] citing declines in habitat and possibly abundance, related to existing and projected hydroelectric development.

Changes affecting fish in the reservoirs are discussed under Dams and reservoirs on page 28.

Key finding 5 **Theme** Biomes

Coastal

National key finding

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.

The eastern Taiga Shield Ecozone+ has coastlines along James and Hudson Bays, Ungava Bay, and the Atlantic Ocean. Little information on status and trends in coastal ecosystems was found for this report. The James and Hudson bays region is undergoing a high rate of isostatic rebound, meaning that new soil and vegetation zones are forming. Eelgrass beds, formerly extensive along the James Bay coast, declined rapidly in the late 1990s, recovering somewhat to 2011. [39]

A severe reduction in eelgrass (*Zostera marina*) along the James Bay coast was reported by Cree residents of the region in 1998; this decline was also detected in monitoring conducted by Hydro Québec.[40] By 2004, monitoring indicated that some recovery had taken place, confirmed by further monitoring in 2009 (Figure 7)[41] and 2011.[39]

Eelgrass beds were among the most extensive in North America, distributed all along the east coast of James Bay, covering 250 km^2, and found at depths of 0.5 to 4 m[42] prior to their rapid decline in density and biomass around 1998 (Figure 7). Eelgrass in James Bay provides shelter for small fish and invertebrates and is important food and habitat for migrating and wintering waterfowl, Canada geese (*Branta canadensis*) and Brant geese (*Branta bernicla*) in particular, and provides foraging areas for Arctic terns.[43-45] Eelgrass distribution and growth are influenced by salinity;[45] low salinity or high temperatures can make eelgrass vulnerable to disease.[43]

Figure 7: Decline of eelgrass in James Bay: example of monitoring results for leaf biomass and shoot density, Kakassituq station, 1988-2009.
Samples were taken at several depths at 6 sites – this figure shows results typical at all depths for 5 of the 6 sites. The 6th site (Dead Duck Bay, the station furthest to the south of the La Grande River mouth) showed no change.
Source: GENIVAR, 2009[41]

Explanations advanced for the decline include:

1. a disease outbreak triggered by unusually high summer and winter temperatures, along with changes in the coast from isostatic rebound and other changes related to a warming climate;[40]
2. impaired growth and survival due to reduced salinity of water in James Bay resulting from larger and more frequent discharges of fresh water via the La Grande River (due to diversions, see Dams and diversions, page 25).[45]

As of 2011, vast eelgrass beds can be seen at various locations along James Bay. Distribution and abundance of eelgrass has not recovered to pre-decline levels, however, and recovery is not uniform along the coast.[39]

Key finding 7 **Theme** Biomes

Ice across biomes

National key finding

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.

Lake ice trends

An analysis of seven large lakes in or at the edges of the ecozone+, between 1970 and 2004, showed variable trends in timing of freeze-up and ice break-up, with few changes being statistically significant.[46] National trends are towards an earlier break-up of lake ice, with less consistent trends in freeze-up timing (1960s or 1970s to 1990s, when most lake ice monitoring was discontinued).[17]

Permafrost trends

Permafrost is thawing at a rapid rate in the eastern Taiga Shield, resulting in a change in the landscape from dry, lichen-heath ecosystems supporting black spruce trees and dotted with ponds to wetter landscapes with ponds, and characterized by fen and bog vegetation.[47-49] As well as altering habitats, these changes affect carbon flux as the thawing of peat and formation of ponds releases carbon to the atmosphere, while the subsequent transition to fen/bog vegetation stores carbon. Permafrost is also degrading in peatlands in northern Manitoba (based on field investigations over the latter half of the 20th century).[50] This trend is likely becoming more widespread in the western Taiga Shield as well, although data are not available.

Broad-scale permafrost distribution in the Taiga Shield Ecozone+ differs between east and west of Hudson Bay, with the east having less extensive permafrost (Figure 8). In the eastern Taiga Shield, the sporadic permafrost zone is characterized by frozen peat plateaus and palsas (mounds of peat or soil containing ice lenses). Formation and degradation of these permafrost landforms are influenced by air temperature and by insulation from snow cover and from peat.[47] When the permafrost is degraded, the resulting melted ice forms ponds (called thermokarst ponds).

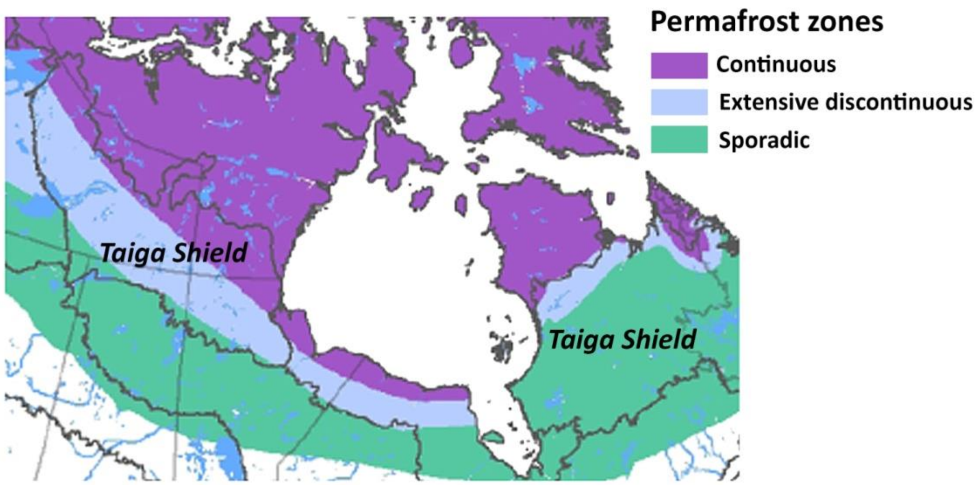


Figure 8: Permafrost distribution, Taiga Shield Ecozone[+].
Source: adapted from Smith, 2011[11]

Three studies in Quebec show the extent of change in permafrost in the past 50 years (summarized in Figure 9).

A. A study mapping palsas and thermokarst ponds along the Boniface River in the discontinuous permafrost zone at the northern edge of the ecozone[+] (site A, Figure 9)[47] found that the area occupied by palsas decreased by 23% between 1957 and 2001, while 76% of present-day thermokarst pond area had formed since 1957. No new palsas developed along the river during this period. Permafrost degradation was most severe close to the river where water fluctuations had a strong influence.

B. A study mapping change in a peatland east of Hudson Bay (site B, Figure 9)[48] found that the area was mainly frozen in 1957, with about 18% of the surface covered in thermokarst ponds. Palsa mounds, being well-drained, supported growth of lichens and black spruce trees. By 2003 only 13% of the surface area remained as permafrost, with the remainder being a mix of thermokarst ponds and fen/bog vegetation (sedges and *Sphagnum* moss). Fen/bog vegetation was virtually absent in 1957 but covered half the study area by 2003. Spruce trees died as the permafrost decayed and their roots became flooded. The annual rate of permafrost degradation approximately doubled in the last decade of the study to -5.3% per year; this acceleration in melt rate was likely related to increasing trends in summer temperatures and precipitation since the mid-1990s.

C. A survey over a broad area of the James Bay region[49] showed that changes documented at the above sites are widespread. The landscape in the zone of sporadic permafrost is in transition from dry, lichen-covered palsas interspersed with ponds to a wetter ecosystem dominated by larger ponds, bogs and fens. The southern limit of permafrost has moved about 130 km north, mainly within about the past 50 years. North of the current permafrost boundary (in the vicinity of "C" on Figure 9), permafrost is in an advanced state of degradation – palsas in bogs observed and surveyed in this region up to 2004 had shrunk or disappeared by 2005.

Lichens, important forage for caribou (*Rangifer tarandus*), are maintained in the James Bay area by periodic fire and by permafrost – both of which create dry micro-environments. If, as seems likely, the permafrost continues to degrade and disappears within a few years, the resulting wetter bog ecosystems will lead to widespread declines in lichen.[49]

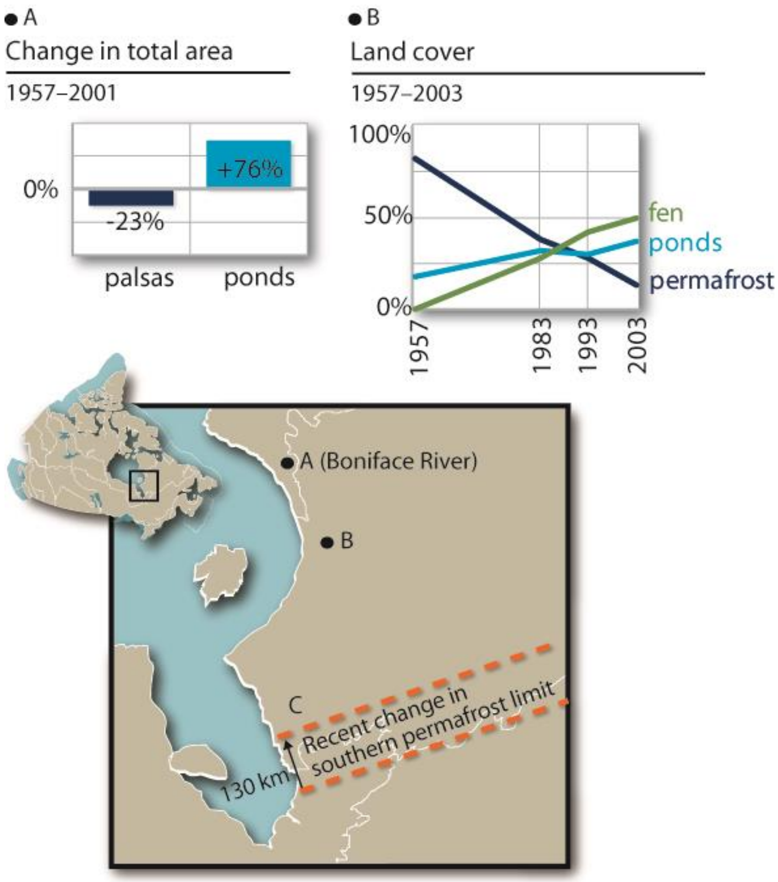


Figure 9: Change in permafrost landforms, thermokarst ponds and extent in permafrost in three studies in northern Quebec.
Studies A and B are based on ground surveys and 1957 air photos.
Study C involved helicopter surveys along two 350 km north-south transects conducted in 2004 and 2005. These were supplemented with ground surveys, defined the northern extent of permafrost by the presence of palsas and the southern extent of thermokarst ponds (the latter indicating the presence of permafrost within about the past 50 years). "C" indicates the approximate location of palsa/thermokarst pond study sites.
Source: Study A. Vallée and Payette, 2007;[47]; Study B. Payette et al., 2004;[48] and Study C. Thibault and Payette, 2009[49]

THEME: HUMAN/ECOSYSTEM INTERACTIONS

Key finding 8 **Theme** Human/ecosystem interactions

Protected areas

National key finding
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.

Prior to 1992 (the signing of the Convention on Biological Diversity), 1.1% of the Taiga Shield Ecozone+ was protected.[1] This was increased to 7.0% of the ecozone+ by May 2009 (Figure 10 and Figure 11), broken down as follows:

- 5.2% (29 protected areas) as IUCN categories I-III. These categories include nature reserves, wilderness areas, and other parks and reserves managed for conservation of ecosystems and natural and cultural features[51]
- 0.5% (three protected areas) as IUCN category V, a category that focuses on sustainable use by established cultural tradition[51]
- 1.4% (five protected areas established since 2005) not classified by IUCN category

[1] Note that there is 6,060 km^2 of protected land in the Taiga Shield Ecozone+ with no information on the year established. If all of this land was protected prior to 1992, then 1.6% of the ecozone+ was protected prior to 1992.

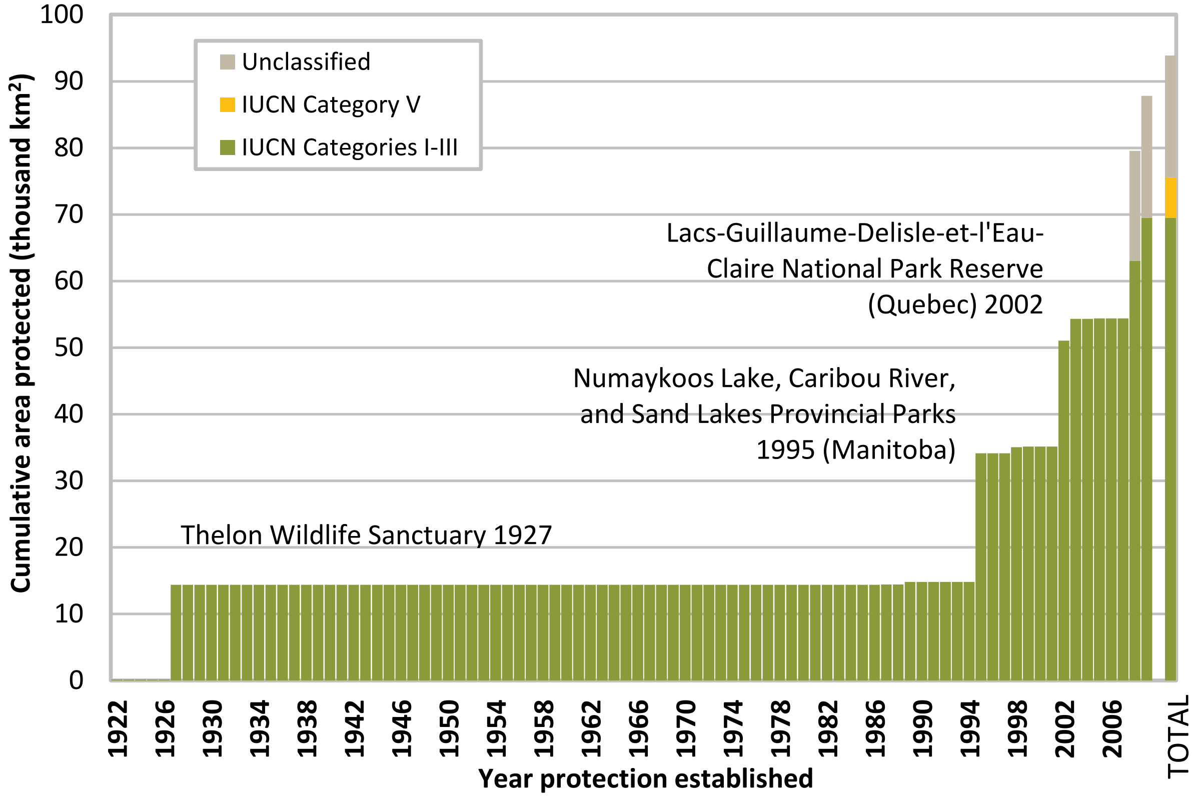


Figure 10: Growth of protected areas, Taiga Shield Ecozone+, 1922-2009.
Data provided by federal, territorial and provincial jurisdictions, updated to May 2009. Only legally protected areas are included. IUCN (International Union for Conservation of Nature) categories of protected areas are based on primary management objectives (see text for more information). There are no Category IV protected areas in the ecozone+. Note: the grey "unclassified" category represents protected areas for which the IUCN category was not provided. The last bar labelled "TOTAL" includes protected areas for which the year established was not provided.
Source: Environment Canada, 2009,[52] data from the Conservation Areas Reporting and Tracking System (CARTS), v.2009.05, 2009[53]

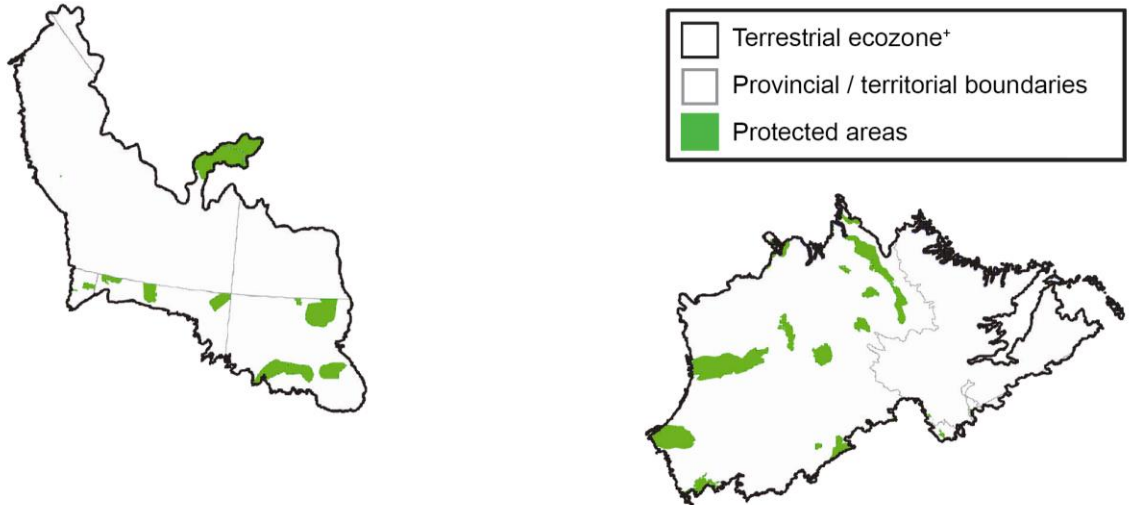


Figure 11: Map of the Taiga Shield Ecozone+ protected areas, May 2009.
Source: Environment Canada, 2009[52]; data from the Conservation Areas Reporting and Tracking System (CARTS), v.2009.05[53]

Key finding 9 **Theme** Human/ecosystem interactions

Stewardship

National key finding
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.

Many Aboriginal people of the Taiga Shield continue to live off the land, in whole or in part, as their ancestors did, and they retain traditional stewardship approaches to the land and wildlife. For example, the Aboriginal peoples of the Taiga Shield observe heightened respect for caribou, a value embedded in spiritual beliefs and customs.[54] Many Dene elders attribute the absence of caribou in some years to a lack of respect shown for the land and animals. Good hunting practices and proper harvesting and preservation of meat are some ways to demonstrate this respect.[54-56]

The Cree have a customary land-tenure system that ensures the continuity of resources vital to the local subsistence economy. Tallymen or "hunting bosses" act as stewards for hunting grounds under their responsibility and oversee both hunting and trapping on those hunting grounds.[57]

Traditional stewardship and science

Traditional approaches to stewardship and the land can occasionally come into conflict with scientific approaches. Many Aboriginal elders consider some contemporary wildlife management techniques, especially capture and handling, disrespectful to the animals.[58-60] For example, 80% of Dene elders involved in a set of interviews disagreed with the practice of tracking caribou with radio-collars.[61]

Theme Human/ecosystem interactions

Ecosystem conversion

Ecosystem conversion was initially identified as a nationally recurring key finding and information was subsequently compiled and assessed for the Taiga Shield Ecozone+. In the final version of the national report,[3] information related to ecosystem conversion was incorporated into other key findings. This information is maintained as a separate key finding for the Taiga Shield Ecozone+.

The largest land conversion in the Taiga Shield Ecozone+ is the flooding of land for hydroelectric development in northern Quebec.

Dams and reservoirs

Churchill Falls in Labrador and the La Grande (James Bay) complex in Quebec have flooded about 14,150 km^2 of land[30], enlarging existing water bodies and creating large reservoirs. The La Grande complex (Figure 12) created eight reservoirs, filled between 1979 and 1993, ranging from 70 to 4,275 km^2 in size. Areas converted from natural lakes to reservoirs, land area flooded, and area deforested (due to reservoirs and infrastructure) are shown in Figure 13. A third project, the Churchill-Nelson development in Manitoba, straddles the Taiga Shield, Hudson Plains, and Boreal Shield ecozones+. Other, smaller hydro projects in the Taiga Shield do not involve reservoirs or river diversions. The majority (88%) of the 177 dams completed in the ecozone+ were built between 1970 and 1990.[17]

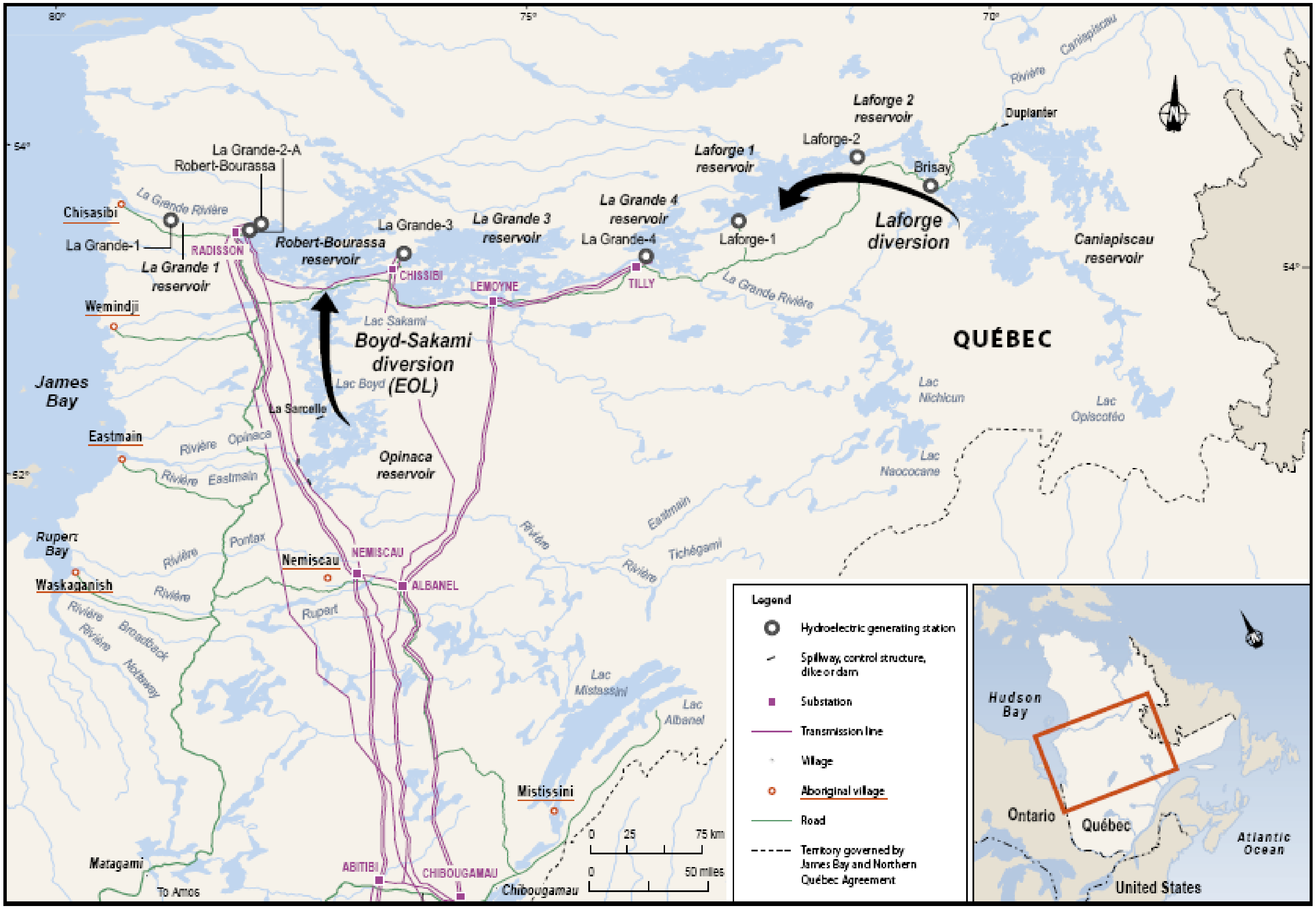


Figure 12: La Grande hydroelectric complex
Source: Hayeur, 2001[30]

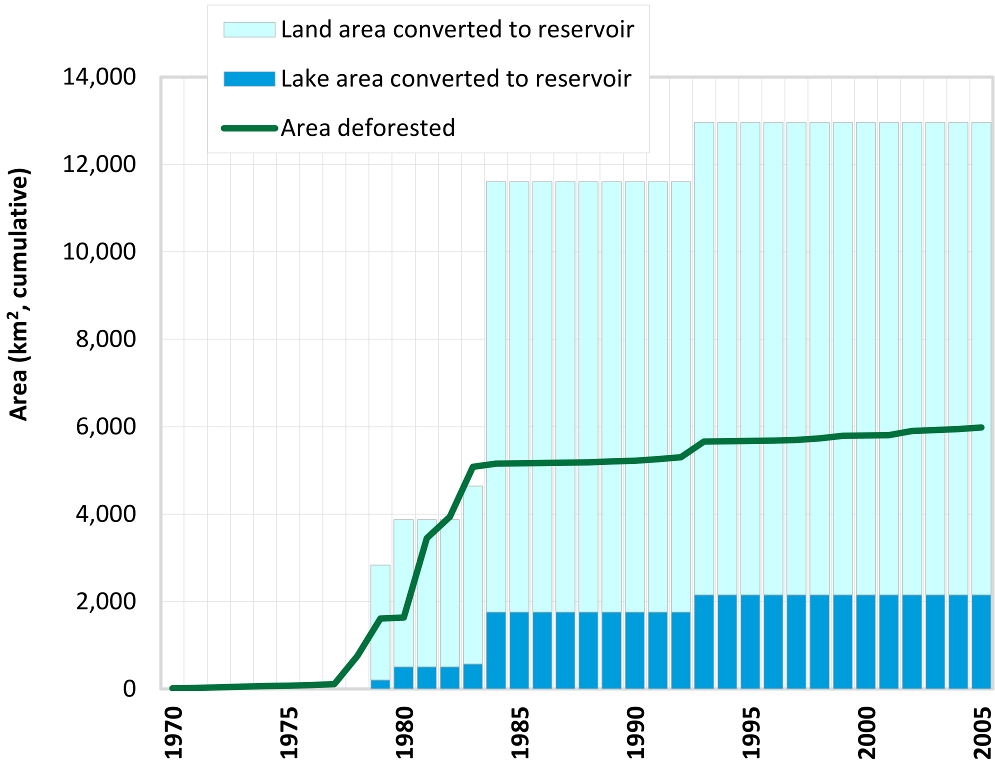


Figure 13: Cumulative area affected by hydro development in La Grande Complex, James Bay, 1970-2005
The total land area flooded is about half the size of Lake Winnipeg, or double the size of Prince Edward Island. Deforested area is land that was covered by trees at least 5 m tall, with a crown closure of 25% before inundation. Landsat imagery and aerial photography were used for the analysis.
Source: CFS deforestation statistics from Leckie et al., 2006;[62] total land area and total lake area converted to reservoir from Hayeur, 2001[30]

Future major projects planned for the eastern Taiga Shield include the Lower Churchill development, with two reservoirs totalling 300 km^2 and associated dams and power lines,[32] and the next phase of the James Bay project, involving diversion of half the annual flow of the Rupert River and construction of a 600 km^2 reservoir.[63]

Ecological change in La Grande project reservoirs

Reservoir creation caused a number of physical changes: rapid increase in water surface area, volume and residence time; change from river to lake conditions in flooded sections of rivers; mixing of waters from different watersheds; changes in flood cycles; changes in freezing and thawing timing; and reduced surface water temperatures.[37]

Models based on data from the reservoirs of the La Grande complex indicate that reservoir creation has a net effect of increasing carbon (CO_2 and methane) emissions to the atmosphere on a long-term basis, mainly due to the increase in the length of time water is stored (an increase of about two years for the Robert-Bourassa reservoir).[64] This increase in storage time increases emissions from organic matter present in the water column. Globally, reservoirs are estimated to account for 4% of anthropogenic CO_2 emissions.[64]

Highlights of results of a comprehensive program of freshwater aquatic ecological monitoring related to the La Grande reservoirs, undertaken by Hydro-Québec, 1977-2000,[30] are presented below.

Water quality

Changes in physical and chemical characteristics of the reservoirs peaked within two to three years of filling, while remaining within ranges favourable to biological productivity (Figure 14). The greatest changes occurred in late winter, under ice, with the formation of deep-water zones with low oxygen. After 9 to 10 years, the main parameters had returned to or approached pre-construction levels in the Opinaca and Robert-Bourassa reservoirs, while this cycle, especially for phosphorus and silica, occurred more slowly in the Caniapiscau reservoir.

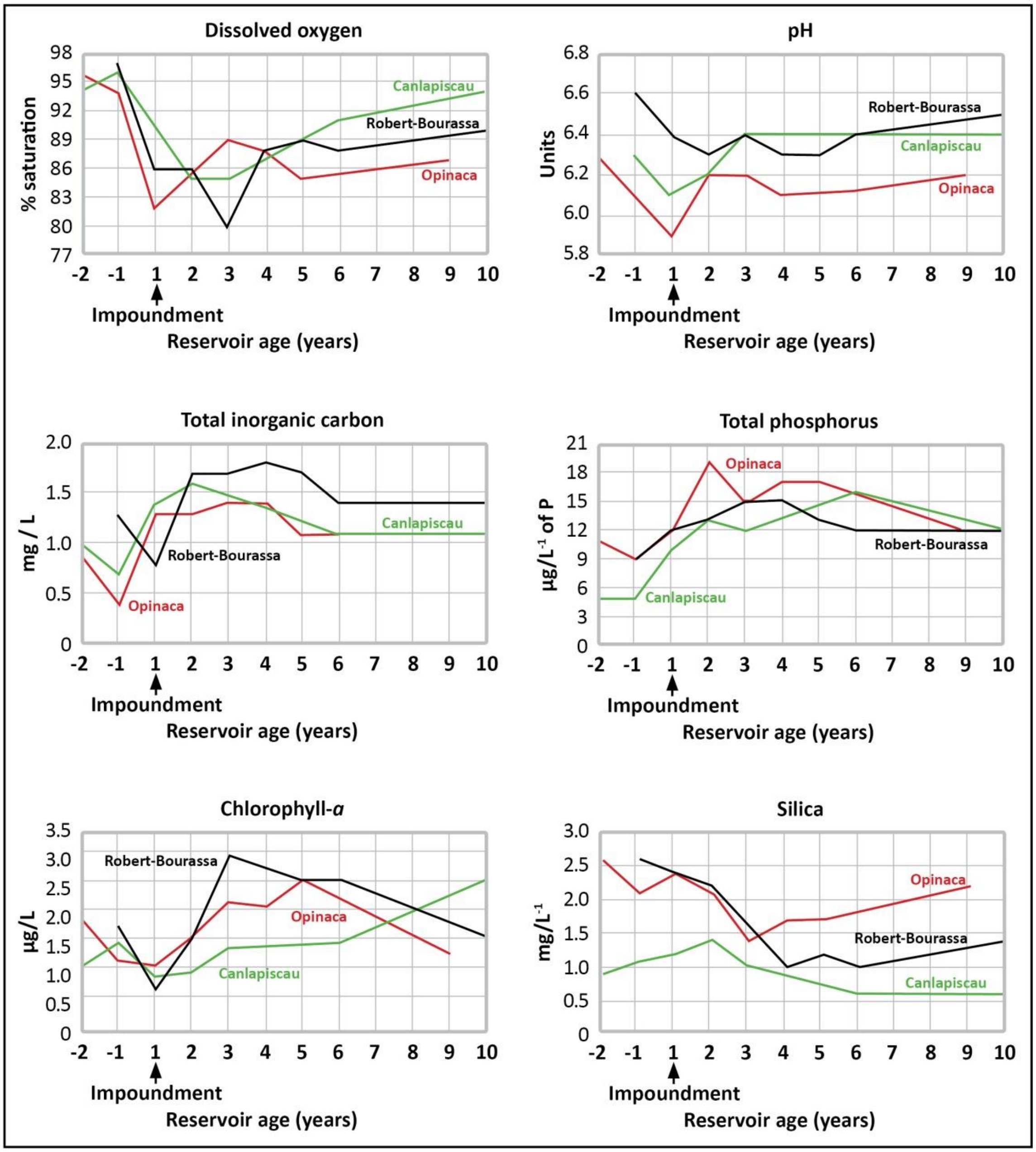


Figure 14: Changes over the first decade of impoundment in water chemistry parameters linked with the decomposition of submerged organic matter, La Grande complex reservoirs.
Measurements are in the zone exposed to sunlight (top about 10 m) during the ice-free period.
Source: Hayeur, 2001[30]

Plankton and benthos

Apart from creating new aquatic environments, the flooding changed planktonic and benthic ecosystems — some on a short-term basis, and some apparently permanently.

- Phytoplankton levels, tracked through measurement of chlorophyll-*a* (Figure 14), rose rapidly from the time of impoundment, then declined and stabilized at levels comparable to natural values. Increases in primary productivity are attributed mainly to the increase in phosphorus.
- Zooplankton abundance and biomass increased in all reservoirs as a result of the increase in nutrients and in organic matter produced by the decomposition of flooded plants (Figure 15). The cycle of change tracked changes in water quality and phytoplankton, with a lag of about a year.
- Benthic communities experienced shifts in species. Diversity declined after impoundment, due to the loss of less mobile species and of species adapted to fast-running water. The reservoirs were rapidly colonized by lake-dwelling species.

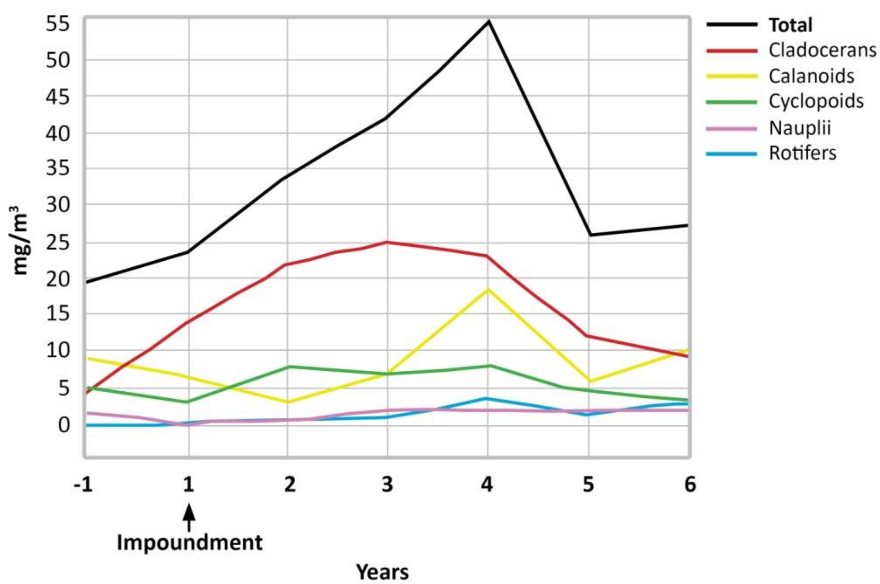


Figure 15: Changes in zooplanktonic biomass: Robert-Bourassa reservoir.
Source: Hayeur, 2001[30]

Fish[37]

Monitoring of fish communities was carried out over a period of more than 20 years, from 1977, two years before the creation of the first reservoir, to 2000, and included monitoring of unaltered lakes as control sites. The general pattern of change was an increase in total fishing yields followed by a gradual return, after about a dozen years, to values comparable to pre-construction. Total fishing yield dropped quickly after impoundment, followed by a rapid increase as the added nutrients during the period of decomposition of flooded plant material influenced food webs (Figure 16).

Some shifts occurred in species composition. Lake whitefish (*Coregonus clupeaformis*), the dominant species in all reservoirs, increased in abundance. Northern pike (*Esox lucius*) also thrived and increased in abundance in some reservoirs. Recruitment was poor in lake trout (*Salvelinus namaycush*), likely because of winter drawdown (low water levels). In the Robert-

Bourassa reservoir, 17 years after impoundment, there were relatively fewer suckers (*Catostomus commersonii*) and walleye and more pike, whitefish, and burbot (*Lota lota*) (Figure 17).

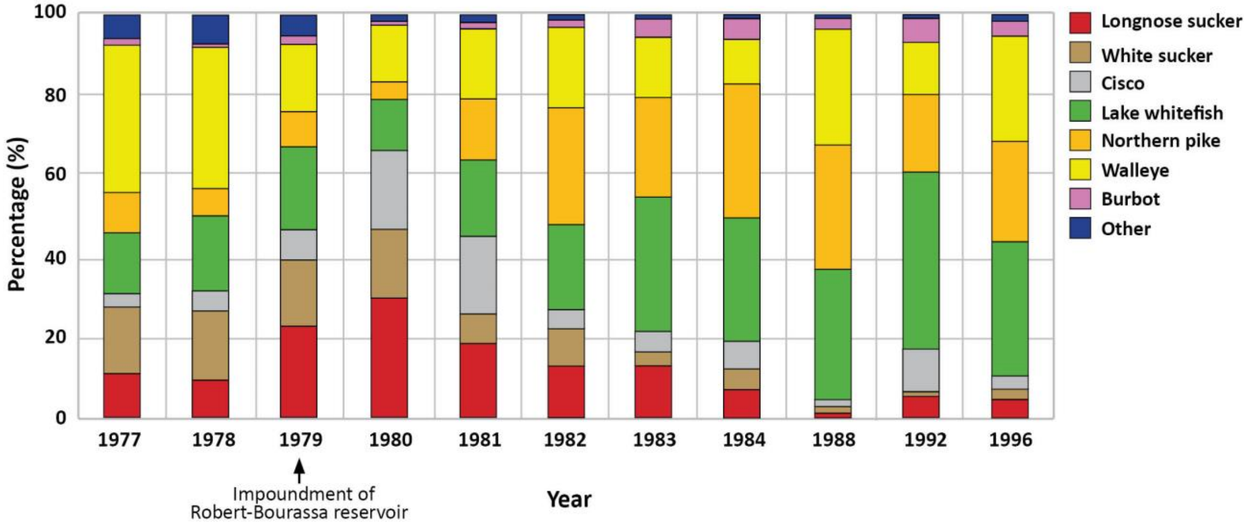


Figure 16: Relative abundance of fish caught in Robert-Bourassa reservoir, 1977-1996.
Source: Therrien et al., 2004[37]

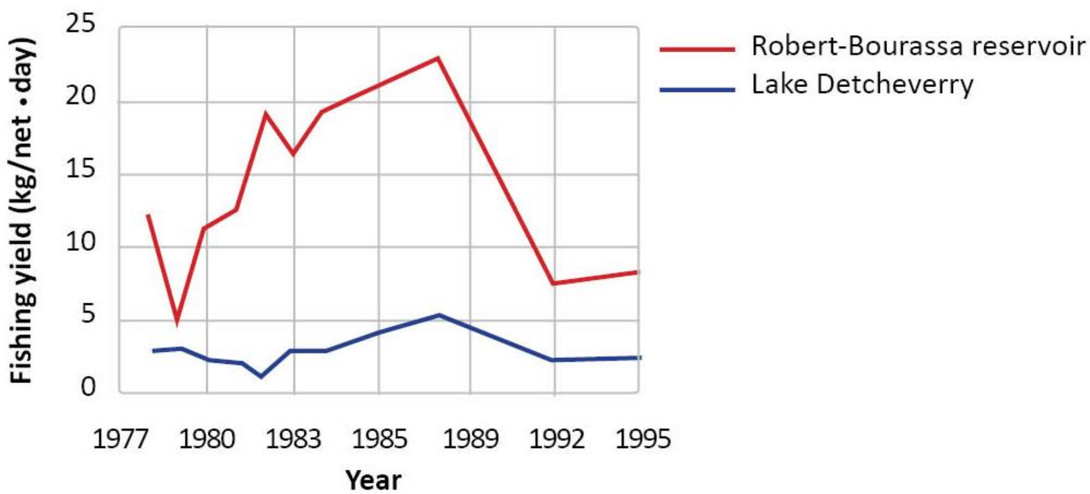


Figure 17: Fishing yields in Robert-Bourassa reservoir, 1977-1995.
Fishing yield data from Lake Detcheverry, a natural lake, are shown for comparison.
Source: Therrien et al., 2004[37]

Key finding 10 **Theme** Human/ecosystem interactions

Invasive non-native species

National key finding

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.

Invasive species are still rare in the Taiga Shield. Lack of roads limits access for many species, and the severe environment may limit the survival of some species. Those species associated with human settlements, such as European house sparrows (*Passer domesticus*), are uncommon, but exist in the western Taiga Shield (in Yellowknife, NWT). Invasive non-native plants are mostly associated with roads and other anthropogenic disturbances. A 2006 roadside survey in the western Taiga Shield[65] found 39 species of non-native vascular plants, including species with known invasive potential in Canada.[66]

The Taiga Shield's aquatic ecology may be especially vulnerable to invasive species since it has relatively few species. The distribution of fish species such as smallmouth bass (*Micropterus dolomieu*), a predatory species that is known to alter species assemblages, is shifting northwards in eastern North America due to warming temperatures.[67] Arctic char (*Salvelinus alpinus*) and rainbow trout (*Oncorhynchus mykiss*) were introduced near Yellowknife, NWT, as recently as 1990 to enhance recreational fishing,[68] but these species have not spread.[69]

A few exotic forest pests have been introduced to the western Taiga Shield.[70] These include the larch sawfly (*Pristiphora erichsonii*), birch leaf edgeminer (*Scolioneura betuleti*), and the amber-marked birch leafminer (*Profenusa thomsoni*). Larch sawfly has been attacking tamarack stands since the late 1960s. Both birch leaf miner species were recently (1994-2003) found in the western Taiga Shield and commonly exist near communities. The amber-marked birch leafminer is now abundant in Yellowknife, extending into the surrounding wild birch stands, mostly along roads.

Key finding 11 **Theme** Human/ecosystem interactions

Contaminants

National key finding

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.

Most contaminants in this ecozone+ are legacy contaminants, transported from long distances away and deposited on snow and vegetation. From there, they make their way into the food chain. Some heavy metals that are considered contaminants if they reach high levels, such as cadmium, are contained in the regional geology. Mercury has three sources in the Taiga Shield Ecozone+: 1) like cadmium, it is found naturally in the environment; 2) it is a component of industrial emissions around the world and is transported to the region through the atmosphere; 3) mercury in the environment becomes more biologically available in freshwater ecosystems through the flooding of land to create reservoirs.

Caribou

The Northern Contaminants Program has monitored persistent organic pollutants (POPs) and heavy metals for the last two decades, including in several caribou herds that range into the Taiga Shield Ecozone+.[71]

POPs such as dichlorodiphenyltrichloroethane (DDT), polychlorinated biphenyls (PCBs), dioxins, and furans, were found at very low levels in barren ground caribou and are not of concern for the health of either caribou or humans who eat caribou. Compared to other herds, cadmium levels are relatively high in the kidneys and livers of Beverly caribou, which range into the Taiga Shield in fall and winter. The probable source is cadmium from the underlying rocks, which accumulates in lichen and is then eaten by caribou. Mercury levels are changing over time in some herds across the country, but results are as yet inconclusive. Monitoring will continue through the Northern Contaminants Program on selected herds to track mercury trends from industrial sources and the degree to which mercury becomes incorporated into terrestrial food chains.

Fish

Contaminants move into the aquatic system as well and become concentrated in higher-level predators such as some species of fish. Mercury is increasing significantly for burbot and lake trout caught in the West Basin and burbot caught in the East Arm of Great Slave Lake, while the trend is not significant for East Arm lake trout (Figure 18). Comparison of these results with analysis of mercury in fish from smaller lakes in the Taiga Plains Ecozone+ indicates that the rates of mercury increase are more pronounced in small, shallow lakes than in Great Slave Lake.[72] There is no clear relationship between increases in mercury in fish in the Great Slave Lake area and climate metrics such as mean air temperature and precipitation. The most recent increases in mercury may be related to increasing global industrial mercury emissions. In Asia, for example, mercury-emitting industrial activities such as coal-fired power plants and steel production are increasing, a trend that is likely to continue in coming decades.[73]

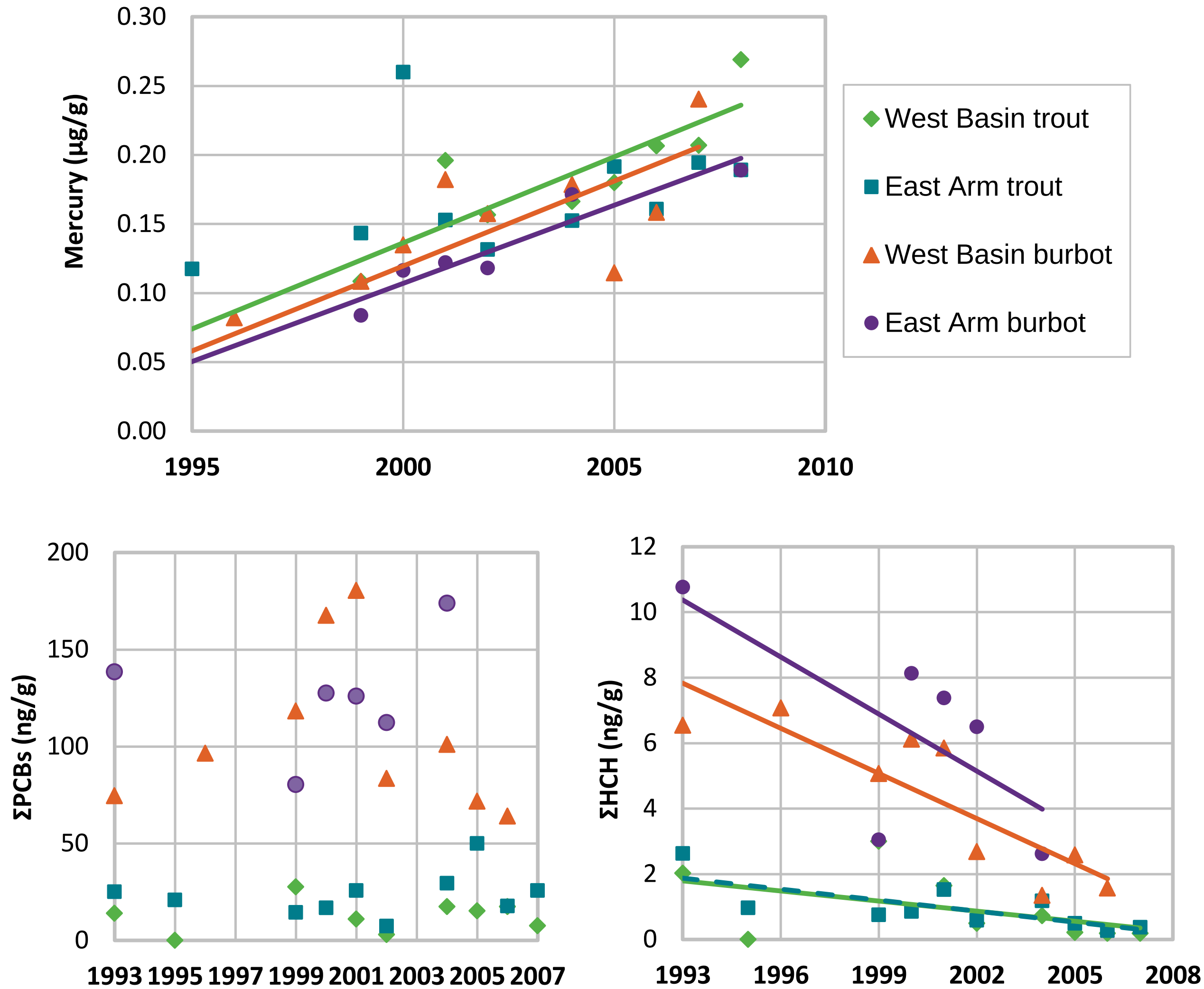


Figure 18: Trends in mercury, PCBs, and HCH for Great Slave Lake, 1993-2008.
The East Arm of Great Slave Lake is in the Taiga Shield Ecozone+. Samples were collected in the Lutsel K'e area. The West Basin of the lake is in the Taiga Plains Ecozone+. Samples were collected in the Hay River area (lake trout) and Slave River outflow (burbot). Lines show significant trends ($p<0.05$). PCBs show no significant trends.
Source: Evans, 2009[72]

Legacy POPs are unchanged or declining in Great Slave Lake fish. PCB and DDT trends were unchanged from 1992-2007, while hexachlorocyclohexane (HCH) decreased significantly in three of the four sample groups (Figure 18). Changes in lake ecology and fish trophic structure in Great Slave Lake may either be accentuating or masking trends in contaminants. For example, organic contaminants accumulate more in fatty tissues and the lake trout fat levels have decreased in recent years, which may be related to changes in the relative numbers of different species in the lake or to other changes in lake ecology.[72]

A study of Mackenzie River burbot[74] concluded that increasing trends in mercury and PCBs may be related to increased productivity in the aquatic environment due to climate change. Contaminants may move more readily into the food web under conditions of higher productivity. The picture may be further complicated by changes in forest fire regime. Kelly et al., 2006[75] in a study in the Jasper, Alberta area, demonstrated that fish from lakes with recent forest fires in their catchment areas had elevated levels of mercury. This was attributed both to increases in mercury input to the lakes and to increases of nutrients that enhanced productivity and altered food webs.

Mercury in fish affected by reservoirs

When new reservoirs are created, the flooded vegetation decomposes, increasing the mercury load, creating low-oxygen conditions and increasing the carbon source for bacteria that convert inorganic mercury to methylmercury – which is then taken up by aquatic organisms, including plankton, insects, and fish. Creation of a reservoir typically leads to a rapid increase in mercury in the food chain, followed by a slower reduction in methylmercury as the store of flooded, rotting vegetation is depleted.[76]

In the James Bay region in the eastern Taiga Shield, the La Grande hydroelectric development affected mercury levels in the associated rivers and wetlands. Mercury levels in fish at the La Grande complex have been monitored since the late 1970s.[77] All La Grande reservoirs show the same pattern of increase and subsequent decrease in fish mercury levels (Figure 19). Concentrations of mercury in fish usually peak between 5 to 13 years after flooding. Peak levels range from to three- to eight-fold increases compared to background levels. Mercury concentrations then gradually decline, 10 to 35 years after flooding, to the range of concentrations measured in natural lakes of the area. The broad time ranges reflect different species, different trophic levels (Table 3), and differing reservoir characteristics. Northern pike, as top predators, acquire the highest levels of mercury and take longest to return to background levels.

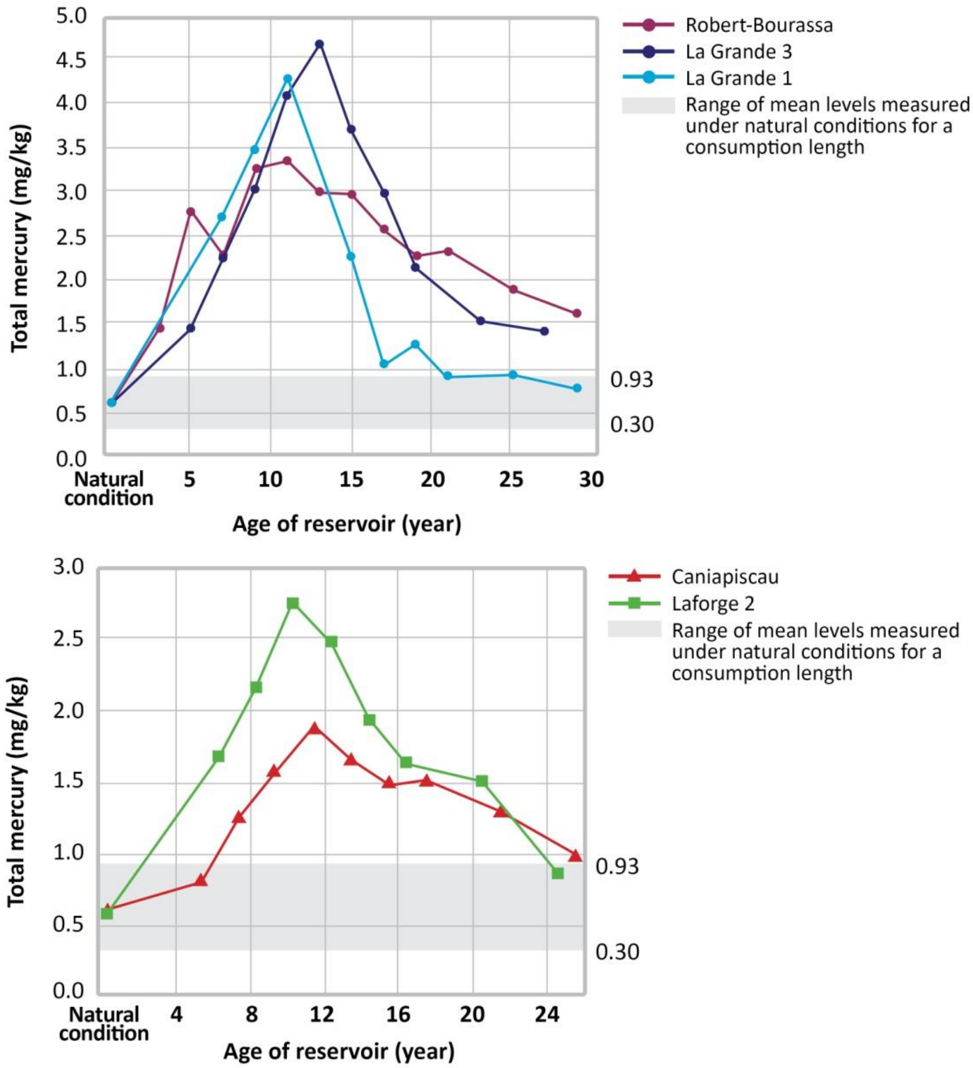


Figure 19. Mercury in northern pike in reservoirs of the La Grande complex, 0 to 29 years following impoundment.
Size class is 700 mm length. Note that the mercury limit for the market of fish is 0.5 mg/kg.
Dates of flooding (beginning of filling period): Robert-Bourassa-1978, La Grande 3-1981, La Grande 1-1993, Caiapiscau-1981, and Laforge 2-1983.
Source: updated from Schetagne et al., 2003[77] *based on data provided by Hydro-Québec*

Table 3: Rise and fall of mercury levels in fish of different trophic levels, La Grande complex

Increasing trophic level	Species	Peak mercury levels	Timing of peak	Return to background
↓	Non-fish-eating (longnose sucker and lake whitefish)	0.3-0.7 mg/kg (3 to 6 times background levels)	5 to 10 years after flooding	10 to 20 years after flooding
	Fish-eating (walleye and lake trout)	2.4-3.1 mg/kg (4 to 6 times background levels)	10 years after flooding	20 to 30 years after flooding
	Northern pike (fish-eating and, in some reservoirs, consuming other fish-eating fish)	1.9-4.7 mg/kg (3 to 8 times background levels)	10 to 13 years after flooding	20 years to (projected) 35 years after flooding

Source: Therrien and Schetagne, 2008, 2009[78-80]

The increases in mercury from impoundment and flooding of land affected streams and lakes downstream of the reservoirs. Mercury was transported downstream mainly dissolved in the water and in suspended particulate matter, but also in plankton.[81] Mercury from flooded soils was taken up by plankton in the reservoirs, a process that was enhanced by the high levels of carbon and nutrients released from decomposing flooded plants.[82] The main route of mercury transfer into downstream fish was through zooplankton drifting down from the impounded waters.[81] Lake whitefish caught in Cambrien Lake, 275 km downstream from the Caniapiscau reservoir, had elevated mercury levels but there was no effect on fish caught 355 km below the reservoir.[81] Mercury returned to pre-development levels in Cambrien Lake whitefish 10 years after impoundment.

Key finding 12 **Theme** Human/ecosystem interactions

Nutrient loading and algal blooms

National key finding

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.

The main anthropogenic source of nutrient addition to freshwater systems in the Taiga Shield Ecozone+ has been hydroelectric development, through flooding and reservoir creation. This is discussed under Dams and reservoirs on page 23.

Key finding 14 **Theme** Human/ecosystem interactions

Climate change

National key finding

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.

Coverage and distribution of climate trend data are poor for this ecozone+. Temperatures increased whereas precipitation was variable; snow cover duration decreased at the three stations with measurements.[7] Most obvious ecological impacts are from changes in permafrost in the south and east of the ecozone+, and changes in hydrology. There are indications of other impacts, for example caribou may be affected by the increase in ice content in snow (see box on page 41).

Climate change will have wide-ranging impacts on the Taiga Shield, because climate is a strong driver of the region's ecological structure and processes. However, with little current monitoring within the ecozone+, most impact projections for the Taiga Shield are based on data collected elsewhere. The land cover is mainly boreal forest and forest tundra. Boreal forest ecosystems and fire regimes are projected to change as trends in climate alter vegetation or fuels, lightning, and fire severity. Climate change will likely reduce the area of boreal forest and increase fragmentation.[83] Warmer temperatures could also introduce new pests and wildlife diseases.

Climate trends

Increasing temperatures and shorter duration of snow cover are the most pronounced trends observed at climate stations in the Taiga Shield Ecozone+ (Table 4).

Table 4: Overview of climate trends for Canada and for the Taiga Shield Ecozone$^+$, 1950-2007

Climate variable	Trends since 1950	Representativeness of trends
Temperature	Canada: annual mean temperatures have increased more (>2°C) in northern and northwestern Canada and less (<1°C) in eastern Canada. Taiga Shield: annual mean temperatures generally increased; Yellowknife and Kuujjuarapik (on the coast of Hudson Bay) showed significant increases of >1.5°C. Seasonal trends are shown in Figure 20.	The Taiga Shield Ecozone$^+$ includes two distinct climate regions either side of Hudson Bay with a poor distribution of stations for computing an ecozone$^+$ average. There are few stations in the western Taiga Shield and those east of Hudson Bay are mainly coastal. Trends are thus described for specific locations.
Precipitation	Canada: total annual precipitation has generally increased, though there are few individual stations with significant trends. Taiga Shield: total annual precipitation changed little at most stations – Fort Reliance being the exception, with a significant increase. Seasonal trends were quite variable – predominantly increasing, but included significant decreases at some seasons at two stations in Labrador (Figure 21).	
Snow	Canada: the duration of snow cover showed the most pronounced decreases in the spring, especially in western and northern stations. Taiga Shield: significant decreases in snow cover duration (1950-2006) occurred in the spring (February-June), at the three stations with sufficient data for analysis: ● Yellowknife (11 days) ● Kuujjuarapik (13 days) ● Kuujjuaq (36 days)	

This table presents highlights of an analysis of Canadian climate records, checked and corrected for sources of systematic error and excluding stations with strong urban warming effects.
Source: Zhang et al., 2011[7] and data provided by the authors

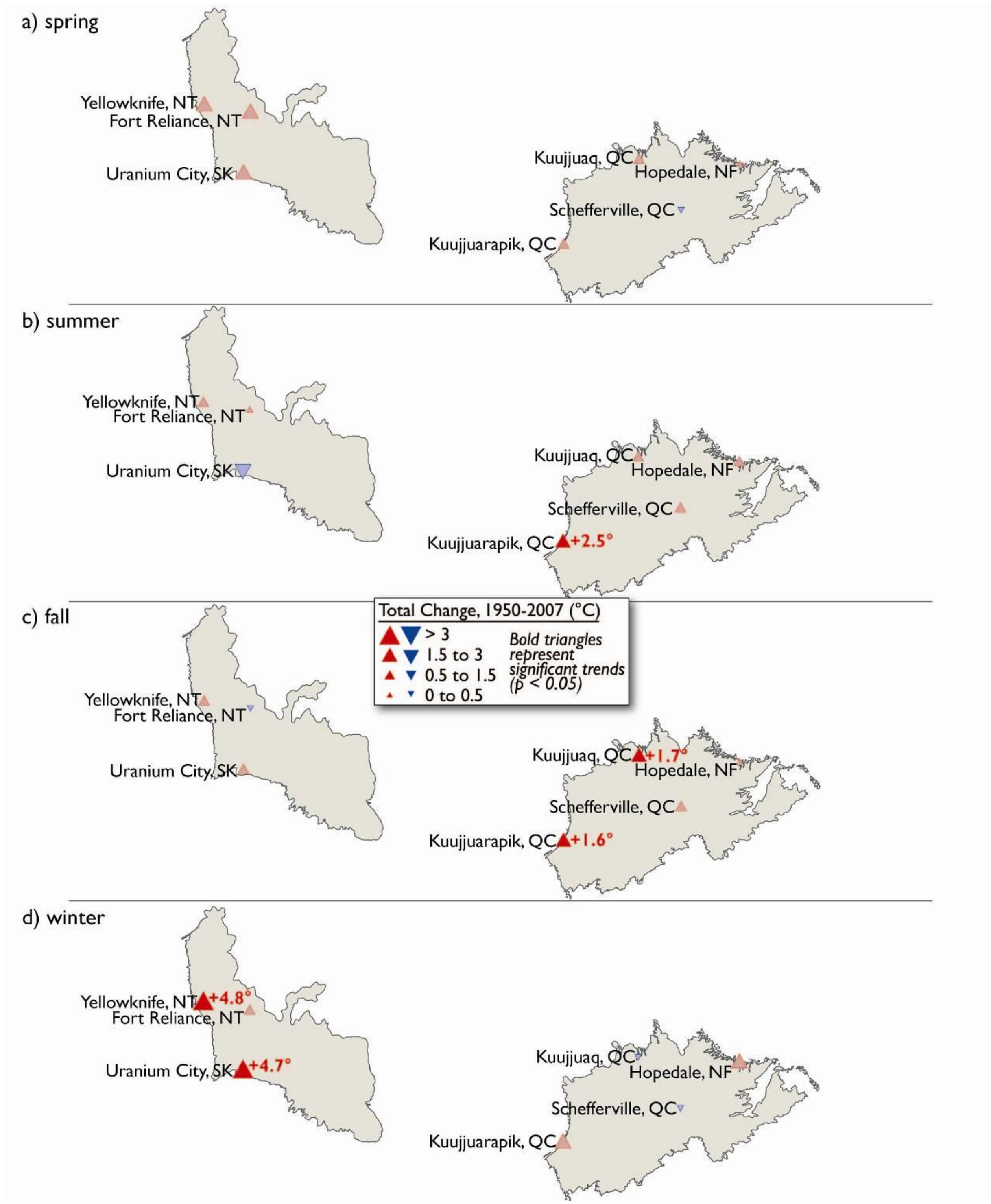


Figure 20: Trends in temperature by season, 1950-2007.
Total change in temperature over the 58-year time period is indicated for sites for which the trend is statistically significant. Season definitions – spring: March-May; summer: June-August; fall: September-November; winter: December-February.
Source: Zhang et al., 2011[7]

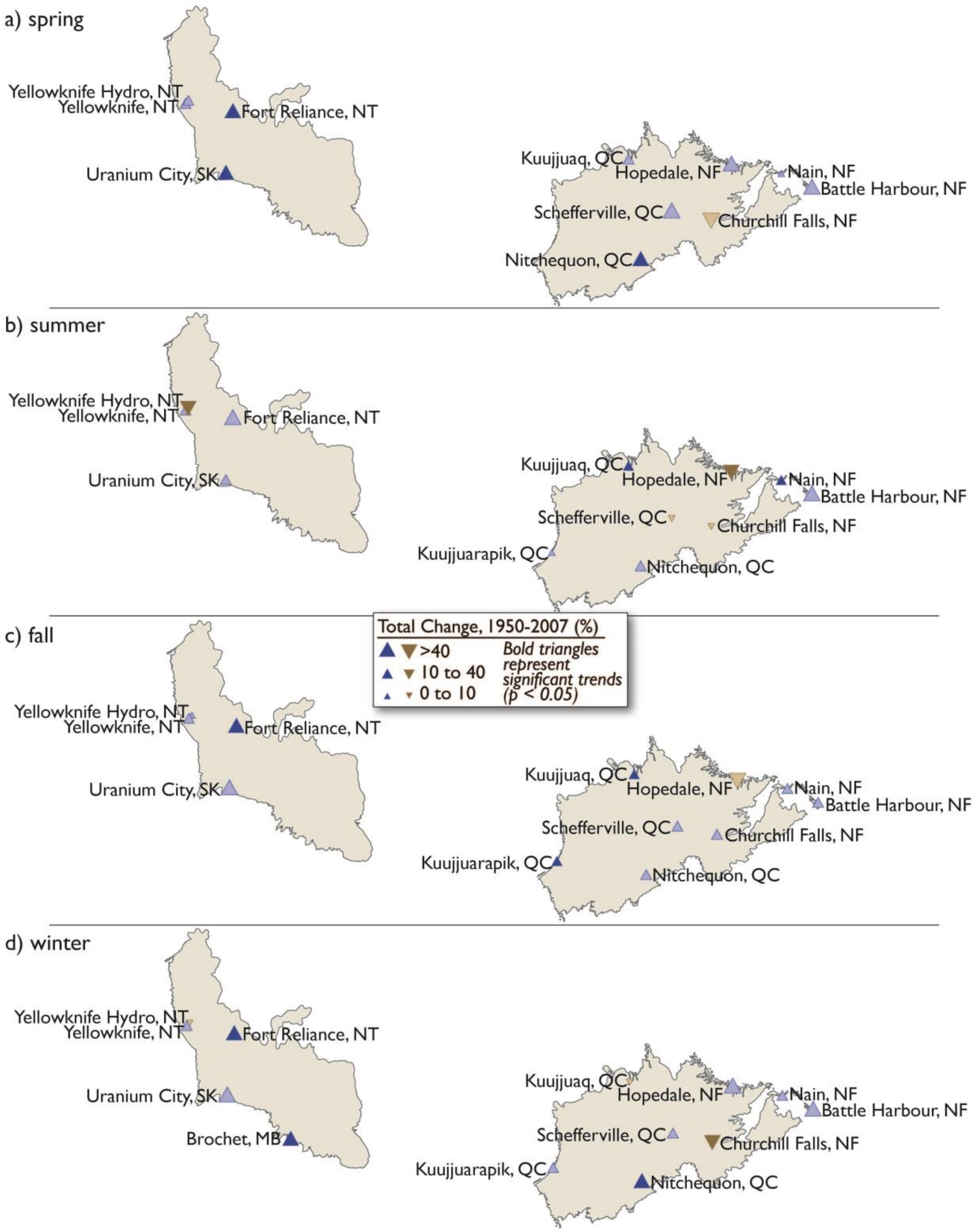


Figure 21: Change in the amount of precipitation, 1950-2007 by season.
Change is expressed as a percentage of the 1961-1990 mean. Season definitions – spring: March-May; summer: June-August; fall: September-November; winter: December-February.
Source: Zhang et al., 2011[7]

Aboriginal knowledge of climate trends

Aboriginal people recognize the trends in increasing temperatures and note that temperatures are more variable and less predictable than in the past.[84] Regional differences are also apparent and highlight how much climate trends vary at local scales. Some specific observations of climate-related change related to winds in the Taiga Shield:

- Winds are stronger and change direction more frequently (Lutsel K'e[54]).
- The strongest winds are coming later in the fall (Nunutsiavut[85]).
- From the mid-1980s to the mid 1990s, April and May winds blew mostly from the north, reducing the size of Canada goose flocks, slowing spring melt, and contributing to spring and summer cooling trends in eastern Hudson Bay.[86]

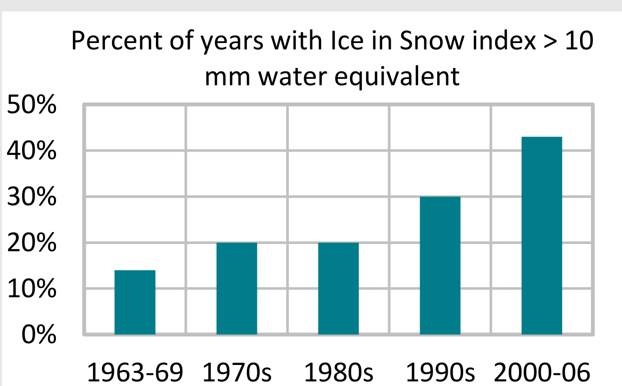
Aboriginal knowledge describes a decline in rainfall in some regions (Northern Saskatchewan, 2006,[87] Nunutsiavut, 2007,[85] James Bay, 2008[88]).

A suite of similar changes in snowfall has been reported for several regions of the eastern Taiga Shield. Snow arrives later in the season and typically there is less of it. Heavy snowfalls are rare, and the snow melts more rapidly, leading to less accumulation, possibly because of increased winds (Nunutsiavut, 2007,[85] Hudson and James Bay regions, 2007-2008[88, 89]).

Climate trends and caribou habitat: Bathurst caribou winter range

The Bathurst Caribou Herd's winter range is in the western Taiga Shield. The 2009 calving ground census for the herd indicates a severe recent population decline (Figure 27), the causes of which are not known. A study of ecological change related to the herd's winter and pre-calving migration conditions found changes in two important climate-related habitat indicators.

1. Caribou tend to move quickly through or avoid areas of recent burns which have low lichen abundance.[90, 91] The extent of mature (older than 50 years) forest declined significantly on the winter range since 1959, due to increased fire, which was in turn positively correlated with summer (June-September) temperature increases. Analysis is based on data from the large fire database presented under Fire trends on page 59, combined with analysis of satellite imagery and of climate records.
2. Caribou dig holes in the snow to access lichens in the winter and adverse snow conditions result in them using up more energy – resulting in changes to body condition, calf survival the following spring, or, in extreme cases, resulting in starvation.[92, 93] Accessibility of lichens in winter for the Bathurst caribou may have deteriorated because the snow has become harder. Ice content in snow, estimated from climate and snow data, increased significantly from 1963-2006. The ice was mainly (90%) from freeze-thaw cycles in spring, with rain-on-snow events accounting for, on average, 10% of the ice content. Researchers have suggested a threshold value for major impacts on caribou of approximately 10 mm water equivalent of ice content in snow.[94] Figure 22 shows the increasing trend in the percent of years in which snow hardness exceeded this threshold. The observation of increasingly "hard" snow or icy crust in the snowpack corresponds with Aboriginal Traditional Knowledge on the subject, as well as with projections of global climate change models.



Bathurst caribou late winter
Photo: A. Gunn, CARMA

Figure 22: Trend in years with high ice content in snow, Bathurst Caribou Herd winter range, 1963-2006.
Ice content in snow (ICIS) is estimated from climate and snow depth data (based on analysis of data to detect conditions that produce layers of ice in snow). ICIS values are based on an average of four climate stations: Yellowknife, Fort Reliance, Rae Lakesand Uranium City. Source: based on Chen et al., In prep.[95]

Key finding 15 **Theme** Human/ecosystem interactions

Ecosystem services

National key finding

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.

Historically, the ecosystem services of the Taiga Shield Ecozone+ supported Aboriginal people, and traditional/country foods and resources remain important, especially in medium and small size communities (Figure 23). Many non-Aboriginal residents also make extensive use of country foods. There are regional and cultural variations. For example, geese account for as much as a quarter of wild meat consumption for the James Bay Cree,[57, 96, 97] while barren ground caribou are important traditional food for the Dene and Innu.[54, 84, 98, 99] Fish are also an important traditional food throughout the ecozone+. Other traditional and contemporary uses of plants and animals include medicines[100] and crafts.[101]

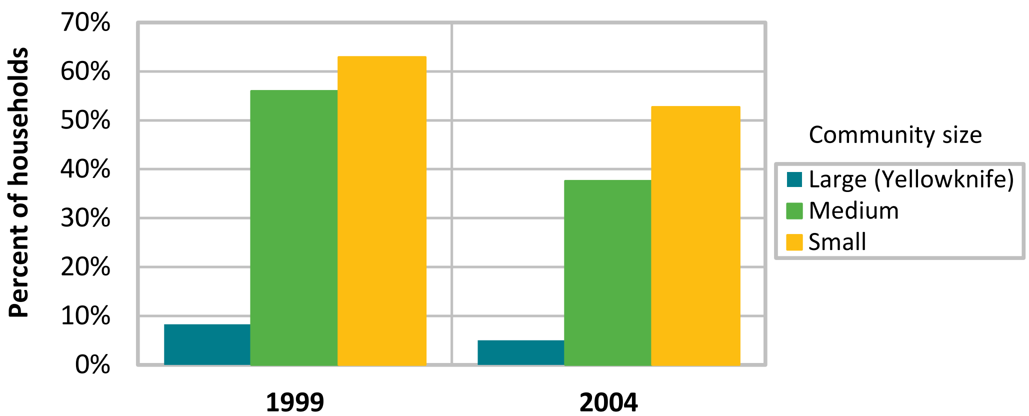


Figure 23: Proportion of households consuming traditional/country foods, 1999 and 2004, NWT communities in the Taiga Shield Ecozone+.
Percent of households reporting that more than 75% of their meat and fish was harvested from the NWT. Communities surveyed: Behchokò (Rae-Edzo), Detah, Gamètì (Rae Lakes), Lutselk'e, Wekweètì, Yellowknife.
Source: data from NWT Bureau of Statistics and 2004 NWT Regional Employment and Harvesting Survey, reported in Northwest Territories Environment and Natural Resources, 2009[69]

Changes in availability of traditional/country foods

Maintaining strong populations of targeted species is not enough to ensure ongoing supply and access to traditional/country foods. Socio-economic factors are important, as are a range of ecosystem characteristics. The examples below illustrate some categories of threats to the ongoing provision of ecosystem goods and services in the Taiga Shield Ecozone+.

Animal population declines

In the western Taiga Shield, barren ground caribou herds have been in decline since the mid-1990s and the Bathurst Herd in particular (which winters in the western Taiga Shield) has declined severely in the past few years (see Migratory tundra caribou on page 47). This has resulted in the implementation of emergency management measures that directly affect hunting in the ecozone+.

Environmental change affecting access to hunting and fishing areas

Trail networks linking communities and harvesting areas in regions with no roads provide access to hunting and fishing areas. Climate change in northern Quebec has affected timing and security of access to local environments and to key food resources along these traditional trail networks.[102]

Deterioration in quality or safety of foods

Contaminants from long-range atmospheric transport (see Contaminants on page 30) present ongoing concerns about food safety across the ecozone+. In the James Bay region, Aboriginal communities were affected by the increases in mercury from the reservoirs of the La Grande complex (see Mercury in fish affected by reservoirs on page 33). Mercury in the Cree population increased to levels of concern, then declined as the levels in fish went down and as people changed their traditional fishing patterns and reduced their consumption of fish.[103] Contaminant-related health advisories have impacts on local economies, nutrition and on social and mental well-being. The threat of harm from a traditional food sources leads to pervasive and persistent anxiety and social effects.[104]

Changes in wildlife

Although the populations of Canada geese have increased since the mid-1990s in the eastern Taiga Shield,[105] hunting success has declined among the James Bay Cree.[106] Hunters say[106, 107] that a number of behavioural changes in both geese and hunters are causing this problem – for example: goose migratory patterns have changed; geese fly higher and the migration period is shorter; geese have changed their migration route, going further inland than they used to. Hunters relate these observations to a range of causes, such as changes in weather patterns, reduction of eelgrass, impacts from hydroelectric development, and changes in hunting practices. Some changes in hunting practices are in turn linked to environmental change. Traditional hunting relies on rotating use of many hunting sites to minimize disturbance to the migrating geese, but in some places environmental change has led to fewer hunting sites being used (Figure 24), reducing the success of the hunt.

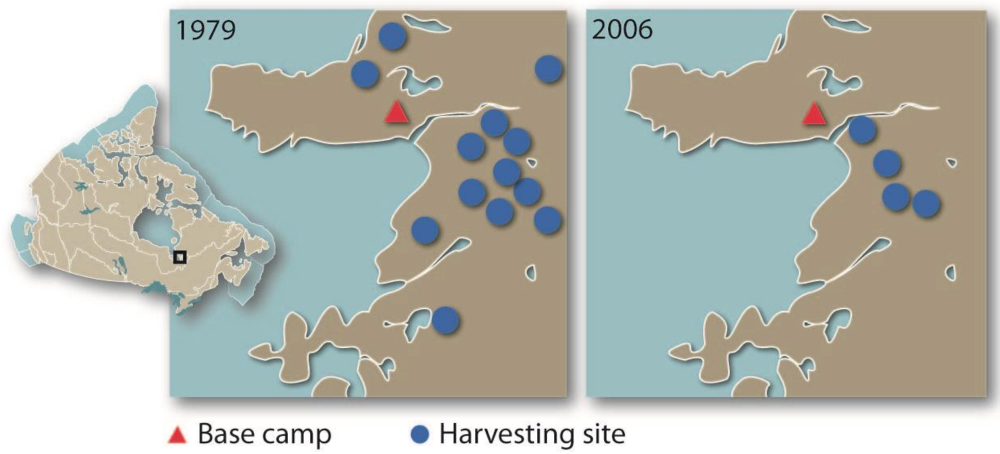


Figure 24: Map of hunting sites used for the spring goose hunt, Blackstone Bay, Wemindji territory, 1979 and 2006.
The reduction in number of sites used and their clustering around a central point, was due to two causes: 1) environmental changes in some sites made them no longer suitable as goose habitat; 2) some sites could not be reached because ice on the bay has become thinner and unsafe in the spring.
The triangle indicates the location of the camp.
Source: Scott, 1983 in Peloquin, 2007[107]

What is the value of a caribou herd?

A holistic approach to valuation of ecosystem goods and services

A study conducted for the Beverly and Qamanirjuaq Caribou Management Board in 2008[108] examined the value of provisioning and cultural goods and services provided by the Beverly and Qamanirjuaq Herds. The study was built on a model that considered the value of these services to include:

- direct-use values: primarily meat, but also hides and antlers as input to arts, crafts and cultural products;
- indirect values:
- values of experiences and other intangible benefits: for example, recreational enjoyment, kinship and bonding, education in traditional ways of life;
- values of the existence of the caribou: as a bequest to future generations and for options to hunt at a later time.

Only the direct-use values can be quantified in terms of market value (Table 5). The Beverly Herd's estimated direct-use value was $4.8 million in 2005/06, primarily ($4.1 million) as domestic harvest, with 76% of the harvest that year being by Aboriginal communities in northern Saskatchewan.

Table 5: Estimates of the annual direct-use value of the Beverly and Qamanirjuaq Caribou Herds

Estimated direct-use values of Beverly and Qamanirjuaq Caribou Herds (total $19.9 million/year)		
	$ million/year	**Percent**
By jurisdiction		
Nunavut	11.8	59
Manitoba	3.8	20
Saskatchewan	3.4	17
NWT	0.8	4
By harvest		
Domestic (Aboriginal)	14.7	74
Outfitter	4.1	21
Commercial and licensed	1.0	5
By herd		
Qamanirjuaq	15	76
Beverly	4.8	24

Calculated for domestic and resident (licensed), outfitting and commercial harvests, based on value of replacing meat and hides (taking into account the costs of hunting and regional differences in costs such as transport). Outfitting was treated as an economic activity and its annual net contribution to the GDP was calculated. Estimates are based on 2005/06 statistics. Source: data from InterGroup Consultants Ltd, 2008[108]

Indirect values were examined based on previous studies in the region augmented with questionnaires and interviews. The authors concluded that hunting caribou and associated activities (such as preparation of and sharing of meat, and community feasts) were viewed by the people throughout the ranges of the two herds as integral to the maintenance and transfer of knowledge, skills, and cultural norms. Many people interviewed talked about how important hunting caribou was to their identity and to the revitalization of their communities.

Small industries

Fur trapping, once a major part of the Taiga Shield's economy, is still pursued by a relatively small number of Taiga Shield residents (Figure 25). Despite the shrinking of the industry, due to changes in social values and consumption patterns, it remains an important source of income in many small communities.

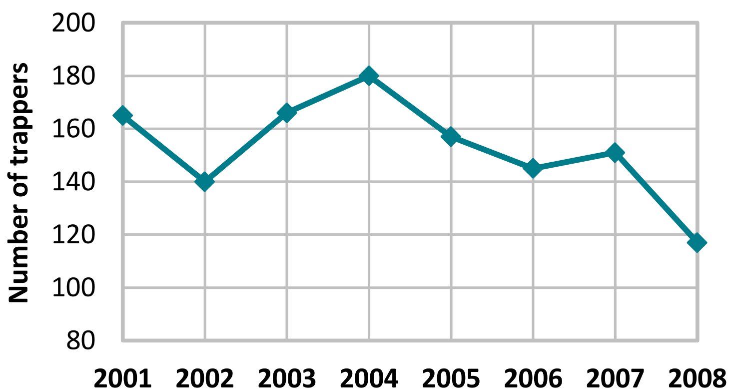


Figure 25: Active trappers in the Northwest Territories portion of the Taiga Shield, 2001-2008. Source: data from the NWT Fur Harvest Database,2008, reported in Northwest Territories Environment and Natural Resources, 2009[69]

Small-scale wood harvesting is another modest consumer of Taiga Shield ecosystem services. Most wood is harvested for firewood or by small-scale local businesses selling lumber and fuel. While the level of harvest is too low to have a serious impact on the Taiga Shield's boreal forest, it is an important contributor to the cash and non-cash economy of many small communities.[69]

THEME: HABITAT, WILDLIFE, AND ECOSYSTEM PROCESSES

Theme Habitat, wildlife, and ecosystem processes

Intact landscapes and waterscapes

Intact landscapes and waterscapes was initially identified as a nationally recurring key finding and information was subsequently compiled and assessed for the Taiga Shield Ecozone+. In the final version of the national report,[3] information related to intact landscapes and waterscapes was incorporated into other key findings. This information is maintained as a separate key finding for the Taiga Shield Ecozone+.

Within the boundaries of the Taiga Shield Ecozone+, there is a relatively low level of human disturbance. Human settlements are thinly scattered, industrial development is comparatively low, and the road network is sparse. At the current rate of human activity, habitat changes are site-specific and local. However, their cumulative footprint is increasing and concerns are growing. For example, the Dene First Nations near Great Slave Lake report that caribou locations have shifted from the past and that the animals are avoiding areas inhabited by people.[54]

Key finding 17 **Theme** Habitat, wildlife, and ecosystem processes

Species of special economic, cultural, or ecological interest

National key finding
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.

Migratory tundra caribou

This section is based on the report on *Northern caribou population trends in Canada,*[12] a technical thematic report prepared for the 2010 Ecosystem Status and Trends Report. As per this report, Northern caribou include migratory tundra caribou of three sub-species: barren-ground caribou (*Rangifer tarandus groenlandicus*) which range east of the McKenzie River, Grant's caribou (*R. t. granti*), which range west of the Mackenzie River, and woodland caribou (forest-tundra population) (*R. t. caribou*) comprised of two large herds in Ungava and two small herds that calve along the south coast of Hudson Bay).

Migratory tundra caribou are a pivotal species ecologically, as well as for people, so their distribution is well monitored through aerial surveys or satellite telemetry. Caribou use the Taiga Shield mainly from fall to spring, although the areas they use vary from year to year. Migratory caribou numbers have generally declined since peak abundance in the mid-1990s – and some have declined severely in recent years. The declines may be part of natural cycles, perhaps augmented by cumulative effects from stressors including climate change, harvest pressures, and increasing human presence on parts of the ranges. Highs and lows in historic abundance since the 1800s have been reconstructed from the frequency of hoof scars on spruce roots for the Bathurst and George River herds.[109, 110]

The following herds – all in decline in 2010– use significant parts of the western Taiga Shield over their annual cycle (Figure 26): Bathurst (Figure 27), Beverly (Figure 28), and Qamanirjuaq (Figure 29). The Bluenose East herd increased from 2006 to 2010[12] but declined in 2013.[111] The status of the Lorillard Herd is unknown and the Ahiak Herd is declining based on preliminary data. In the eastern Taiga Shield, the George River Herd (Figure 30) summers and winters in the ecozone+. The Leaf River Herd (Figure 31) uses the area in winter only. Both herds are in decline.

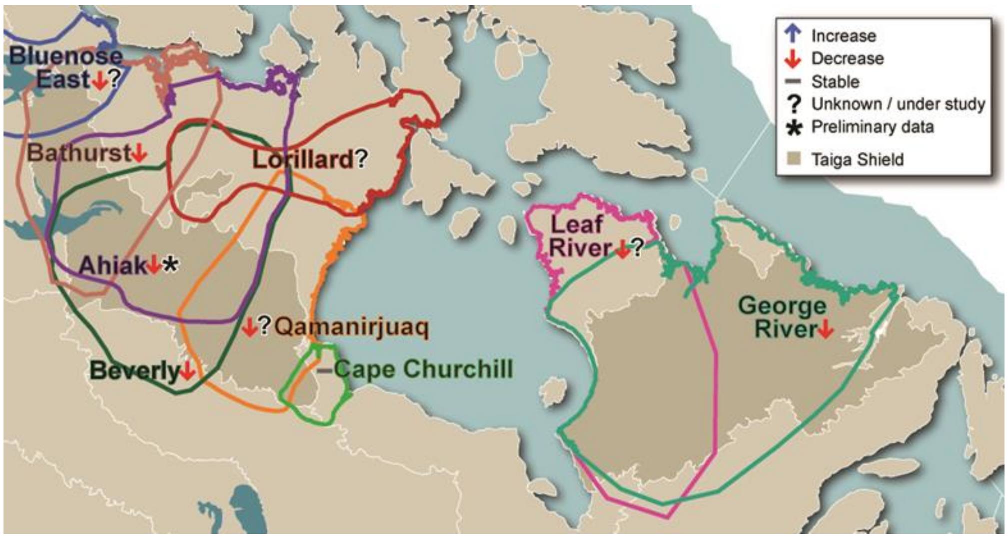


Figure 26: Distribution and status of migratory tundra caribou herds with ranges extending into the Taiga Shield Ecozone+.
Source: Gunn et al., 2011[12] Bluenose East Herd information updated with 2013 census information from Government of Northwest Territories Environment and Natural Resources[111]

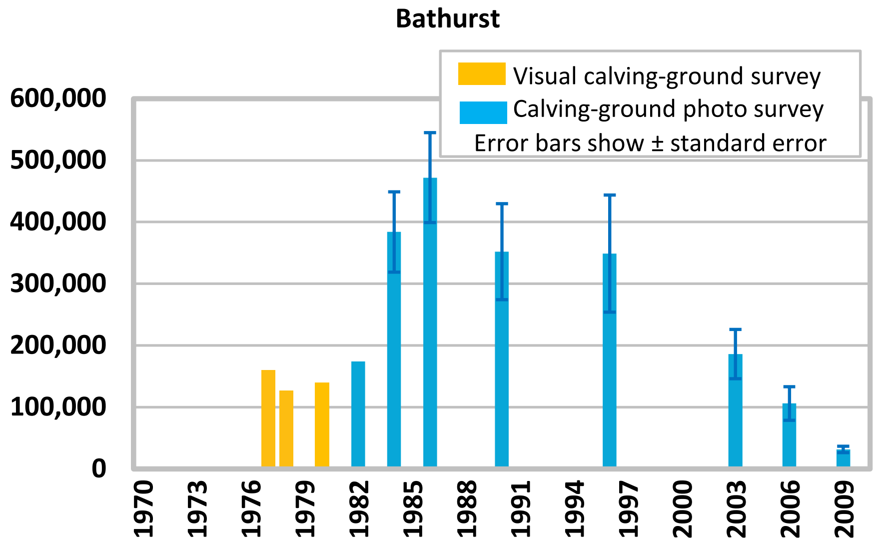


Figure 27: Bathurst Caribou Herd population estimates, 1977-2009. Source: Gunn et al., 2011[12]

The Bathurst Herd uses the Taiga Shield in fall and winter. The historical trend, based on Tlicho elders' recollections of enough caribou in fall hunting camps, was high numbers in 1940s, low in the 1950s and increasing during the 1970s and 1980s. Since 1998, the southern boundary of the winter range has contracted.

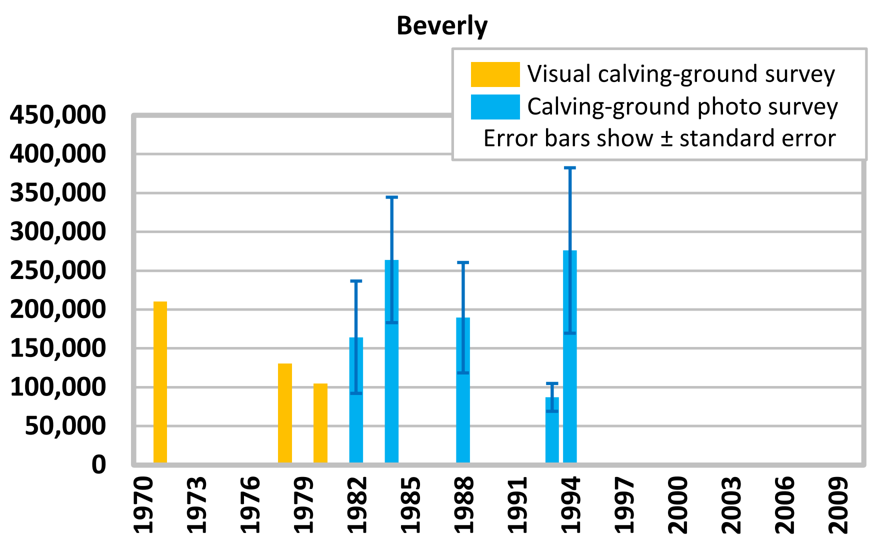
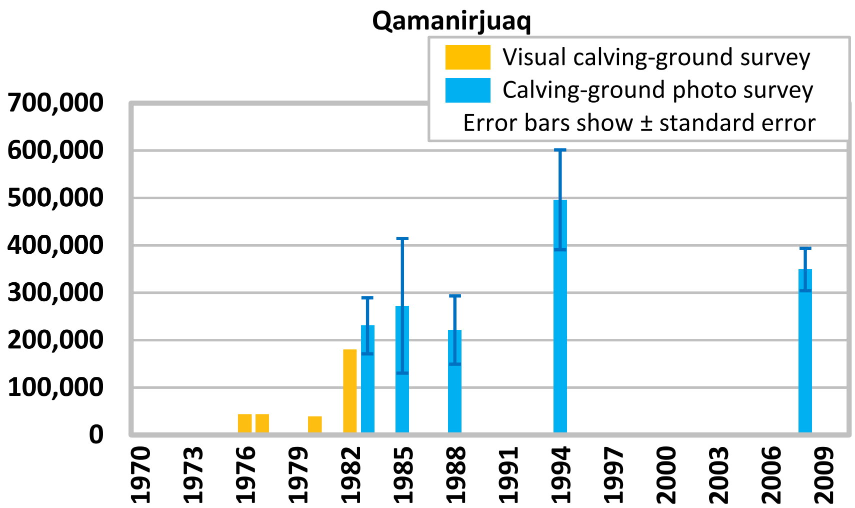


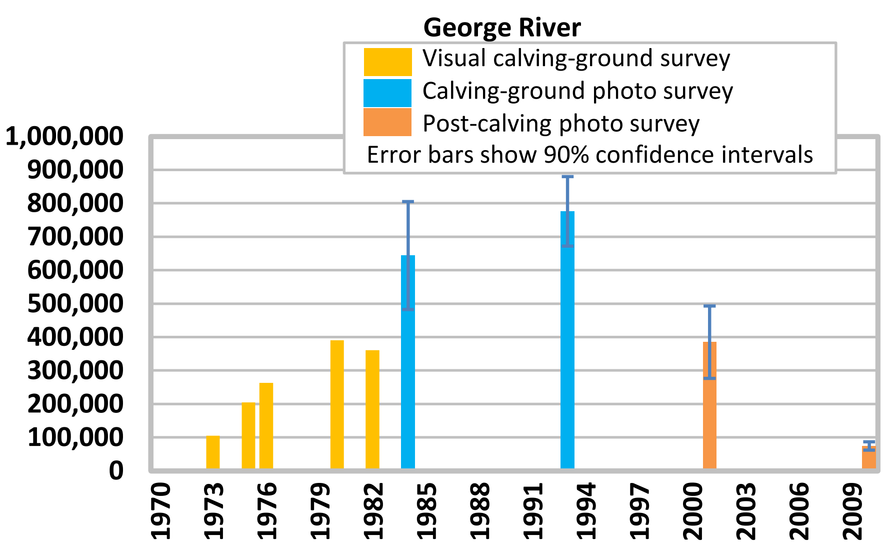
Figure 28: Beverly Caribou Herd population estimates, 1971-2008. Source: Gunn et al., 2011[12]

The Taiga Shield provides fall and winter range for the Beverly Herd. The herd's trends in abundance and vital rates were not monitored between 1994 and 2008. However, a 2002 systematic reconnaissance survey reported lower densities than in 1994. Four calving ground delineation surveys from 2006 to 2009 also found few cows and even fewer calves. This information suggests a declining population. However, population estimates were unable to be determined from this data and are not shown in Figure 28.



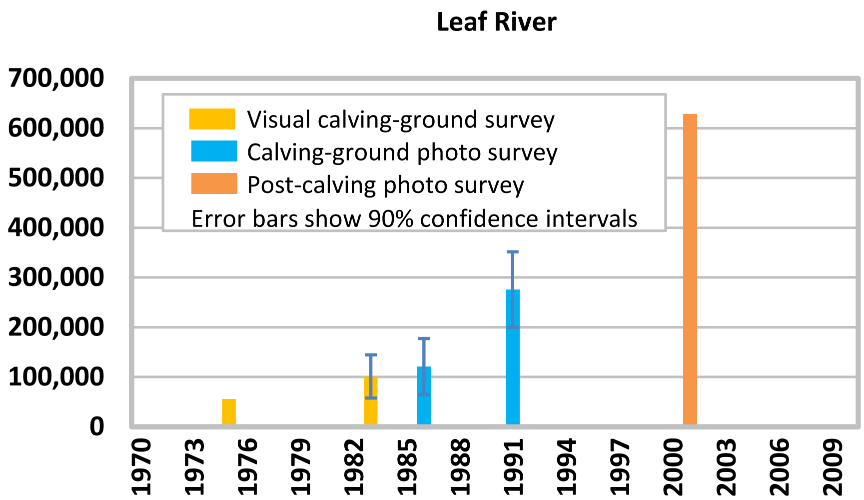
The Taiga Shield is fall and winter range for the Qamanirjuaq Herd. Numbers were very low in the 1970s and increased until at least 1994. Nunavut completed a calving ground survey in 2008 and determined the herd had declined but that the trend was not statistically significant.[112]

Figure 29: Qamanirjuaq Caribou Herd population estimates, 1976-2008. Source: Gunn et al., 2011[12]



The herd increased from the 1950s to the mid-1990s. Degradation of summer habitat may have facilitated the decline to 74,100 individuals in 2010.

Figure 30: George River Caribou Herd population estimates, 1973-2010. Source: Gunn et al., 2011[12]



The Leaf River (Rivière-aux-Feuilles) Herd increased from 1975 to the last census in 2001. Observations of body condition and calf recruitment in 2007 and 2008 suggest the population has likely declined since 2001.

Figure 31: Leaf River Caribou Herd population estimates, 1975-2001. Source: Gunn et al., 2011[12]

Boreal caribou

Woodland caribou, boreal population (i.e., boreal caribou) was listed as Threatened under the *Species at Risk Act* (SARA) in 2003.[113] The classification of caribou used in this report follows the current *Species at Risk Act* (SARA) classification system. In 2011, COSEWIC adopted 12 designatable units for caribou in Canada that will be used in caribou assessments and subsequent listing decisions under SARA beginning in 2014. This section on boreal caribou is based on the *2011 Scientific Assessment to Inform the Identification of Critical Habitat*[114] and the *2012 Recovery Strategy for the Woodland Caribou* (Rangifer tarandus caribou)*, boreal population in Canada*.[115] The information in this section has been updated since the release of the ESTR national thematic report, *Woodland caribou, boreal population, trends in Canada.*[13]

Six boreal caribou local populations have ranges that are fully or partially in the Taiga Shield Ecozone+. Very small portions of the range in the Northwest Territories and the range in Northern Saskatchewan, both with unavailable population trends, occur in the western Taiga Shield.[13] In the eastern Taiga Shield, four local populations extend across the south of the ecozone+. The Quebec local population is considered stable; the three local populations in Labrador are declining (Figure 32).

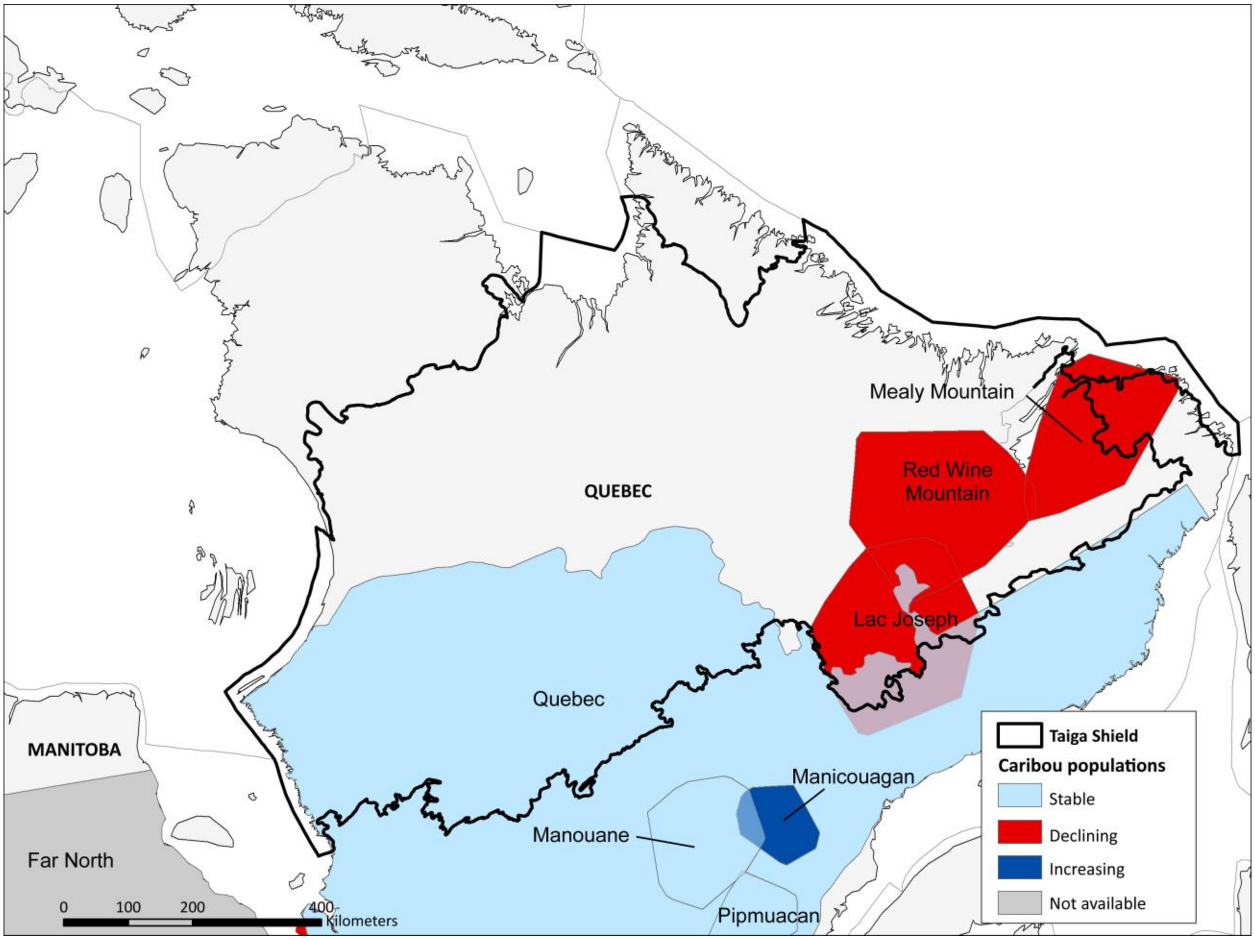


Figure 32: Status of boreal caribou local populations in the Taiga Shield (east) Ecozone+.
Source: updated from Callaghan et al., 2011,[13] based on Environment Canada 2012[115]

Broad-scale reduction of range and population declines of boreal caribou in Canada are associated with loss and degradation of mature coniferous forest habitat.[13] The most immediate effect of this reduction in mature forest is an increase in younger forest types that favour other ungulates such as moose (*Alces alces*) and white-tailed deer (*Odocoileus virginianus*). This change in turn results in more predators and increased predation on caribou.[114-127] Although deer are rare, their abundances are increasing and the distributions of moose are changing in the Taiga Shield (see Major range shifts in species native to Canada on page 56).

Human disturbances (right of ways, for example), will also facilitate predator movement. This increases the risk of predation by increasing predator-caribou encounter rates.[128] Boreal caribou are closely associated with late-successional coniferous forests and peatlands[129] that function as refugia, away from high densities of predators and their alternate prey.[120, 122, 124, 130, 131]

The extent of hunting is poorly understood in most areas. Analyses of historical population trends, data from radio-collared animals, and current demographic information indicate that hunting remains an important component of adult female boreal caribou mortality and hence is a primary threat to some local populations.[132] In Labrador, harvest by humans is the most significant threat to boreal caribou.[13] Hunting of boreal caribou by humans and predators, such as wolves, is facilitated by construction of roads and other linear features and by use of off-road vehicles that permit access to previously inaccessible areas.[128]

Waterfowl

This section is based on *Trends in breeding waterfowl in Canada,*[10] a technical thematic report prepared for the 2010 Ecosystem Status and Trends Report. Analyses of trends by ecozone+ in the waterfowl report included data up to 2006 and have not been updated here.

Scaup (*Aythya* spp.), American wigeon (*Anas americana*), and scoters (*Melanitta* spp.) are experiencing population declines in the western part of the Taiga Shield (Figure 33). Declining trends were also reported for neighbouring ecozones+ for most of these species, suggesting common factors are at work. Climate change may be driving at least some of these declines. Lesser scaup (*A. affinis*), white-winged scoters (*M. deglandi*) and American wigeon are relatively late nesters,[133-135] and DeVink et al.[136] suggest that, if there is a dependence on photoperiod as a breeding cue, there may be a growing mismatch between timing of nesting and food availability. The availability of their invertebrate food source may be shifting with changing temperatures, resulting in decreased hen and duckling survival.

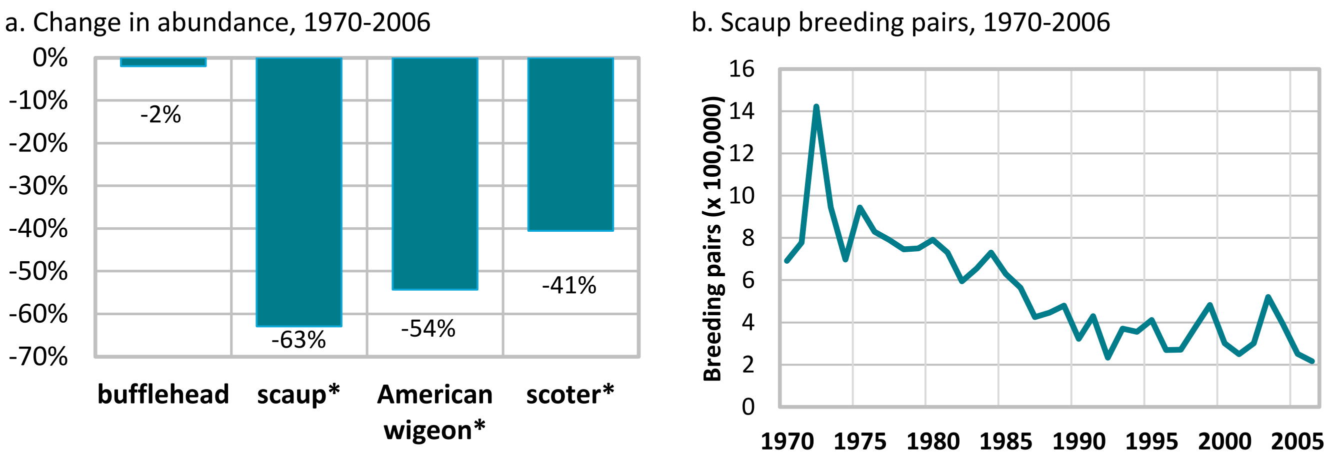


*Figure 33: a. Changes in abundance of bufflehead, scaup (*Aythya affinis *and* A. marila *combined), American wigeon, and scoter (*Melanitta deglandi *and* M. perspicillata *combined) and b. scaup breeding pairs in the western Taiga Shield Ecozone+, 1970-2006.*
Changes are significant (p<0.05) for species marked with an asterisk. Species: scaup, American wigeon, and scoters.
Source: Fast et al. 2011[10]

Surveys since 1991 in the eastern Taiga Shield Ecozone+ show considerable year-to-year variation, but the trends suggest stable population levels for ring-necked duck (*Aythya collaris*), scaup , American black duck (*Anas rubripes*), and green-winged teal (*Anas carolinensis*) (Figure 34).

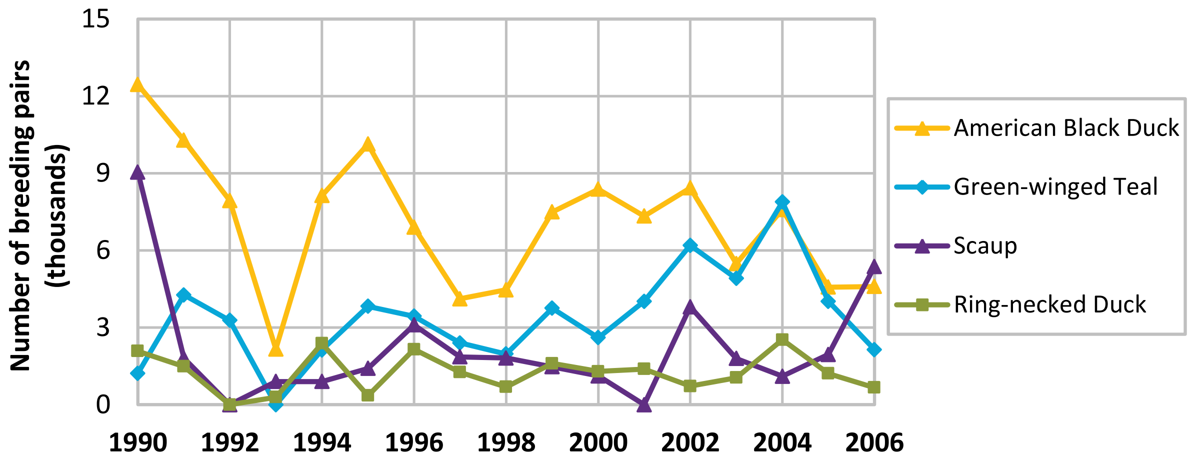


*Figure 34: Number of breeding pairs of American black duck, green-winged teal, scaup (*Aythya affinis *and* A. marila *combined), and ring-necked duck in the Eastern Taiga Shield Ecozone⁺, 1990-2006. There were no significant trends.*
Source: Fast et al. 2011[10]

Landbirds

Because few data were available for landbirds breeding in the taiga, landbird information was combined for all taiga ecozones⁺.[14] Populations of some species are monitored on their wintering ranges in the United States and southern Canada through the Christmas Bird Count (CBC). North American trends are shown below (Table 6) for six landbird species with breeding ranges that included portions of the three taiga ecozones⁺. Canada has a high stewardship responsibility for all of these species because large portions of their western hemisphere breeding populations are in Canada.

Table 6: Trends in annual abundance of selected landbirds from the three taiga ecozones+, 1966-2005

Species	Main breeding range	Population trend (%/yr)	P	CBC abundance index				
				1970s	1980s	1990s	2000s	Change
Rusty blackbird (*Euphagus carolinus*)	Hudson Bay Lowlands, taiga and boreal	-5.46%	*	1.5	0.7	0.4	0.3	-78%
Boreal chickadee (*Poecile hudsonicus*)	Taiga and boreal	-1.73%	*	1.6	1.3	1.2	1.2	-29%
Northern shrike (*Lanius excubitor*)	Taiga	-0.79%	*	1.1	1.0	1.0	0.8	-29%
Pine grosbeak (*Pinicola enucleator*)	Taiga and boreal	-0.78%		5.1	3.4	2.8	2.5	-52%
Smith's longspur (*Calcarius pictus*)	Taiga	-0.32%		0.05	0.06	0.07	0.08	57%
Lincoln's sparrow (*Melospiza lincolnii*)	Taiga and boreal	-0.08%		1.5	1.5	1.7	1.6	8%

Shown are the annual rate of change and the average CBC abundance index by decade. Asterisks (*) indicate statistically significant trends (P<0.05).
Source: based on data from the Christmas Bird Count (courtesy of D. Niven, Audubon) as reported in Downes et al., 2011[14]

Three of six species show statistically significant long-term declines. In particular, the rusty blackbird (*Euphagus carolinus*), a temperate migrant that winters in the United States, declined by 78% between the 1970s and the 2000s (Figure 35). This decline was supported by surveys[137] from other parts of its range that showed an even steeper rate of decline for Canada overall. Circumstantial evidence suggests that declines have not been as dramatic in the north.[138] The declines in boreal chickadee (*Poecile hudsonicus*) and pine grosbeak (*Pinicola enucleator*) were also supported by evidence of declines from surveys in other parts of their breeding ranges.[14]

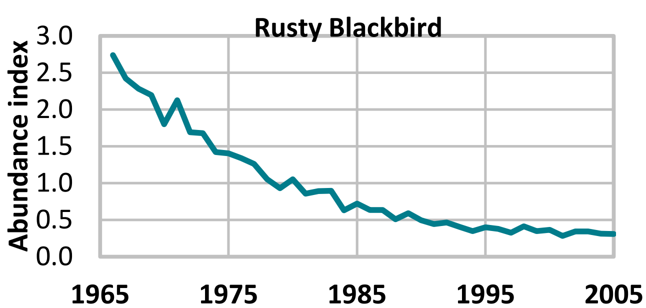


Figure 35: Trend in annual abundance index for the rusty blackbird, 1966-2005
The decline is statistically significant (p<0.05).
Source: based on data from the Christmas Bird Count (courtesy of D. Niven, Audubon) as reported in Downes et al., 2011[14]

Fish

Information about general fish health from Aboriginal Traditional Knowledge in the western portion of the Taiga Shield shows varying changes. The Dene report fewer fish in the Mackenzie River area[139] and near Great Slave Lake, while other reports say fish populations in Great Slave Lake are at least as good as in the past.[54, 84, 140] In the Hudson Bay region, there are reports that fish behaviour and health have changed, that migration patterns have altered, and that dams and changing water levels stop fish moving upstream and into lakes.[88]

In the eastern portion of the Taiga Shield, hydroelectric development has had a dramatic impact on a number of river basins. Changes affecting fish are discussed under Dams and reservoirs on page 23.

Vascular plants

Aboriginal peoples report many local changes in vegetation, for example:

- Anaktalak Bay area of Nunutsiavut (south of Nain), 2007: an increase in the growth and abundance of some plants, such as berries, that are good for food.[85]
- Wemindji, James Bay, 2005: terrestrial vegetation is replacing aquatic vegetation, and willows and other shrubs cover previously bare ground. Both changes have impacts on geese. In areas that previously grew berries, trees now grow.[57]
- Near Great Slave Lake, 2002: pin cherries, trees that commonly grow on disturbed ground, appeared after a new road was built.[99]

Major range shifts in species native to Canada

Range extensions to the Taiga Shield Ecozone+ from ecozones+ to the south have been noted in some areas since the 1960s. Newly arrived species include: white-tailed deer in the NWT[141] and Alberta,[142] coyote (*Canis latrans*) in the NWT[143] and Labrador,[144] wood bison (*Bison bison athabascae*),[143] and magpies (*Pica pica*).[145]

Several range shifts have been directly associated with human activities.[143] White-tailed deer, coyote, and wood bison likely followed the Yellowknife highway corridor northward into the Taiga Shield.[146] Elders report that when bison populations were high in the Slave River Lowlands (Taiga Plains Ecozone+), there was some westward spillover into the Taiga Shield, but because habitat patches were small, the animals would not stay.[146] Some species, such as coyote and magpie rarely venture beyond the Yellowknife city limits.[145, 146] Climate change is expected to make larger areas more hospitable to new arrivals and these and other species may spread further.[147, 148]

Photo: James Sangris with a white-tailed deer doe harvested at Wool Bay, Great Slave Lake, western Taiga Shield, October 2007. © GNWT-D. Cluff

Range changes are often noticed first by local residents and hunters and observations of unusual animal sightings are an important way to track species distribution changes.[142] Some examples of range change information based on local knowledge:

- Range expansion or vagrancies from the north into the western Taiga Shield have been noted for grizzly bear (*Ursus arctos*) and muskoxen (*Ovibos moschatus*).[142, 145]
- The Dene First Nation reported an increase in moose and bears along the tree line in the Artillery Lake area.[140]
- Along the Labrador coast Inuit have observed moose (around Anaktalak Bay) and consider that they are moving northward because of climate change.[85]
- The communities of eastern James Bay have observed a decrease in moose and moose habitat and a decline in moose body condition.[86, 149]

Key finding 18 **Theme** Habitat, wildlife, and ecosystem processes

Primary productivity

National key finding

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.

This section is based on analyses and interpretations in *Monitoring biodiversity remotely: a selection of trends measured from satellite observations of Canada.*[16] Additional material has been added on the relationship between primary productivity and forest fires.

Over 36% of the land area of the Taiga Shield Ecozone+ showed a significant increase in NDVI (an index related to primary productivity, derived from remote sensing) from 1986-2006 (Figure 36). Less than 1% of the land showed a decreasing trend. The increase in this ecozone+,

one of the highest in Canada,[16] was strongest in the east, especially south of Ungava Bay (an area dominated by tundra vegetation), and also in southern Labrador (conifer forest and shrubland). The NDVI in the area between these two "hotspots" also exhibited a positive but less pronounced trend. NDVI increased in large parts of the northern portion of the western Taiga Shield. This area, characterized by the most productive soil in the western Taiga Shield,[22] is predominantly covered with conifer forests, but shrub and tundra vegetation are also well represented.

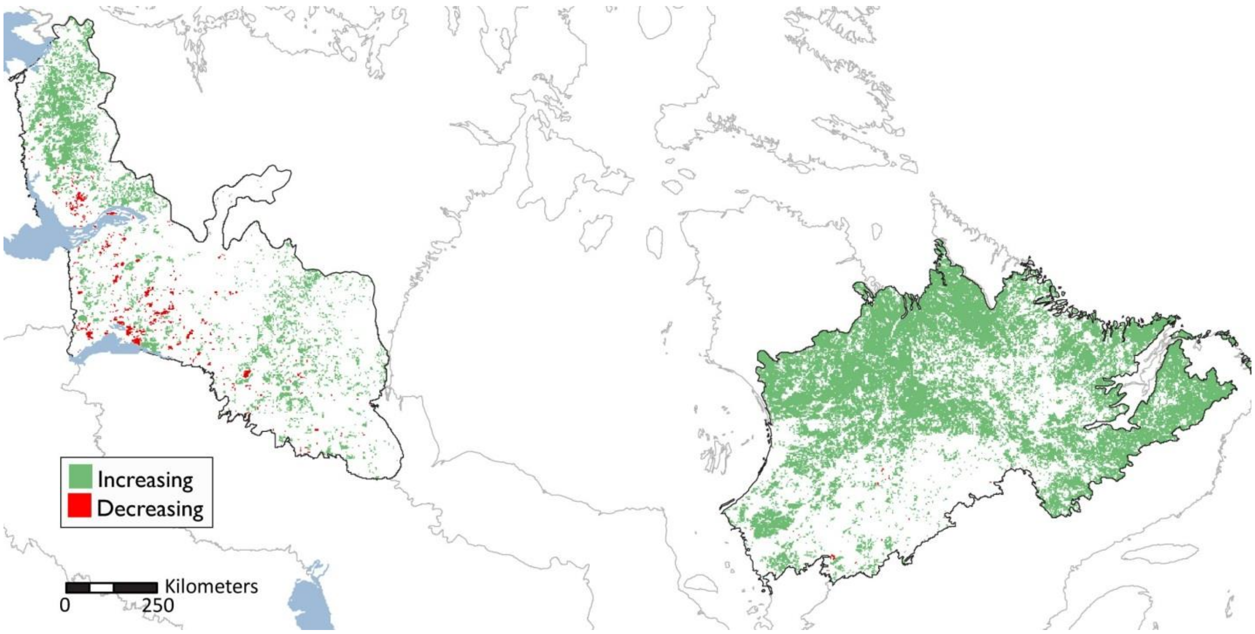


Figure 36: Trend in Normalized Difference Vegetation Index (NDVI), Taiga Shield Ecozone+, 1985-2006
Trends are in annual peak NDVI, measured as the average of the 3 highest values from 10-day composite images taken during July and August of each year. Spatial resolution is 1 km, averaged to 3 km for analysis. Only points with statistically significant changes (p<0.05) are shown.
Source: NDVI trend analysis by Pouliot et al., 2009;[150] ecozone+ analysis by Ahern et al., 2011[16]

Pouliot et al. (2009)[150] found that burns can have positive, negative, and zero NDVI trends, depending on the age of the burn. For example, an analysis of burned and unburned sites in the boreal forest of central Canada[151] found significant increases in NDVI at all sites with fires since 1984 and at 50% of unburned sites. Fire cannot, however, account for all the substantive increase in NDVI in the Taiga Shield – a comparison of the NDVI trend map with the map of large fires since the 1980s (Figure 37) shows that the main areas of increased NDVI are not areas that have recently burned. The areas in the western Taiga Shield showing negative NDVI trends may be recently burned black spruce-lichen woodland occupying poor soils. On better soils, lichen does not compete well with vascular understory plants. After fire in spruce-lichen woodland, soil surfaces may remain blackened for many years as black spruce and lichen are very slow to recover.[145, 146]

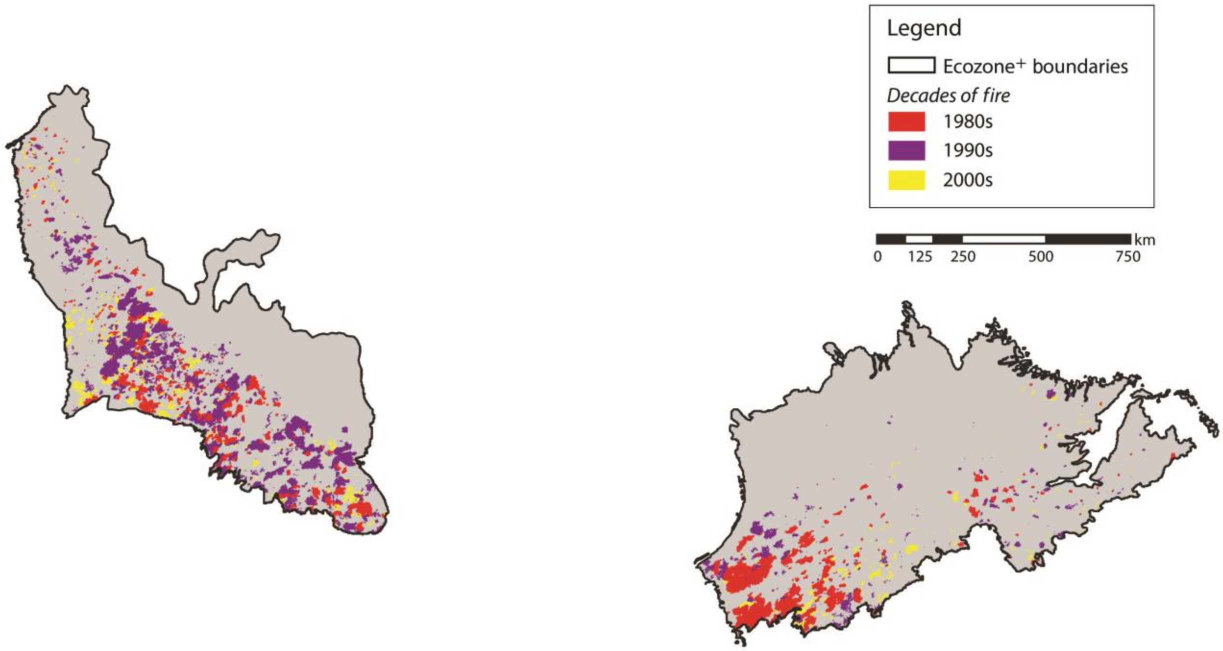


Figure 37: Locations of large fires by decade, 1980s to 2000s.
Source: Krezek-Hanes et al., 2011[8]

Key finding 19 **Theme** Habitat, wildlife, and ecosystem processes

Natural disturbance

National key finding
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.

Fire, weather extremes, and diseases shape and modify the flora and fauna of the Taiga Shield Ecozone+. Disturbances such as forest fires tend to be small and frequent or large and rare, and so the calculation of trends of disturbances requires longer temporal datasets. Other than data on forest fires, relatively little specific information has been compiled for the Taiga Shield.

Fire trends

This section is based on analyses and interpretations in *Trends in large fires in Canada, 1959-2007*.[8] and *Monitoring biodiversity remotely: a selection of trends measured from satellite observations of Canada.*[16]

The fire regime in the Taiga Shield is characterized by large, severe fires.[152-154] Trees and other plants in the Taiga Shield evolved in a fire environment and a changing fire regime will impact the distribution of species and plant communities. For example, fire plays a stronger role than climate in determining the northern limit of jack pine (*Pinus banksiana*).[155]

The area burned in the Taiga Shield (Figure 38) increased from the 1960s until the 1990s, a trend attributed to changes in detection methods and warmer temperatures.[156, 157] The decline since the

1990s is similar to the pattern shown for the Taiga Plains Ecozone+, and the magnitude of the decline is the same as changes between previous decades. The decline may be related to large atmospheric oscillations.[8]

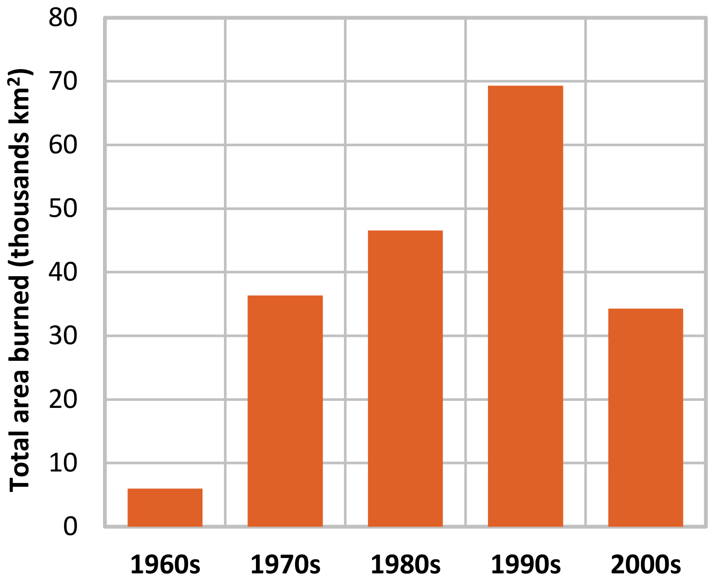


Figure 38: Trend in total area burned per decade in the Taiga Shield Ecozone+, 1960s-2000s. The value for the 2000s decade was pro-rated over 10 years based on the 2000-2007 average. Source: Krezek-Hanes et al., 2011[8]

The average duration of the active fire season, about 75 days, has not changed significantly over the period of record (Figure 39).[8] Fires occur most commonly between June and August, peaking in July, but there was a significant increase in May fires from the 1960s to the 1990s. Few May fires were recorded, however, and the record is relatively short. There are no comparable records, for example, for fires in the warm, dry decade of the 1940s, which may have experienced fires in May. Fires in the eastern portion of the Taiga Shield generally occurred earlier than fires in the west.[158]

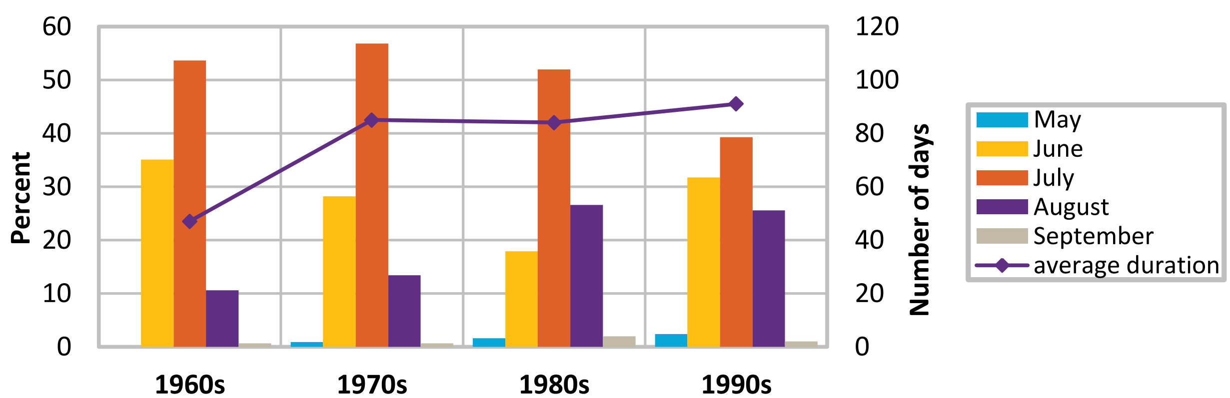


Figure 39: The proportion of large fires that occur in each month of the fire season by decade. This fire trend is based on the number of large fires (over 200 ha in size). Monthly numbers are the percentage of the total number of fires that occurred during the month. Source: Krezek-Hanes et al., 2011[8]

Lightning causes, on average, 92% of large fires in the Taiga Shield. The proportion of fires caused by lightning has increased over the last 40 years due to a decrease in human-caused fires. The absolute number of fires caused by lightning also increased over the same time period, although this increase was not statistically significant.[8]

Insect outbreaks

There is little information on insect outbreaks specific to the Taiga Shield. In the eastern Taiga Shield, insect disturbance seems to play a less important role than in the drier northwestern part of the continent.[159]

The spruce bark beetle (*Dendroctonus rufipennis*), the main pest affecting white spruce at the north of its distribution, appears to occur sporadically in the eastern Taiga Shield. A large section of lowland forest along Napaktok Bay, Labrador experienced severe tree mortality from 1989 to 1991, likely caused by an outbreak of spruce bark beetles. [27] Tree-ring analyses in the Kuujjuarapik region of James Bay found low levels of spruce bark beetle activity, but without regional outbreaks, extending back about 400 years (the age of the trees).[159] At one of the three study sites, an outbreak resulted in extensive tree mortality in the late 20th century.

Outbreaks of the spruce bark beetle may become more significant in the Taiga Shield in the future as summer and winter temperatures increase. Outbreaks are normally associated with forest disturbances such as windthrow, fire, or land clearing. A severe, recent outbreak in the Boreal Cordillera Ecozone^{+}, however has been attributed to an increase in drying out of spruce trees in the summer (making the trees more vulnerable to bark beetle attack) and to increased beetle reproductive success in the warmer summers along with decreased beetle mortality in the milder winters.[160]

Key finding 20 **Theme** Habitat, wildlife, and ecosystem processes

Food webs

National key finding

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.

Population cycles

Detecting changes in ecosystems dominated by seasonality and climate variability generally requires long-term monitoring, which is rare in this ecozone^{+}. The low level of species diversity means that both predators and herbivores are vulnerable to fluctuations in the abundance of their food supplies, accentuating the natural pulses in the ecosystem. Most mammals in the Taiga Shield have cyclic dynamics. The principal exceptions are large-bodied mammals, such as moose and muskoxen. The latter are at the edge of their range in the Taiga Shield, but are increasing in the ecozone^{+}.[145]

Variations in high densities of snowshoe hare populations have been linked with variations in fire frequencies across their range in North America. Fires create abundant early succession plants that are eaten by hares in winter.[161] The highest densities of snowshoe hares in peak years have been measured where fire frequencies are the highest, including in the western Taiga shield.[162]

An increasing body of evidence identifies climate variables, especially snow and winter temperatures, as drivers in cyclic dynamics. For example, a decreasing amplitude of cyclic dynamics and collapse of cycles are reported for voles, grouse, and the larch budmoth (*Zeiraphera diniana)* in northern Fennoscandia, coinciding with climatic change.[163] The variability in the amplitude of small mammal cycles in the Taiga Shield (Figure 40), however, means that detecting trends requires a longer series of data than is currently available.

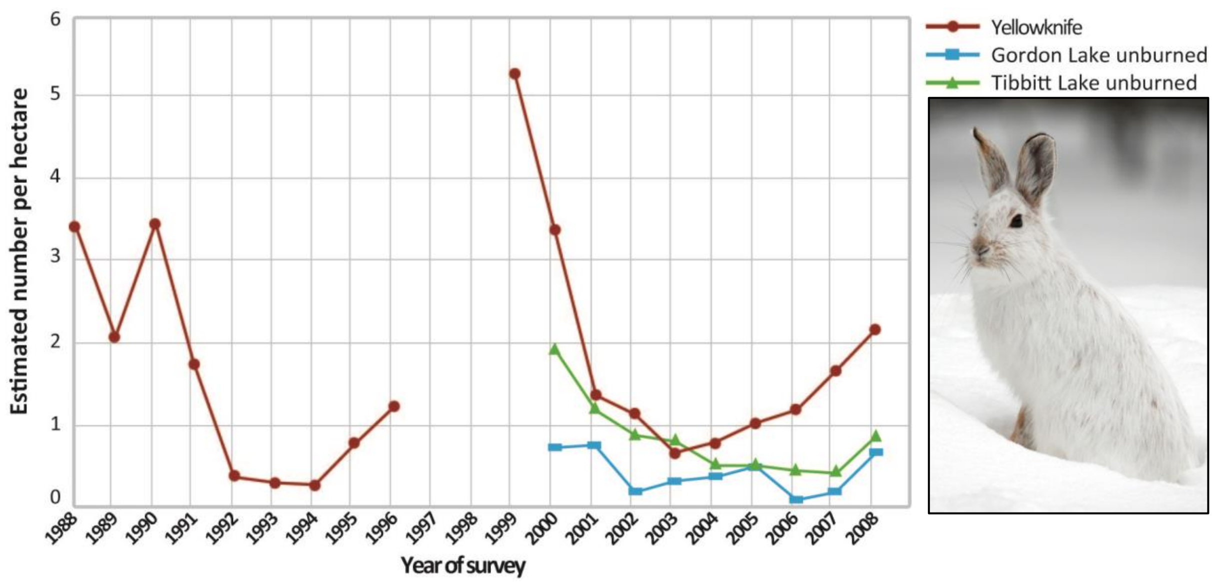


Figure 40: Snowshoe hare density at three sites in the western Taiga Shield, 1988-2008.
Data were missing for 1997 and 1998; according to local knowledge numbers were increasing rapidly during these years.
Source: Data provided by S. Carrière, Government of the Northwest Territories. Photo © iStock.com

Migratory species

The Taiga Shield Ecozone⁺ has a high proportion of migratory species. Most species that glean insects from foliage or hunt on the wing, including bats, migrate to southern ecozones⁺ in winter. Twenty-nine bird species use the boreal forest as a stopover during migration.[164] The Taiga Shield is also the seasonal destination for migrants from more northern ecozones⁺, from ptarmigan (*Lagopus* sp.) to barren ground caribou.

There is much uncertainty about the implications and cascades of effects related to changes in population dynamics of migratory species. For example, many species of migratory insectivorous birds are declining, some due to changes in their winter ranges. How these declines are linked to the population dynamics of their insect prey and how they might influence insect outbreaks and tree health in the Taiga Shield are unknown, though these chains of effects have been demonstrated in other regions.[165, 166]

THEME: SCIENCE/POLICY INTERFACE

Key finding 21 **Theme** Science/policy interface

Biodiversity monitoring, research, information management, and reporting

National key finding

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.

Because the Taiga Shield Ecozone+ is so lightly populated, there is little road access to much of the landscape, making research and monitoring difficult and expensive. Few ecological monitoring programs are designed for ecozones+ with limited access and a small population from which to draw volunteers. The consequence is a shortage of data about most aspects of the Taiga Shield ecosystems, from streamflow to animal populations. Understanding how ecosystems react to change – for example, under what circumstances accumulated changes trigger rapid (catastrophic) change or a gradual transition to a new state[167] – is lacking. A problem for ecozones+ such as the Taiga Shield is how to recognize thresholds, given the lack of information available about the ecosystems themselves.

The Taiga Shield Ecozone+ is characterized by a relatively large proportion of species at the edge of their ranges, whose abundances cycle, and/or are migratory. Predicting population trends within the Taiga Shield requires understanding the factors that limit the distribution of species. Both peripheral and migratory populations are vulnerable to environmental changes in the parts of their range that lie outside the Taiga Shield, so research both within and beyond the ecozone+ is vital for detecting and explaining trends.

Specific strengths and gaps in information that emerged in the preparation of this report

Monitoring and research strengths include studies that aid in understanding the ecology of Canada's remaining large migratory caribou populations, for example for the George River herd in the eastern Taiga Shield and the Bathurst herd in the western Taiga Shield (see the Northern caribou population trends in Canada thematic technical report[12]). Research that links impacts from climate change, development activity, and increased human presence in the Taiga Shield, along with monitoring of herd abundance, distribution, and caribou health and body condition, are needed on an ongoing basis.

Existing information on the Taiga Shield Ecozone+ is scattered over several jurisdictions and academic research groups – there is little ongoing ecological monitoring. Much of the information that is available is in the "grey literature" rather than in the published scientific literature. The disadvantage of this is that interpretations of results are not always adequately scrutinized and records are not always readily accessible, especially in the long term.

Coverage of the ecozone+ by climate stations is poor – the existing coverage does not allow for generalization to regional trends.

Knowledge about forest ecosystem processes is crucial for understanding taiga biodiversity. Critical gaps, especially for the western part of the ecozone+, are forest processes in relation to climate change and fire ecology, including the ecological importance, status and trends of invertebrates, fungi, and other poorly studied species assemblages.

Information is lacking on causes of the decline of eelgrass and continued trend monitoring is needed. (The issue of the condition of eelgrass beds in James Bay was referred to the Standing Committee on Fisheries and Oceans which, in 2008, presented a report to the House of Commons recommending in-depth research into the effects of environmental change on the eelgrass beds, as well as larger scale monitoring in James and Hudson bays.[43])

Information about population cycles, natural disturbances and human impacts comes from time lines too short to provide good insights. Gathering historical information from early records, landscape and proxy studies would provide a broader perspective on trends.

Understanding of ecological thresholds and causes of rapid change in the boreal forest is poor. Thresholds related to weather conditions – for example, for species range extensions, wildlife disease and forest insect outbreaks – are particularly important to understand in order to foresee and detect early signs of major ecological impacts from climate change in the Taiga Shield Ecozone+.

Key finding 22 **Theme** Science/policy interface

Rapid change and thresholds

National key finding
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.

There are two clear instances of abrupt change for this ecozone+:

1. the precipitous decline in at least one population of migratory tundra caribou in the past few years (see Migratory tundra caribou on page 47 and Changes in availability of traditional/country foods on page 42).
2. the rapid breakdown of permafrost in peatlands of the eastern Taiga Shield (see Permafrost trends on page 17).

Compounded disturbances that occur could push communities past their ability to recover.[168] For example, boreal forests may be resilient to climate trends until the interaction of human-induced changes such as the introduction of non-native species, diseases, or changes in fire regimes combine with atmospheric deposition of nitrogen or heavy metals.[169]

In addition, species diversity is low in the Taiga Shield. A relatively few species drive ecosystem functioning. The low species diversity, combined with cyclic abundance of some species, suggest that changes to ecosystem structure could be large-scale and relatively unpredictable.

CONCLUSION: HUMAN WELL-BEING AND BIODIVERSITY

Much of the Taiga Shield Ecozone+ is intact wilderness, a vast expanse of boreal forest thinning to tundra on its northern margin. Split in two by Hudson Bay, it crosses several political boundaries and encompasses part or all of the traditional territories of the Inuit, and a number of First Nations. The biological resources of the Taiga Shield were once the sole support of its human inhabitants.

Today, they are still important to residents, particularly to Aboriginal peoples. The Taiga Shield's biodiversity supports the region's non-cash economy, providing physical essentials such as food, clothing, and fuel. It also serves as a cultural foundation for peoples that have lived in the area for millennia. The growing number of parks and protected areas in the ecozone+ offers some opportunities for future development of the cash economy through tourism and associated services.

The Taiga Shield is also important to people outside the ecozone+. It is the southern edge of the range of the great migratory caribou herds that still sustain many peoples and communities further north. It is also the northern edge of moose habitat, supporting a species important to both people and ecosystems further south. In addition, the Taiga Shield sustains a wide range of migratory birds through part of their yearly cycle, offering a relatively undisturbed respite to species that might be under pressure elsewhere in their range.

The greatest threats to the biodiversity of the Taiga Shield Ecozone+ come from human activity, both locally and on a global scale. The physical resources of the Taiga Shield—mainly hydroelectric capacity and mineral resources—have attracted development, with more planned for the near future. Hydro development in the eastern Taiga Shield has flooded large tracts of land and substantially altered the hydrological regimes of several major river systems, with consequences for both terrestrial and aquatic biodiversity. Mineral resource development—particularly in the western Taiga Shield—is still largely in the exploration phase, but a major discovery could lead to a rapid increase in linear disturbance for transportation and communication corridors, resulting in increasing fragmentation of the Taiga Shield's great stretch of boreal forest.

The other major threat to biodiversity in the Taiga Shield is global climate change. Already, the ecozone+ is showing the effects of warming, and it is vulnerable to stronger impacts as the trend increases. The cumulative impact of climate change and local human activities can be particularly powerful. For example, in the eastern part of the ecozone+, extensive areas of permafrost have decayed, along with the growth of thermokarst ponds.

Maintaining the biodiversity of the Taiga Shield and the undisturbed character of its wilderness is valuable to people within and beyond the boundaries of the ecozone+. It is part of the complex natural mechanism of the boreal forest, one of Earth's major ecosystems and a significant—if not wholly understood—component of global physical and biological systems.

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