Taiga Plains Ecozone+
evidence for key findings summary

Canadian Biodiversity: Ecosystem Status and Trends 2010

Evidence for Key Findings Summary Report No. 13

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Cover photo: boreal caribou, Gwich'in Settlement Area. Photo by John A. Nagy, provided by GNWT

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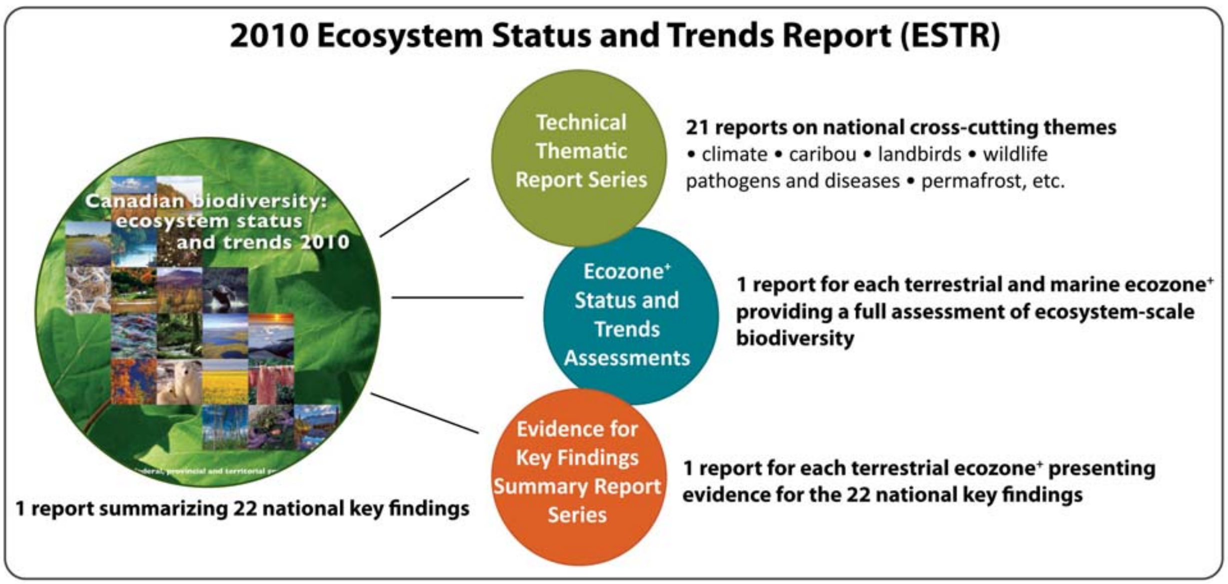
PREFACE

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 background technical reports prepared on the status and trends for many cross-cutting national themes (the Technical Thematic Report Series) and for individual terrestrial and marine ecozones+ of Canada (the Ecozone+ Status and Trends Assessments). More than 500 experts participated in data analysis, writing, and review of these foundation documents. Summary reports for each terrestrial ecozone+ present 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):

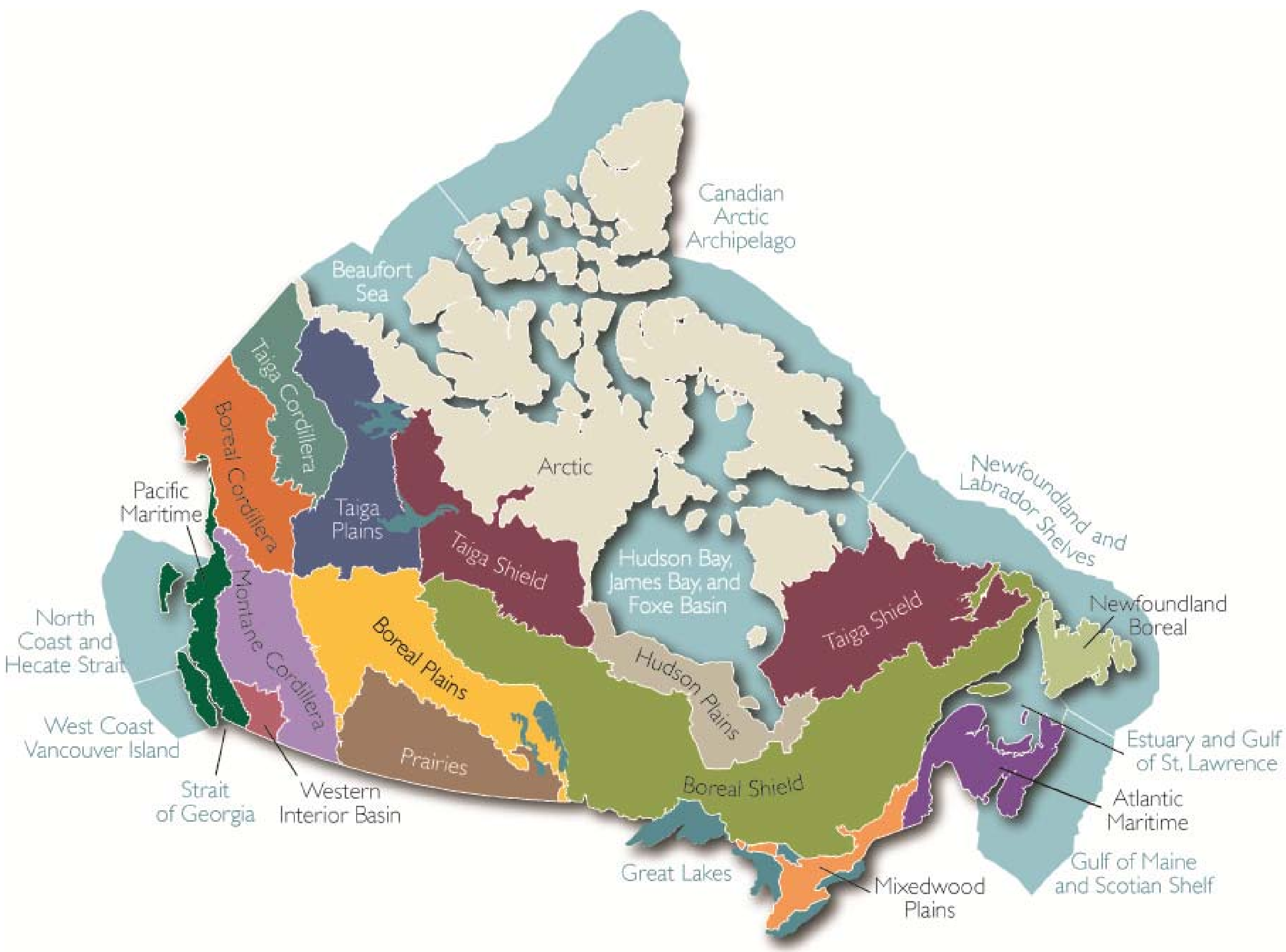


This report, *Taiga Plains Ecozone+ Evidence for Key Findings Summary*, presents evidence from the *Taiga Plains Ecozone+ Status and Trends Assessment* related to the 22 national key findings and is therefore not a comprehensive assessment of all ecosystem-related information. The level of detail presented 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.

There have been extensive environmental impact assessments conducted in this ecozone+ in relation to oil and gas exploration and transportation proposals. The baseline studies conducted for the Mackenzie Gas Project[4] are a source of compiled research and monitoring for parts of the Taiga Plains Ecozone+. Some results from this work have been included, but the scope and timing of the report precluded extensive use of this resource.

Ecological classification system – ecozones+

A slightly modified version of the Terrestrial Ecozones of Canada, described in the *National Ecological Framework for Canada*,[5] 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.[6] Changes made for the Taiga Plains, based on ground-truthing: (1) reduce the area along its boundary with the Taiga Cordillera Ecozone+, (2) extend the area along its boundary with the Arctic Ecozone+ and, (3) move the southeastern boundary to include lands formerly considered part of the Taiga Shield.



Acknowledgements

This report has been written by the ESTR Secretariat with significant assistance from Anne Gunn and Joan Eamer. It is based on the report, *Taiga Plains Ecozone+ Status and Trends Assessment.*

Additional reviews of this summary report were provided by scientists and resource managers from relevant provincial and federal government agencies, as well as one external expert review. Further information about this ecozone+ can be found in the associated supplementary material, taken from the draft Technical Ecozone+ Report. Contributions to the *Taiga Plains Ecozone+ Status and Trends Assessment* are listed below.

Taiga Plains Ecozone+ Status and Trends Assessment[7] (Technical Ecozone+ Report) acknowledgments

Lead authors: Anne Gunn, Joan Eamer, and Suzanne Carrière

Contributing authors, specific sections or topics

Northwest Territories ecozone classification: B. Oosenbrug
Protected areas: Jean-Francois Gobeil, Robert Helie and Robert Vanderkam

Authors of ESTR Thematic Technical Reports from which material is drawn:

Large-scale climate oscillations influencing Canada, 1900-2008: B. Bonsal and A. Shabbar[8]
Canadian climate trends, 1950-2007: X. Zhang, R. Brown, L. Vincent, W. Skinner, Y. Feng and E. Mekis[9]
Trends in large fires in Canada, 1959-2007: C.C. Krezek-Hanes, F. Ahern, A. Cantin and M.D. Flannigan[10]
Wildlife pathogens and diseases in Canada: F.A. Leighton[11]
Trends in permafrost conditions and ecology in northern Canada: S. Smith[12]
Monitoring ecosystems remotely: a selection of trends measured from satellite observations of Canada: F. Ahern, J. Frisk, R. Latifovic and D. Pouliot[13]
Climate-driven trends in Canadian streamflow, 1961-2003: A. Cannon, T. Lai and P. Whitfield[14]
Biodiversity in Canadian lakes and rivers: W.A. Monk and D.J. Baird[15]

Review conducted by scientists, traditional knowledge specialists, and renewable resource and wildlife managers from provincial (BC only), territorial, and federal government agencies, and from wildlife co-management boards through a review process recommended by the ESTR Steering Committee. Substantial changes to the report were made as a result of this process.

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 Donna D. Hurlburt.

Table of Contents

List of Figures

List of Tables

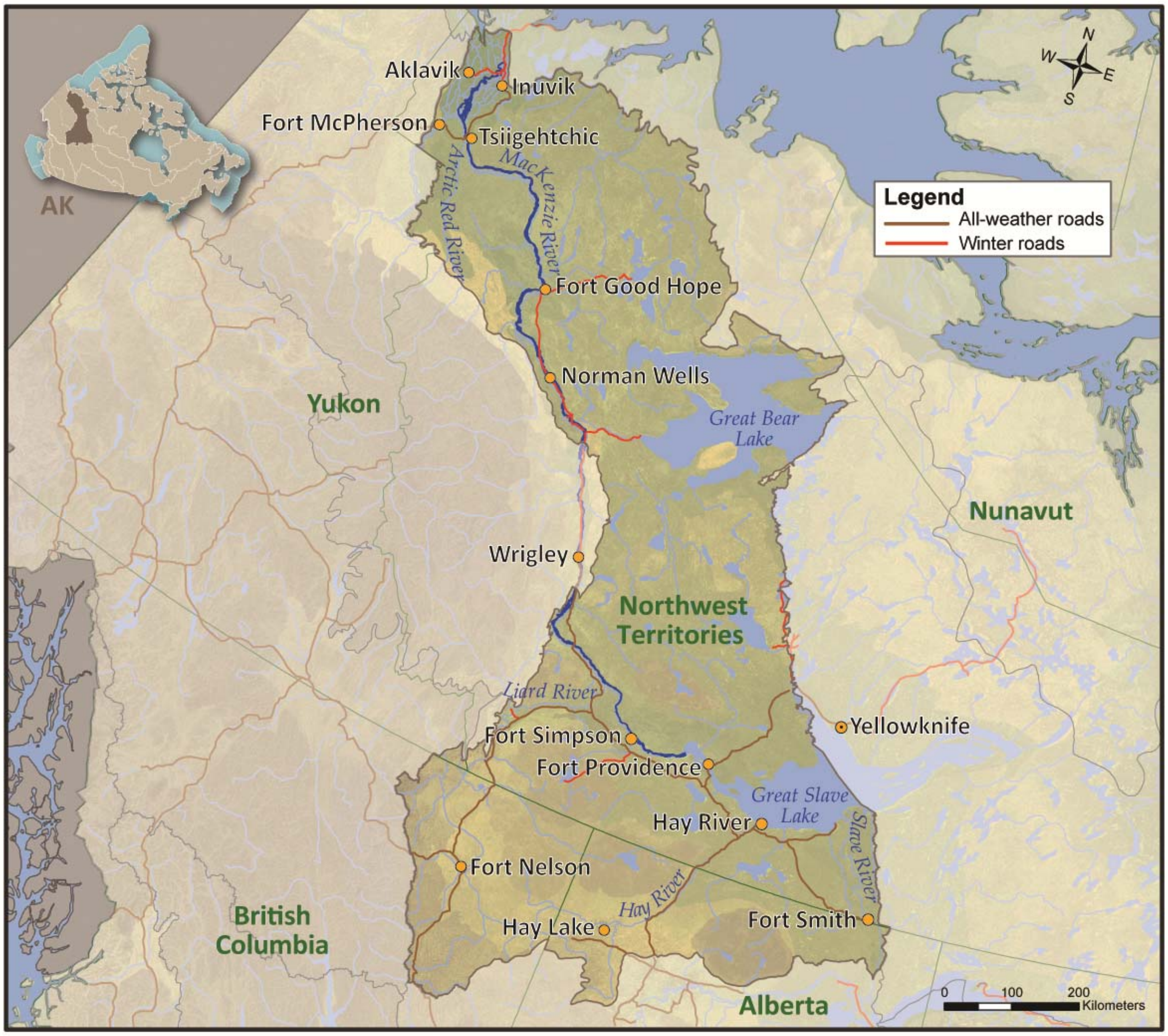


Figure 1. Overview map of the Taiga Plains Ecozone⁺

ECOZONE⁺ BASICS

The Taiga Plains Ecozone⁺ is the large extent of boreal forest sweeping from the Arctic coast south along the Mackenzie River. The ecozone⁺ with its extensive peatlands, wetlands and intact blocks of forest provides important habitat for wildlife, especially waterfowl, endangered whooping cranes, the threatened wood bison, and caribou, including the threatened boreal caribou. The footprint from human development is greatest in the south (especially northeastern BC), along parts of the Mackenzie Valley, and around Inuvik. Oil and gas projects and pipelines, existing and potential, are the focus of industry and economic development, though hunting, fishing, trapping, and berry gathering remain very important to residents. Climate change is apparent in the ecozone⁺, with an average increase of 2°C year-round and over 5°C in winter since 1950 and corresponding changes in growing season, permafrost, and river ice.

Table 1. Taiga Plains Ecozone⁺ overview.

Area	604,628 km^2 (6.2% of Canada)
Topography	Extended plains and a few isolated, low-elevation plateaus Landscape modified by rivers that have cut deep gorges and created meandering channels and ox-bow lakes
Climate	Strong north-south gradient, with Growing Degree Days about double in the south compared to the north[16] Precipitation relatively low as are both summer rainfall and evapotranspiration rates. Snow pack accumulates mostly in the fall, with typically light snow from December to March[16]
River basins	Drainage to the Arctic Ocean through the Mackenzie River Basin, including through Great Slave and Great Bear lakes
Geology	Underlain by sedimentary rocks with horizontal layers of sandstones, shales, conglomerates, and limestone[17] Retreating ice sheets from the last ice age deposited till over most of the ecozone⁺ (Figure 2)
Land Cover	68% forest; 20% shrub cover (Figure 3) North: vegetation open with stunted stands of white spruce Further south: more closed canopy forests – species include black and white spruce, jack pine, Alaska paper birch, aspen, and balsam poplar[13]
Permafrost	North: continuous permafrost over shallow active layer Central: extensive discontinuous permafrost South: sporadic permafrost
Settlement	Population increased 36% from 1971 to 2006 (Figure 4) 9 communities with populations over 600 (Table 2); 7 smaller communities in NWT and additional small population centres in Indian reserves in BC
Economy	Historical and current economy centred on: 1) wildlife and fish abundance, 2) oil and gas reserves, 3) transportation (including pipelines)

Development	Roads are in the north and south portions of the ecozone+ (Figure 1) Additional minor roads and linear features are mainly related to access to oil and gas or, in the southern part of the ecozone+, forestry Industrial development is primarily oil and gas exploration and development, focused on the Mackenzie Delta and parts of the Mackenzie Valley. Major pipelines and associated infrastructure extending the length of the ecozone+ along the Mackenzie Valley are proposed and were approved in 2010 to proceed to the permit application stage[18]
National/global significance	Lower portion of Mackenzie River, longest river in Canada, draining 20% of the nation[19] Ramsar sites (wetlands of international significance): Hay-Zama Lakes and Whooping Crane breeding wetlands[20] World Heritage Site: Wood Buffalo National Park[21]

Jurisdictions: Mainly within the Northwest Territories; extends into northeast BC and northwest Alberta and includes a very small section of southeastern Yukon (Figure 1). Four settled land claims with jurisdiction in the ecozone+: Inuvialuit, Gwich'in, Sahtu, and Tlicho, plus the Deh Cho Interim Measures Agreement.

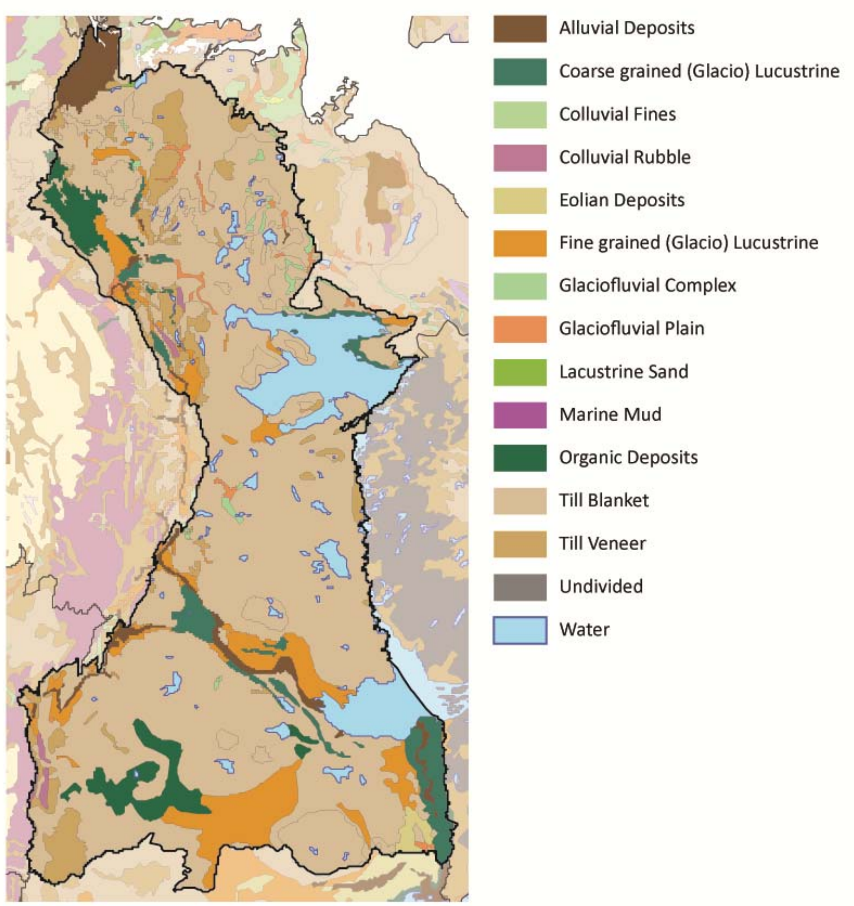


Figure 2: Surficial materials, Taiga Plains Ecozone+
Source: based on data from Geological Survey of Canada, 1994[17]

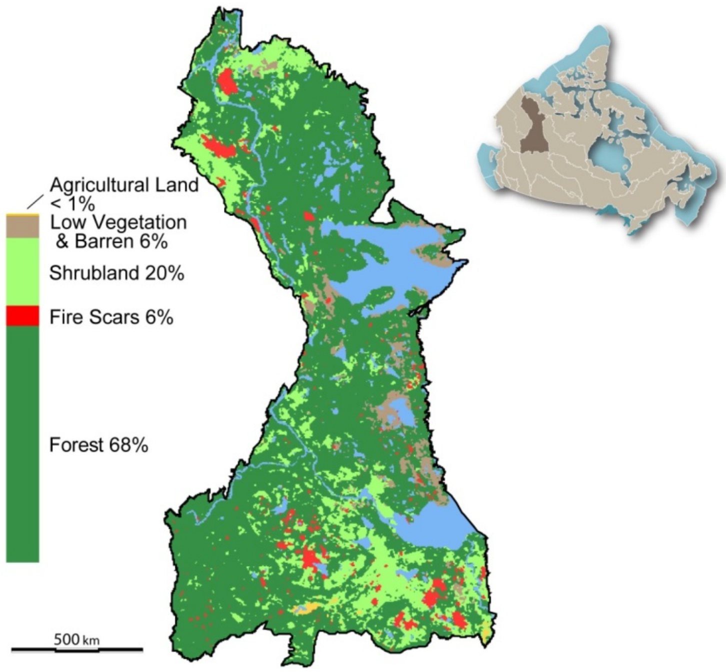


Figure 3. Land cover, Taiga Plains Ecozone+
Source: data for ecozone+ provided by authors of Ahern et al., 2011[13]

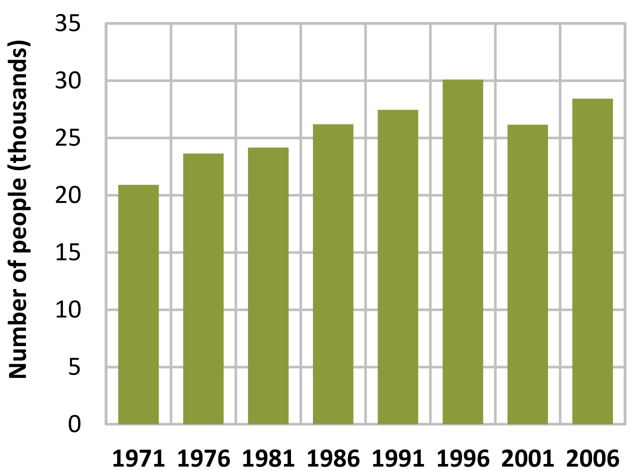


Figure 4. Human population trends, Taiga Plains Ecozone+, 1971-2006
Source: population data for the ecozone+ compiled from Statistics Canada 2000[22] *and 2008*[23] *and census reports for Wrigley, Fort Resolution, Fort Smith and Inuvik.*

Table 2. Main communities and their 2006 populations

Community	Population
Fort Nelson BC	4,514
Hay River NT	3,648
Inuvik NT	3,484
Fort Smith NT	2,364
Fort Simpson NT	1,216
Hay Lake 209 Indian Reserve AB	951
Fort McPherson NT	776
Norman Wells NT	761
Fort Providence NT	727

Source: Statistics Canada, 2009[24]

KEY FINDINGS AT A GLANCE: NATIONAL AND ECOZONE+ LEVEL

Table 3 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 Plains Ecozone+. Topic numbers refer to the national key findings in *Canadian Biodiversity: Ecosystem Status and Trends 2010*. Topics that are greyed out were identified as key findings at a national level but were either not relevant or not assessed for this ecozone+ 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 3. Key findings overview

Themes and topics	Key findings: NATIONAL	Key findings: TAIGA PLAINS 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.	Boreal forest is the dominant ecosystem type in the Taiga Plains. Fragmentation from roads and other linear development, resulting in loss of large intact blocks of forest, is most evident in northeastern BC. Climate-related changes in the treeline zone at the north of the ecozone+ include increased shrub growth, a small net increase in tree cover resulting from increased conifer cover at the northern part of the treeline zone balanced with reduction in coniferous forest in the south of the zone (1985-2006), and reduced growth rates, likely due to drought stress, of the majority of white spruce trees since the 1930s.
2. Grasslands	Native grasslands have been reduced to a fraction of their original extent. Although at a slower pace, declines continue in some areas. The health of many existing grasslands has also been compromised by a variety of stressors.	Not relevant

Themes and topics	Key findings: NATIONAL	Key findings: TAIGA PLAINS ECOZONE+
3. Wetlands	High loss of wetlands has occurred in southern Canada; loss and degradation continue due to a wide range of stressors. Some wetlands have been or are being restored.	Wetlands are diverse and widespread in the ecozone+ and are vulnerable to anthropogenic threats including climate change. Periodic spring flooding along the Mackenzie River Basin, which maintains the diversity of delta lakes, has been shown to be more related to climate variables than to the influence of the upstream W.A.C. Bennett dam. There are, however, indications that spring flooding may be less frequent. Delta lakes are affected by the longer ice-free season but also by increased erosion from permafrost slumping, which causes abrupt changes in water quality.
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.	The most widespread hydrological change is a trend to increased minimum and winter flows, both in the Mackenzie River as a whole (including tributaries upstream of the Taiga Plains) and in several smaller rivers monitored within the ecozone+. While upstream tributaries to the Mackenzie River are generally exhibiting trends to earlier peak flows, there is no clear trend in timing at most sites on smaller watercourses within the ecozone+. There are indications of a trend to increased streamflow variability within the ecozone+, with implications for riparian habitat.
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.	Not Relevant (coastal region just to the north of this ecozone+ is in the Arctic Ecozone+)

Themes and topics	Key findings: NATIONAL	Key findings: TAIGA PLAINS ECOZONE+
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.	Changes in permafrost, well documented for this ecozone+, include: increased temperatures of permafrost, changes in active layer depth, reduction of the continuous permafrost zone, and thawing of discontinuous permafrost in some areas. This has resulted in landscape changes, including loss of frozen peat plateaus. River ice within the Mackenzie Basin shows trends to earlier break-up; datasets are poor for both river and lake ice within the ecozone+.
THEME: HUMAN/ECOSYSTEM INTERACTIONS		
8. Protected areas	Both the extent and representativeness of the protected areas network have increased in recent years. In many places, the area protected is well above the United Nations 10% target. It is below the target in highly developed areas and the oceans.	In 2009, 5.6% of the ecozone+ had a high level of protection, by far the largest protected area being Wood Buffalo National Park, established in 1922. There was little change in protected areas from 1922 to the early 2000s when several, mainly quite small, protected areas were established. Candidate protected areas have been identified for the Mackenzie Valley in response to the proposed pipeline development. The aim is to maintain ecological integrity by developing buffer zones and connecting wildlife corridors through a network of protected areas.
9. Stewardship	Stewardship activity in Canada is increasing, both in number and types of initiatives and in participation rates. The overall effectiveness of these activities in conserving and improving biodiversity and ecosystem health has not been fully assessed.	Stewardship in the ecozone+ is associated with aboriginal cultural and spiritual values, incorporated into land-use planning through, for example, community conservation plans. Public-private sector partnerships and national and international initiatives also contribute to stewardship of ecosystems.

Themes and topics	Key findings: NATIONAL	Key findings: TAIGA PLAINS ECOZONE+
10. Invasive non-native species	Invasive non-native species are a significant stressor on ecosystem functions, processes, and structure in terrestrial, freshwater, and marine environments. This impact is increasing as numbers of invasive non-native species continue to rise and their distributions continue to expand.	There is some incursion of non-native plant species, especially along roadways, in the Taiga Plains, with only a few being moderately invasive. An invasive non-native forest insect, the larch sawfly, has spread to the ecozone+, with regionally significant outbreaks in the 1990s. Increasing access, development, and climate change are liable to increase the rate of introduction and spread of non-native species in terrestrial and aquatic environments.
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.	Some legacy contaminants are declining in fish in the ecozone+ but the trends are not clear or consistent with, for example, DDTs increasing in recent years in Mackenzie River burbot. Brominated flame retardants in fish increased sharply up to the mid-2000s and then dropped, based on limited sampling. Mercury levels are naturally high in the Mackenzie Basin and have increased in fish, including in the Mackenzie River and Great Slave Lake within the ecozone+. Changes in aquatic ecology related to climate change may be either accentuating or masking trends in some contaminants.
12. Nutrient loading and algal blooms	Inputs of nutrients to both freshwater and marine systems, particularly in urban and agriculture-dominated landscapes, have led to algal blooms that may be a nuisance and/or may be harmful. Nutrient inputs have been increasing in some places and decreasing in others.	Not considered to be a concern for this ecozone+
13. Acid deposition	Thresholds related to ecological impact of acid deposition, including acid rain, are exceeded in some areas, acidifying emissions are increasing in some areas, and biological recovery has not kept pace with emission reductions in other areas.	Not considered to be a concern for this ecozone+

Themes and topics	Key findings: NATIONAL	Key findings: TAIGA PLAINS 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.	The Taiga Plains Ecozone+ has experienced some of the greatest increases in temperature of any Canadian region since 1950 – with the annual mean temperature increasing over 2°C and winter temperatures rising about 5°C at all stations since 1950. This warming has translated into some clear ecosystem trends, such as changes to permafrost landscapes and increases in terrestrial primary productivity. There are indications of other emerging, climate-related trends, such as the northward movement of some forest insect pests.
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 of the ecozone+ include harvest of fish, wildlife, and plants, of cultural, spiritual, nutritional, and economic importance. Reliance on these provisioning services is high and not declining, especially in rural communities. Quality of these services generally remains high, with the exception of declines in barren-ground caribou, leading to harvest restrictions and reduced harvest success in some communities.
THEME: HABITAT, WILDLIFE, AND ECOSYSTEM PROCESSES		
16. Agricultural landscapes as habitat	The potential capacity of agricultural landscapes to support wildlife in Canada has declined over the past 20 years, largely due to the intensification of agriculture and the loss of natural and semi-natural land cover.	Not relevant

Themes and topics	Key findings: NATIONAL	Key findings: TAIGA PLAINS ECOZONE$^+$
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.	The Taiga Plains Ecozone$^+$ is important nationally for boreal woodland caribou, who are dependent upon intact blocks of mature boreal forest. Trends are unknown for half of the populations; populations in the more fragmented, southern part of the ecozone$^+$ are decreasing, although one population is reported as being stable. Bluenose-West barren-ground caribou have declined precipitously in recent years. Several waterfowl species that breed in the ecozone$^+$ are declining; causes are not clear. The Taiga Plains is home to most of the global populations of two iconic species that were nearly driven to extinction in the early 20th century and are still considered at risk: the whooping crane and the 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.	Overall, primary productivity increased on 22.7% and decreased on 1.5% of the land area of the Taiga Plains from 1985 to 2006. Increased primary productivity was mainly in the north part of the ecozone$^+$, where studies show increased growth of shrubs along with some impairment of growth of lichens and of some white spruce. The large fires characteristic of the ecozone$^+$ influence primary productivity but do not account for the overall increase.
19. Natural disturbances	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.	Natural disturbances in the Taiga Plains show signs of change related to climate. On a decadal basis, the area of forest burned increased from the 1960s then declined again in the most recent decade, though data are incomplete for this latter decade. There are indications of a trend to more fires earlier in the season, a pattern consistent with the observed temperature trends. The main forest insect pest, spruce budworm, is endemic in the southern part of the ecozone$^+$ and there are indications that it may be moving northward. Both the forest tent caterpillar and the mountain pine beetle, relatively new to the ecozone$^+$, show signs of becoming more abundant and expanding northward.

Themes and topics	Key findings: NATIONAL	Key findings: TAIGA PLAINS ECOZONE+
Wildlife disease and parasites (ecozone+-specific key finding)		Wildlife disease is of importance to the Taiga Plains Ecozone+ for ecological, economic, and human health reasons. Bovine tuberculosis and brucellosis affect a high percentage of wood bison and present risks to human health and to economic activities. There is emerging evidence and growing concern that some wildlife diseases and parasites (including anthrax, ungulate parasites, and viruses and funguses affecting frogs) may be increasing in prevalence and/or range, or may do so in the future, in response to warmer weather and changes in wildlife species distribution.
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.	There is little information on changes in food webs in the Taiga Plains. Abundance of many mammals in the Taiga Plains is cyclic, driven or influenced by food web effects as well as drivers like climate. Changes in small mammal cycles have been reported in other northern regions, and a recent dampening of snowshoe hare and lynx cycles is noted in the NWT. Northern tundra caribou wintering in the Taiga Plains have declined in abundance which may reflect a low period on a population cycle. Declining boreal caribou populations in the south of the ecozone+ may be affected by changes in predator-prey dynamics related to habitat alteration.
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.	Important data sets collected through broadscale monitoring programs for the ecozone+ are mainly at the non-biological level: climate, hydrology, and permafrost monitoring. In addition, data on some species groups, notably some caribou populations, small mammals, and waterfowl, provide good trend information. A combination of remote sensing and short-term research projects, often extending into the past through the use of proxy records, provides some data on landscape-level changes. A priority often identified for the region is improvement of the use of Traditional Knowledge along with results from science-based studies.

Themes and topics	Key findings: NATIONAL	Key findings: TAIGA PLAINS ECOZONE+
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.	There are signals of rapid ecosystem change in the Taiga Plains, related to climate change. Loss of frozen peatlands is occurring in some areas; increasing permafrost temperatures at several sites is an early warning that other areas will cross the phase-change threshold leading to permafrost degradation, altering terrestrial and aquatic ecosystems. Other large-scale changes observed in recent years include increases in primary productivity, mainly in the north of the ecozone+, and alteration of vegetation communities in the treeline zone.

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.

Ecozone+ key finding: Boreal forest is the dominant ecosystem type in the Taiga Plains. Fragmentation from roads and other linear development, resulting in loss of large intact blocks of forest, is most evident in northeastern BC. Climate-related changes in the treeline zone at the north of the ecozone+ include increased shrub growth, a small net increase in tree cover resulting from increased conifer cover at the northern part of the treeline zone balanced with reduction in coniferous forest in the south of the zone (1985-2006), and reduced growth rates, likely due to drought stress, of the majority of white spruce trees since the 1930s.

Spatial characteristics

The Taiga Plains Ecozone+, with its large variations in latitude, elevation, and climate, varies in density of forest cover and degree of forest fragmentation. It is an area of frequent large wildfires and thus the vegetation is often a mosaic of uneven-aged forest at different stages of regeneration.[13] Predominantly coniferous forest covers the valleys of the Mackenzie River and its tributaries, all the way to the Mackenzie Delta, although the lowlands of the Liard Valley tend toward mixed woods. Slightly higher elevations, such as the Cameron Hills, and regenerating burns are shrub-covered, while the highest elevations, primarily the eastern slopes of the Mackenzie Mountains, are characterized by tundra vegetation.

Much of this ecozone+ exhibits a proportion of forest greater than 50%. Lower forest densities are found immediately south of Great Slave Lake in the northern portion of Wood Buffalo National Park, the uplands near Norman Wells, in a large area west of Lac la Martre that burned in the mid-1990s, and in portions of the lower reaches of the Mackenzie Valley.[13]

Characteristics of Canadian forested regions were examined using remote sensing data.[13] The habitat requirements for many species are strongly influenced by the spatial characteristics of land cover types. These spatial characteristics can include the proportion of particular land cover types in an area and the amount of fragmentation and connectivity of particular land cover types. The presence of edges, implying a certain degree of fragmentation, is important for many species, while others, notably woodland caribou, are adversely affected by fragmentation.

Two methods were used to examine forest spatial characteristics and provide a baseline for future trend analyses, both calculated from the Earth Observation for Sustainable Development dataset of pixels at 30 m spacing within 1 km^2 cells (from the year 2000):

(1) forest density (proportion of land area that is forested): results are shown in Figure 5; and,
(2) edge density (the length of all edges between forested and non-forest pixels in each 1 km^2 cell): The forest edge density in the Taiga Plains is higher than in many more southerly forests, with a typical value of 250 m/km^2, increasing to 500-600 m/km^2 in tundra areas flanking the eastern foothills of the Mackenzie Mountains.

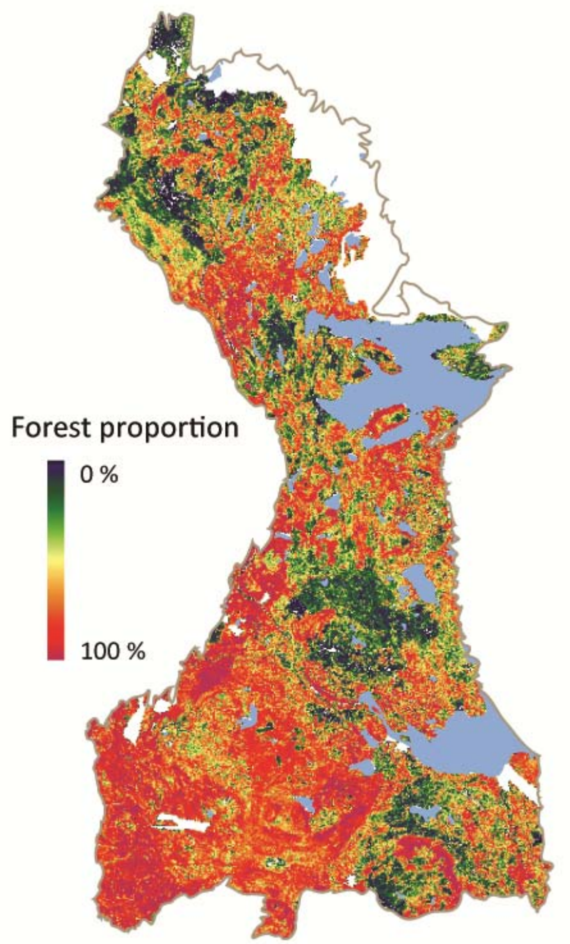


Figure 5. Map showing forest density, Taiga Plains, 2000
Proportion of 30 m^2 pixels that are forested in each 1 km^2 unit is shown. The northern white section is an artefact of the methodology – it corresponds with the boundary of the Taiga Plains ecozone under the 1995 classification. Density is not the number of trees, but the appearance of land cover from space. Lower proportion of forest may represent stands of black spruce or jackpine or regenerating forest with sparse canopy cover, while the higher forest proportion areas may represent mature white spruce stands with a lower density of trees but a dense canopy cover.
Source: Ahern et al., 2011[13]

Intact forest blocks

Figure 6 shows areas of intact forest blocks in the Taiga Plains Ecozone+. Note that northeastern BC, which has the lowest density of intact forest blocks, is a region with high forest density (Figure 5). This indicates that the lack of extensive areas of intact forest is due to fragmentation of the forest, rather than to large-scale land conversion or the presence of other natural land cover types.

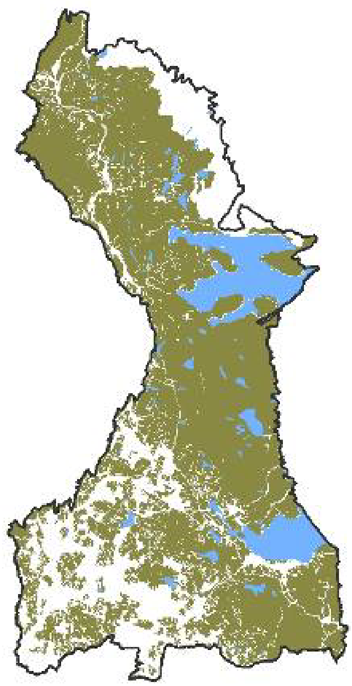


Figure 6. Intact forest blocks, Taiga Plains Ecozone+
Green shows contiguous blocks of forest undisturbed by anthropogenic features. Minimum block size is 10,000 ha. The northern white section is an artefact of the methodology – it corresponds with the boundary of the Taiga Plains Ecozone under the 1995 classification.
Source: based on data compiled by Lee et al., 2006[25]

The treeline zone

The following text box, which provides a broader perspective on treeline change, is excerpted from *Canadian biodiversity: ecosystem status and trends 2010.*[3]

Changes in the treeline zone

The term "treeline" is deceptive – there is not a sharp line where trees end, but rather a zone of transition from increasingly sparse trees to tundra. Treeline zones in Canada are both latitudinal, across the north of the country, and altitudinal, on the slopes of hills and mountains. The emerging picture is one of change, but not a uniform expansion of the treeline. In northern Quebec, trees in the forest-tundra zone have grown faster and taller since the 1970s[26] but distribution of trees has not changed greatly.[27] In Labrador, treelines have expanded northward and up slopes over the past 50 years along the coast, but not inland.[28] In the mountains of northwestern Canada, tree growth and density have changed more than the position of alpine treelines.[29]

A study on the treeline in western Canada found only a small net increase in tree cover, but major changes in vegetation within the treeline zone. Tree cover increased in the northern half of the zone, but this was mainly offset by decreases in the southern half, especially west of the Mackenzie Delta – likely related to drier conditions due to higher temperatures.[30] 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).

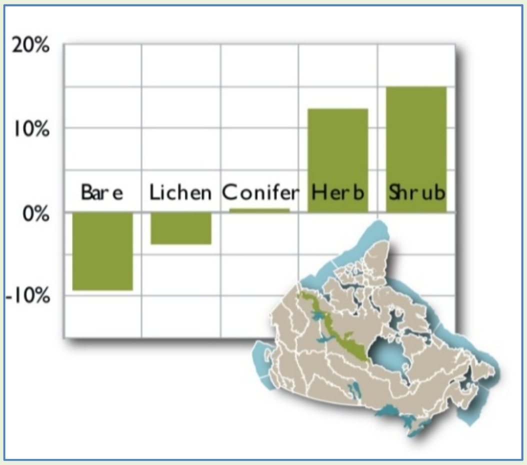


Figure 7. Vegetation changes in the treeline zone of Western Canada, between 1985 and 2006
Mean change across the zone over 22 years based on analysis of early spring and summer satellite images.
Source: data from Olthof and Pouliot, 2010[31]

Global perspective

Since 1900, treeline has advanced at 52% of the 166 sites examined around the world and has receded at only 1% of the sites.[32]

Several studies have shown strong correlations between summer temperatures and variation in vegetation patterns at the northern edge of the treeline zone in the Taiga Plains, indicating that increasing temperatures are likely to alter shrub abundance, vegetation structure, and species composition.[33, 34] There are indications that this change is underway. Lantz et al., 2010[35] in a study along a transect from the Beaufort coast to the region of Fort McPherson in the south, found that green alder (a tall shrub) at sites at the northern edge of the forest-tundra transition zone showed patterns of recruitment markedly different from green alder at sites to the south. There was a higher proportion of younger shrubs in the northern transition zone, indicating recent colonization of the sites by green alder. The study also showed that green alder growth and reproduction were significantly greater on burned sites, with tall shrubs dominating burned sites in all vegetation zones. The combined effects of increased fire and warmer growing seasons are likely to result in continued northern movement of tall shrubs.

As in other regions of northwestern North America, white spruce stands in or near the treeline zone of the Taiga Plains show signs of decreased growth as the climate warms – perhaps due to the crossing of a physiological threshold for summer temperature and/or drought stress in the warmer summers.[36-38] An analysis of annual growth, based on tree ring width, of 654 white spruce trees from 9 sites in the Mackenzie Delta[30] showed that there was a high degree of similarity in growth rates among all trees up from 1600 to about 1930, when growth rates diverged. From about 1930 to the end of the study in 2003, growth rates for about 25% of the trees increased (this group is called positive responders), while growth rates for the remaining 75% of the trees (negative responders) declined (Figure 8). White spruce growth rates were compared with climate records from Inuvik (starting in 1927) and with Northern Hemisphere growing season temperatures (records starting in 1856). Annual growth of positive responders was strongly correlated with June temperatures in Inuvik and with North American growing season temperatures, while the low annual growth rates of negative responders were inversely related to temperatures from the current and, especially, the previous summer. This apparent slowing of growth in warmer summers was somewhat mitigated in years with higher April precipitation – an indication that both temperature stress and drought stress may be affecting white spruce in the region.

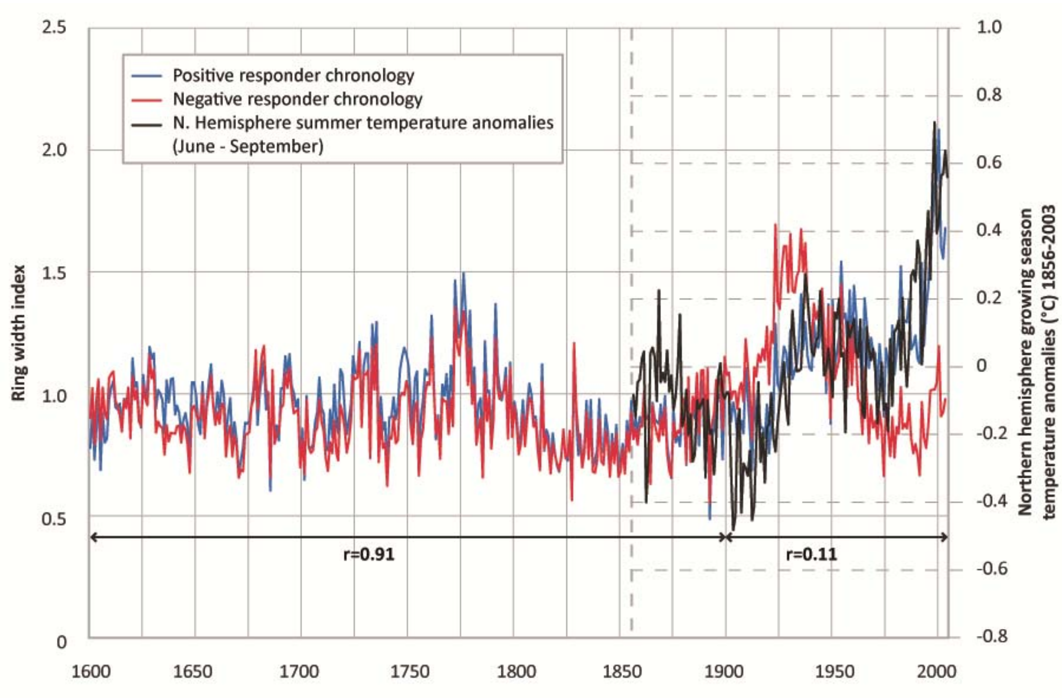


Figure 8. Growth of white spruce in the Mackenzie Delta, reconstructed from tree rings, 1600-2003, plotted with Northern Hemisphere growing season temperature anomalies, 1856-2003
The black line that starts in 1856 is the trend in temperature anomalies. The two groups of white spruce are the lines starting in 1600: the red line represents the average annual growth "negative responders" (trees showing an inverse relation between growth and summer temperatures after 1930) and the blue line represents the annual growth of "positive responders" (trees showing a positive correlation between growth and summer temperatures). The correlation coefficients show the strength of the relationships between the growth rates of the two groups of trees from 1600 to 1899 (r=0.91) and from 1900 to 2003 (r=0.11).
Source: adapted from Pisaric et al., 2007[30]. Reproduced with permission of John Wiley & Sons, Inc.

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.

Ecozone⁺ key finding: Wetlands are diverse and widespread in the ecozone+ and are vulnerable to anthropogenic threats including climate change. Periodic spring flooding along the Mackenzie River Basin, which maintains the diversity of delta lakes, has been shown to be more related to climate variables than to the influence of the upstream W.A.C. Bennett dam. There are, however, indications that spring flooding may be less frequent. Delta lakes are affected by the longer ice-free season but also by increased erosion from permafrost slumping, which causes abrupt changes in water quality.

Wetland types include extensive river deltas, floodplain lakes and ponds, meandering river channels bordered by wetlands, thermokarst lakes, peatlands, and marshes. The wetlands of the Taiga Plains provide habitat for hundreds of thousands of migrating and nesting water birds, as well as supporting a diversity of fish and providing habitat for mammals including moose, caribou, muskrats, and beavers. Wetlands are traditional hunting and fishing locations and important culturally to the residents of the Taiga Plains. This section focuses on aspects of wetlands undergoing change or vulnerable to change from anthropogenic threats.

As with the boreal forest in general, large blocks of undisturbed wetlands are important in maintaining wetlands biodiversity. Some species are not tolerant of disturbance and fragmented habitat – the extreme example for the ecozone⁺ being the whooping crane, a water bird that was driven almost to extinction from habitat loss. Disturbance and habitat alteration in nesting grounds may also be linked to reductions in species of waterfowl breeding in the Taiga Plains (see key finding on Species of special interest on page 54).

Ramsar sites

There are two Ramsar sites (wetlands designated as being of international significance) in the Taiga Plains Ecozone⁺:

1. Hay-Zama Lakes, in Alberta. This 486 km^2 complex of lakes and wetlands, a staging area for migrating waterfowl, is protected as an Alberta park. Oil and gas exploitation, however, predated the creation of the park and is permitted to continue until reserves are depleted.[39] It is a traditional harvesting area for the Dene Tha'.

2. Whooping Crane Summer Range, in NWT and Alberta, within Wood Buffalo National Park. This 16,895 km^2 area is the only remaining natural nesting area of the whooping crane; it contains thousands of water bodies including lakes, bogs, marshes, shallow ponds and streams.[20]

Ecozone⁺ wetlands and ponds are formed and maintained by low evapo-tranpiration rates and permafrost conditions as well as by the physical depressions left by glaciations, and thus are vulnerable to environmental shifts. While there are indications of changes in ponds in the Taiga Plains due to warming and thawing permafrost (discussed below), no widespread reduction in pond area has been observed in the ecozone+. Rising temperatures causing increased evapo-transpiration and changing permafrost have led to a regional trend of shrinking ponds in Alaskan boreal forests[40] and there has been some reduction of total pond area in the Old Crow Flats in northern Yukon (Taiga Cordillera Ecozone+).[41] As wetlands dry out and fire frequency increases due to global warming, wetland plant species composition could change dramatically because of deep burning into the organic layers.[42]

Deltas and river-associated lakes and wetlands

The extensive Mackenzie River Delta (13,000 km^2),[43] with its 45,000 lakes, is partly in the forest and shrub zones of the Taiga Plains Ecozone+ and partly across the tundra of the Arctic Ecozone+. It is a productive aquatic ecosystem, unusually so for its latitude.[44] Its high productivity is considered to be related to both the longer ice-free season of floodplain lakes (compared with nearby lakes) and their replenishment from the nutrient-rich river sediments.[44] Many of the lakes of the Mackenzie Delta and throughout the continuous permafrost zone are thermokarst wetlands, formed in depressions on top of permafrost.

There are also two major freshwater deltas in the ecozone+: the Slave (the mouth of the Slave River, flowing into Great Slave Lake), and Mills Lake (a widening of the Mackenzie River at the mouth of the Horn River, near Fort Providence). The Slave River Delta, covering an area of 554 km^2,[45] is a stopover in spring and fall for birds on all four major continental flyways.[45, 46] Mills Lake (381 km^2), is a major staging area for waterfowl during spring and fall migrations, a refuge for moulting diving ducks in summer[45] and a grazing area for wood bison.[47]

Flood regime

Periodic flooding associated with spring discharge and ice events creates and maintains the diversity of habitat provided by the lakes and wetlands of the Slave and Mackenzie river deltas.[48-51] A study of lakes and ponds in the Slave River Delta (2003 to 2005) indicated that the degree and frequency of river flooding is the dominant factor controlling water chemistry and plant and diatom plankton communities and biomass in each body of water.[52]

The Slave River is influenced by flow regulation from the W.A.C. Bennett dam and associated reservoir (see Lakes and rivers key finding). A study that reconstructed the frequency of spring break-up flood periods over 80 years[48] showed that floods have tended to be cyclical, alternating through periods of about a decade each of high and low flooding (Figure 9). Spring floods appear to be more related to climate-driven conditions in the upper reaches of the Mackenzie River Basin than to water regulation by the W.A.C. Bennett dam (which started in 1968). Periods of low flooding preceded flow regulation and periods of high flooding followed the onset of flow regulation. The authors predicted that floods will become less frequent with lowered snow pack and thus less headwater runoff resulting from climate change. There are indications that this trend to reduced spring flooding may have begun in this and other parts of the watershed.[48]

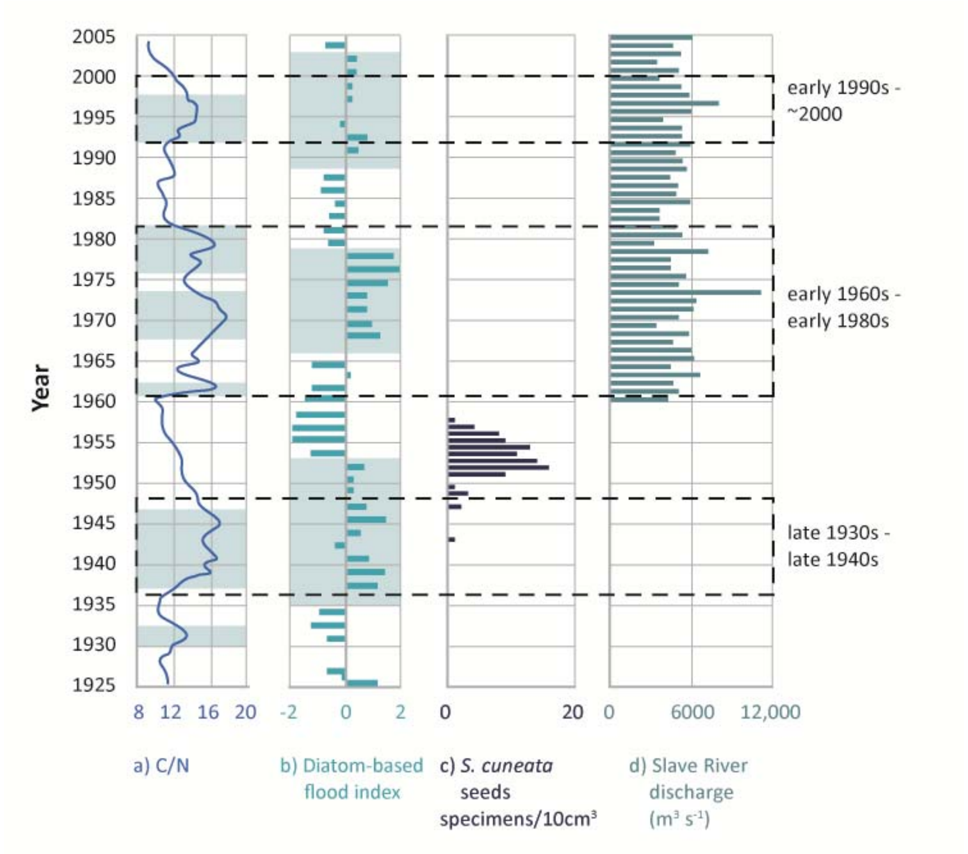


Figure 9. Flood events in the Slave River Delta, 1925-2005
Flood events are reconstructed from proxy data, as indicated (columns a through c) and from measured discharge (column d). Shaded boxes show periods of high flood frequency inferred from each proxy and the horizontal boxes outlined in dashed lines indicate the main periods of high flooding.
Source: Brock et al., 2010[48]. Used with permission of Canadian Water Resources Journal

Permafrost degradation

Changes in spring melt and break up are also leading to changes in water quality due to increased erosion from permafrost slumping.[46, 53]

Melting and slumping permafrost erodes and alters the physical configuration of wetlands as well as the water quality and shoreline and lake bottom characteristics.[19] An analysis of aerial photographs at 23 study sites in the Mackenzie Delta[54] showed an increase in thaw-slump activity from 1950 through 2004 (Figure 10). Retrogressive thaw slumping is a slope failure caused by thawing of ground ice and slumping of thawed soil, forming headwalls.[55]

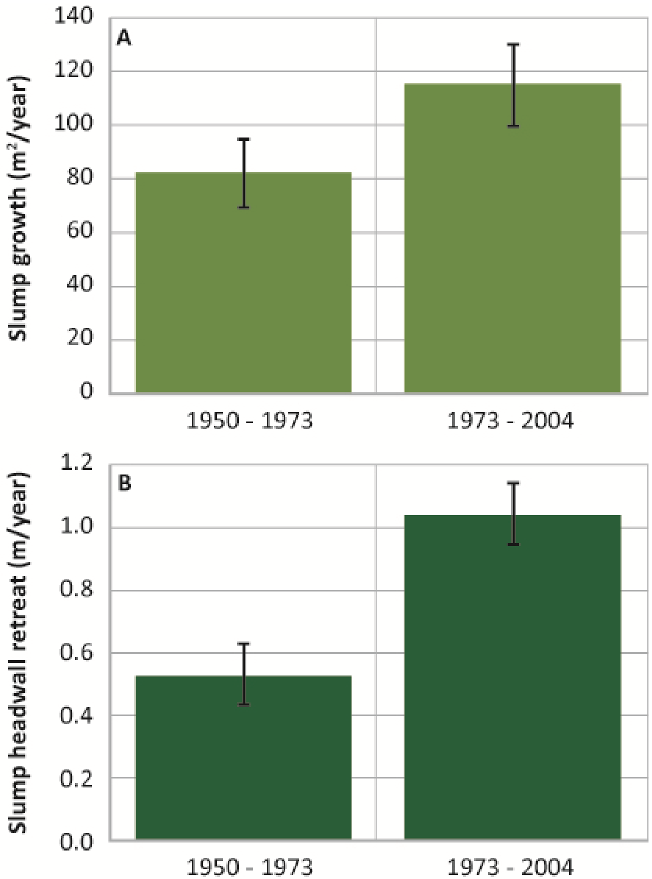


Figure 10. Increase in retrogressive thaw slumps, Mackenzie Delta, 1973-2004 compared with 1950-1973
A. Average annual rates of slump growth (based on changes in area of disturbance from thaw slumping)
B. Average annual rates of headwall retreat
Error bars are +/- SE.
Source: Lantz and Kokelj, 2008[54]. Reproduced with permission of John Wiley & Sons, Inc.

Impacts of changes in the deltas on biodiversity

Permafrost degradation was the main environmental factor explaining differences in water quality in a study of 73 lakes, about half of which were affected by retrogressive thaw slumping, in the Mackenzie Delta (both in the tundra region, Arctic Ecozone+, and in the region along the boundary with the Taiga Plains Ecozone+).[53] The effect was mainly on water clarity and the concentration of ions, rather than on total organic carbon. The affected aspects of water quality are strong determinants of lake biotic communities. The authors concluded that the abrupt changes in lake chemistry brought about by thaw slumping can be expected to lead to abrupt shifts in aquatic food webs.

The wide ranges in extent of and in periods of connectivity between Slave and Mackenzie delta lakes and rivers are important in creating a diversity of habitats, which are then able to support many different communities of species of invertebrates, water birds, fish, and mammals.[46, 50] Changes in river flow (reduced flooding) combined with the rise in sea level associated with climate change may result in fewer types of wetlands, with a lowering of habitat diversity in the Mackenzie Delta.[50]

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.

Ecozone+ key finding: The most widespread hydrological change is a trend to increased minimum and winter flows, both in the Mackenzie River as a whole (including tributaries upstream of the Taiga Plains) and in several smaller rivers monitored within the ecozone+. While upstream tributaries to the Mackenzie River are generally exhibiting trends to earlier peak flows, there is no clear trend in timing at most sites on smaller watercourses within the ecozone+. There are indications of a trend to increased streamflow variability within the ecozone+, with implications for riparian habitat.

The Taiga Plains Ecozone+ drains to the Arctic Ocean through the Mackenzie River catchment area. As Canada's largest river basin (draining 20% of the nation's area),[56] the Mackenzie River drains a total area of 1,787,000 km^2. The Mackenzie River Basin (Figure 11) includes a number of other important river systems, including the Athabasca, Peace, Liard, Slave, Arctic Red, and Peel rivers.[57, 58] The extensive Mackenzie River Delta is partly within the Taiga Plains Ecozone+ and partly within the Arctic Ecozone+. The Mackenzie basin has three major lakes: Lake Athabasca (along the Taiga Shield/Boreal Shield ecozones+ boundary), Great Slave Lake (partially within the Taiga Plains Ecozone+ and partially within the Taiga Shield Ecozone+), and Great Bear Lake, which is fully within the Taiga Plains Ecozone+. There are two major freshwater deltas: the Peace-Athabasca (flowing into Lake Athabasca, in the Boreal Shield Ecozone+) and the Slave (flowing into Great Slave Lake, within this ecozone+). Within the Taiga Plains Ecozone+ the Horn River also forms a delta at its confluence with the Mackenzie River. Lakes and wetlands of the Mackenzie and Slave deltas are discussed in the Wetlands key finding, above. Changes related to lake and river ice are discussed in the Ice across biomes key finding, below.

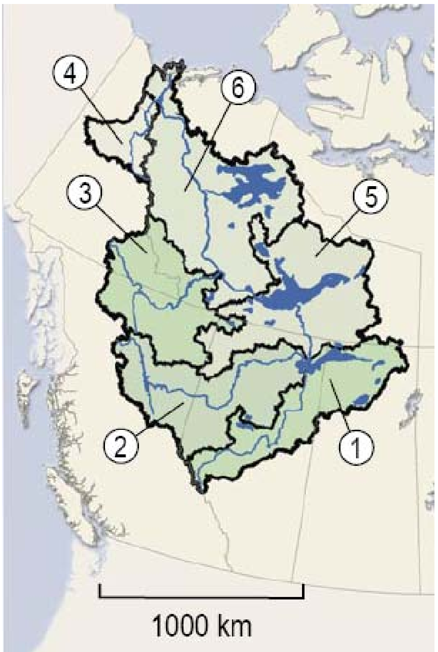


Figure 11. Sub-basins of the Mackenzie River Basin
Sub-basins: 1. Athabasca; 2. Peace; 3. Liard; 4. Peel; 5. Great Slave; 6. Mackenzie-Great Bear
Source: Mackenzie River Basin Board, 2004[59]. Reproduced with the permission of the Mackenzie River Basin Board.

Trends in hydrology for the Mackenzie River

The total annual discharge from the Mackenzie River did not change from 1968 to 1999, despite significantly increased air temperatures in the river basin over this period.[60] However, changes in timing and seasonal distribution of river discharge have occurred, with the strongest single effect of climate change being the trend to earlier peak flows at different locations throughout the basin, correlated with increasing spring temperatures.[19] Trends towards an earlier onset of spring freshet were detected in analyses of the Mackenzie River and its main tributaries[61-63] and were shown to be correlated with increases in air temperature[62] and with climate oscillations.[61] Figure 12 shows this trend for the Liard River, measured at Upper Crossing, Yukon, upstream of the Taiga Plains Ecozone+.

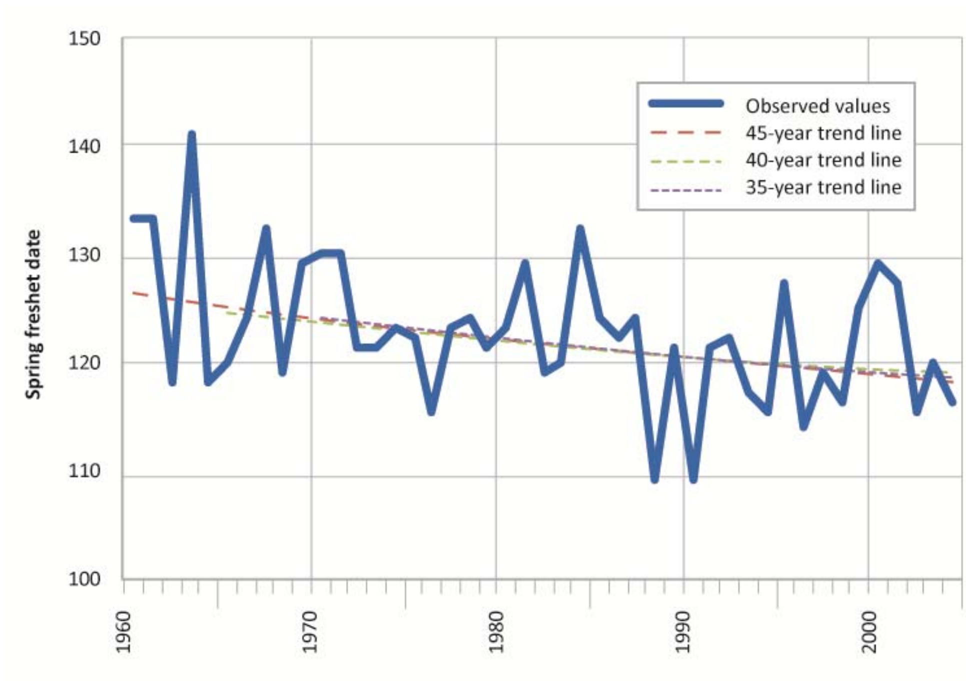


Figure 12. Trend to earlier spring freshet date in the Liard River at Upper Crossing, upstream of the Taiga Plains Ecozone+, 1961-2005
Source: Burn, 2008.[61] Reprinted with permission from Elsevier

Analyses of hydrometric data at the river basin scale demonstrate a widespread trend to increased minimum and winter flows: in the Liard, 1960-1999,[62] and in the Mackenzie, Liard, Athabasca, Peace, Slave, and Peel rivers, 1960-2000.[63] The increased winter flows in the Liard River (1960-1999) have been attributed in part to the Pacific Decadal Oscillation.[62] Increased winter flows have also been linked to thawing of permafrost from climate change.[19]

Trends in hydrology within the ecozone+

Indicators of hydrological alteration

This section is based on Canada-wide analyses performed by Monk and Baird, 2011[15] for the 2010 Ecosystem Status and Trends Report. Gauging sites that form the Reference Hydrological Basin Network (RHBN) that provides Canada's contribution to the World Meteorological Organization monitoring program for climate change[640] were examined for trends across a range of hydrological characteristics. Variables were calculated for 172 hydrometric sites across Canada for each hydrological year (1970 to 2005). The variables calculated are "indicators of hydrological alteration" which quantify aspects of streamflow of ecological significance.[65] There was high variability in the results across the country. A main conclusion drawn by the authors was that the shortage of long-term continuous hydrometric records in Canada (particularly in the northern ecozones+) severely limits our ability to monitor current trends and project future trends in hydrological regimes. Many sites have been discontinued and the majority of sites in the national database have fewer than 18 years of data.

Eleven gauging sites with suitable data for this analysis were available for the Taiga Plains Ecozone+. Statistically significant trends in indicators of hydrological alteration at these sites are summarized in Figure 13. Trends in monthly flows varied, with significant increasing trends during winter months at several sites. Six sites showed statistically significant increases in various measures of minimum runoff (which occurs during winter); five sites had significant increases in baseflow (the seven-day minimum flow divided by the mean annual flow). There were few significant changes in peak flows or in timing of maximum and minimum flows.

The increases in baseflow indicate that a greater component of streamflow is being supplied through groundwater at several of the sites; this is likely to be related to the increased degradation of permafrost throughout the region. One of the most profound projected consequences of permafrost thaw is a transition from surface-water-dominated rivers to groundwater-dominated rivers.[66] Changes in water quality accompany an increase in baseflow, including increases in major ions from the more mineral-rich groundwater – though the overall impacts on nutrient levels and many other water characteristics remain uncertain.[66]

Nine sites had significant increasing trends in the number of hydrologic reversals (changes in the direction of the trend in streamflow), suggesting increased variability in runoff (Figure 13). This trend was also seen in many of the sites in neighbouring ecozones+. Ecological impacts of increased variability include: stranding of species in isolated habitat patches (falling levels); entrapment on islands and floodplains (rising levels); and drought and desiccation stress to stream-edge organisms,[65, 67] with the net effect of changes in riparian communities.

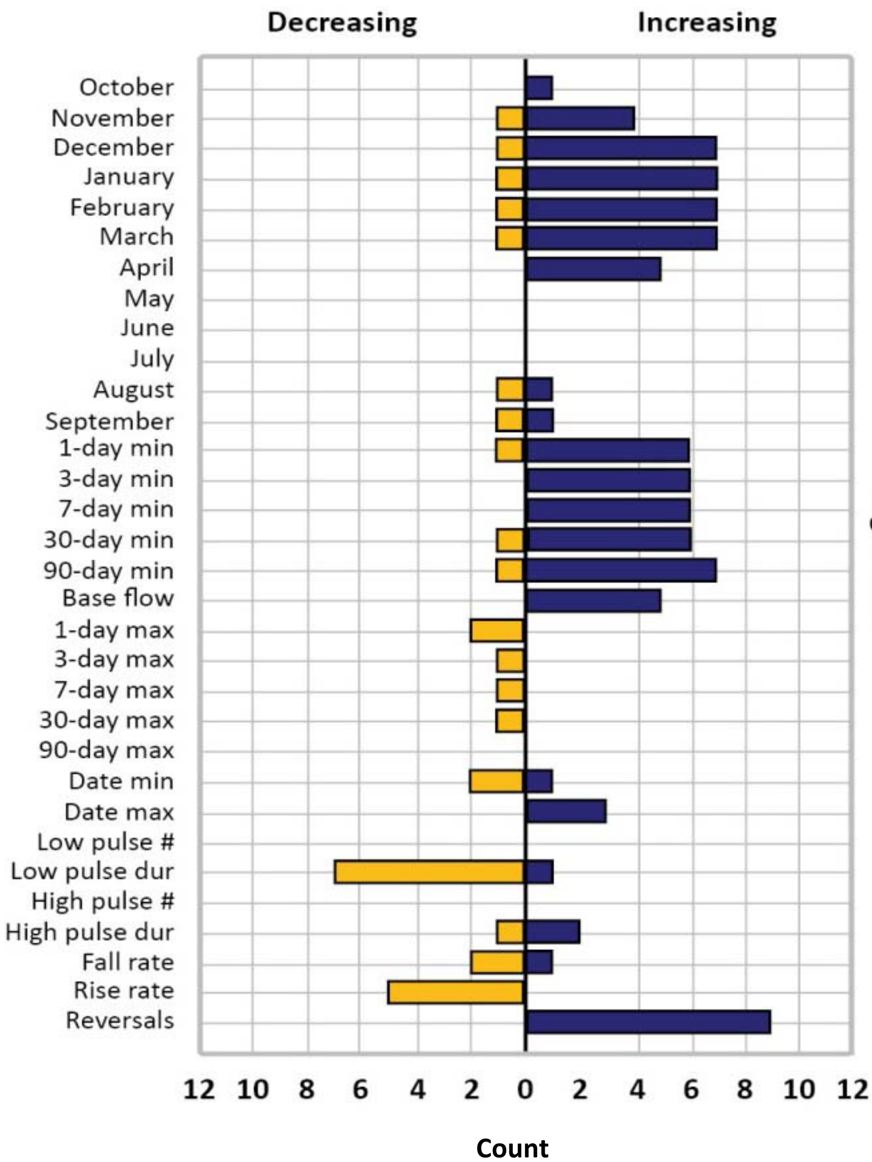


Figure 13. Number of sites displaying significant increasing and decreasing trends in indicators of hydrological alteration for the Taiga Plains Ecozone+
Trends shown are significant at the p<0.1 level. Parameters listed on the vertical axis refer to river discharge except: date min/max (decreasing date means earlier and increasing date means later for minimum and maximum annual discharge), low/high pulse # (number of discharge pulses), fall/rise rate (rate of change in discharge), and reversals (number of reversals)
Source: Monk and Baird, 2011[15]

Trends through the seasons at two hydrometric sites

This section is based on Canada-wide analyses performed by Cannon et al., 2011[14] for the 2010 Ecosystem Status and Trends Report. Trends in hydrology over the course of the seasons (at five-day intervals) and the relationship to trends in climate were examined for Canada's ecozones+. Analyses were based on climate and hydrology data from Environment Canada's monitoring networks from 1961-2003 (thus using different subsets of the same data as the above analysis of indicators of hydrological alteration).

Only two sites in the Taiga Plains Ecozone+ had data records that met the study requirements for the period 1961-2003: 1) Hay River, where it drains northeast into Great Slave Lake in the NWT; and, 2) Muskwa River near Fort Nelson in BC, a main tributary of the Fort Nelson River, which in turn drains to the Liard River. With only two points for analysis, the results cannot be interpreted to apply to the entire ecozone+, but instead highlight the hydrologic and climatic changes at these two locations.

Both Hay River and Muskwa River are streams driven by snowmelt processes, but they differ in their annual discharge patterns. Hay River has a distinctively sharp streamflow peak during freshet, whereas the Muskwa River exhibits a broad summer freshet with higher flows lasting for several months. The shifts in climate variables for these rivers were similar, but the hydrologic responses differed due differences in snowmelt processes between the two streams.

Hay River

At the Hay River site, temperature increases were seen over the entire year except during the fall. Summer temperatures remained relatively unchanged, whereas winter and spring temperatures showed increases of up to 3°C, comparing the periods 1961-1982 and 1983-2003. The highest monthly precipitation occurred in July, when a 30% increase occurred between the two periods. Precipitation decreased before and increased marginally after the summer peak, except during December. The hydrograph (Figure 14) shows that the spring freshet occurs between April and May. The magnitude of this peak flow did not change much (comparing averages over 1961-1982 and 1983-2003). The timing of the peak, however, shifted to slightly earlier. The higher summer and fall flows were likely the result of greater precipitation. Winter flows increased between the two time periods, attributed to warmer winters enhancing snowmelt. Monk and Baird, 2011[15] considered permafrost degradation to be a probable cause of the increase in winter discharge observed at the majority of Taiga Plain sites.

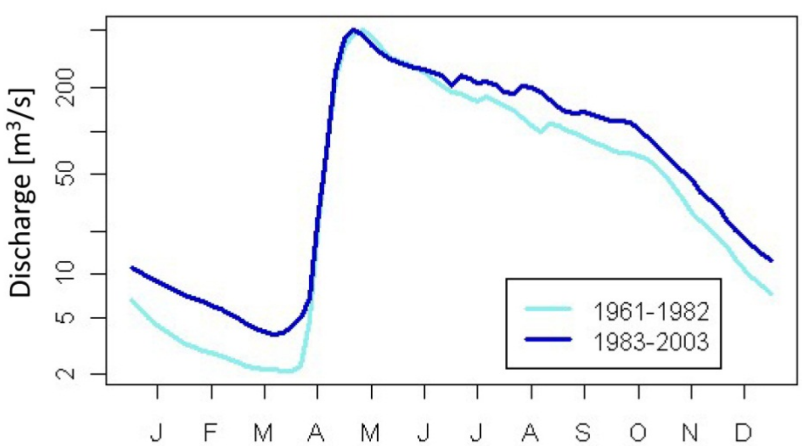


Figure 14. Changes in streamflow over the seasons, Hay River, comparing 1961-1982 and 1983-2003 Measurements are from hydrometric station 07OB001.
Source: Cannon et al., 2011[14]

Muskwa River

Between the periods 1961-1982 and 1983-2003, the only streamflow shift at Muskwa River was an additional 20-25 m^3/s of discharge occurring from November to the end of March (Figure 15). This was likely related to the much warmer average winter air temperature in the second time period. Precipitation decreased at this site in winter and increased in the remaining seasons, especially during the July streamflow peak. There was, however, no clear relationship between these observed precipitation changes and the changes in streamflow.

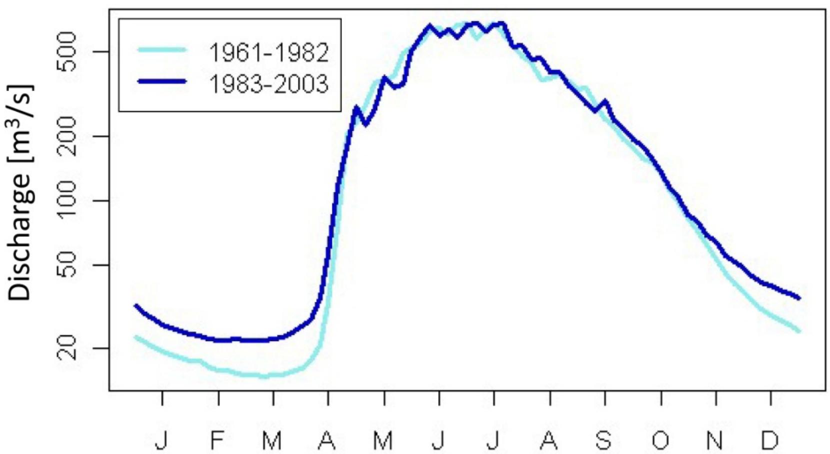


Figure 15. Changes in streamflow over the seasons, Muskwa River, comparing 1961-1982 and 1983-2003 Measurements are from hydrometric station 10CD001.
Source: Cannon et al., 2011[14]

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.

Ecozone⁺ key finding: Changes in permafrost, well documented for this ecozone⁺, include: increased temperatures of permafrost, changes in active layer depth, reduction of the continuous permafrost zone, and thawing of discontinuous permafrost in some areas. This has resulted in landscape changes, including loss of frozen peat plateaus. River ice within the Mackenzie Basin shows trends to earlier break-up; datasets are poor for both river and lake ice within the ecozone⁺.

Permafrost

The forested peatlands that characterize much of the Taiga Plains are underlain by varying degrees of permafrost (Figure 16) and are vulnerable to climate warming.[68] Both loss and warming of permafrost are occurring. One result has been a shrinking of the zone of continuous permafrost. A study that repeated, in 1988 to 1989, a 1964 permafrost survey along the Mackenzie Highway from Hay River south to Alberta showed that the northern fringe of discontinuous permafrost had migrated northward by about 120 km in 26 years.[69]

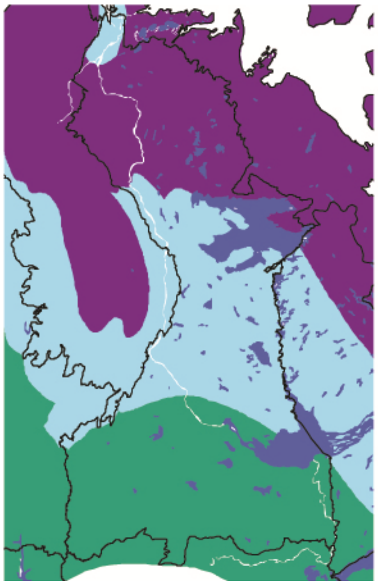


Figure 16. Permafrost zones of the Taiga Plains.
Source: Smith, 2011[12] based on Heginbottom et al., 1995[70]

A permafrost monitoring network in the Mackenzie Valley provides records of permafrost temperature in the upper 20 to 30 m. This monitoring network is supplemented with results from research on permafrost and on changes in frozen peatlands. Trends, from south to north are:

- Frozen peatlands are decreasing in parts of the southern Mackenzie Valley, with an average loss of frozen peatland area of 22% at four study sites over the latter half of the 20th century.[71]
- Permafrost temperatures monitored at other sites in the south-central part of the valley, however, show little change (Fort Simpson and Northern Alberta in Figure 17). At these sites, permafrost is likely being preserved by an insulating layer of peat.[72, 73]
- Permafrost temperatures are increasing in the central Mackenzie Valley (shown for Norman Wells and Wrigley in Figure 17), where permafrost is both thicker (up to 50 m deep) and colder.[74, 75]
- Similar rates of permafrost temperature increase, 0.1 to 0.2°C per decade at a depth of 15 m, have occurred since the 1960s in the colder permafrost (-2 to -3°C) at spruce-forested sites in the Mackenzie Delta in the north of the ecozone+.[76, 77]

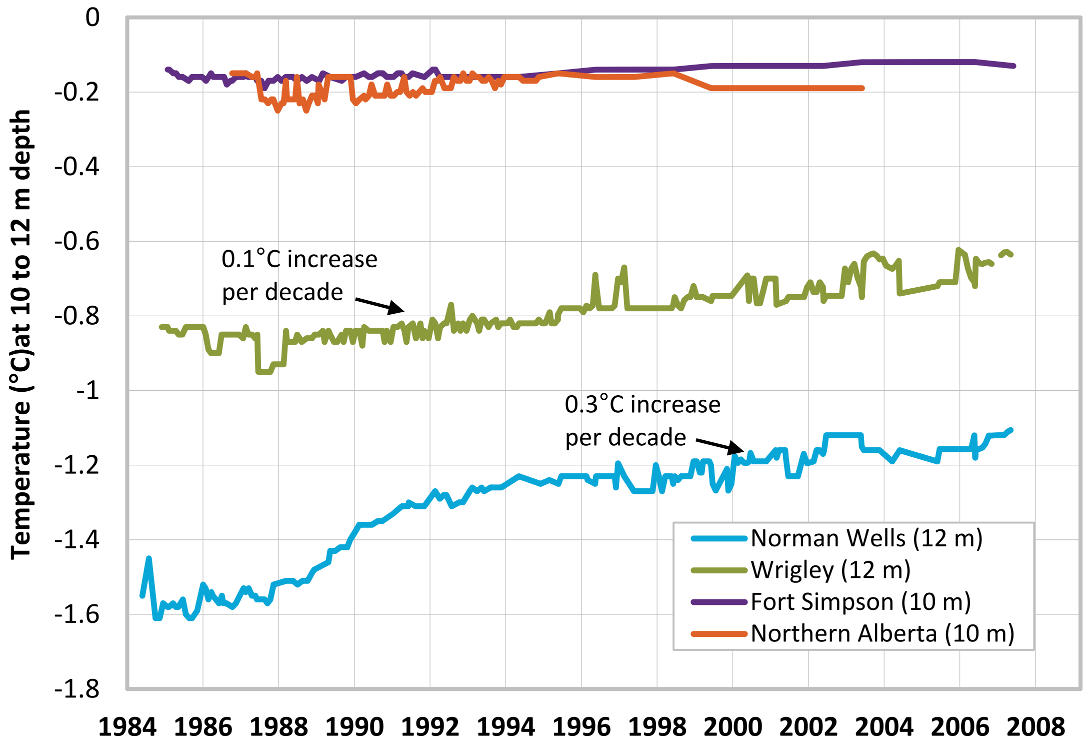


Figure 17. Ground temperatures in the central Mackenzie Valley, 1984-2007
Measurements are at depths near 10 m. Note that the frequency of measurements was reduced in the mid-1990s at the two most southern sites.
Source: adapted from Smith et al., 2010[78]

While these changes are consistent with trends in air temperature over the past few decades, changes in snow cover[79, 80] and in wildfires[81] are also affecting rates and locations of warming and thawing of permafrost. Fires may trigger a long-term process of permafrost decay,[82] though in sphagnum-moss-dominated peatlands fires are infrequent[73] and in other peatlands fires rarely burn deeply enough to have lasting effects on permafrost.[83] The distribution of peatlands, fire, and extent of snow cover are interrelated, leading to locally diverse permafrost dynamics.[84]

Degradation of permafrost leads to major impacts on landscapes with, for example, loss of frozen peat plateaus. A study of peatlands in the southern Taiga Shield concluded that peat plateaus in what is currently the discontinuous permafrost zone are unlikely to be sustained under a warming climate and that the landscape-level effects of this loss need further investigation.[85]

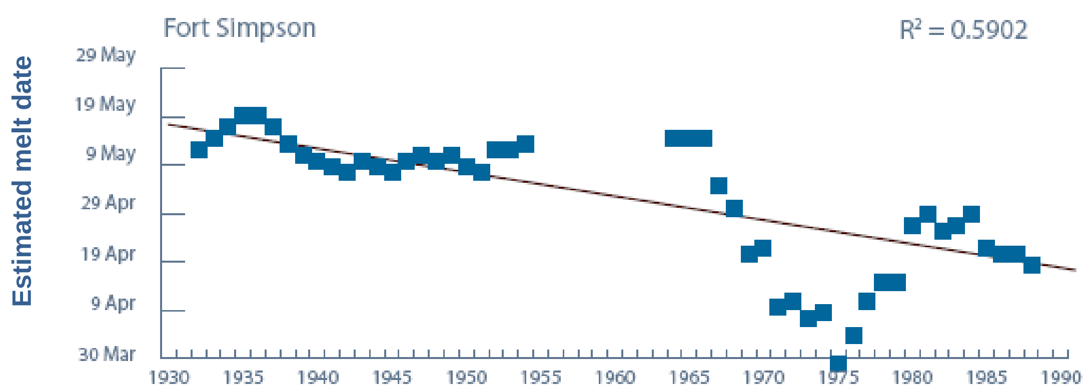
River and lake ice

Across Canada, lake ice break-up times show consistent trends to earlier dates, while freeze-up dates show fewer trends.[86] Little data, however are available for lake sites within the Taiga Plains Ecozone+. In an analysis that used records from both *in situ* measurements and remote sensing observations, large lakes in Canada showed an overall trend toward earlier break-up of ice and later freeze-up over the period 1970 to 2004.[87] Three sites in the Taiga Plains Ecozone+ were included in this analysis. Freeze-up was significantly later at two of the sites. There were no significant trends in ice break-up.

Seventeen river sites within the Mackenzie River Basin showed evidence of ice break-up occurring earlier over the period from 1970 to 2002, at a rate of approximately one day earlier per decade in the upstream basin.[88] This analysis was based on hydrological events that correspond with ice break-up.

Spring thaw was measured *in situ* at sites in the Mackenzie River at Fort Simpson until the late 1980s when the monitoring program was discontinued (Figure 18A). The mean thaw date moved forward by about a month from 1932 to 1988, with the date of thaw accounting for about 60% of the variability. As the spring thaw date is strongly related to April temperatures, and as April temperatures have continued to increase (Figure 18B), it is probable that this trend has continued since 1988.[19] The same degree of change has not occurred in the fall, with fall temperatures at Fort Simpson showing no significant trends.[19]

A



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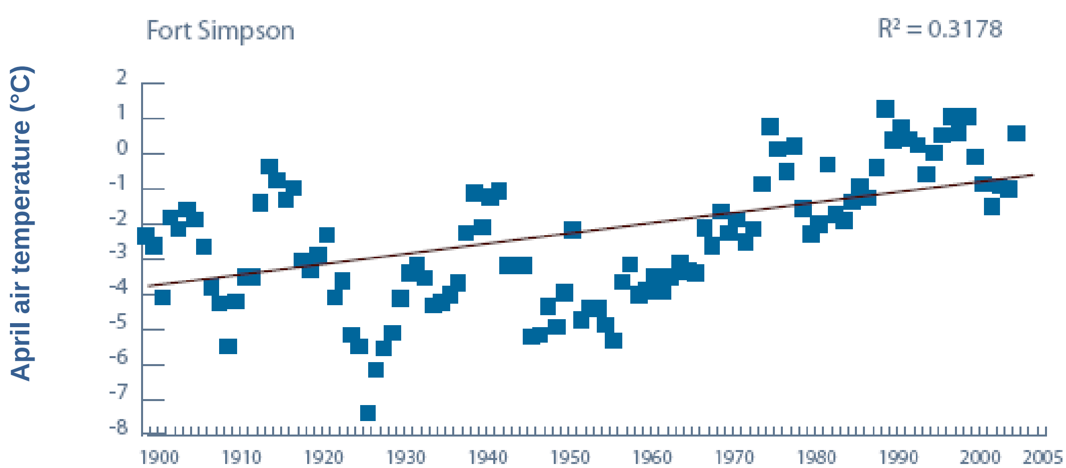

Figure 18. (A) Estimated Mackenzie River melt date, 1932 to 1988; and (B) five-year running average of April air temperatures, 1900 to 2005, Fort Simpson
Source: Mackenzie River Basin Board, 2010,[19] based on Environment Canada data

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.

Ecozone+ key finding: In 2009, 5.6% of the ecozone+ had a high level of protection, by far the largest protected area being Wood Buffalo National Park, established in 1922. There was little change in protected areas from 1922 to the early 2000s when several, mainly quite small, protected areas were established. Candidate protected areas have been identified for the Mackenzie Valley in response to the proposed pipeline development. The aim is to maintain ecological integrity by permanently protecting areas of relatively undisturbed and important wildlife habitat which would be managed as a network to provide as much connectivity between them as possible.

Protected areas in northern Canada are planned and managed to safeguard culturally important areas and maintain biodiversity and ecological processes.[89] In the Taiga Plains Ecozone+, there was little change in protected area coverage from 1922 to the early 2000s. Settlement of some land claims in the ecozone+ and growing awareness of the need for protected areas in the face of oil and gas development led to protected areas studies and plans in the NWT part of the ecozone+,[90, 91] with new protected areas being established starting in the early 2000s. Protected areas in BC and Alberta portions of the ecozone+, with the exception of Wood Buffalo National Park, are small. An example is Hay River Protected Area, a 23 km^2 BC park (shown in the northeast corner of BC in Figure 19) that protects black spruce muskeg and wetlands of cultural significance to First Nations in the Fort Nelson region.

The approach in protected area planning in northern Canada in recent years is to focus on ecological integrity, designing protected areas to meet the needs of sensitive species and to maintain ecological processes.[89] Along the Mackenzie Valley, this involves connecting wildlife corridors to establish a network of protected areas.[91] This is partly accomplished with buffer zones, areas managed to serve as transition zones between core protected areas and lands or waters subject to development.[92, 93]

Status
Overall, in 2009, 5.6% of the ecozone+ was protected through 28 protected areas of IUCN categories I-III, by far the largest protected area being Wood Buffalo National Park, established in 1922 (Figure 19 and Figure 20). The second largest is Caribou Mountains Wildland Park, an Alberta wilderness area established in 2001 adjacent to Wood Buffalo Park. IUCN categories I-III include nature reserves, national wildlife areas, wilderness areas, and other parks and reserves managed for conservation of ecosystems and natural and cultural features.[94] In addition, 22 km^2 of the

ecozone+ (<0.01%) was protected through three category V and VI protected areas, categories that focus on sustainable use by established cultural tradition within the protected area.[94] Eighteen protected areas not classified by IUCN category protect a further 1.4% of the ecozone+. The most recent of these were Sahyoue and Edacho protected areas, established in 2009.

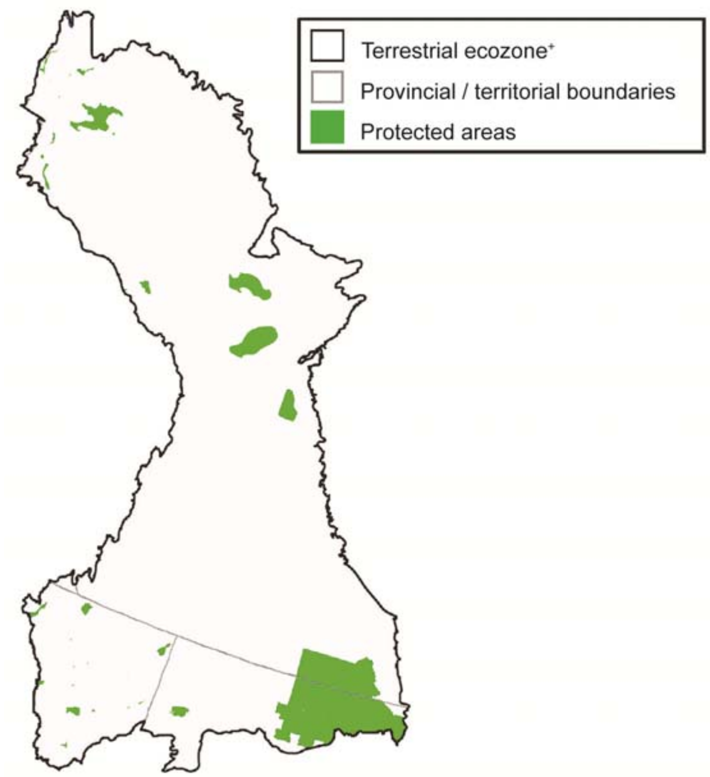

Figure 19. Map of protected areas in the Taiga Plains Ecozone+
Source: Environment Canada, 2009;[95] data from the Conservation Areas Reporting and Tracking System (CARTS), v.2009.05, 2009[96]

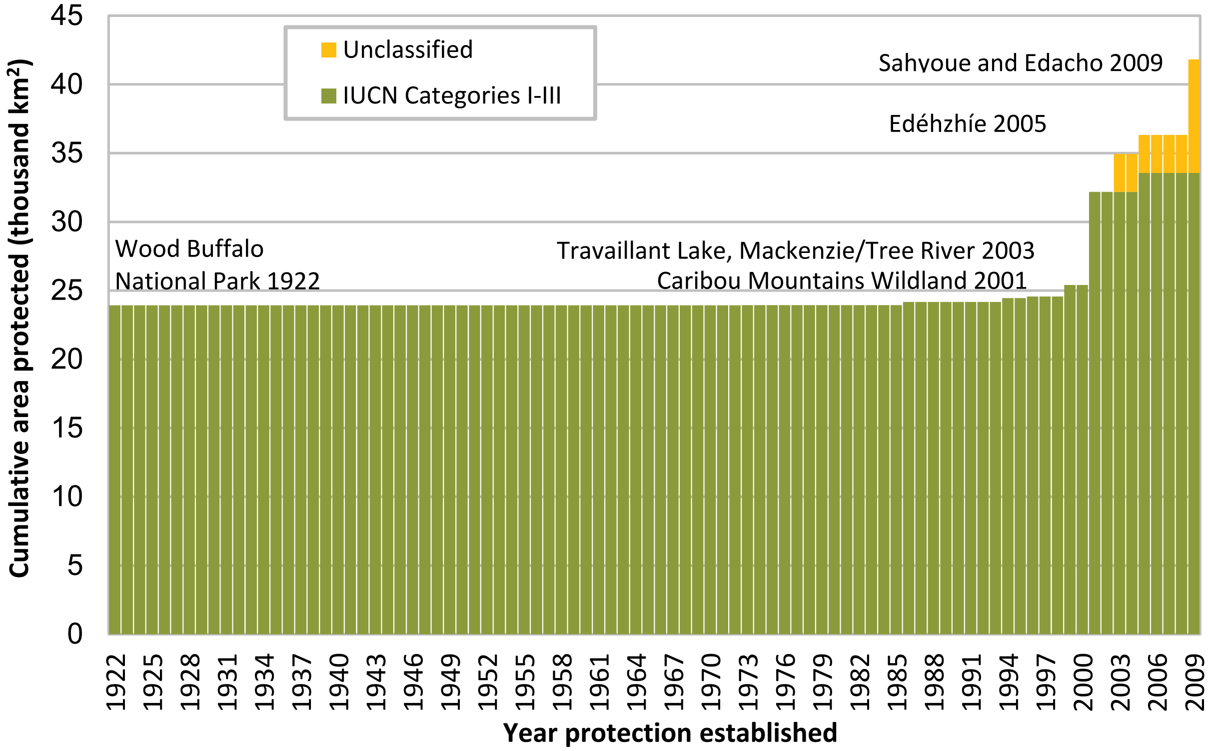

Figure 20. Growth of protected areas, Taiga Plains Ecozone+, 1922-2009
Data provided by federal, territorial and provincial jurisdictions, updated to May 2009. Only legally protected areas are included. IUCN (International Union for Conservation of Nature) categories of protected areas are based on primary management objectives (see text for more information). Names and establishment dates of the larger protected areas are shown. Note: the yellow "unclassified" category represents protected areas for which the IUCN category was not provided.
Source: Environment Canada, 2009;[95] data from the Conservation Areas Reporting and Tracking System (CARTS), v.2009.05, 2009[96]

Cultural and wildlife values are represented in the protected areas in the Taiga Plains that are proposed through the NWT Protected Areas Strategy. Areas were identified under a five-year plan for the Mackenzie Valley to accelerate selection of areas in the face of the proposed Mackenzie Gas Pipeline.[90] Protected areas are also proposed to address specific biodiversity conservation concerns. For example, the conservation zone by Great Bear Lake (Edaįįla) that is included in the proposed Sahtu Land Use Plan is intended to protect parts of the summer, fall, and winter ranges for the Bluenose-East Caribou Herd,[97] while Edéhzhíe is intended to protect important migratory bird habitat.[91]

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.

Ecozone+ key finding: Stewardship in the ecozone+ is associated with aboriginal cultural and spiritual values, incorporated into land-use planning through, for example, community conservation plans. Public-private sector partnerships and national and international initiatives also contribute to stewardship of ecosystems.

Planning, co-management, and Traditional Knowledge

Stewardship in the Taiga Plains involves aboriginal people who are committed to stewardship through their cultural and spiritual values. These values are reflected in land-use planning which involves community-based development of conservation plans. Land-use planning in the Mackenzie Valley involves four settled land claims (Inuvialuit, Gwich'in, Sahtu, and Tlicho) as well as the Deh Cho Interim Measures Agreement. The Mackenzie Valley Resource Management Act (MVRMA) applies to the Gwich'in, the Sahtu Dene, and the Métis, but does not apply to the Inuvialuit Settlement Region. The MVRMA sets the framework for land-use planning through regional and valley-wide land and water boards.

An important feature of stewardship in the Taiga Plains Ecozone+ is the incorporation of Aboriginal Traditional Knowledge (ATK) into co-management and regulatory boards (for example, Gwich'in Renewable Resources Board, 2012[98]), into environmental assessments (for example, Mackenzie River Basin Board, 2010[19]), and into research and monitoring (for example, Eamer, 2006[99] and Woo et al., 2007[100]). Much effort has gone into developing ways to incorporate ATK into decision making in the Taiga Plains (for example, Mackenzie Valley Environmental Impact Review Board, 2005[101]). An assessment of effectiveness of the use of ATK by the Mackenzie Valley Environmental Impact Review Board concluded that, while substantial and sincere efforts had been made in incorporating ATK into their practices, the board was limited in its capacity to fully incorporate it by the need to deal with complex regulatory issues.[102]

Public-private sector partnerships

Stewardship initiatives are also undertaken through public-private sector partnerships. Ducks Unlimited, an international non-profit organization, recognizing the importance of the western boreal forest to waterfowl, started a stewardship program in the late 1990s aimed at wetland conservation.[103] The program includes collection of baseline information on waterfowl habitat, including surveys of waterfowl, habitat mapping, and water quality analyses, as well as research to fill knowledge gaps. The information acquired is used in helping to set conservation priorities, through land-use management and practices and through development of protected areas, with the aim of establishing interconnected areas of wetlands. The project includes, where relevant, working with industry to develop industrial practices that conserve waterfowl habitat.[103]

There are four Ducks Unlimited boreal forest wetlands initiatives in the Taiga Plains, developed through partnerships with the forest industry (in British Columbia), government agencies, First Nations and Inuvialuit management boards and renewable resource councils, universities, and private foundations. Taiga Plains projects (Figure 21) are:

- Fort Nelson: 35,000 km^2; partners include the forest industry and the BC Ministry of Forestry;
- Sahtu: 32,000 km^2; reports completed 2003; partners include Government of NWT and the Sahtu Renewable Resources Board;
- Middle Mackenzie: 52,000 km^2; partners include Gwich'in and Sahtu renewable resource boards and the Government of the NWT; and
- Lower Mackenzie: 34,000 km^2: partners include renewable resource boards and committees for the Inuvialuit and Gwich'in, as well as the Government of the NWT.

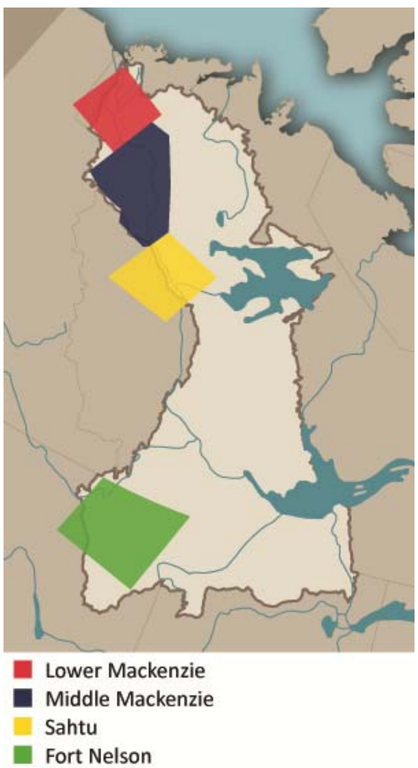

Figure 21. Locations of four western boreal forest wetlands projects led by Ducks Unlimited
Source: Ducks Unlimited Canada, 2012[104]

National and international initiatives contributing to stewardship in the Taiga Plains

At the national and international scale, several relevant management and habitat plans exist, especially for birds. They are used as means to identify areas for nomination as protected areas, including Ramsar sites (see the key finding on Wetlands). Wiken et al., 2006[105] estimated that approximately 6% of the 166,487 km^2 of wetlands in the Taiga Plains (using the 1995 ecozone classification[5]) are protected through National Parks. The North American Waterfowl Management Plan, signed in 1986 and 1993 by the governments of Canada, the United States, and Mexico in response to the loss of wetlands and declines in waterfowl, was updated in 2004 and in 2007[106] to include interim land withdrawals for protected areas in the Mackenzie Valley.

Other responses to declines in birds include voluntary partnerships such as Partners in Flight[107] and the North American Bird Conservation Initiative[108] have been started and have drafted management plans to assign conservation priorities and list actions (for example, Partners in Flight physiographic region plans, North American Landbird Conservation Plan, and Framework for Landbird Conservation in Canada). These initiatives have no binding provisions but can be useful in identifying and setting priorities for areas for conservation.

Under the Species At Risk Act, critical habitat has to be defined for Endangered or Threatened Wildlife which, in the Taiga Plains includes boreal woodland caribou. In 2012, critical habitat for boreal caribou was identified in the *Recovery Strategy for the Woodland Caribou (*Rangifer tarandus caribou*), Boreal population, in Canada.*[109]

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.

Ecozone+ key finding: There is some incursion of non-native plant species, especially along roadways, in the Taiga Plains, with only a few species being moderately invasive. An invasive non-native forest insect, the larch sawfly, has spread to the ecozone+, with regionally significant outbreaks in the 1990s. Increasing access, development, and climate change are liable to increase the rate of introduction and spread of non-native species in terrestrial and aquatic environments.

Currently invasive non-native species are not a significant threat to biodiversity in the ecozone+. However, this situation could change with the introduction and spread of non-native species from increased development and climate change.[110] Road travel is one of the most important pathways of introduction of non-native species to the ecozone+.[111] Non-native species generally take hold after ecosystems have been disrupted, creating niches that the new species can exploit. Both the means of transport and the disruption to ecosystems are generally needed for invasive species to become established in terrestrial mainland ecosystems. In isolated habitats, such as lakes and islands, a transport mechanism alone may be sufficient. Roads remain uncommon in most parts of the ecozone+, but are likely to increase with proposed development, increasing the risk to the biota of the ecozone+ from invasive non-native species.[111]

Plants

About 10% of plant species in the NWT are not native to the region, a proportion comparable with other northern and western jurisdictions, and only a few of these are moderately invasive.[110] By 2010, 116 non-native plant species had been identified in the NWT, mostly near communities or along linear disturbances, such as roads and cut-lines. Yellow and white sweet clover (*Melilotus officinalis* and *M. alba*), which have spread along rivers in Alaska and the Yukon,[112] are found north as far as Inuvik but, at least in the NWT, appear not to have spread beyond communities and roadways.

In BC, the Fort Nelson Invasive Plant Management Area has the lowest incidence of invasive plant species in the province. Non-native species have been identified and categorized by current status or whether they are at risk of entering the region. There are 12 species or groups of closely related species in northeast BC classified as highly competitive with an ability to spread rapidly. These include hawkweeds (*Hieracium* spp.), hound's tongue (*Cynoglossum officinale*), and knapweeds (*Centaurea* spp.).[113]

Forest pests

A few non-native forest insect pests have been introduced to the Taiga Plains, including the larch sawfly (*Pristiphora erichsonil*), a European species. First reported in western Canada in the 1930s, larch sawfly spread north to the Fort Nelson area in 1952.[114] It continued its northward spread, attacking tamarack (larch) stands in the southern NWT part of the Taiga Plains since the late 1960s.[115] An outbreak of larch sawfly that damaged tamarack appeared in the South Slave in the mid-1990s and quickly moved westward and northward. The outbreak only lasted one year in the Hay River area but persisted in the Norman Wells area for about seven to eight years, but at lower defoliation levels.[115] An outbreak occurred in northwestern Alberta in 1996 to 1999, defoliating large tracts of tamarack.[114]

Aquatic species

The community structure of a water-body influences the chances of a non-native species establishing itself.[116] The aquatic ecology of the Taiga Plains may be especially vulnerable to invasive species as it has relatively few species. Increasing water temperatures are shifting distributions of some fish species northwards in eastern North America: for example, the smallmouth bass (*Micropterus dolomieu*), a predatory species that has been shown to change species assemblages and thus alter food webs.[117] Warmer waters in the Taiga Plains will also likely provide conditions that non-native species introduced from south of the ecozone[+] will thrive in and will alter distributions of aquatic species, with consequences for food webs.

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.

Ecozone+ key finding: Some legacy contaminants are declining in fish in the ecozone+ but the trends are not clear or consistent with, for example, DDTs increasing in recent years in Mackenzie River burbot. Brominated flame retardants in fish increased sharply up to the mid-2000s and then dropped, based on limited sampling. Mercury levels are naturally high in the Mackenzie Basin and have increased in fish, including in the Mackenzie River and Great Slave Lake within the ecozone+. Changes in aquatic ecology related to climate change may be either accentuating or masking trends in some contaminants.

Contaminants are substances that are introduced into the environment through human activity. Some, like mercury, are naturally occurring but may be augmented through human activity to levels that could harm ecosystems and humans. Contaminants can harm species and ecosystems and impair ecosystem services. They can directly affect animals when present in their diets, for example by impairing reproduction. Contaminants can also become a health risk for humans who rely on animals that accumulate contaminants for food – particularly for aboriginal people with diets heavily reliant on marine mammals and fish.[118] This key finding only covers contaminants that persist in the environment and accumulate in the tissues of plants and animals.

Persistent organic pollutants enter the atmosphere through evaporation or industrial emissions and return to the surface of the Earth after travelling great distances. These contaminants are then deposited through rain or attached to small dust particles, falling on snow, ice, rocks, and vegetation. As the snow melts, it carries the particles and pollutants into aquatic ecosystems.

"Legacy contaminants" are those that have been banned or restricted but are still widespread in the environment. Several persistent organic pollutants, including the pesticide DDT and the industrial chemicals PCBs and HCHs, are considered legacy contaminants.

"Emerging contaminants" are newer chemicals, or substances that have been in use for some time and have recently been detected in the environment – usually emerging contaminants are still in use or only partially regulated. Despite being banned or restricted, some of these substances persist at levels that may impair animal health in some populations of long-lived top predators.[3] Brominated flame retardants, for example PBDEs, are one class of emerging contaminants that have been detected in the environment, even in remote locations, at increasing levels since the mid-1980s. Concentrations of some brominated flame retardants show signs of stabilizing or declining in the last few years in response to new regulation and reductions in their use.[118] Other emerging contaminants include some pesticides and herbicides in current use.

Mercury is another contaminant that can accumulate in wildlife. Much of the mercury in marine and freshwater systems is from industrial sources such as coal burning – and mercury releases are increasing in parts of the world.[119] Mercury levels in animals are highly variable and trends are mixed.[118]

Mercury in the Mackenzie River Basin

Mercury in the Mackenzie River Basin has been a focus of study in recent years partly due to increasing concentrations of mercury detected in marine mammals in the Beaufort Sea, as well as detection of relatively high levels of mercury in fish in the northern part of the basin.[120] Sources of mercury to the Mackenzie River were estimated by Carrie et al., 2012[120] as:

- weathering of sulfide minerals in the mountains in the western part of the river basin (about 78% of the total mercury flux);
- erosion of coal deposits (about 10%);
- atmospheric deposition (about 6%); and,
- mercury bound up in organic matter (about 5%).

All mercury is not equally available to biota, however, and, while relatively small fractions, mercury deposited from the atmosphere and mercury bound up in organic matter may move into the food chain more readily than mercury from other sources.[120] Mercury is magnified through the food chain and levels in predatory fish in many lakes in the basin sometimes exceed Health Canada's guidelines.[59]

Discharge of the Mackenzie River has been increasing over the past 35 years, which will have directly increased the amount of mercury discharged to the Beaufort Sea by a small fraction.[121, 122] As well, the higher water levels erode banks, contributing to higher sediment and mercury loads. An increase in forest fires, one of the predicted impacts from global warming, will likely increase mercury runoff to the Mackenzie River because most of the mercury from atmospheric deposition accumulates in the organic matter in the upper layer of soil which is exposed to erosion following fire.[122]

Trends in mercury and persistent organic pollutants in the Taiga Plains

Mercury increased in lake trout and burbot from both east and west areas of Great Slave Lake from 1992 to 2008 (Figure 22). Legacy contaminants are generally declining in Great Slave Lake fish (represented by HCH levels in Figure 22), though there were no clear trends for PCB concentrations from 1992 to 2007. Changes in lake ecology and fish trophic structure in Great Slave Lake may be either 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. This reduction in fat levels may be related to changes in the relative numbers of different species in the lake or to other changes in lake ecology.[123]

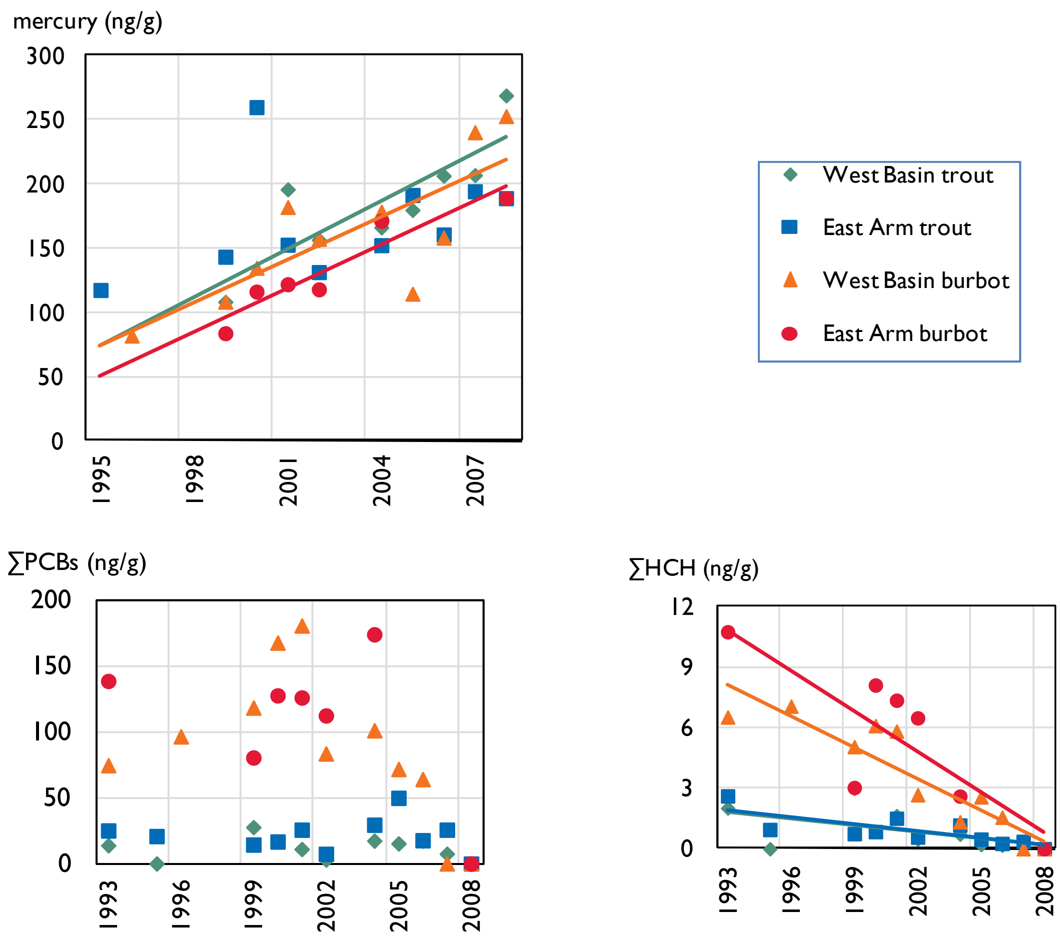

Figure 22. Trends in mercury, PCBs and HCH in lake trout and burbot from Great Slave Lake, 1992-2008
The East Arm of Great Slave Lake is in the Taiga Shield Ecozone+. The West Basin of the lake is in the Taiga Plains Ecozone+; samples were collected in the Hay River area.
Source: based on data from Evans, 2009[123]

Burbot, which tend to accumulate organic contaminants in their large, fatty livers, have been sampled at Fort Good Hope in the Mackenzie River since the 1980s. Burbot livers are a food favoured by First Nations and Inuvialuit in the ecozone+.

Since the 1980s, mercury concentrations have almost doubled in burbot muscle (Figure 23) and have increased somewhat more in livers (not shown). There were no significant correlations between fish age or length and mercury concentrations, so the trends are not related to differences among the samples. Mean concentration over the whole time period was 343 ng/g in muscle and the maximum sample mean was 420 ng/g in 2007, approaching but not exceeding the recommended maximum for mercury in fish for commercial sale of 500 ng/g (more commonly expressed as 0.5 parts per million). Mercury levels in liver were much lower, averaging 86 ng/g. While the legacy contaminant HCH decreased over the sampling period (not shown), DDTs continued to rise, contrary to the general trend in Canada's North. There was no clear trend for PCBs. PBDEs (brominated flame retardants) increased significantly over the 20-year period, declining in the most recent two years of sampling.

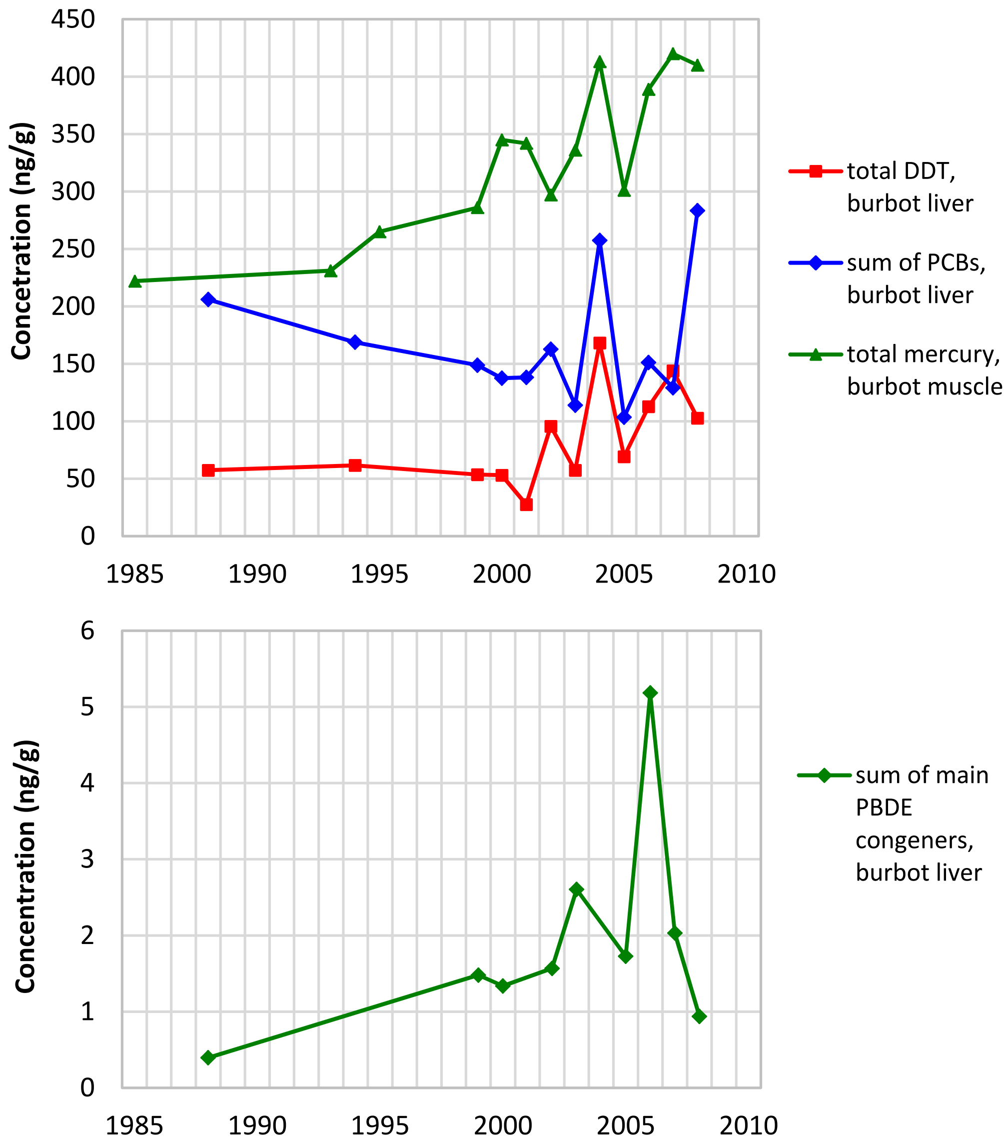

Figure 23. Contaminants in burbot, Mackenzie River at Fort Good Hope
Sample information: muscle tissue for mercury (males); liver tissue for organochlorines (sexes combined, lipid weight); liver for PBDE, sexes combined, wet weight. PBDE congeners analysed for: 47, 99, 100, 153, and 154.
Source: based on data from Stern, 2009[124]

A study of Mackenzie River burbot habitat in the Fort Good Hope vicinity[125] concluded that the increasing trends in mercury in burbot may be related to increased productivity in the aquatic environment due to climate change, with contaminants moving more readily into the food web under conditions of higher productivity. This conclusion is supported by the work of Sanei et al., 2012[126] who looked at long-term trends in mercury in sediments in Mackenzie Delta lakes. Their results suggest that increasing phytoplankton productivity can lead to increases in mercury content in lake sediments – meaning that increases in mercury in biota may not be solely a result of increases in atmospheric deposition of mercury.

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.

Ecozone+ key finding: The Taiga Plains Ecozone+ has experienced some of the greatest increases in temperature of any Canadian region since 1950 – with the annual mean temperature increasing over 2°C and winter temperatures rising about 5°C at all stations since 1950. This warming has translated into some clear ecosystem trends, such as changes to permafrost landscapes and increases in terrestrial primary productivity. There are indications of other emerging, climate-related trends, such as the northward movement of some forest insect pests.

Trends since 1950

Annual mean temperature has increased about 1.4°C since 1950 over the country as a whole, though the amount of temperature increase differs among ecozones+.[9] The strongest warming has occurred in the west and the northwest of Canada, with an increase in annual mean temperature of over 2°C for the Taiga Plains Ecozone+. When looked at by seasons, the increase occurred only in winter and spring. This warming trend has been accompanied by changes in snow and a lengthening of the growing season.

Results for the Taiga Plains Ecozone+ are summarized in Table 4. The analyses are based on 6 stations for temperature, 10 stations for precipitation, and 4 stations for snow variables. Station distribution is biased (see Figure 24), with more stations in the south; this means that ecozone+ averages should be interpreted with the understanding that they are more representative of what is occurring in the southern part of the ecozone+.

Table 4. Overview of Taiga Plains Ecozone+ climate trends, 1950-2007

Climate Variable	Trends 1950-2007
Temperature	• Significant increases in winter and spring for the ecozone+ as a whole (Figure 25). No significant trends in summer and fall overall, and at only one station in the summer. • Strong warming trend especially for the winter season (along with the Boreal Cordillera Ecozone+, the highest in Canada) – with an average increase of 5.2°C (Figure 24). • An increase in the length of the growing season by 9 days for the ecozone+ as a whole, but no significant change in the timing of the start or end of growing season.
Precipitation	• No significant change in precipitation in any season across the ecozone+ as a whole, and few significant changes at individual stations.
Snow cover	• A significant mean decrease of 11.4 days in snow cover duration (13% of the 1961-1990 average) in the spring half of the snow season (early melt), with no change in snow cover duration during the snow cover onset period, based on data from 4 stations. • A significant mean decrease in annual maximum snow depth of 23.6 cm (38% of the 1961-1990 average), based on data from 4 stations. • No significant trend in the fraction of annual precipitation falling as snow.

Source: Zhang et al., 2011[9] and supplementary data provided by the authors

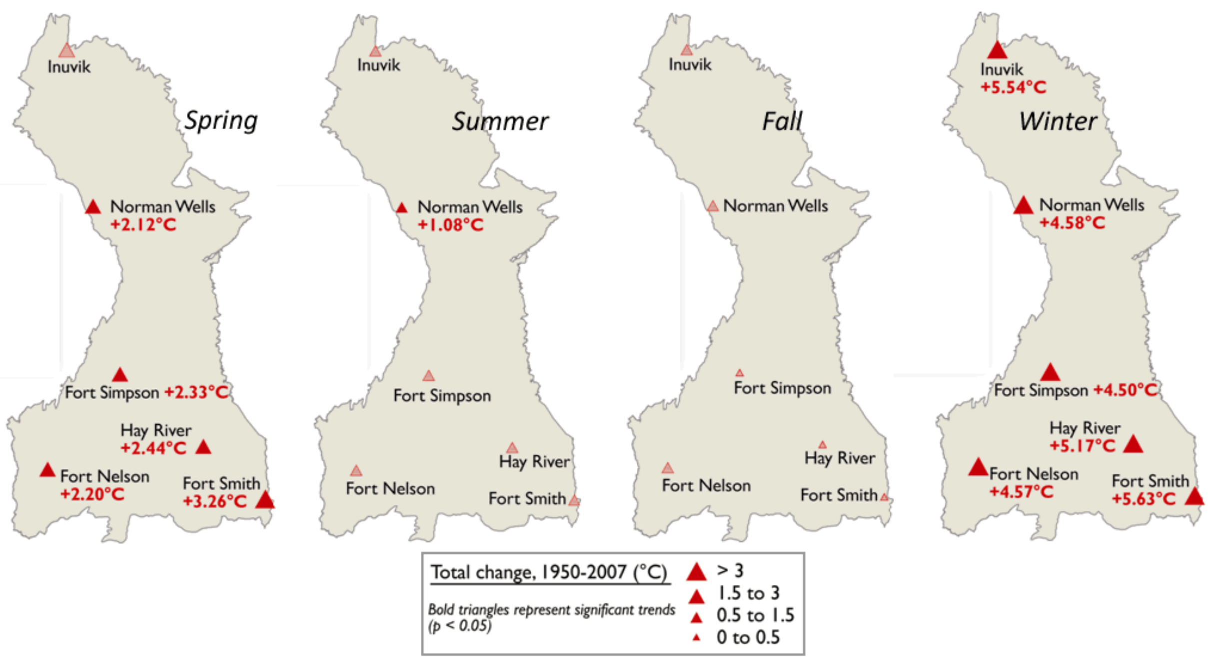

Figure 24. Trends in seasonal temperatures at six climate stations, 1950-2007
Trends are based on temperature anomalies, measured as the difference from the base period (1961 to 1990) mean. Triangles are, coloured intense red when the trend is significant at the 5% level. Magnitude of the change (°C) is shown for all significant trends. There are no decreasing trends. Seasons are, spring: March-May; summer: June-August; fall: September-November; winter: December-February.
Source: Zhang et al., 2011[9] and supplementary data provided by the authors

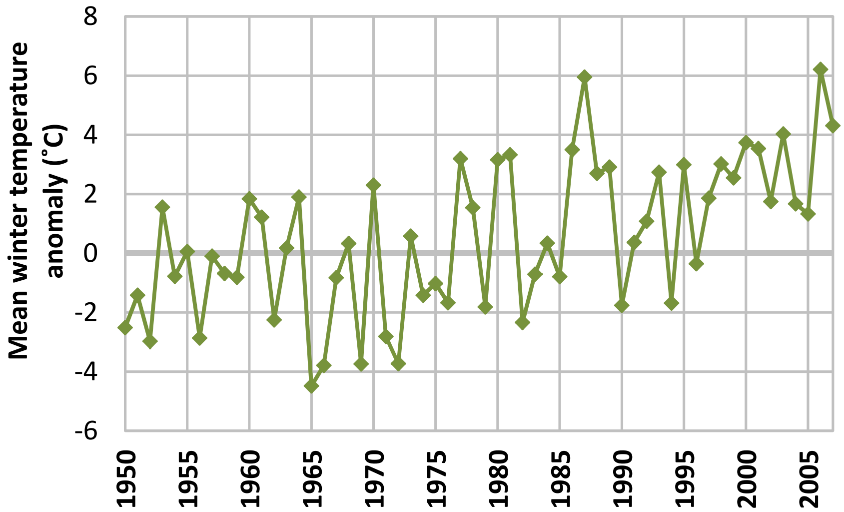

Figure 25. Average winter temperature trend, 1950-2007
Temperature anomalies, measured as the difference from the base period (1961-1990) mean, are plotted. The data indicate a significant ($p < 0.05$) increase of 5.2°C from 1950-2007. This analysis is based on data from 6 stations (shown in Figure 24).
Source: Zhang et al., 2011[9] and supplementary data provided by the authors

Influence of climate oscillations

Large-scale oscillations of the atmospheric system in the Pacific Ocean influence the precipitation and temperature patterns of the Taiga Plains Ecozone+, especially cold-season temperatures.[8] These oscillations include El Niño/Southern Oscillation (ENSO) events that occur on average every two to seven years and the Pacific Decadal Oscillation (PDO), characterized by abrupt shifts between contrasting phases every 20 to 30 years.[8] The shift to positive PDO and more frequent ENSO events in the mid-1970s appears to have led to contrasting changes across the continent, resulting in greater winter and spring warming in the west than in the east, trends that are particularly strong in this ecozone+.[9]

Climate trends and impacts based on local observations and Aboriginal Traditional Knowledge

In this ecozone+ and more generally in the Mackenzie Basin, documented Aboriginal Traditional Knowledge and local observations speak to a range of trends in climate and related ecological impacts. This knowledge is specific to areas and timeframes so is best interpreted within the context of the knowledge holder (see the references provided). It is beyond the scope of this report to synthesize available information. Some examples of documented observations and interpretations are presented in Table 5.

Table 5

Table 5. Selected Aboriginal Traditional Knowledge related to climate change and ecosystem impacts.

Examples of observations of climate trends
• Overall warmer temperatures throughout the year.[127-129] Summers and winters are now warmer than in the past.[130, 131] Hot temperatures occur sooner in the year and last longer.[132] Previously temperatures went down to -40 to -60˚C, but now they rarely go below -20˚C and usually only after December.[129, 133-135] • Generally, there are fewer rainy days, but more rainfall per rain event.[131] Some communities report an increase in rainfall.[129, 131-133, 136] • Fewer snow storms per year;[129] sometimes, unlike in the past, the ground remains bare in winter[135] possibly because the snow is blown away and does not accumulate.[131] Snow arrives later in the winter than in the past [131]. Some residents of some communities (for example, Aklavik) report an increase in snowfall.[137]
Examples of observations on ecological impacts, as reported in the *Mackenzie River Basin state of the aquatic ecosystem report 2003*[59]
• Thinner ice leads to danger to people travelling and hunting, and to migrating caribou and other wildlife.[138-140] • Water levels have decreased over a period of one to two decades and small lakes and streams have disappeared[139-142] leading to reduced habitat for fish, waterfowl, and muskrat, which have declined in some areas,[141] interfering with fishing, because traditional fishing sites are too shallow to set nets[143] and interfering with travel when important boating routes become too shallow to navigate.[141] • Changes in vegetation and less berry production; increases in forest fires resulting in loss of wildlife habitat and loss of trapping areas; new species appearing (such as cougars) that were never in the area before.[138, 139, 142]

Climate change impacts

Changes in indicators such as air temperature and permafrost are well documented for the Taiga Plains and show clear trends consistent with climate change. Effects on ecosystems are not as apparent, partly because they are not as well documented.[19] There are indications of ecosystem trends that are primarily climate related, discussed under many of the key findings in this report. Examples:

- Vegetation community changes in the treeline zone and altered growth rates of white spruce (Forests key finding).
- Increases in terrestrial primary productivity especially in the north of the Taiga Plains (Primary productivity key finding).
- Early indications of a trend to reduced frequency of periodic spring flooding in delta wetlands and lakes (Wetlands key finding).
- Widespread trend to increased streamflow in winter. Some indications of earlier peak flows (upstream in the Mackenzie River Basin) and of increased streamflow variability (Lakes and rivers key finding).

- Loss of frozen peatlands (Ice across biomes key finding) and increased slumping from thawing ground ice in delta lakes, affecting water quality (Wetlands key finding).
- Northward spread of some forest insect pests, likely related to warmer temperatures (Natural disturbances key finding).

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.

Ecozone$^+$ key finding: Provisioning services of the ecozone$^+$ include harvest of fish, wildlife, and plants, of cultural, spiritual, nutritional, and economic importance. Reliance on these provisioning services is high and not declining, especially in rural communities. Quality of these services generally remains high, with the exception of declines in barren-ground caribou, leading to harvest restrictions and reduced harvest success in some communities.

Putting a value to ecosystem services: the boreal forest

Typically, ecosystem goods and services are described through economic analyses to estimate the value of natural capital. However, there are clearly other goods and services that cannot be expressed in economic terms. For example, the Taiga Plains Ecozone$^+$ provides services as a migratory corridor and as the breeding grounds for many boreal forest birds. Cultural services are particularly difficult to assign value to.

The Pembina Institute identified and valued the natural capital of Canada's boreal forests, including in the analysis the value of forests, agriculture, mineral and energy resources, fish and wildlife, wetlands, peatlands, lakes, and rivers.[144] The analyses focused on ecosystem services such as atmospheric stabilization; climate stabilization; disturbance avoidance; water stabilization; water supply; erosion control and sediment retention; soil formation; nutrient cycling; waste treatment; pollination; biological control such as bird predation of insect pests; habitat; raw materials; genetic resources; and recreation and cultural use. The value of the boreal forest's ecosystem services ($93.2 billion) is at least 2.5 times greater than the market values of forestry, mining, oil and gas, and hydroelectricity combined ($37.8 billion). The market values do not include either societal or environmental costs separately valued at $11.1 billion. This analysis was not undertaken at the ecozone$^+$ scale.

Provisioning services

Harvest of fish, wildlife, and plants

Harvesting fish, birds, mammals, and plant species in the Taiga Plains has long supported the needs and culture of aboriginal people. Across the NWT, about 37 to 45% of NWT residents went hunting or fishing in 2002, a statistic that has changed little since the first survey in 1983.[145] The number of aboriginal subsistence hunters in the Taiga Plains is about 5,800; there are no trend data for hunting activity for this group of residents. The number of resident hunters (non-aboriginal hunters) declined by about 3% per year from 1990 to 2004 and stabilized at about 1,200-1,300 hunters annually in recent years.[145]

Since hunting and fishing are a way of life for many Taiga Plains residents, earlier river ice break-up[131] is a concern. Freeze-up timing tends to be less predictable now than it was in the past[137] and the ice is thinner. Changes in freeze-up patterns are raising concerns about hunter and fisher safety, especially in Gwich'in and Inuvialuit communities, where frozen lakes and rivers provide transportation routes and are used for much of the year for traditional activities such as ice fishing.[131]

Between 20 and 30% of households in the NWT portion of the Taiga Plains rely heavily on the provisioning services provided by local fish and game (Figure 26). The percentage would be considerably higher for Taiga Plains households outside of Inuvik, as, for all of the NWT, about 50% of households in small communities reported obtaining most or all meat and fish from local harvest in 2009, in contrast with 16% of households in medium sized communities, which includes Inuvik.[145]

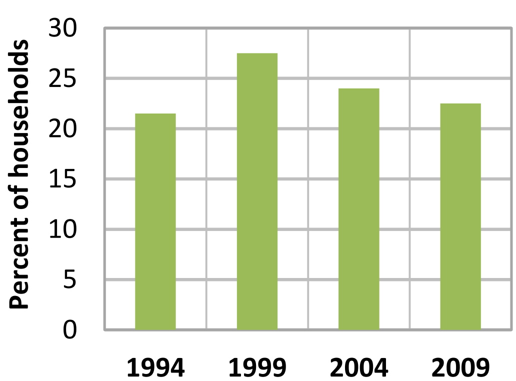

Figure 26. Percent of households in the Taiga Plains and Taiga Cordillera (NWT) reporting that most or all of their meat and fish was harvested from the NWT, 1994-2009
Note that this primarily represents households in the Taiga Plains, as there is only one small community (Wrigley) in the NWT part of the Taiga Cordillera Ecozone+.
Source: data from Environment and Natural Resources, 2011[145]

Mammals

Mammal species harvested in the middle to northern part of the ecozone+ are shown in Figure 27. The three land claims settlement areas for which data are shown do not fully coincide with the ecozone+ (for example, the small muskox harvest would be mainly outside of the ecozone+), but the data provide a good indication of mammal species important to humans through much of the ecozone+. The mammal harvest is a mix of harvest for meat and for fur. The dominant mammal harvested for meat is the barren-ground caribou.

There is limited information on trends in caribou harvest – some is available through harvest studies established under land claims legislation.[146] Information on the western Northwest Territories herds (Cape Bathurst, Bluenose-West, and Bluenose-East) is available through the Gwich'in Harvest Study[147] and Inuvialuit Harvest Study[148] for community caribou harvests from 1988 to 1997. Information for 1998 to 2005 is available through the Sahtu Harvest Study.[149, 150] As an example of harvest trends drawn from these studies, harvest from the Bluenose-West Herd in the Sahtu decreased from 1,022 in 1999 to 270 caribou in 2005.[151] The Bluenose-West Herd is subject to harvest restrictions due to a decrease in population (see the section on caribou in the key finding on Species of special interest, on page 59).

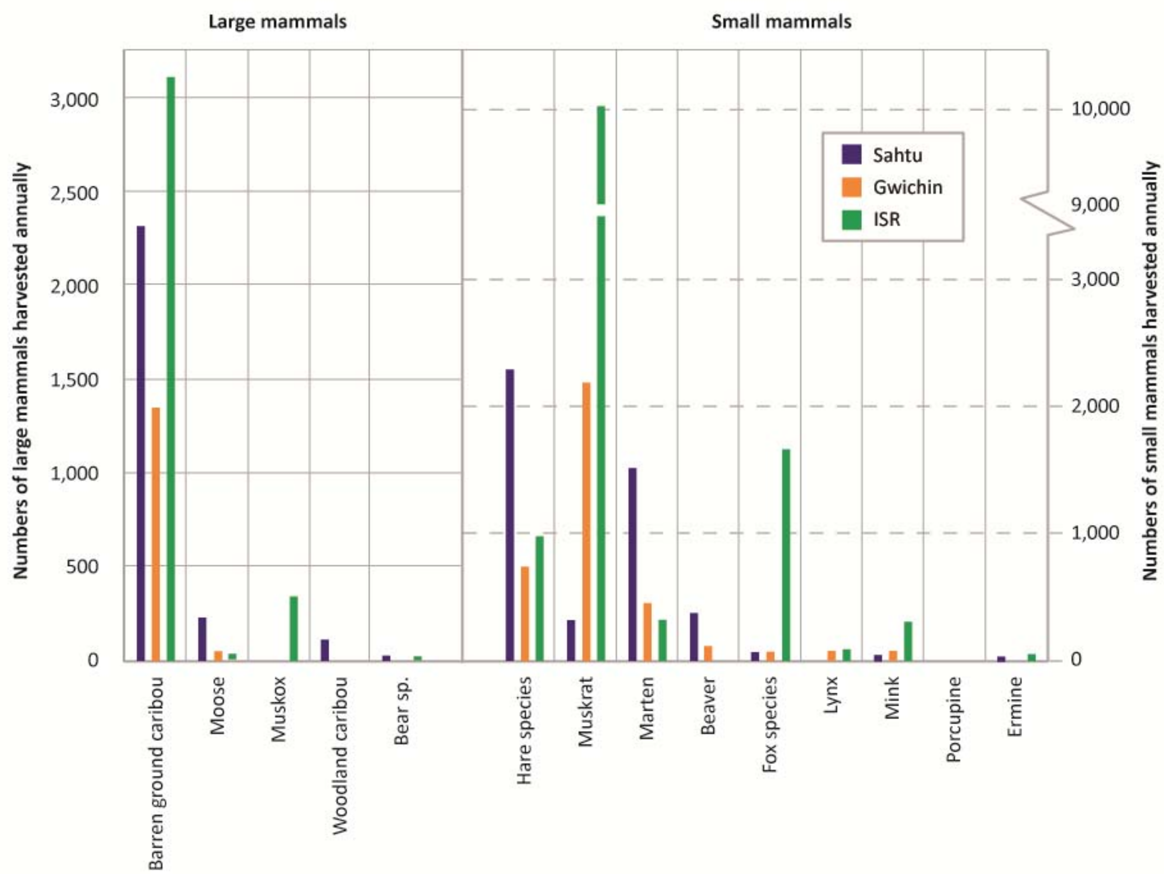

Figure 27. Summary of annual harvest levels of major mammal species in the Gwich'in and Sahtu settlement areas and the Inuvialuit Settlement Region
Note: four of the six communities included in the Inuvialuit Settlement Region lie outside the Taiga Plains Ecozone+
Source: Joint Secretariat, 2003 as presented in SENES Consultants Ltd., 2005[152]

Waterfowl

The numbers of waterfowl harvested for sport and subsistence in the NWT are relatively low, but ducks and geese are important in the traditional diet.[152] In the Gwich'in region, the top three waterfowl species for subsistence harvest are scoters, mallard, and snow geese.[147]

Fish

Fisheries in the Taiga Plains include household, commercial, and recreational, both in rivers and lakes. Some examples of locally important fisheries in the ecozone+:

- Eleven species of fish are caught using nets in the household fishery in the Gwich'in Settlement Area in the north of the ecozone+, the most important being inconnu (locally called coney, *Stenodus leucichthys*), Dolly Varden char (*Salvelinus malma malma*), burbot (locally called loche, *Lota lota*), and lake whitefish (locally called crookedback, *Coregonus autumnali*).[19]
- There are both commercial and sport fisheries for lake trout, pike, and inconnu in Great Slave Lake, managed through a mix of area closures, catch limits and gear restrictions.[19]
- Great Bear Lake, as well as being a source of fish for household fisheries, supports a lodge-based sport fishery for lake trout.[153]

Berries and products of the boreal forest

Non-timber forest products such as mushrooms, berries, birch sap syrup, floral greens, medicinal herbs, and forest crafts have a long history of traditional use and trade in the Taiga Plains.[145] Participation rates in plant and berry gathering activities during 2002 in the NWT portion of the Taiga Plains are shown in Figure 28.

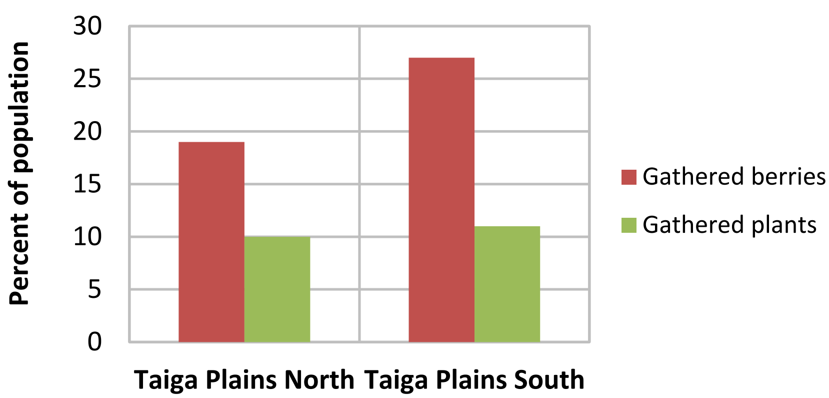

Figure 28. Percentage of population 15 years of age and older involved in harvesting berries and plants in 2002, north and south Taiga Plains, NWT
Source: NWT Bureau of Statistics, 2002[154]

However, when looked at on a household basis, and for communities in the Gwich'in Settlement Area, the use of berries is much higher – with almost all households collecting berries and 82% of households collecting Labrador tea leaves, based on a random survey of Gwich'in households in 2000 (Figure 29). The plant names in Figure 29 are the commonly used English names in the region;

Latin and Gwich'in names, respectively, are: cranberry: *Vaccinium vitis-idaea*, natå'at; blueberry: *Vaccinium uliginosum*, jàk zheii; yellowberry (cloudberry): *Rubus chamaemorus*, nakàl; Labrador tea: *Ledum palustre* and *groenlandicum*, lidii maskeg/maskig.

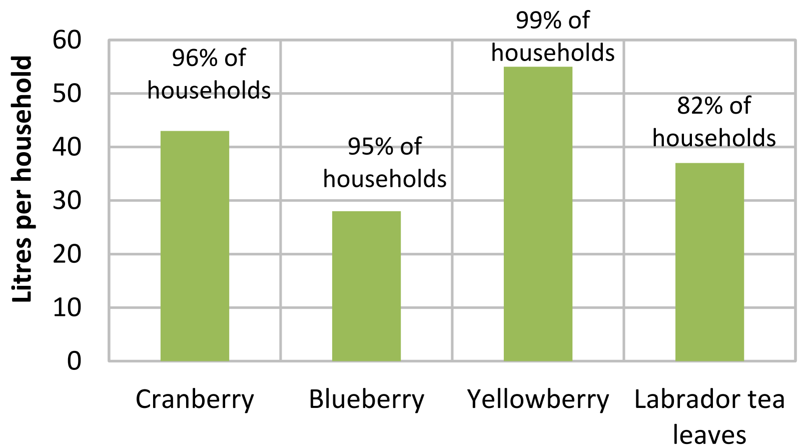

Figure 29. Use of berries and Labrador tea by Gwich'in households, Fort McPherson, Inuvik, Aklavik, and Tsiigehtchic, 2000
The bars show the estimated average volume of berries and Labrador tea leaves collected per household, averaged over the four communities. The percentage on top of each bar is the estimated percentage of households across the communities active in collecting the particular plant product during the year 2000. Source: data from Government of the Northwest Territories, 2009[155]

Trapping

Wild fur from the NWT is considered among the very best in the world and has a long history. In the 1960s and 1970s several species contributed about equally to the total annual fur harvested in the NWT (marten, lynx, muskrat and beaver). However, marten has accounted for most of the NWT fur value during the past 20 years. Marten are a good indicator for trapping because they are widely distributed, relatively easy to trap, and their consistently high pelt value is an incentive for trappers to target this species. Furbearer abundance and availability, fashion trends, international market demand for fur, and the amount of trapping effort all influence trends in fur sales.[145] The number of people trapping in the NWT has decreased since the early 1980s, but leveled to more stable numbers in recent years.[145] Trapping remains an activity of cultural importance and provides ongoing supplementary income to approximately 500 people in the NWT portion of the Taiga Plains (Figure 30).

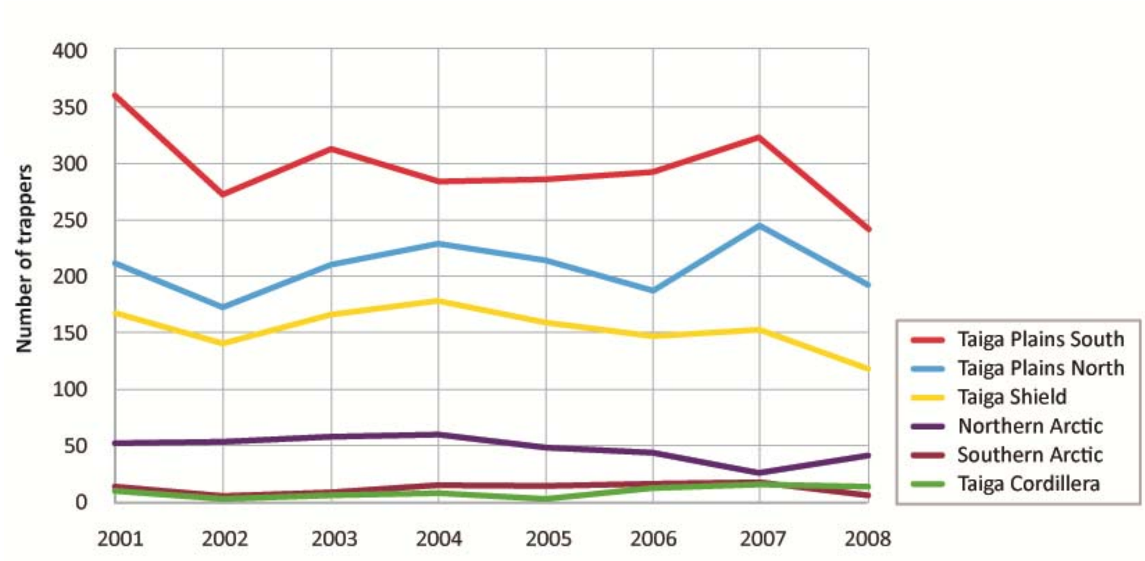

Figure 30. Trends in numbers of trappers in NWT Taiga Plains communities compared with other NWT ecozones
Note that the two upper lines represent trapping in the Taiga Plains.
Source: Environment and Natural Resources, 2011;[145] data from the GNWT Fur Harvest Database, GNWT Department of Industry, Tourism and Investment

Commercial timber harvest

The commercial timber harvesting in the NWT portion of the Taiga Plains is a minor industry. The volume of timber cut down during seismic exploration projects is estimated to be at least an order of magnitude greater than the volume cut by commercial timber harvest operations.[145] In the NWT, wood is harvested for saw logs and firewood. Typical commercial harvest operations are small-scale local businesses harvesting from 500 to 10,000 m^3 per year. The trend in timber harvesting (across the territory) showed an increase during the 1990s, then decreased in the early 2000s before increasing slightly.[145]

By contrast, commercial timber harvest has been an important influence in the southwestern part of the ecozone+. Forest products were significant to the economy of the Fort Nelson region until the recent decrease in demand for building materials in the U.S. led to the closure of the Tackama Mill in Fort Nelson. The Fort Nelson mill was, in the mid-2000s, BC's largest plywood facility.[156]

THEME: HABITAT, WILDLIFE, AND ECOSYSTEM PROCESSES

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.

Ecozone+ key finding: The Taiga Plains Ecozone+ is important nationally for boreal woodland caribou, who are dependent upon intact blocks of mature boreal forest. Trends are unknown for half of the populations in the Taiga Plains Ecozone+; populations in the more fragmented, southern part of the ecozone+ are decreasing, although one population is reported as being stable. Bluenose-West barren-ground caribou have declined precipitously in recent years. Several waterfowl species that breed in the ecozone+ are declining; causes are not clear. The Taiga Plains is home to most of the global populations of two iconic species that were nearly driven to extinction in the early 20th century and are still considered at risk: the whooping crane and the wood bison.

This section presents accounts of status, trends, and conservation issues for selected species in the Taiga Plains Ecozone+. Two iconic species that had been driven close to extinction by human settlement and exploitation, the wood bison and the whooping crane, have seen population increases due in large part to conservation measures taken in the ecozone+, but restricted ranges and other concerns mean that ongoing efforts are required to maintain healthy, viable populations. The Taiga Plains Ecozone+ provides important habitat for caribou and grizzly bears, species valued by humans living within and outside of the ecozone+, and, with its numerous boreal forest wetlands, is important both as breeding habitat and as staging habitat during migration for waterfowl.

In the accounts below, COSEWIC refers to the Committee on the Status of Endangered Wildlife in Canada, a committee of experts that assesses wildlife species and designates which are in danger of disappearing from Canada. SARA refers to the Species at Risk Act.

Wood bison

The conservation ranking for wood bison (*Bison bison athabascae*) has improved due to intense efforts to re-build populations. COSEWIC initially assessed wood bison as Endangered in 1978, then down-listed the species to Threatened in 1988. This status was reaffirmed in 2000. Wood bison are protected under the Species at Risk Act.[157]

During historic times, wood bison, Canada's largest terrestrial mammal and a northern subspecies of the American bison, ranged over most of the boreal region of North America west of the Precambrian Shield. Historical estimates are reported as about 150,000[157] or over 168,000.[158] Abundance declined in the 19th century due to the invention and spread of firearms and the consequent overharvest of wood bison.[159] The population was about 300 animals in 1893, confined to a small area in the southeastern Taiga Plains, when the first protective legislation was enacted to control hunting.[160] Wood bison numbers reached an all-time low of about 250 animals in 1896.[158] The remaining habitat was protected as Wood Buffalo National Park in 1922. A national recovery program was established in 1957. Eighty to ninety percent of the total wood bison population is in the Taiga Plains Ecozone+ and the adjacent section of Wood Buffalo National Park (Table 6).

Disease (brucellosis and tuberculosis, as well as outbreaks of anthrax – see also key finding on Wildlife diseases on page 77), cross-breeding with plains bison, and habitat loss through development (agriculture, forestry, and oil and gas) are the main threats faced by wood bison.[157] From 1925 to 1928, 6,673 plains bison were shipped from Buffalo National Park, near Wainwright, Alberta, to Wood Buffalo National Park. These plains bison were from a herd that was being culled due to infection with tuberculosis, but the young animals introduced to Wood Buffalo National Park were thought to be disease-free. The relocated plains bison hybridized with the endemic wood bison and introduced tuberculosis to the herd. The source of brucellosis is less clear.[161]

Conservation efforts include measures to keep disease-free populations from making contact with diseased animals. The NWT's Bison Control Area (Figure 31), established in 1987, is surveyed annually and kept free of bison to protect the Mackenzie herd from disease.[162] In 2011 and 2012 infected bison have spread to the west of Wood Buffalo National Park, leading to intensified management efforts in this part of Alberta. The aim is to keep the disease-free Hay-Zama herd from contact with diseased animals and to control the risk of tuberculosis and brucellosis spreading to cattle.[163] Maintaining bison-free zones has a cost in terms of habitat loss. About 50% of the historical range of wood bison is unavailable for recovery because of the need to control the spread of wildlife disease.[164] Ranges of wood bison populations in or near the Taiga Plains Ecozone+ are shown on Figure 31 and status and trends are outlined in Table 6.

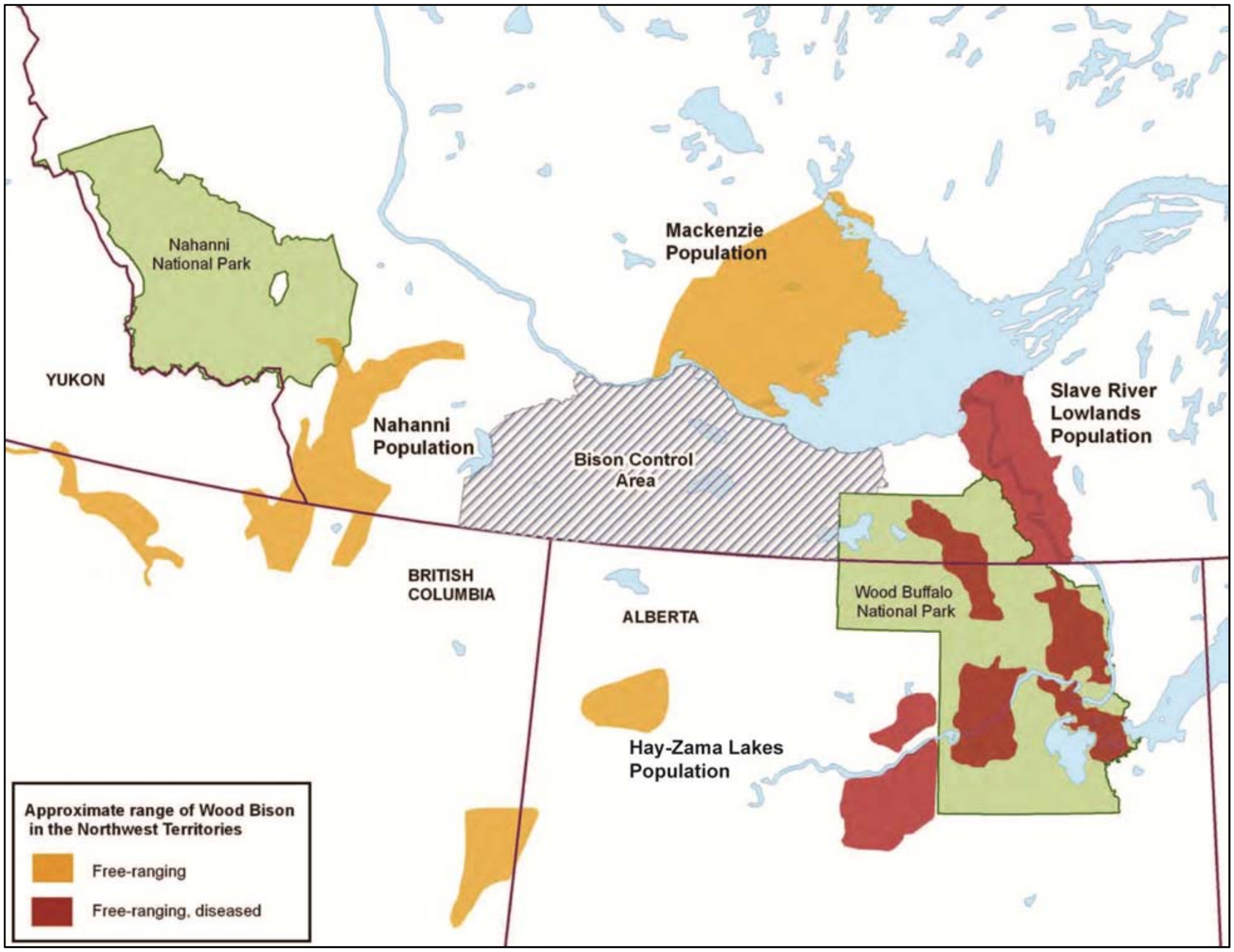

Figure 31. Wood bison populations in the Taiga Plains Ecozone+ and vicinity
Source: Environment and Natural Resources, 2013[165]

Table 6. Wood bison populations in the Taiga Plains: status and trends.

Population	Status and trends
Wood Buffalo National Park	The total population was about 12,000 in the 1960s, declining to 2,100 in 1999. In 1974/75, 3,000 bison perished due to flooding in the Peace-Athabasca Delta. The population has increased in recent years and was estimated at 5,000 in 2009.[160, 166] The herd expanded to the west in 2011 and 2012.[163] Infected with bovine tuberculosis and brucellosis (introduced through importation of infected plains bison in the late 1920s)[160] and subject to several severe anthrax outbreaks since 1962.[167]
Slave River Lowlands	Considered part of the Wood Buffalo National Park population. Also infected with bovine tuberculosis and brucellosis[162] and subject to anthrax outbreaks.[167] Declined from between 1,300 and 2,500 bison in the 1960s to about 500 by the 1980s, remaining stable for the next 20 years, then increasing to about 1,700 by the year 2009.[162, 166]
Nahanni	Established 1980 with release of 28 bison.[162] Between 1989 and 1998, 71 more bison were released and, by March 2004, there were an estimated 400 bison.[162] A survey in 2011 showed that the population numbers have remained stable at about 400.[166]
Hay-Zama Lakes	Established 1984 with introduction of 29 bison; population grew to about 500 by 2007.[39] A 2012 survey counted 587 bison, within the management goal of 400 to 600.[163] Permit hunt started in 2008, in part to keep the herd from expanding and coming in contact with infected animals from the Wood Buffalo National Park population.[168] All animals tested through the harvest have been determined to be disease-free.[163]
Mackenzie	The largest healthy herd in northern Canada.[162, 166] Established 1963 by releasing 18 bison near Fort Providence. The herd expanded its territory and increased to 2,400 animals by 1989, followed by a decline to 1,600 bison in 2008. An anthrax outbreak in August, 2012 killed 440 bison, reducing the herd to fewer than 1,000 animals.[166] Sources of mortality include anthrax outbreaks in 1993[169] and 2012[166] and loss of bison through thin spring ice in 1989.[162]

Whooping crane

COSEWIC designated the whooping crane (*Grus Americana*) as Endangered in Canada in 1978 and the species is protected under SARA.[170] The whooping crane, never a common species, was reduced to an estimated 1,400 birds in 1860, with most of these remaining birds disappearing over the next 40 years due to encroachment of settlement on all but the northernmost of its breeding grounds. Wintering habitat also contracted during this time. The all-time low for the population was 14 known adults.[171] The breeding range, which had extended across much of the central and northern prairies of North America, was reduced to a single site in Wood Buffalo National Park.

The only remaining self-sustaining wild population in the world breeds in Wood Buffalo National Park within the Taiga Plains Ecozone+ and migrates to the Aransas National Wildlife Refuge along the Gulf of Mexico, in Texas.[171] Two additional non-self-sustaining populations have been established in the United States. One, with reintroduction starting in 2001, migrates between the Wisconsin and Florida.

The Canadian whooping crane wild population has increased from 18 in 1938 to 283 in the winter of 2010/11.[172] Current threats include limited genetic diversity of the species and loss and degradation of migration stopover habitat and coastal wintering habitat, as well as threat of chemical spills in Texas.[173]

Whooping cranes breed in isolated wetlands with soft substrates, substantial amounts of open water (creating long sight lines for spotting predators), and suitable vegetation for nesting materials. They have, over the years, expanded their breeding range locally, and it is considered that there is ample suitable habitat in the vicinity of their current range in the Taiga Plains Ecozone+.[171] Population growth is likely to be controlled more by limitation of suitable habitat on the wintering grounds in Texas.[171, 173] Predation on the breeding range may, however, influence the rate of population growth. The 10-year cycle for predators, especially wolves, in Wood Buffalo National Park was considered by Boyce and Miller, 1985[174] to account for the slight periodicity in population abundance, with slowed growth and slight dips approximately every 10 years (Figure 32). A national recovery strategy[175] and an international recovery plan[173] are in place to coordinate monitoring, research, and conservation measures for the whooping crane.

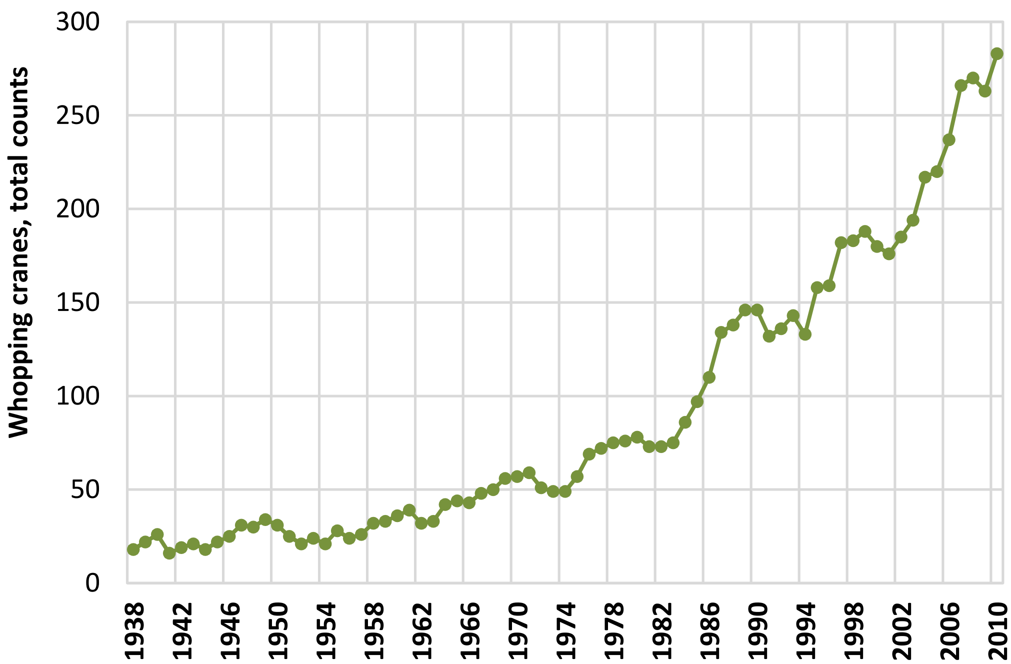

Figure 32. Growth of the Aransas-Wood Buffalo whooping crane population, 1938-2010
Total population, based on winter counts.
Source: based on data from COSEWIC, 2010;[171] 2010 and 2011 data from Whooping Crane Conservation Society, 2011[172]

Caribou

Migratory barren-ground caribou (*Rangifer tarandus groenlandicus*) winter in the Taiga Plains Ecozone+ and non-migratory woodland caribou (*Rangifer tarandus caribou*) range through much of the ecozone+ year-round.

Barren-ground caribou

This section, based on the report on *Northern caribou population trends in Canada,*[97] a technical thematic report prepared for the 2010 Ecosystem Status and Trends Report, presents population trend information for the two barren-ground caribou herds: the Bluenose-East and the Bluenose-West. Both herds calve in the Southern Arctic (Arctic Ecozone+) and winter in the Southern Arctic and the Taiga Plains ecozones+.

Bluenose-East Herd

The Bluenose-East Herd was not officially recognized as a distinct herd until 1999.[176] A photographic post-calving survey was undertaken in 2000, providing an estimate of 104,000 ± 22,100 (95% CI) (Figure 33). This was followed by a decline to an estimated 70,100 ± 8,100 in 2005 and 66,800 ± 5,200 in 2006. This translates into a 10% exponential rate of decline from 2000 to 2006. However, by 2010, the post-calving herd estimate was 98,600 caribou ± 7,100. There are gaps in the information as demographic rates were not monitored and information on distribution based on collared caribou has not been analyzed.

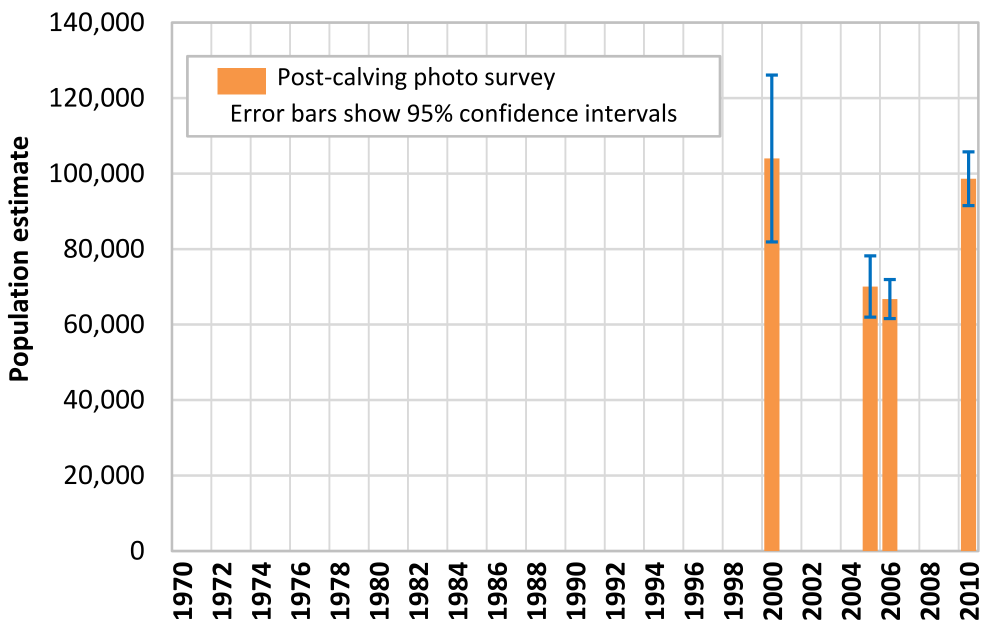

Figure 33. Bluenose-East Caribou Herd population estimates
Estimates are for caribou one year and older. Surveys were conducted in July.
Source: Gunn et al., 2011[97]

Trends in vital rates are uncertain as monitoring has been infrequent until recently. Spring calf:cow ratios ranged between 25 and 52 calves: 100 cows and showed no trend between 2001 and 2009 (R. Popko, unpublished data in Adamczewski et al., 2009).[177]

Bluenose-West Herd

Although the Bluenose-West Herd was not officially recognized as a distinct herd until 1999,[176] population estimates were derived for 1986, 1987, and 1992 based on locations of radio-collars during post-calving surveys of the Bluenose Herd. The herd peaked at 112,400 ± 25,600 (95% CI) in 1992 and then declined to 76,400 ± 14,300 in 2000, and 20,800 ± 2,040 in 2005 (Figure 34). The 2005 estimate was confirmed by an estimate of 18,050 ± 530 caribou in 2006. Since then, the trend appears to have leveled out, with a preliminary estimate for a July 2009 survey of 17,900 ± 1,300 caribou.[178]

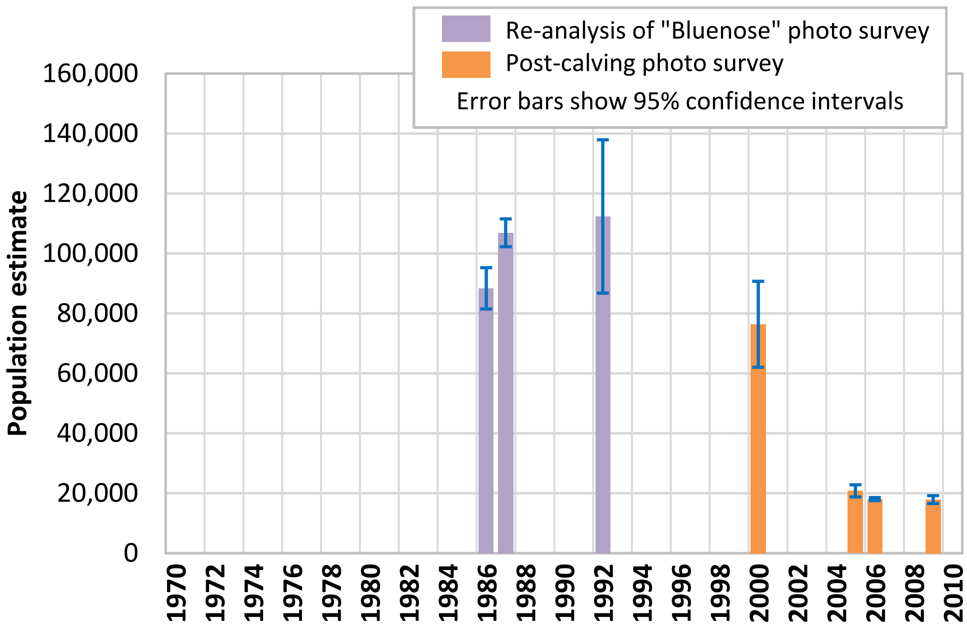

Figure 34. Bluenose-West Caribou Herd population estimates
Population estimates are for caribou one year and older. Data obtained during photocensus surveys of the "Bluenose" herd prior to 2000 were re-analyzed to estimate Bluenose-West population trends. These estimates should not be considered as reliable as the later estimates.[179]
Source: Gunn et al., 2011[97]

Based on recommendations of the Wildlife Management Advisory Council (NWT), the Gwich'in Renewable Resources Board, and the Sahtu Renewable Resources Board, co-management boards in the herd's range, all non-aboriginal hunting of the Bluenose-West Herd ceased in 2006. The co-management boards made further recommendations to restrict aboriginal harvesting of the Bluenose-West Herd by establishing a total allowable harvest and the requirement for a tag to harvest, measures that were implemented in 2007.[97]

Woodland caribou, boreal population

This section is based on the 2011 scientific assessment and 2012 recovery strategy for the woodland caribou (*Rangifer tarandus caribou*), boreal population.[109, 180] Note that this information has been updated since the release of the ESTR national thematic report, *Woodland caribou, boreal population, trends in Canada.*[181]

Woodland caribou are distributed throughout the boreal region of Canada.[182] There are two genetically distinct varieties, or ecotypes, of woodland caribou: 1) forest-dwelling woodland caribou, which are non-migratory and live in relatively small groups year-round in the boreal forest; and 2) forest tundra woodland caribou, which are migratory and live in large herds and winter in the boreal forest. The forest-dwelling ecotype of woodland caribou is made up of ten geographically distinct populations – the boreal population (referred to as "boreal caribou"), which is found through most of the Taiga Plains Ecozone+, is the most widespread. In 2002, COSEWIC assessed the boreal caribou as Threatened[183] and boreal caribou were added to Schedule 1 of the federal *Species at Risk Act.*[184]

The range of the woodland caribou, including the boreal population, has retracted significantly from historical distributions. The southern limit of distribution has progressively receded in a northerly direction since the early 1900s, a trend that continues to the present day.[109, 183, 185-187]

Taiga Plains Ecozone+ status and trends

Boreal caribou primarily inhabit Canada's boreal, rather than taiga, ecozones+, with the exception of the Taiga Plains Ecozone+, which provides some of the largest tracts of habitat for these at-risk caribou. This is due to the prevalence of mature or old growth coniferous forests and peatlands, the preferred habitat of boreal caribou.[188] Studies have shown that treed fen and bog peatlands are crucial to the survival of boreal caribou in northern Alberta. This finding would apply to the entire zone of sporadic permafrost that reaches into northern BC and southern NWT (Figure 16).[189] Fifteen boreal caribou local populations[*] (or components thereof) occur in the Taiga Plains Ecozone+. Of these, 33.3% (n=5) are in decline, 6.7% (n=1) are increasing, and the status of the remaining 60% (n=9) is unknown (Figure 35).

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[*] A boreal caribou local population is a group of boreal caribou occupying a defined area distinguished spatially from areas occupied by other groups of boreal caribou. Local population dynamics are driven primarily by local factors affecting birth and death rates, rather than immigration or emigration among.[109]

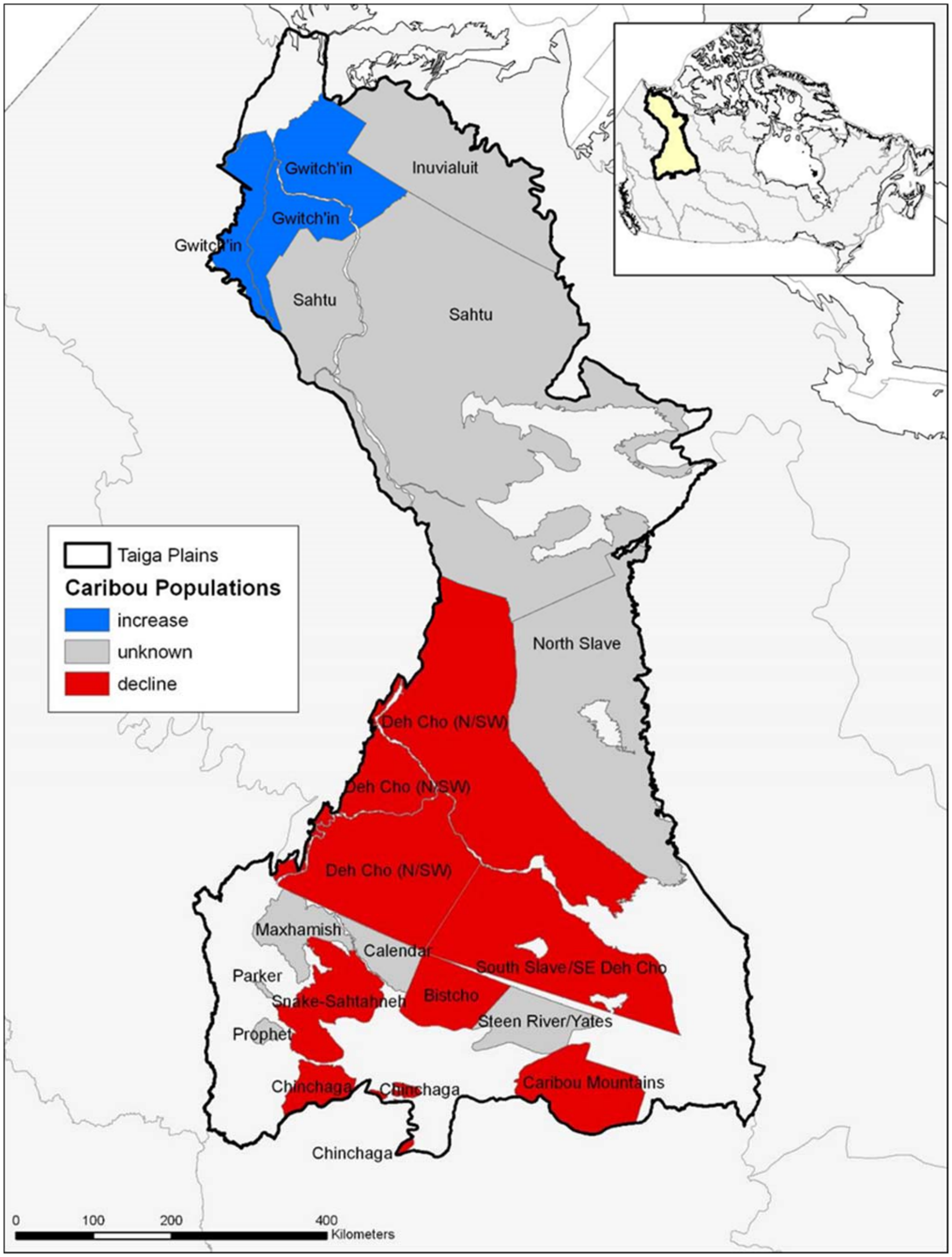

Figure 35. Estimated population status of boreal caribou local populations in the Taiga Plains Ecozone+
Source: Callaghan et al., 2011[181]

Causes of declines

Broad-scale range recession and population declines of boreal caribou in most areas are associated with human settlement and industrial resource extraction due to the loss, degradation, and fragmentation of their coniferous-forest habitat.[187, 190-192] Proximate causes of decline associated with landscape-level habitat change include increased predation,[109, 187, 193-197] increased access by hunters,[190, 194] and linear disturbance.[198, 199] Weather and climate change may affect several aspects of boreal caribou ecology by combining with other threats in complex ways that magnify the principle causes of decline.

In the Taiga Plains Ecozone+ boreal caribou populations known to be in decline have relatively small ranges in the southern part of the ecozone+ (Figure 35).

Table 7 presents an analysis of the proportion of disturbance, both from fire and from anthropogenic sources (defined in the caption), on the ranges of each of the populations completely or partially in the Taiga Plains Ecozone+. This analysis indicates that 57 to 87% of the range of each population that is known to be declining is classified as "disturbance", with the populations in BC and Alberta having the highest degree of anthropogenic disturbance (see also Figure 6 in the Forest biome key finding). Fire is the main cause of disturbance for the populations in the NWT. Boreal caribou can shift their range use to avoid burned areas provided sufficient old-growth forest remains. Although fire may have short term adverse effects, large fires prepare the conditions for future large, even-aged stands of mature forest that are vital to boreal caribou. In a healthy ecosystem, as one large tract of habitat is disturbed by fire, another is reaching maturity.

Table 7. Boreal caribou population range disturbance.

Population Status	Local population or unit of analysis	Local Population Range Disturbance		
		Fire %	Anthropogenic %	Total % of Disturbance
?	NWT	24	8	31
?	BC Maxhamish	0.5	57	58
?	BC Calendar	8	58	61
↓	AB/Bistcho	20	61	71
↓	BC Snake Sahtaneh	6	86	87
?	BC Parker	1	57	58
?	BC Prophet	1	77	77
→	AB/Yates	43	21	61
↓	AB/BC Chinchaga	8	74	76
↓	AB Caribou Mountains	44	23	57

↓ = decline; ↑ = increase; → = stable; ? = not available

Population status is taken from Figure 35. Note that the ranges of some of the populations extend into neighbouring ecozones+

"Fire %" is the percent of the range area burned within the past 40 years (since 2010). Fire data from the Canadian Large Fire Database, augmented by additional coverage for the Northwest Territories and Parks Canada, that contained wildfires >2 km² were also used.

"Anthropogenic %" is the percent of the range area affected by anthropogenic disturbance, based on mapping conducting by the Landscape Science and Technology Division of Environment Canada in collaboration with Global Forest Watch Canada (GFWC). All visible linear and polygonal anthropogenic disturbances were digitized from Landsat images. Linear disturbances included roads, railroads, seismic

lines, pipelines, power transmission lines, airstrips, dams and other/unknown; polygonal features included settlement areas, mines agricultural areas, cutblocks, oil and gas activities , well pads and other/unknown. All features in the database were buffered by 500 m to create a "zone of influence", and merged to create a non-overlapping coverage of all anthropogenic disturbances.
Source: Environment Canada, 2011[180] and 2012[109]

Waterfowl

This section draws from *Trends in breeding waterfowl in Canada,*[200] 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.

Waterfowl population composition and abundance in the Taiga Plains Ecozone+ is surveyed by the joint Canadian Wildlife Service and US Fish and Wildlife Service waterfowl breeding survey that was established in 1955.[201] Long-tailed duck (*Clangula hyemalis*), scoters (combined white-winged scoter (*Melanitta fusca*), surf scoter (*M. perspicillata*) and black scoter (*M. nigra*), scaup (combined lesser scaup (*Aythya affinis*) and greater scaup (*A. marila*)), northern pintail (*Anas acuta*), mallard (*A. platyrhynchos*), and American wigeon (*A. Americana*) show declining population trends (Table 8, Figure 36, and Figure 37). These populations overlap during breeding, whereas most have different wintering areas,[202] suggesting that the reasons for their declines may be associated with this ecozone+. Waterfowl are patchily distributed across the ecozone+ and trends are also variable from location to location, as shown for scaup in Figure 38.[203]

Table 8. Abundance trends for selected waterfowl species in the Taiga Plains Ecozone+, 1970s-2000s

Species	Nesting habitat	Trend (%/yr)	P	Annual Abundance Index (in 1,000s)				
				1970s	1980s	1990s	2000s	% change
Bufflehead	Cavity	0.104		96.3	96.2	85.6	97.4	1.2
Long-tailed duck	Ground	-4.164	*	42.6	30.6	12.5	11.6	-72.8
Scoter (white-winged, surf, and black)	Ground	-4.089	*	250.3	233.1	86.4	87.9	-64.9
Scaup (lesser and greater)	Ground	-3.273	*	951.8	744.5	427.6	384.3	-59.6
Northern pintail	Ground	-2.722	*	94.5	69.3	37.6	44.7	-52.7
Mallard	Ground	-2.155	*	232.9	237.2	168.8	131.6	-43.5
American wigeon	Ground	-2.024	*	194.1	185.5	119.7	121.7	-37.3
Green-winged teal	Ground	0.665		141.7	249	163.5	201.4	42.2
Canada goose		0.472		54.7	68.1	63.3	65.4	19.5
P is the statistical significance: * indicates P<0.05; no value indicates not significant								

Source: Fast et al., 2011[200]

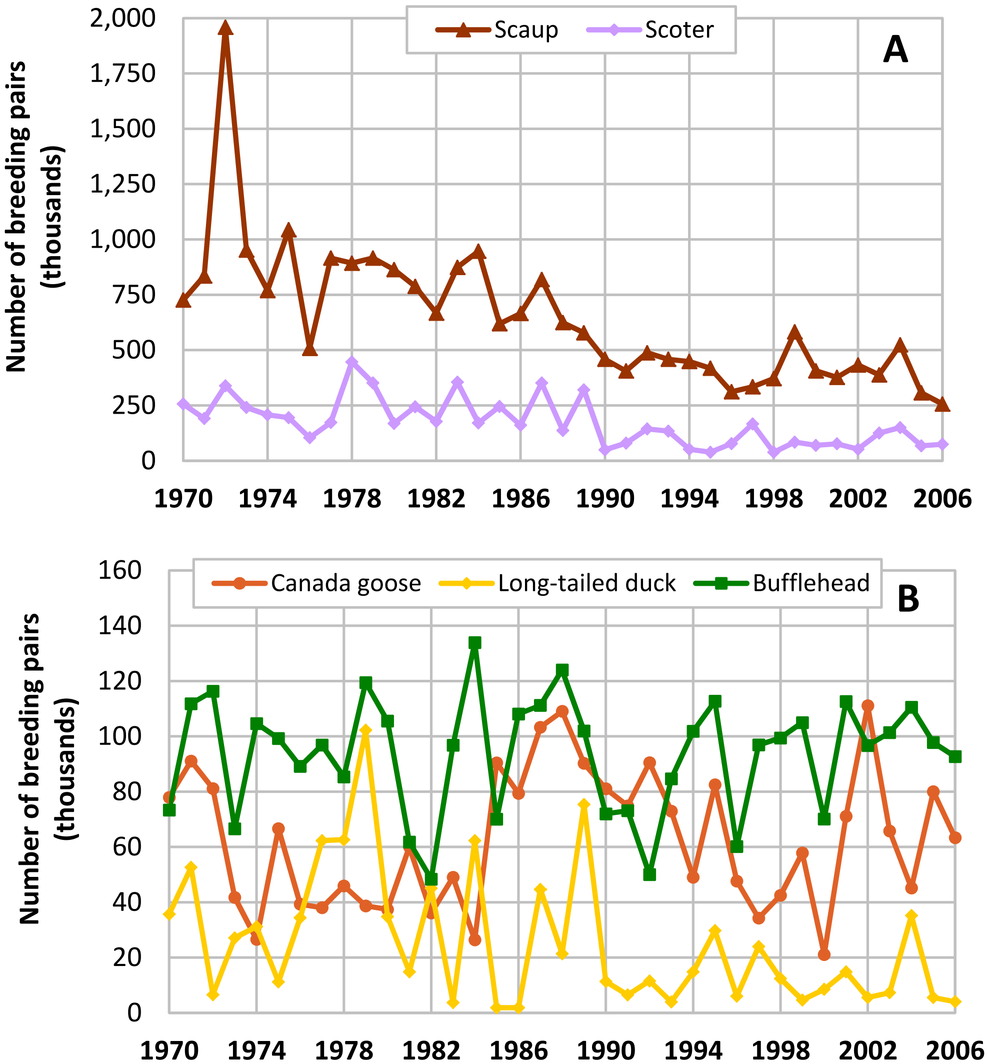

Figure 36. Taiga Plain Ecozone⁺ population trends for (A) scaup and scoter; (B) Canada goose, long-tailed duck, and bufflehead, 1970-2006
Source: Fast et al., 2011[200]

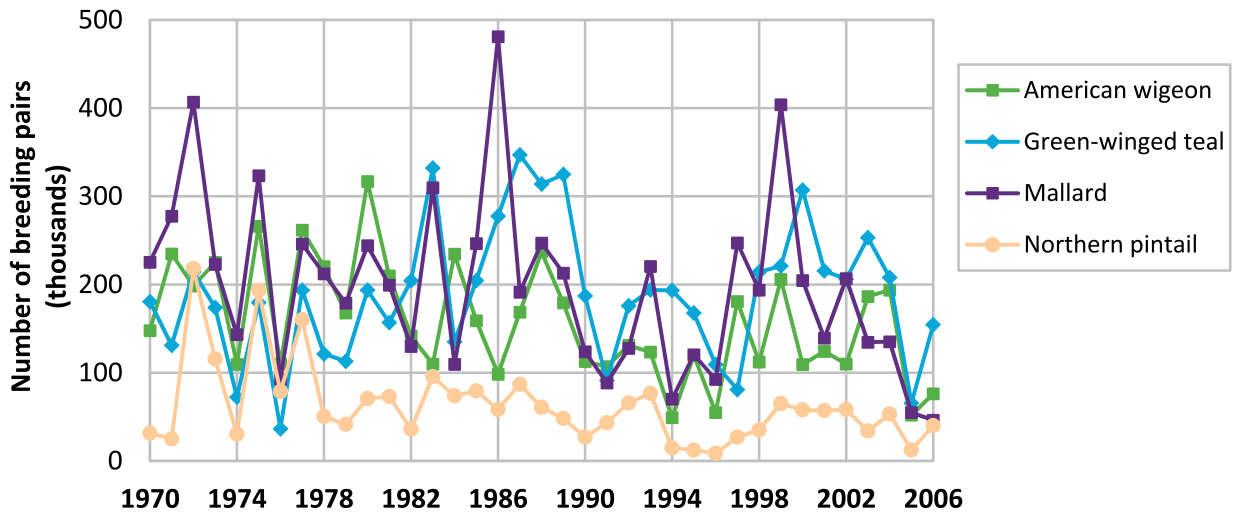

Figure 37. Taiga Plains Ecozone+ population trends for American wigeon, green-winged teal, mallard and northern pintail, 1970-2006
Source: Fast et al., 2011[200]

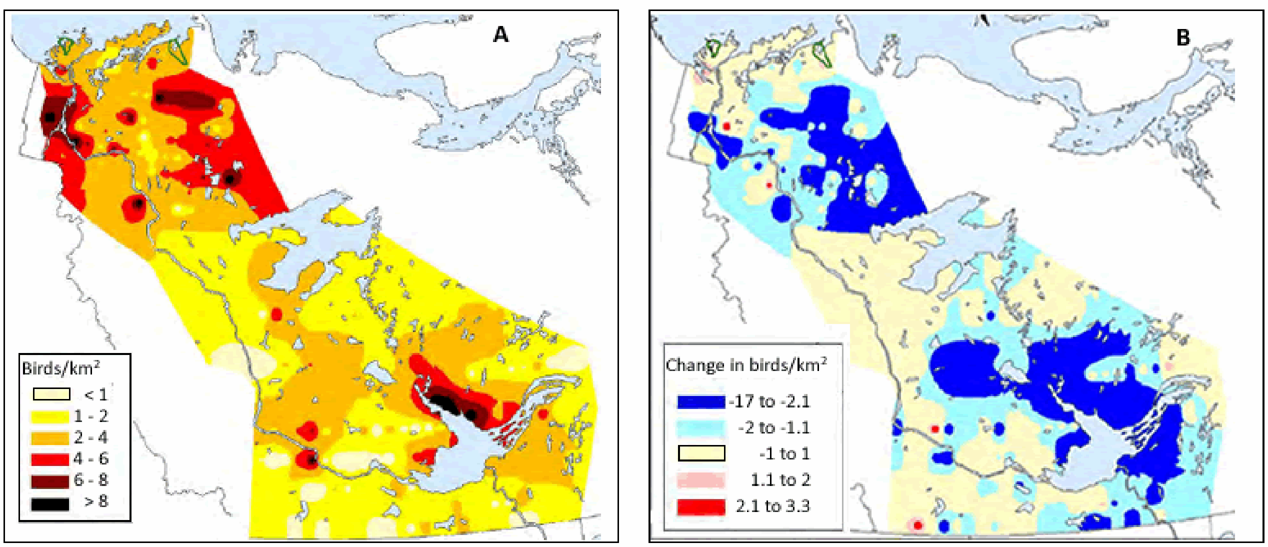

Figure 38. Geographic distribution of breeding scaup and of trends in scaup, 1976 to 2003
The densities shown in map A are averages over the study period. The map of change in scaup abundance (B) compares count data from the years 1976 to 1980 with data from 1999 to 2003. These maps are based on the survey results that are summarized in Figure 36, Figure 37, and Table 8.
Source: adapted from Fournier and Hines 2005[203]

Despite their abundance, total populations of greater and lesser scaup have been declining since the mid-1980s, with most of the decline being for those breeding in the western boreal forests (Figure 39). Population growth rate for lesser scaup may be most sensitive to adult female survival during the breeding and non-breeding seasons, and, to a lesser extent, to nesting success, duckling survival, and juvenile survival.[204] This suggests that changes to breeding habitat may greatly influence population growth.

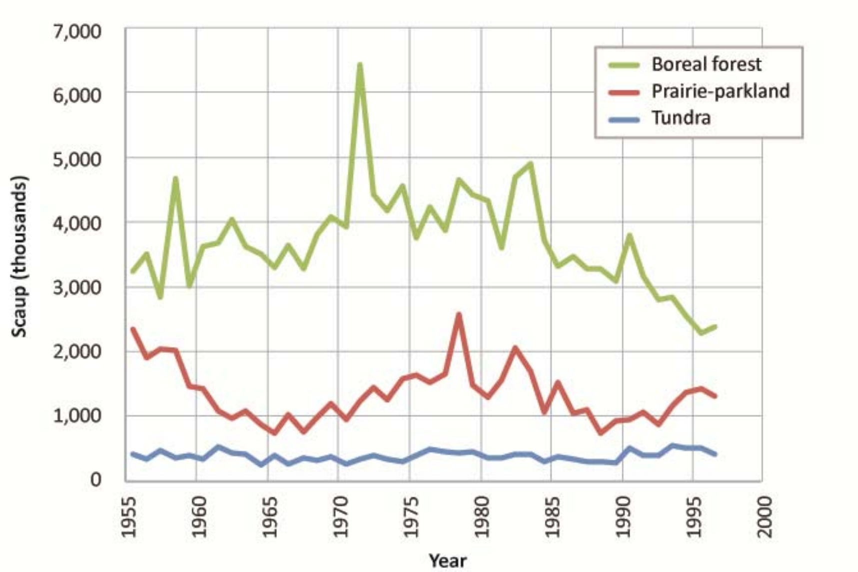

Figure 39. Declines in scaup in the boreal forest compared with trends in tundra and prairie-parkland, 1955-1997
Greater and lesser scaup total breeding population estimates are combined.
Source: Afton and Anderson, 2001[205]

The reasons for the declines of these waterfowl populations are not well understood, as very few waterfowl studies have been conducted in the Taiga Plains. Climate change may play an important role, especially for late-nesting long-tailed ducks, scoters, and scaup.[206, 207] As photoperiod is likely the main breeding cue for these species, mismatches in timing may be occurring between their relatively fixed late nesting dates (but see Anteau and Afton, 2009[208]) and invertebrate phenology, which is driven by temperature and has likely changed recently due to climate warming.[209] The mismatch hypothesis between breeding birds and changing food supply, although not yet tested in the taiga regions, has been demonstrated elsewhere (for example Thomas et al., 2001[210]). The mismatch hypothesis however, is one of many that may explain declines in scaup populations (see review in Austin et al., 2000[211]).

Causes of the declines observed for northern pintail, mallard and American wigeon remain unclear. These species fluctuate greatly between years, and some have declined in other regions as well. Canada goose and green-winged teal populations show no statistically significant trends.

Fish

Three fishes in the Taiga Plains Ecozone+ are considered at risk in the Northwest Territories: the shortjaw cisco (*Coregonus zenithicus*) is classified "at risk" and the bull trout (*Salvelinus confluentus*), and inconnu (*Stenodus leucichthys*; Upper Mackenzie River and Great Slave Lake stocks only) are classified as "may be at risk".[212]

In 1987, COSEWIC designated the shortjaw cisco as Threatened based on the reduced population and level of habitat exploitation across Canada. The rating was confirmed during a status review in 2003.[213] In the NWT, the shortjaw cisco inhabits Great Slave Lake, which is at the northern edge of its known range; there are also unconfirmed reports of the species in Great Bear Lake.[212] Population status and trends in the ecozone+ are poorly known.[213]

The presence of bull trout was confirmed in the early 2000s in the Sahtu region of the Taiga Plains, extending its previously known distribution northward by 4° latitude.[214] Bull trout, which are likely quite widely distributed in high gradient streams and rivers of the south-central Mackenzie River Valley, have been shown to be highly sensitive to a variety of individual and cumulative anthropogenic impacts; many populations south of the ecozone+ have been extirpated or may be threatened.[214]

In the upper Mackenzie and Great Slave Lake, inconnu populations appear to have been decimated by net fisheries close to their spawning rivers.[215] Elders recount that their demise began when the flourishing fur trade in the 1940s and 1950s demanded large amounts of feed for dog teams.[216] The decline continued with commercial fishing and loss through bycatch by the lake whitefish fishery in Great Slave Lake. Conservation measures, now in place for many years, have yielded only a slow recovery.[215]

Baseline information on fish stocks is summarized in the Mackenzie Basin report on the state of the aquatic environment[59] and through the NWT Environmental Audit and the Cumulative Impacts Monitoring Program.[217] The status for most fish stocks, where data are available, is considered to be stable or increasing. In Great Bear Lake, the lake trout population declined between the early 1970s and the mid 1980s. Quotas were assigned in 1987. Since then, the lake trout harvest has been much lower than the maximum sustainable yield (Figure 40). Arctic grayling stocks in the upper Mackenzie River Basin were adversely affected by a warm-water-induced outbreak of waterborne pathogens in 1989, but stocks appear to have recovered to their former levels, based on information related to sports fisheries, for example, on the Kakisa River (southwest of Great Slave Lake).[217]

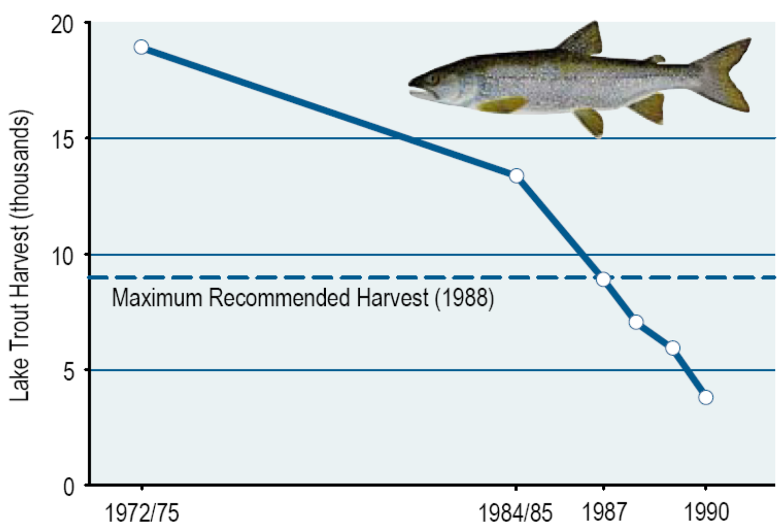

Figure 40. Harvest of lake trout in Great Bear Lake, 1972-1990
Source: Mackenzie River Basin Board, 2004;[59] data from Department of Fisheries and Oceans, Hay River.

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.

Ecozone+ key finding: Overall, primary productivity increased on 22.7% and decreased on 1.5% of the land area of the Taiga Plains from 1985 to 2006. Increased primary productivity was mainly in the north part of the ecozone+, where studies show increased growth of shrubs, along with some impairment of growth of lichens and of some white spruce. The large fires characteristic of the ecozone+ influence primary productivity but do not account for the overall increase.

This section is based on analyses and interpretations in *Monitoring biodiversity remotely: a selection of trends measured from satellite observations of Canada.*[13] Additional material has been added on the relationship with forest fires, forage quality, and on aquatic productivity.

The Normalized Difference Vegetation Index (NDVI) measures vegetation vigour due to chlorophyll activity, or "greenness". Changes in NDVI over the period 1985 to 2006 were examined by Ahern et al., 2011[13] for each ecozone+, based on the findings of Pouliot et al., 2009[218] Results are shown in Figure 41. Overall, 22.7% of the Taiga Plains Ecozone+ showed a statistically significant (95% confidence limits) positive change and 1.5% showed a significant negative change in NDVI.

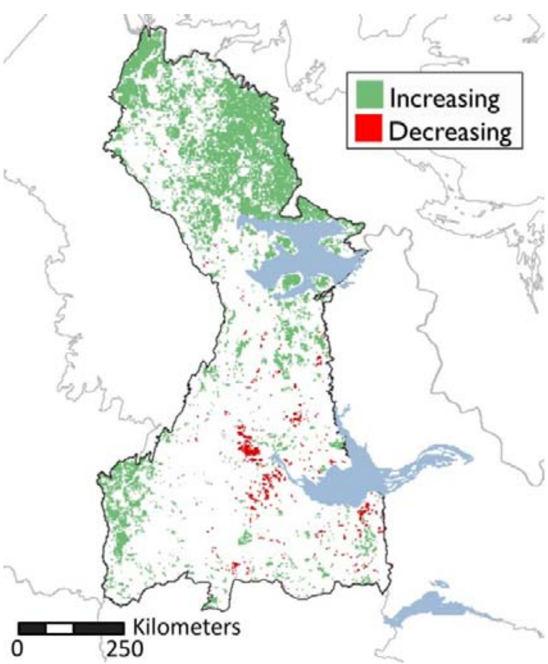

Figure 41. Trend in Normalized Difference Vegetation Index, Taiga Plains Ecozone+ 1985-2006
Source: Ahern et al., 2011[13]

In the northern Taiga Plains, the extensive area of strong NDVI increase visible in the map corresponds to a large area of conifer forest north of Great Bear Lake to the east of the Mackenzie Valley. A similar but smaller patch lies in the lower Mackenzie Valley. Further south, areas of increasing NDVI are more isolated. The area of decreasing NDVI west of Great Slave Lake does not correspond to any recent burns. The region has a high water table and areas previously vegetated with forest and tall shrubland have been flooded during years of high precipitation.[216]

Pouliot et al., 2009[218] also examined the influence of climate and land cover change on the observed NDVI trends in eight regions of Canada. Climate influence was examined by analyzing, on a grid basis, correlations between monthly temperature and precipitation data (Mitchell 2005 in Pouliot et al., 2009[218]) and annual peak NDVI. This analysis suggested that NDVI in the Taiga Plains is strongly influenced by climate, more so than in any other region in Canada. As in other northern regions, NDVI was negatively correlated with precipitation and positively correlated with temperature.[218]

Olthof et al., 2008[219] examined NDVI trends in a portion of the Taiga Plains Ecozone+ (as well as tundra areas to the north) using the same dataset used by Ahern, 2011[13] and Pouliot, 2009[218] along with higher resolution Landsat data. They found that lichen-dominated communities had consistently lower NDVI trends than vascular-plant-dominated communities, though all showed increasing trends. This is consistent with ground studies[220-224] and was attributed to increasing vigour and biomass of vascular plants and some impairment of lichen growth due to drying.[219] White spruce in this northern region also show signs of decreased growth rates, likely related to drought stress (see the Forest biome key finding and Figure 8).

In the boreal forest, using satellite-based measurements to index primary productivity is complicated by the effects of forest fires. Productivity is decreased for about a decade following a forest fire[225] and then post-fire succession vegetation or age of the trees can also complicate interpreting remote sensing measured trends in plant productivity.[226, 227] Ahern, 2011[13] analyzed the changes in NDVI in relation to fire history across Canada: NDVI trends were negative in areas recently affected by fire (1994 to 2004), positive in areas affected by fires from 1980 to 1990 (where regeneration would have dominated), and generally positive or close to zero in areas affected by fire prior to 1980 (1960 to 1980). The authors concluded that, in the northern portion of Canada's forested zone, many of the observed changes may be a result of the natural cycle of fire and succession, however, trends in wildfire alone cannot account for the scale and the distribution of the change in NDVI observed over the 22-year period.

Trends of increasing plant productivity as indexed by satellite-based measures (NDVI) may not translate into an increase in forage quality for herbivorous insects or mammalian herbivores. One interacting factor, for example, is that the amount of solar radiation (or cloud cover) and temperature also affect the levels of compounds such as tannins in plants, which affects forage quality.[228] Thus the conditions that promote greater primary productivity may also lower the quality of some of the vegetation as food for herbivores.

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

Natural disturbances

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.

Ecozone+ key finding: Natural disturbances in the Taiga Plains show signs of change related to climate. On a decadal basis, the area of forest burned increased from the 1960s then declined again in the most recent decade, though data are incomplete for this latter decade. There are indications of a trend to more fires earlier in the season, a pattern consistent with the observed temperature trends. The main forest insect pest, spruce budworm, is endemic in the southern part of the ecozone+ and there are indications that it may be moving northward. Both the forest tent caterpillar and the mountain pine beetle, relatively new to the ecozone+, show signs of becoming more abundant and expanding northward.

Fire

The interest in monitoring trends in forest fires has increased recently because of the relationship between a warming climate, fires, and the implications for carbon cycling and storage. People in the communities take note of increases in fire frequency in relation to warmer temperatures. However, it is unclear whether the reported frequency or landscape patterns of fire are different from in the past. For example, 90 fires were reported in the Fort McPherson area in 2003, a hot, dry summer,[129] but it is difficult to interpret this in terms of long-term trends because the number of fires and the area burnt annually is highly variable – a few years can be expected to have exceptionally high rates. The Taiga Plains experienced large fires in the 1940s, a warm and dry decade, as documented, for example, in the Fort Smith area.[229] In a Fort Providence study of fire history over the 19th and 20th centuries, the highest proportion of forest stands began their growth following the extensive fires in the 1940s.[230] Few trees survived fire beyond 200 years. In addition to the 1940s, the 1860s, 1880s, and 1920s were decades in which large areas were burned.

Patterns of human involvement with fire have changed with changes in settlement, cultural and economic practices: both patterns of accidental or deliberate fire ignition and those of fire suppression. For example, in the past, aboriginal people in the central and southern part of the ecozone+ used burning as a management tool to improve conditions for important food sources such as moose, wood bison, hare, beaver, grouse, and berries that thrive in early successional habitats.[216, 230, 231] This resulted in a landscape that included grasslands that have since reverted to forest.[232]

Fire behaviour in the boreal forest is partly related to the age of the tree stands.[233] After a rapid increase over the first few decades, flammability decreases and remains at a lower level in the mature forest, rising again as the stand deteriorates. Short fire intervals promote regrowth of deciduous trees over conifers. Intense fires in young conifer stands clear areas that can then become deciduous stands, via seeds that can travel long distances by wind. Variation in the depth of burn results in great differences in seedling density. A warmer, drier climate with increased fire frequency will result in more severe, deeper fires that burn soil organic matter and kill more below-ground plant parts than light surface fires.[233]

The discussion below summarizes recent trends in fire extent, duration and timing. It is based on *Trends in large fires in Canada, 1959-2007*,[13] a technical thematic report prepared for the *2010 Ecosystem Status and Trends Report*. Data used in analyses for the report were current to 2007 and have not been updated.

Some of the largest fires in the country occur in the Taiga Plains Ecozone⁺.[234, 235] This is due to a combination of factors, including the dry, continental climate;[236] the remote location with little suppression effort;[234] and, a dominance of boreal fuel types with relatively high average fuel loads that lead to higher consumption rates.[237, 238] These factors result in relatively severe fires that burn over large areas.

Area burned

On average an area of 2,858 km^2 burns each year, with great variability from year to year (Figure 42). In many years the annual area burned (by fires over 2 km^2) is less than 100 km^2, while in other years it can be very high – 17,354 km^2 burned in 1995. Some low values early in the period of record may be due to limited monitoring in this northern ecozone⁺, but this trend continues into recent decades, validating the occurrence of very low fire years (see, for example, 1991, 1997 and 2002 in Figure 42). In comparison with other ecozones⁺, the average annual area burned is high (0.71% of the forested ecozone⁺ area, second only to the Taiga Shield), despite the frequency of very low fire years.[10]

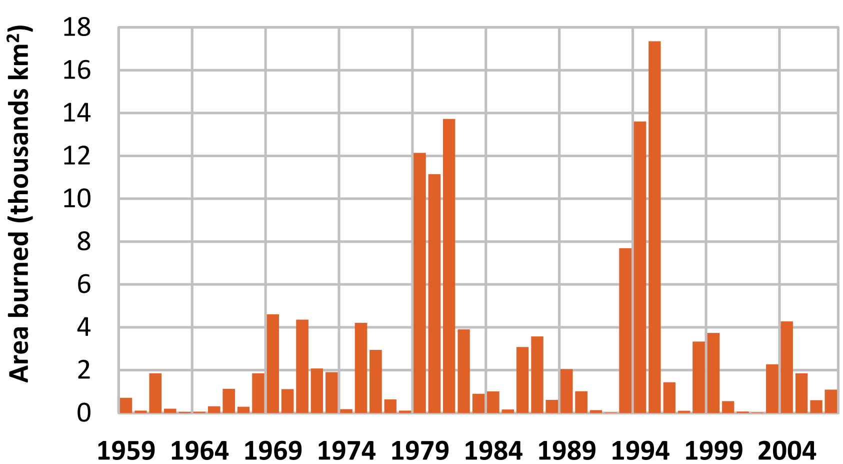

Figure 42. Annual area burned by large fires in the Taiga Plains Ecozone⁺, 1959-2007.
Note: this fire trend is based on large fires (fires over 2 km^2 in size, rather than the total area burned).
Source: Krezek-Hanes et al., 2011[10]

The long-term trend in area burned is similar to trends at the national level. Area burned is shown by decade since the 1960s in Figure 43 and the fires are mapped in Figure 44. Area burned increased from the 1960s until the 1990s and then fell sharply in the 2000s. As noted above, the low numbers at the beginning of the record may be attributed to data collection techniques that improved starting in the 1970s.[236] Although the numbers for the 2000s should be considered with caution since they do not include a full decade, the recent decline may be related to changes in large atmospheric oscillations.[10]

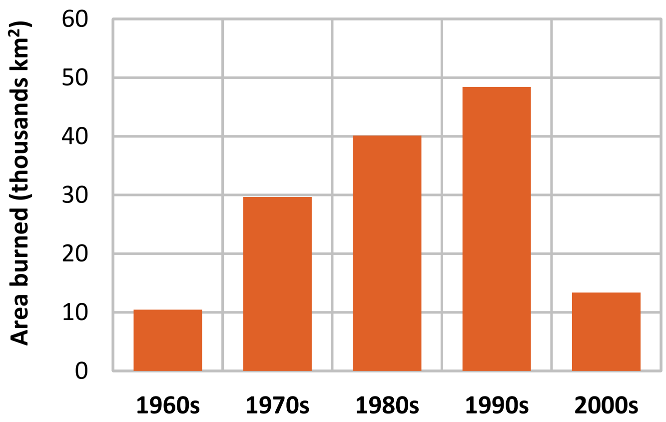

Figure 43. Trend in total area burned per decade for the Taiga Plains Ecozone+
The value for the 2000s decade was pro-rated over 10 years based on the average from 2000-2007
Source: Krezek-Hanes et al., 2011[10]

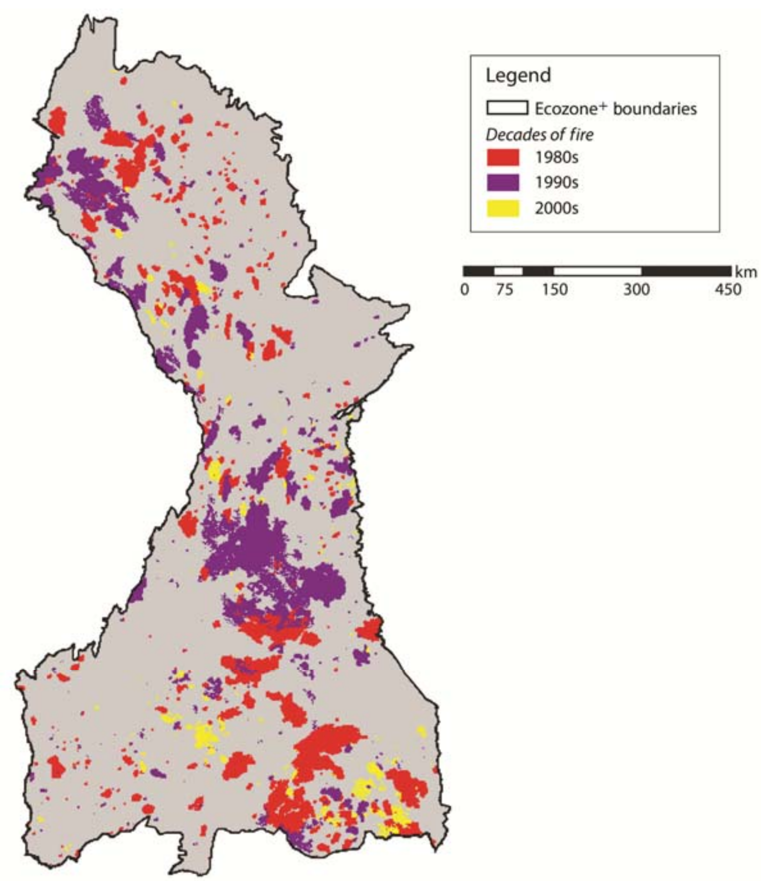

Figure 44. Map of distribution of large fires in the Taiga Plains Ecozone+, 1980s-2000s
Fires shown for the 2000s include through 2007 only.
Source: Krezek-Hanes et al., 2011[10]

Duration and timing of fires

The average duration of active large fire occurrence is 81 days (about 4 months), which has not changed significantly. This is different from the fire season duration, which is calculated based on fire weather indices and is longer, at approximately 173 days.[239] The fire season is the period of time that the weather is conducive for fires to occur. The numbers documented here are based on the actual occurrence of large fires. Based on this analysis, fires most commonly occur in June through to August, but can occur as early as April and as late as September (Figure 45).

The average duration of the period of fire occurrence has not changed over time but the distribution of fires within the fire season has undergone some subtle changes over the last four decades. The proportion of fires that occur in April has shifted from zero in the 1960s to 1.2% in the 1990s. The proportion of fires that occur in May has been steadily increasing, a statistically significant change (R^2=0.93, p=0.035). All fires that were reported in April were human caused; those in May were equally distributed between being caused by humans or lightning. Early-season fires may also occur in dry years when fires from the previous season have smoldered in deep layers of peat throughout the winter, re-emerging as surface fires in the spring.[216] More data are needed to determine if these small changes are the start of a lengthening of the fire season or are artifacts of the large fire database limitations.

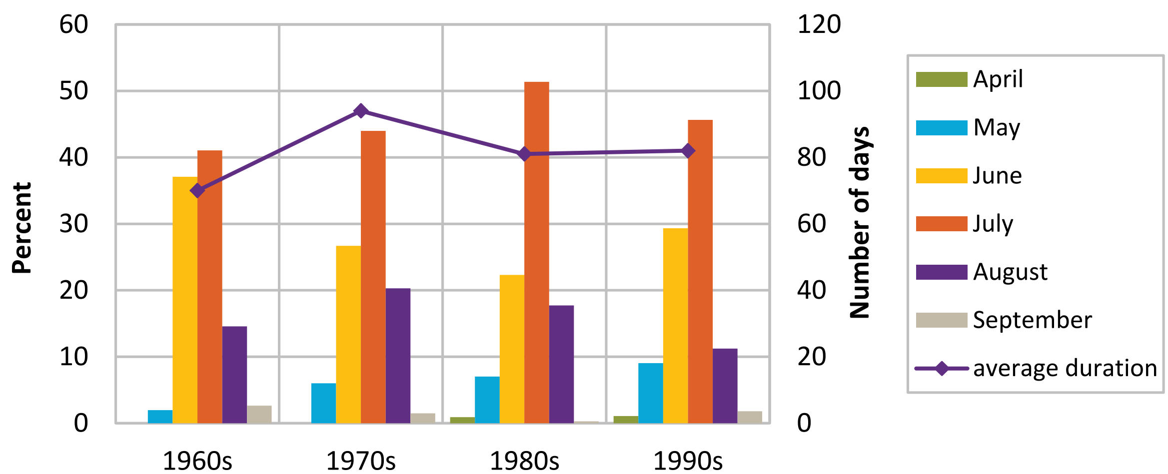

Figure 45. Percent of all large fires that occur in each month of the fire season, by decade, 1960s-1990s
Note: this fire trend is based on the number of large fires over 2 km^2 in size.
Source: Krezek-Hanes et al., 2011[10]

There were no changes in how fires were distributed among the latter months of the fire season, with late-season fires being predominantly caused by lightning, the cause of 83% of Taiga Plains Ecozone+ large fires (Figure 46a). The proportion of fires caused by lightning in comparison to those caused by humans increased from the 1960s to the 1990s (Figure 46a). The total area burned as a result of lightning ignitions also increased over the 40 year period (Figure 46b). This increase in area burned by lightning is most likely due to warmer temperatures during the fire season in the 1990s.[239, 240]

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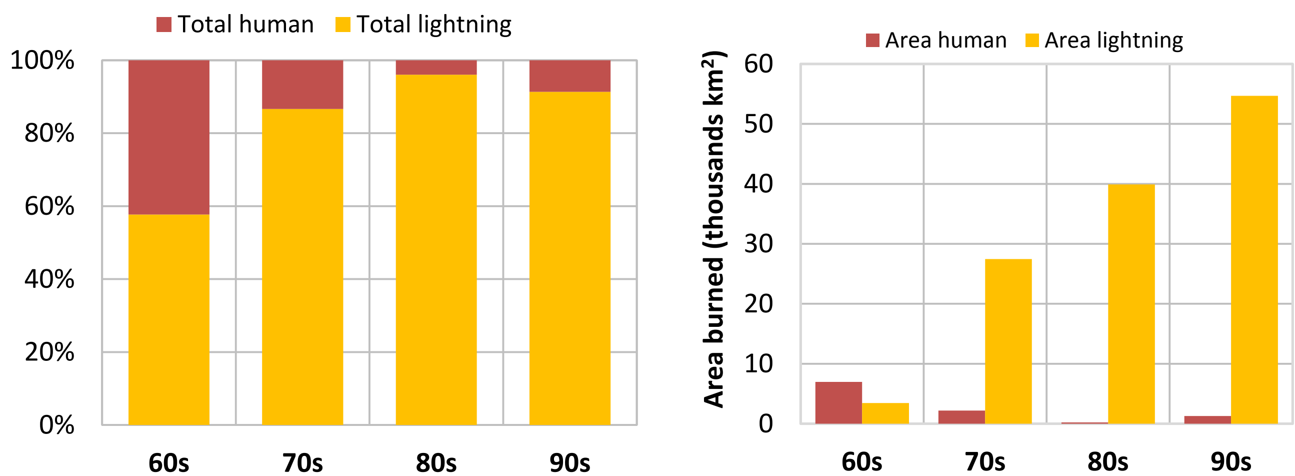

Figure 46. Trends in a) proportion of large fires by cause and b) total area burned by lightning and through humans ignitions, by decade, 1960s-1990s
Large fires are defined as over 2 km^2.
Source: Krezek-Hanes et al., 2011[10]

Insect outbreaks

Trends in large-scale native insect outbreaks are correlated with weather conditions and forest fires, both of which influence the likelihood of insect outbreaks. Insect outbreaks can repeatedly defoliate trees, causing failure of the trees to reproduce (produce cones) and causing reduction in growth and vigour. Additionally, multi-species infestations may further damage trees already weakened by an initial attack. Significant insect pests in the ecozone+ are spruce budworm (*Choristoneura fumiferana*), larch sawfly (*Pristiphora erichsonii*), and forest tent caterpillar (*Malacosoma disstria*).

Spruce budworm, by far the most serious pest in the Taiga Plains Ecozone+, is a small moth known for severe and extensive outbreaks causing heavy defoliation in fir and spruce trees, particularly in the boreal forest.[241] The outbreaks can last 5 to 15 years and populations can reach extremely high densities.[242] Outbreaks of the spruce budworm are closely tied to climate, although the specific weather factors favouring outbreaks are not well understood.[243] Outbreaks are initiated by tight synchrony between the larvae forming feeding sites and the tree's developing buds. Spring frosts can affect the buds and cause budworm collapses[244] and frosts probably limit the northern distribution of the budworm.

In the NWT, a recent outbreak was severe. At its peak (2002), the budworm moderately or severely defoliated approximately 24,000 km^2 of white spruce.[243] Although this outbreak collapsed throughout most of the NWT between 2003 and 2005, it has persisted in and moved progressively further north in the Sahtu (Norman Wells) region.[46, 115]

Spruce budworm outbreaks in the Fort Nelson area are concentrated in mature white spruce stands and aspen/spruce mixed stands.[241] Based on analysis of tree rings, outbreaks in this part of the ecozone+ occur on average every 26 years, with five to six outbreaks in the 20th century. The most recent outbreak extended from about 1987 to 2003.[245, 246]

Forest tent caterpillar is a hardwood defoliator, in particular attacking trembling aspen. Otvos et al., 2010[247] analyzed the six outbreaks that have occurred since the start of detailed record keeping in 1944 in British Columbia. They found that outbreaks have become larger in extent and longer in duration. Forty-six percent of aspen defoliation in the province (resulting from all six outbreaks combined) occurred in the boreal white and black spruce biogeoclimatic zone. The outbreak in the 1990s was concentrated around Fort Nelson.[246]

The NWT experienced its first outbreak of forest tent caterpillar in the mid-1990s in the Liard Valley in the southwest corner of the NWT part of the ecozone+.[248] The outbreak lasted two to three years, peaking in 1996.[248] As forest tent caterpillar eggs are susceptible to mortality during winter cold spells,[249] the strong trend to warmer winters experienced in the Taiga Plains over the past 50 years has likely contributed to the increase in tent caterpillar outbreaks in the ecozone+.

Mountain pine beetle reached the Fort Nelson Forest District in 2010, spreading along the Kechika River corridor.[250] There are extensive pine plateaus in this region potentially at risk if the infestation increases in intensity and extent.[246]

Mountain pine beetle is present in the Alberta part of the Taiga Plains Ecozone+, and reached a few kilometers into the Northwest Territories in the summer of 2012.[251] Infestation levels in the northern part of Alberta are low relative to the most affected area in the centre of the province.[252] However, surveys of the ratio of new infestations to infestations from the previous year in Alberta, conducted in the summer of 2010, showed that the beetle is spreading in the north.[252] A survey of winter mortality conducted the following spring (2011) concluded that there was a high survival rate of beetles, leading to forecasts of further increases in beetle infestation.[253] Beetles were first detected in the west-central part of Alberta in 2006, rapidly becoming abundant and spreading east.[252] There have been localized outbreaks of mountain pine beetle in Alberta in the past, including small pockets of infestations in the north since 2001.[254]

The mountain pine beetle's preferred host is mature, even-aged pine stands[250] – thus forest management practices, including fire suppression, have an impact on the spread of this insect pest. Climate is also an important factor: temperatures of -40°C are required to cause sufficient winter mortality to result in declines.[254] While the mountain pine beetle is likely at the far northern limit of its range in the Taiga Plains under current climatic conditions, there is potential for more serious eruptions and further expansion of its range under future climate change.[255]

Key finding specific to ecozone+ **Theme** Habitat, wildlife, and ecosystem processes

Wildlife disease and parasites

Ecozone+ key finding: Wildlife disease is of importance to the Taiga Plains Ecozone+ for ecological, economic, and human health reasons. Bovine tuberculosis and brucellosis affect a high percentage of wood bison and present risks to human health and to economic activities. There is emerging evidence and growing concern that some wildlife diseases and parasites (including anthrax, ungulate parasites, and viruses and funguses affecting frogs) may be increasing in prevalence and/or range, or may do so in the future, in response to warmer weather and changes in wildlife species distribution.

The status of wildlife health in the Taiga Plains is mostly undescribed although the knowledge base is starting to improve through community-based monitoring, at least for wildlife species important to people. For example, the status of caribou health in parts of the ecozone+ was monitored through hunters working with biologists and veterinarians from 2003 to 2008. Hunters and Elders were interviewed to document their local ecological knowledge of wildlife health and local hunters were trained as monitors to collect tissue samples and measurements to assess body condition and monitor health of harvested caribou (n=69) and moose (n=19). In 2007 the program was extended to include participation in the annual caribou hunt held by one community.[256]

Changes can be expected in disease and parasites in the ecozone+ from two climate-change-related factors:

1. Temperature dependency of parasites and pathogens for some diseases. For example, moose tick outbreaks in Alberta are known to coincide with warmer temperatures in spring and with earlier snow loss.[257]
2. Expansion of the range of endemic species or the colonization of regions of the ecozone+ by non-native species. An example is the spread of muskoxen into the northeast Taiga Plains starting in the 1990s from northeast of Great Bear Lake where the muskoxen were known to be infected with a lungworm. In this example, there was a concern that the muskoxen could pass the infection to Dall sheep. However, studies showed that infection across species did not occur under experimental conditions.[258]

This section draws from *Wildlife pathogens and diseases in Canada*[11] and *Northern caribou population trends in Canada,*[97] technical thematic reports prepared for the 2010 Ecosystem Status and Trends Report.

Diseases affecting ungulates

Bovine tuberculosis

Bovine tuberculosis (BTb) is caused by infection with the bacterium *Mycobacterium bovis*. It readily infects domestic cattle, and in people it causes a disease indistinguishable from human tuberculosis (infection with *M. tuberculosis*). Infected animals, meat products, and milk are significant health hazards for people, and for public health reasons, BTb was successfully eradicated from Canada's domestic animal population through a long and costly program of testing all herds and slaughtering entire herds in which any infected animals were detected.

Bison in Wood Buffalo National Park and adjacent areas became infected with BTb in the 1920s (see section on wood bison in the Species of special interest key finding on page 54). Infection has persisted in this herd and surveys between 1997 and 1999 found that approximately 49% of these bison were infected.[259] In the past two decades, other populations of wild bison, apparently free of infection with BTb, have become established in the Taiga Plains[260] (Figure 31). Measures to prevent the spread of BTb to these infection-free herds are not fully effective and the disease has spread west in recent years.[163, 261] Thus, the potential spread of BTb from infected to non-infected wild bison, all of which are assessed as Threatened by the Committee on the Status of Endangered Wildlife in Canada, and also to livestock, is a major conservation and socio-economic issue.

Brucellosis

Brucellosis is the name given to all diseases caused by infection with any of the several different species of the bacterial genus *Brucella*. The clinical manifestations of brucellosis are many, but the most common are infection and inflammation of the female and male reproductive tracts with resulting abortion and male infertility, and infection of joints and tendon sheaths resulting in progressive lameness. Infection persists, often for the lifetime of the animal. People are similarly susceptible to infection with *Brucella* sp., and brucellosis in animals with which people have contact is a public health risk.[262-264]

Infection with *Brucella* sp. is of potential ecological and public health significance in bison in and around Wood Buffalo National Park, where the bison populations infected with bovine tuberculosis are co-infected with bovine brucellosis caused by *Brucella abortus*.[265] Approximately 30% of bison in Wood Buffalo National Park area are infected.[259]

Brucella suis biotype 4 is present in barren-ground caribou in northern Canada:[263] 20 to 50% of animals in various herds are infected.[266, 267] However, the ecological impact, if any, on infected populations is not known. Infection of northern people with this bacterium occurs and is associated with consumption of caribou.[263, 264] Whether or not *B. suis* biotype 4 is a naturally occurring pathogen in North America or a pathogen introduced from Europe in imported reindeer also is not known. There are no records of this infection in woodland caribou.

As noted for bovine tuberculosis, it seems certain that without effective intervention of some form bovine brucellosis will spread to non-infected wild bison herds progressively over time, and that the vast majority of wild bison in Canada then will be infected.[260] This will place bison recovery efforts further at odds with livestock economies and public health interests. Too little is known about the ecology of *Brucella* in caribou to identify current trends or predict future trajectories.

Anthrax

Anthrax is the name given to all forms of disease caused by infection with the bacterium *Bacillus anthracis*. It is most typically a disease of wild and domestic ungulates, in which it usually is rapidly fatal. Mammalian predators and scavengers also die regularly during anthrax outbreaks in ungulates. Humans are susceptible to anthrax and disease in people ranges from a self-limiting infection of the skin to fatal disease. Ungulates generally become infected from bacterial spores in soil. Environmental conditions that cause these spores to persist for decades or even centuries in soil and to concentrate on the soil surface, such as high-calcium soil chemistry for spore persistence, and flooding followed by dry periods for spore concentration, appear to be major risk factors in outbreaks of anthrax in wild and domestic ungulates. Animal to animal transmission of the bacterium plays only a minor role. Anthrax probably was introduced to North America by European exploration and settlement.[268-270]

In Canadian wildlife, anthrax has been recognized most often in bison in and around Wood Buffalo National Park. The first recognized outbreak was in 1962 and sporadic outbreaks have occurred ever since, often with inter-outbreak time spans of many years (see the wood bison section of the Species of special interest key finding on page 54). The total number of bison and other species to have died of anthrax is unknown, but a minimum of 1,309 bison in the Taiga Plains died of the disease in outbreaks between 1962 and 1993 and a 2012 outbreak killed 440 bison.[166] The occurrence of outbreaks in wild bison and in livestock appear linked to climatic factors, particularly intense precipitation followed by drought. To date, no predictive models have been published with respect to outbreaks of anthrax in Canada and predicted climate change.

Johne's disease

The bacterium causing Johne's disease, known for causing chronic wasting and diarrhea in cattle, has been found in caribou from Greenland and was found at low levels in Bluenose-West caribou in 2008.[271] The bacterium has also been found in wood bison.[272]

Parasites affecting ungulates

Besnoitiosis

Besnoitia is a genus of protozoan parasite which develops pin-head sized cysts in the skin and connective tissues of its herbivore intermediate host and typical coccidial forms in the intestines of its carnivore definitive hosts. No disease due to *Besnoitia* has been recognized in definitive hosts, but intermediate hosts sometimes develop disease conditions associated with severe infections.[273] In Canada, *Besnoitia tarandi* infects caribou and probably muskoxen. Infection is very common in barren-ground caribou and has been described in woodland caribou.[274, 275] Although occasional severe manifestations of infection on the skin have been seen, most infections appear to have little or no health consequences for these species.

The status of *Besnoitia*, assessed from caribou harvested in the fall from 2007 to 2009 from several Canadian herds, was variable, with the Bluenose-West Herd having an infection rate in the range of 30 to 45%.[276]

Winter tick

Throughout most of their range in North America, moose suffer periodic events of high mortality in late winter associated with severe infestations with winter tick, *Dermacentor albipictis*. This tick is native to North America and infests other hosts including woodland caribou and bison. However, severe infestations frequently resulting in death are common only in moose. Winter ticks occur in the southern Taiga Plains ecozone[+],[277] and have recently been found further north in the Mackenzie Valley between Tulita and Fort Good Hope.[278, 279]

Weather events affect the abundance of the ticks, particularly conditions in April when gravid adult female ticks drop to the ground and may survive to lay eggs, thus affecting the numbers of larvae available to infest moose the following fall. Environmental conditions also affect the resilience of the moose, particularly conditions in late winter and early spring the following year when infested moose must endure the ticks. There are not sufficient historical records to determine if there are trends in winter tick infestations and their effects on moose populations. Hunters along the Mackenzie River in the Northwest Territories have recently observed moose in the spring with severe hair loss typical of winter tick infestation, a phenomenon new to the Traditional Knowledge of First Nations in the region.[280]

Diseases affecting amphibians

Frogs are at the northern limit of their distribution in the Taiga Plains. Pathogens that are affecting amphibians globally have recently been detected in the ecozone+.

- Ranaviruses, lethal viruses responsible for die-offs of amphibians world-wide wide[281] have recently been found in wood frogs in the NWT portion of the Taiga Plains.[282]
- Chytrid fungus, *Batrachochytrium dendrobatidis* (*Bd*), which infects the skin of amphibians, has been linked to catastrophic amphibian declines around the world since the 1990s.[283] There is strong evidence linking *Bd* to the declines of amphibian species in western North America.[284, 285] *Bd* was found in samples at a single site in the Taiga Plains in a 2007 to 2008 study,[282] but was detected in all three species of amphibians in the survey area (wood frogs, boreal chorus frogs, and western toads).

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.

Ecozone+ key finding: There is little information on changes in food webs in the Taiga Plains. Abundance of many mammals in the Taiga Plains is cyclic, driven or influenced by food web effects as well as drivers like climate. Changes in small mammal cycles have been reported in other northern regions, and a recent dampening of snowshoe hare and lynx cycles is noted in the NWT. Northern tundra caribou wintering in the Taiga Plains have declined in abundance which may reflect a low period on a population cycle. Declining boreal caribou populations in the south of the ecozone+ may be affected by changes in predator-prey dynamics related to habitat alteration.

Cycles in population abundance

Cyclic abundance is perhaps the best-known feature of community and population dynamics in the Taiga Plains. The amplitude and frequency of cyclic abundance depend on body mass (smaller species cycle at a higher rate). Large-bodied mammals: moose, muskoxen, boreal caribou, and wood bison, do not appear to exhibit cyclic dynamics.

Migratory tundra (barren-ground) caribou wintering in the northern Taiga Plains likely are cyclic in their abundance, based on what is known about herds elsewhere,[127] with the halving time in their herd size being from 5 to 7 years (see Species of special interest key finding on page 59). The Bluenose-West herd has experienced a sharp decline – a drop in abundance from 1992 to 2004 from over 110,000 to about 18,000 caribou – followed by a leveling off at this lower population. This may be a low point in the cyclic patterns of northern caribou abundance. Management actions have been taken to reduce harvest. Continued monitoring will show if altered conditions in the caribou range (for example, changes in fire ecology or in snow condition on winter range)[97] affect the herd's ability to rebound from the current phase of low abundance.

Typically, the highs and lows in abundance of cyclic mammals can differ by an order of magnitude and vary in timing and extent even between neighbouring regions.[286] Cycles or fluctuations in mice, voles, lynx, and snowshoe hare are well documented (Figure 47 and Figure 48 and Danell et al., 1998[287]). The amplitude of the snowshoe hare and lynx cycles has dampened over time (Figure 48). Fluctuations in abundance among grouse and ptarmigan species have also been noted in this ecozone+.[288] Cycles in prey species are linked to cycles in predators, especially for specialized predators (Figure 48). Prey abundance also influences generalist predators such as foxes and they, in turn, influence the abundance of alternate prey species.[289]

Climate variability also has a role in entraining spatial and temporal variability in abundance in the boreal forest.[290] However, how climate interacts with direct and indirect effects on mechanisms causing cycles is both complex and only partially understood. Across North America, the amplitude of hare populations in peak years and forest fires (total burned area) are correlated.[291, 292] Changes in climate and fire activity have the potential to affect both the synchrony and the amplitude of hare cycles across large areas in the ecozone+. Murray, 2003[293] reported that synchrony in hare population cycles across North America have recently declined, although the reasons for the decoupling are uncertain. Similarly in northern Europe, the cyclic abundance for grouse, mice and voles as well as the larch bud moth has diminished or disappeared. These collapses may be linked to changes in climate.[294] With the exception of the dampening of the snowshoe hare and lynx cycle in the NWT (Figure 48), changes and collapses in hare and small mammal cycles have not been observed in the Taiga Plains so far, however longer datasets from continuing monitoring programs will be required to detect changes in synchrony and amplitudes of cycles in all northern ecozones+.

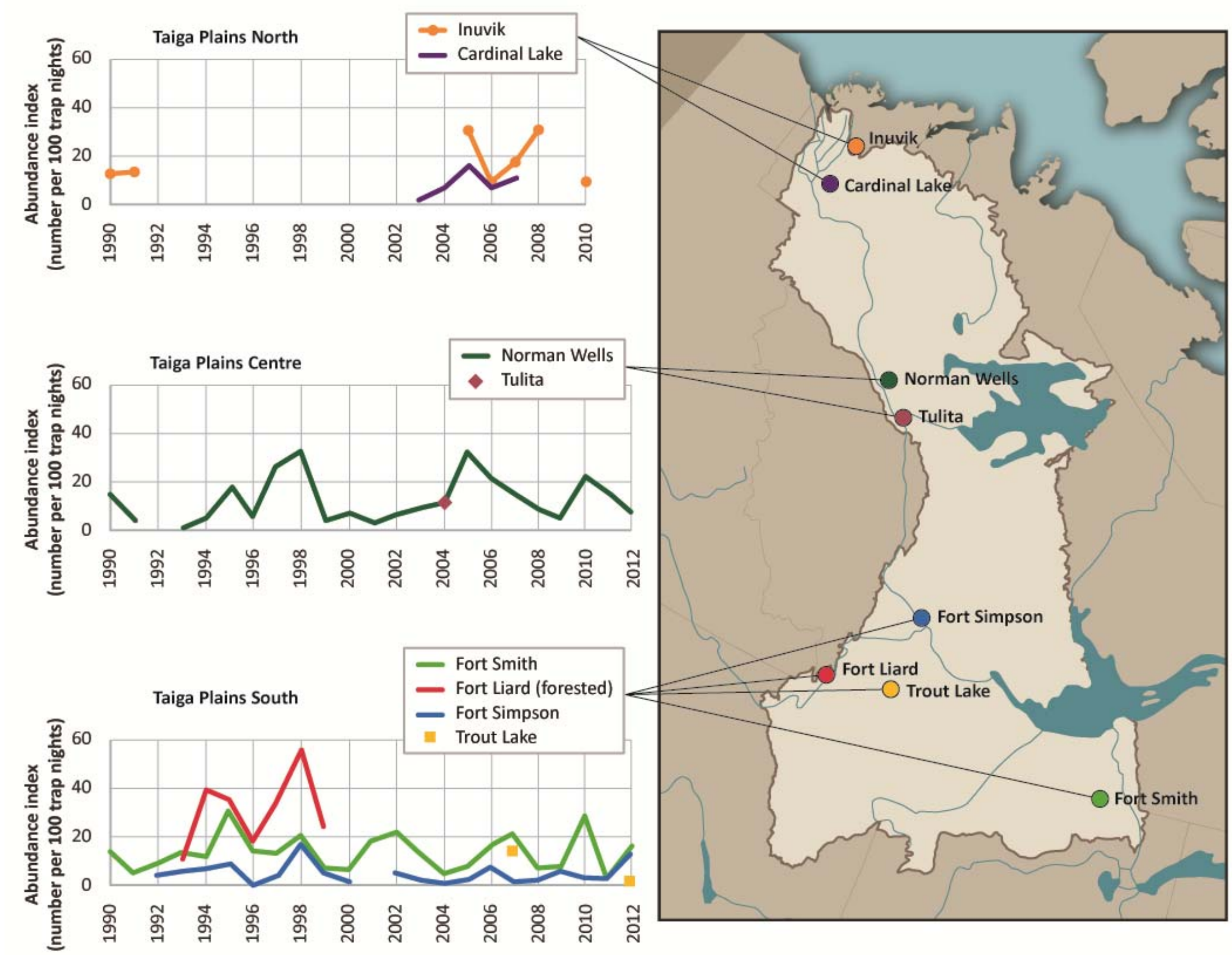

Figure 47. Trends in small mammal abundance in northern, central, and southern areas of the Taiga Plains Ecozone+, 1990-2012
Based on surveys over 5 nights in August, 100 traps per night.
Source: Environment and Natural Resources, 2012.[295] Data coordinated by the NWT Small Mammal Survey, Government of the Northwest Territories. Participating groups: Ducks Unlimited Canada (Cardinal Lake); Sahtu Renewable Resources Board (Tulita); Gwich'in Renewable Resource Board (Inuvik); Protected Areas Strategy Secretariat (Trout Lake); ENR (all other sites).

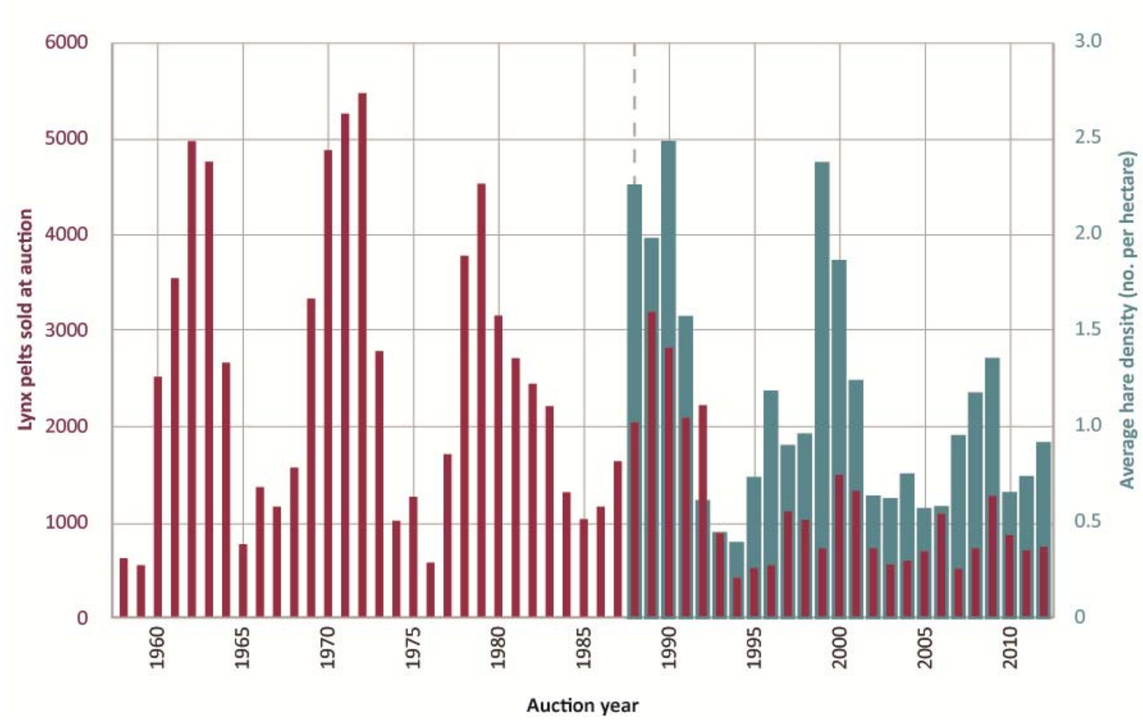

Figure 48. Density of snowshoe hares, 1987-2012, and trapper success for lynx, 1958-2012 in the NWT part of the Taiga Plains Ecozone⁺
Source: Environment and Natural Resources, 2012[295]

Predator-prey relations: boreal caribou

There may be impacts on boreal caribou in the southern part of the ecozone⁺ related to changes in predator-prey relations, in turn related to habitat changes from forest harvest practices and habitat fragmentation, possibly combined with higher rates of areas burned. This is based on the conclusion from several studies that the most significant proximate cause of boreal caribou declines in Canada is increased predation driven by landscape changes that favour younger forests and higher densities of alternative prey (moose and deer, in this part of the ecozone⁺).[181] Boreal caribou are declining in the southern part of the ecozone⁺ (see the Woodland caribou, boreal population section of the Species of special interest key finding on page 60).

Aquatic food webs

Food webs are complex and the first indications of significant changes can be through indirect, unpredictable effects. In aquatic ecosystems, food web changes are a suspected cause of increases in some contaminants (or less of a decrease than would be expected, based on declines in legacy contaminants elsewhere). This has been proposed as one explanation for contaminant levels and trends in Great Slave Lake[123, 296] (see Contaminants key finding). In the Boreal Cordillera, this effect was demonstrated for lake trout: differences in the food web compared with neighbouring lakes (related in part to fishing pressure) resulted in a higher degree of biomagnification of organochlorines Lake Laberge in the southern Yukon.[297, 298]

Other factors that can be expected to alter aquatic food webs (and may be altering them now) include warmer water temperatures, resulting in changes in fish distribution in streams. The extent of thaw slumping (slope failure from thawing of ground ice) is increasing in Mackenzie Delta lakes, and is leading to changes in aspects of water quality that determine biotic communities, with an expected consequence of shifts in aquatic food webs (see Wetlands key finding on page 18).

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.

Ecozone⁺ key finding: Important data sets collected through broadscale monitoring programs for the ecozone⁺ are mainly at the non-biological level: climate, hydrology, and permafrost monitoring. In addition, data on some species groups, notably some caribou populations, small mammals, and waterfowl, provide good trend information. A combination of remote sensing and short-term research projects, often extending into the past through the use of proxy records, provides some data on landscape-level changes. A priority often identified for the region is improvement of the use of Traditional Knowledge along with results from science-based studies.

Relatively long-term monitoring programs that are established in the Taiga Plains include small-mammal monitoring to track trends in food webs and population cycles in the boreal forest, and permafrost monitoring along the Mackenzie Valley, providing a latitude transect and a time series of permafrost trends. Most wildlife population data are sporadic, and information is lacking particularly on several boreal caribou herds, landbirds, and predators. Wildlife parasites and disease and forest insect pests show early indications of changes that warrant follow-up through monitoring and research.

Detecting trends over the extensive deltas and forested river valleys and plateaus can only be accomplished by monitoring over large areas. Studies that look at patterns of vegetation and landforms in relation to latitude and climate (for example, Lantz et al., 2010[33]) provide the baseline information needed to design effective monitoring at this scale.

Because of this need to monitor changes at broad scales in the ecozone+, and because ground-based monitoring is in short supply, surveys and studies conducted through remote sensing hold potential for improving understanding of status, trends, and ecosystem processes in the Taiga Plains. In some cases, where ground-based monitoring that has been discontinued (for example, monitoring of lake ice phenology[299]), satellite-based monitoring can be used to look at short-term trends or to extend existing time series. Results from studies conducted by remote sensing have provided trend data reported on here – including data on primary productivity, fires, and changes in the treeline zone.

Effective ecological monitoring needs ecosystem-based research to direct priorities and to help interpret results. Studies such as the Mackenzie GEWEX (Global Energy and Water Cycle Experiment) Study (MAGS) provide detailed information on the status and trends in the atmospheric and hydrological systems of the Mackenzie River Basin. MAGS involves coordinated research into many atmospheric, land surface, and hydrological issues associated with cold climate systems.[300]

A monitoring and research priority frequently identified for the region is the need to develop methods that make use of all types of knowledge more effectively.[100, 102, 142, 301] Both science-based work and Traditional Knowledge studies have their limitations when used to look ahead to consequences of future stressors. Baselines are shifting; Traditional Knowledge roots are deep in the past and often based on knowledge gained under a less changeable environment with different conditions. The same dilemma occurs with science-based studies, though on a more compressed timescale, as older studies often are not applicable any more. This points out the need to understand current baseline conditions and drivers of change, as well as to combine forces through coordinated Traditional Knowledge and science studies.[19]

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.

Ecozone+ key finding: There are signals of rapid ecosystem change in the Taiga Plains, related to climate change. Loss of frozen peatlands is occurring in some areas; increasing permafrost temperatures at several sites is an early warning that other areas will cross the phase-change threshold leading to permafrost degradation, altering terrestrial and aquatic ecosystems. Other large-scale changes observed in recent years include increases in primary productivity, mainly in the north of the ecozone+, and alteration of vegetation communities in the treeline zone.

Early detection of rapid change requires coordination of ecosystem research and monitoring (science-based and local knowledge) to observe and interpret the responses of ecosystems to stresses. Signals from research and monitoring in the Taiga Plains that may indicate rapid change or approaching thresholds:

Loss of frozen peat plateaus – an observed trend in parts of the ecozone+, has led to significant changes in ecosystems in the Taiga Shield Ecozone+ (in northern Quebec), with conversion of lichen-rich black spruce forest to wetlands. Permafrost monitoring in the Mackenzie Valley reveals that permafrost is warming —this in itself does not have ecological impacts – but signifies an approaching period of more extensive permafrost thawing that is known to have widespread ecological consequences.[12, 19] Thawing of permafrost is a phase change – abrupt by definition (Ice across biomes key finding on page 22).

Signs of change in the treeline zone that indicate fundamental alteration of ecosystems: broadscale increase in tall shrubs, decrease in lichen cover. (Forest key finding on page 13).

Annual growth rates of white spruce in relation to spring temperature: About 75% of white spruce in the study area in the north of the ecozone+ experienced an abrupt change in this relationship (with decreased growth rates), indicative of a threshold having been crossed.[30] (Forest key finding on page 13).

Mismatches in timing: an emerging issue to track for the ecozone+, with warmer temperatures in the spring resulting in earlier ice break-up and earlier peaks of plant growth. A mismatch between peak food source abundance and hatch dates may be a cause of declines of scaup in the western boreal forest (Species of special interest key finding on page 54 and discussion above on climate trends since 1950).

Delta flood regime. A possible emerging trend with potential for rapid, extensive ecosystem change is alteration of flood regimes in the Slave and Mackenzie deltas. The thousands of small lakes and wetlands provide a diversity of habitats important to wildlife; wetland productivity and diversity are maintained by periodic replenishment of sediments and nutrients from high spring floods. Reduction of flooding in north-flowing river systems in North America is a predicted consequence of climate change. In the Slave Delta, high flood frequency may be declining (Wetlands key finding on page 18).

CONCLUSION: HUMAN WELL-BEING AND BIODIVERSITY

The Taiga Plains Ecozone+, with its forested plateaus and river valleys dotted with thousands of lakes and wetlands, forms a broad, uninterrupted corridor extending from Canada's boreal forest ecozones+ in the south almost to the Arctic Ocean. It is bordered to the west by the Taiga Cordillera and to the east by the Taiga Shield, both with predominantly patchy, often sparse, forest stands and bare rock. Continuation of the trend of expansion and intensification of settlement, agriculture, and industrial development along the southern zone of Canada's boreal forest brings with it increases in fragmentation and landuse conversion. Associated forest harvest and fire suppression alter age characteristics and structure of the forest in the more densely settled parts of Canada's boreal ecozones+. The Taiga Plains may increasingly become nationally important as a refuge and a corridor for boreal forest biota that require large intact tracts of mixed-age and mature coniferous forest.

This is illustrated by the distribution of boreal caribou in Canada (Figure 49). The range of the woodland caribou, including the boreal population, has retracted significantly from historical distributions. The southern limit of distribution has progressively receded in a northerly direction since the early 1900s, a trend that continues now.[183, 185-187] The Taiga Plains Ecozone+ is also important as a migration corridor and connecting habitat for other species, including predators and migratory birds. Two iconic at-risk species, wood bison and whooping crane, extirpated throughout most of their North American ranges through habitat change, were left with tiny remnant populations in the Taiga Plains. Both have been subjects of decades of recovery actions and the continuation of both species is still dependent upon large blocks of intact, protected habitat within the ecozone+.

*Figure 49. Current distribution of boreal caribou and historical (early 1900s) distribution of woodland caribou (*Rangifer tarandus caribou*) in Canada.*
Source: Environment Canada, 2012[109]

The people who live in the Taiga Plains are well aware of the value of their land. Hunting, fishing, berry and plant gathering, and trapping remain important cultural and economic activities for many residents – for example, almost all households in Gwich'in communities collect berries and 20 to 30% of Taiga Plains households in the NWT obtain most or all of their meat and fish from the land. Forest harvest in the south, wilderness tourism, recreation, and guided hunting and fishing are other economic sectors dependent upon healthy ecosystems.

Because of this strong attachment to the land and because the Taiga Plains and the lands and the sea to its north contain oil and gas reserves, this ecozone+ has a rich history of grappling with issues around sustainable development. The ecozone+ is a centre of studies, dialogue, and co-operatively managed work aimed at balancing the goal of conservation of (and respect for) the land (encompassing ecosystems and traditional cultures) with the goal of creating flourishing, sustainable community economies.

Processes and initiatives centred in the Taiga Plains have influenced land claim settlements, co-management processes, and ideas and practices around involving Aboriginal Peoples and Traditional Ecological Knowledge across much of the North. Proposed oil and gas and pipeline developments led to assessments, consultations, and recommendations, from the Berger inquiry of the 1970s[302] to the recent Mackenzie Gas Project assessment.[303, 304] Agencies and renewable resource management boards and councils in the ecozone+ have supported major research and monitoring programs and projects on cumulative effects, ecological indicators, baseline information, land-use planning, and methods and promotion of the use of Traditional Ecological Knowledge in environmental monitoring, planning, and management.[59] Examples are the Mackenzie River Basin Impact Study,[305] the West Kitikmeot Slave Study,[306] the NWT Cumulative Impact Monitoring Program,[217] and the Arctic Borderlands Ecological Knowledge Co-op.[99]

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