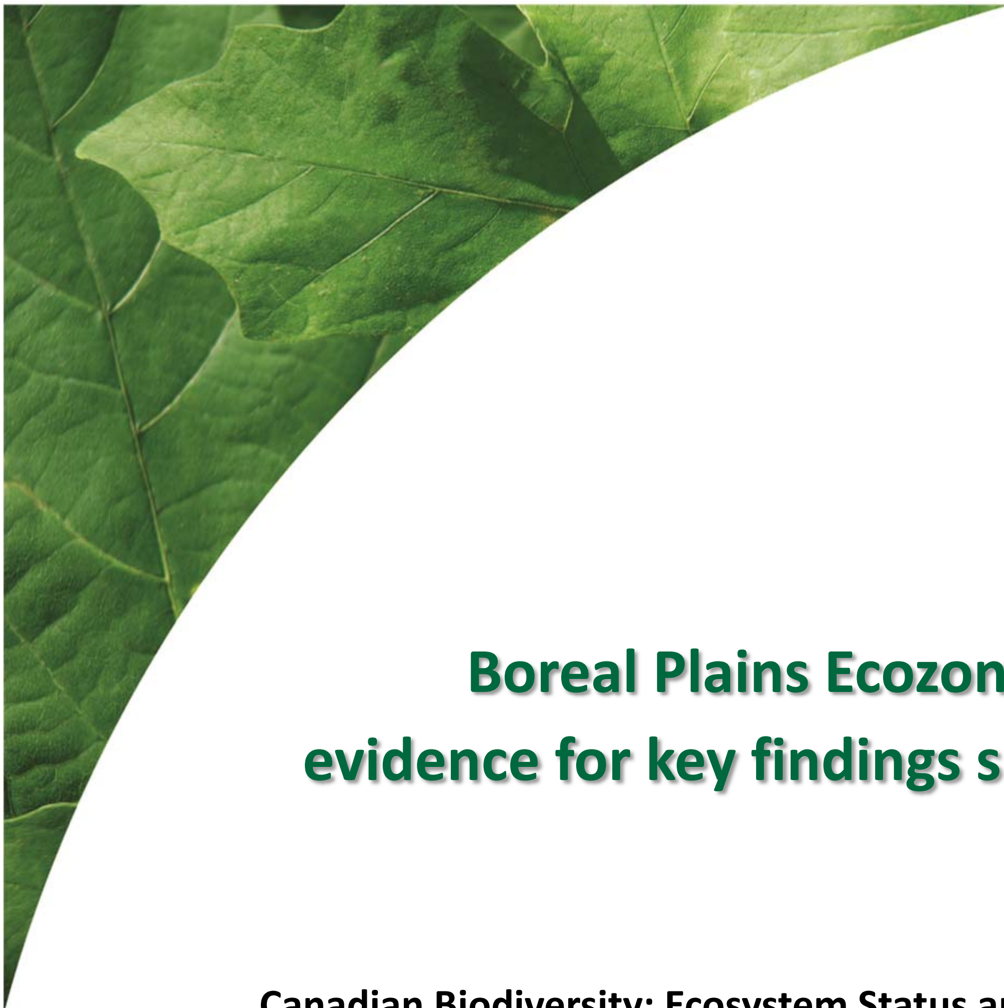

Boreal Plains Ecozone⁺ evidence for key findings summary

Canadian Biodiversity: Ecosystem Status and Trends 2010

Evidence for Key Findings Summary Report No. 12

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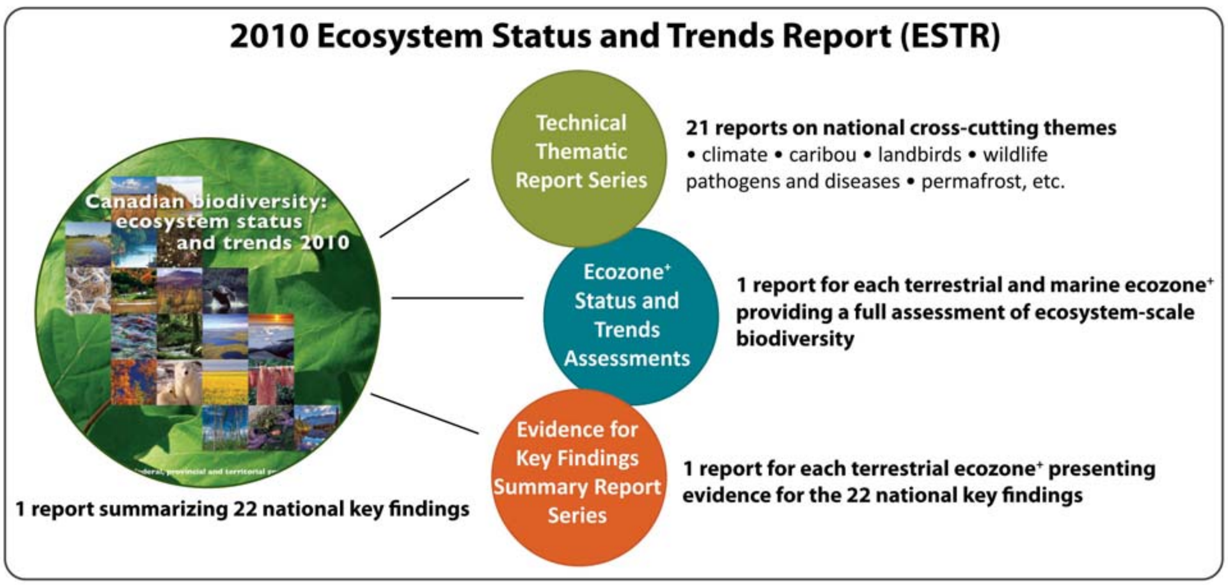
PREFACE

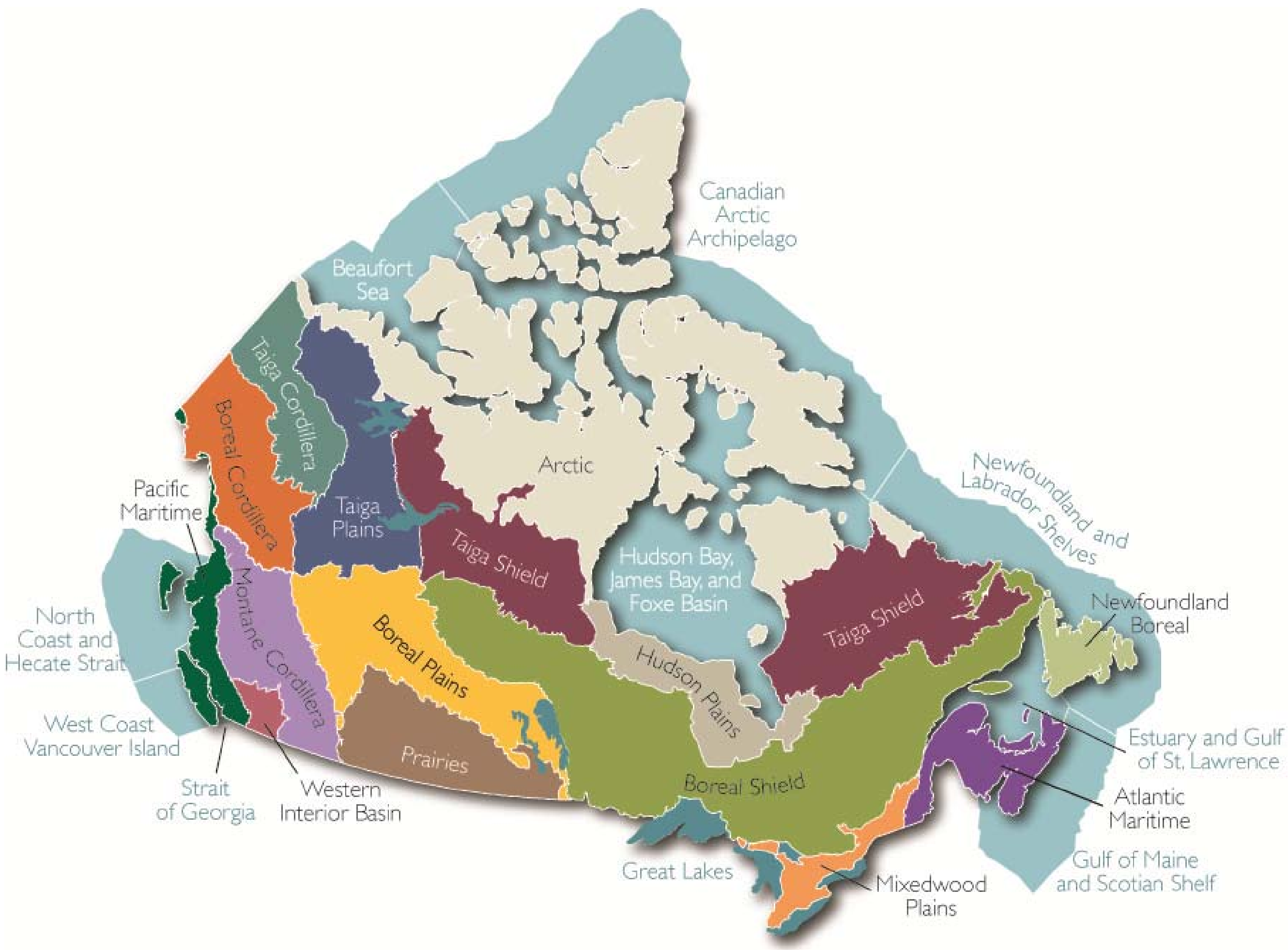
The Canadian Councils of Resource Ministers developed a Biodiversity Outcomes Framework[4] in 2006 to focus conservation and restoration actions under the *Canadian Biodiversity Strategy*.[7] *Canadian Biodiversity: Ecosystem Status and Trends 2010*[8] was the first report under this framework. It presents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



This report, *Boreal Plains Ecozone⁺ Evidence for Key Findings Summary*, presents evidence from the Boreal Plains Ecozone⁺ related to the 22 national key findings and highlights important trends specific to this ecozone⁺. It is 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. Some emphasis has been placed on information from the national Technical Thematic Report Series. As in all ESTR products, the time frames over which trends are assessed vary – both because time frames that are meaningful for these diverse aspects of ecosystems vary and because the assessment is based on the best available information, which is over a range of time periods.

Ecological classification system – ecozones+

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



Acknowledgements

The ESTR Secretariat acknowledges Diane Haughland and the Alberta Biodiversity Monitoring Institute for the preparation of various drafts of the report. This report was overseen and edited by Emily Gonzales and Debbie Martin. Kelly Badger was the lead graphics designer. Additional support was provided by Ellorie McKnight, Michelle Connolly and others. This report is based on the draft Boreal Plains Ecozone+ Status and Trends Assessment. Other experts made significant contributions to that draft report and are listed below. Reviews were provided by scientists and resource managers from relevant provincial/territorial and federal government agencies. The Canadian Society of Ecology and Evolution also coordinated reviews with external experts.

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Review conducted by scientists and renewable resource and wildlife managers from relevant provincial and federal government agencies through a review process recommended by the ESTR Steering Committee. Additional reviews of specific sections were conducted by university researchers in their field of expertise at the request of the authors.

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

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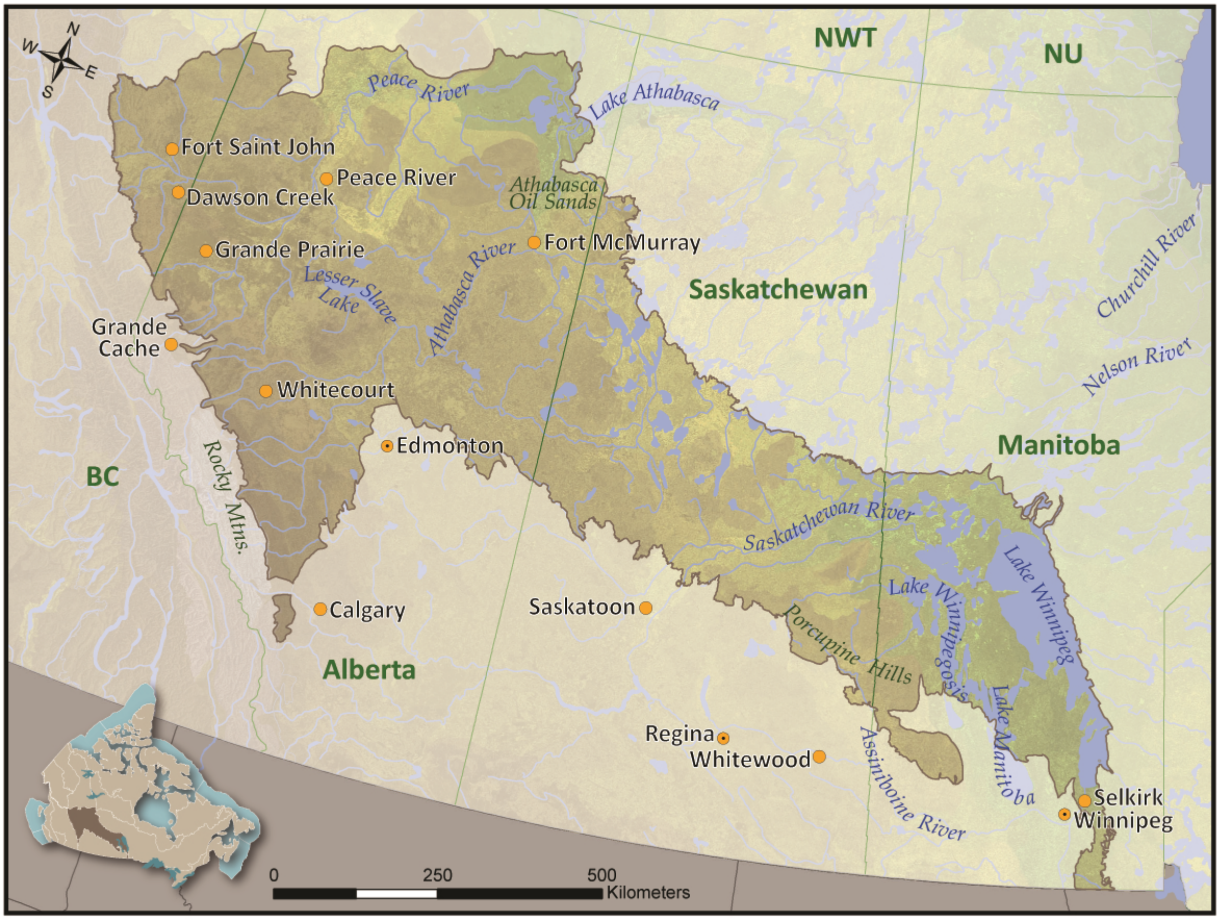


Figure 1. Overview map of the Boreal Plains Ecozone⁺.

ECOZONE⁺ BASICS

Extending from northeastern British Columbia, across northern and central portions of Alberta and central Saskatchewan, to Lake Winnipeg in Manitoba (Figure 1), the Boreal Plains Ecozone⁺ is characterized by a cool climate, generally flat topography, thick surface organic soil layers, poor drainage, low nutrients, and discontinuous permafrost (Table 1).[11] Over 60% forested (Figure 2), with low tree species diversity and relatively slow tree growth, the ecozone⁺ is interspersed with wetlands, shrublands, and some of Canada's largest water bodies. Frequent wide-spread natural disturbances including fire, insect outbreaks, and wind drive the structure of the ecozone⁺. The Boreal Plains Ecozone⁺ is rich in renewable and non-renewable resources, with resource-based industries being the primary economic drivers. At almost 21% of its landbase, the region provides Canada's second largest contribution of agriculture land. It has a robust forestry industry, and a rapidly growing energy sector (including the oil sands).

Table 1. Boreal Plains Ecozone+ overview.

Area	701,750 km^2 (7.0% of Canada)
Topography	Typically flat to gently rolling, hummocky and kettled terrain; generally decreasing in elevation in an eastward direction
Climate	Cool, northern continental climate, with long, cold winters and short cool summers; maintaining average annual temperatures around 0°C Climate varies with cooler and wetter conditions in the north, and warmer and drier conditions in the south Total annual precipitation generally remains below 500mm, typically occurring in the summers
River basins	Falls within Great Slave Lake, Western and Northern Hudson Bay, and Nelson River drainage areas. Tributaries provide for the Peace–Athabasca Delta, Lake Winnipeg, Lake Winnipegosis, and Lake Manitoba Major rivers include the Peace, Athabasca, and Saskatchewan
Geology	Postglacial terrain consists primarily of glacial till deposits and some morainal, lacustrine, and aeolian deposits over Cretaceous shales and sandstones
Permafrost	Patchy distribution of permafrost, confined to peatlands along the northern edge coinciding with the southern edge of the sporadic permafrost zone
Settlement	Small groups of Aboriginal peoples have inhabited the area for the last 5000 years European settlement started in the mid-1800s following the fur trade and subsequent agricultural expansion and resource extraction Settlement typically along the south and near areas of high resource concentration Major municipalities include Fort St. John, Peace River, Grand Prairie, Fort McMurray, Prince Albert, The Pas, and Gimli
Economy	Predominantly resource-based including agriculture, forestry, and energy development, particularly oil and gas extraction
Development	Extensive development is focused around resource deposits and human access Most agricultural and forestry activity occurs along the southern edge or near population centres
National/global significance	Peace–Athabasca Delta is Canada's largest inland delta and is designated as a Ramsar Wetland of International Importance as one of the world's largest freshwater deltas, and as an Important Bird Area for migratory waterfowl on all four continental flyways Wood Buffalo National Park is the world's second largest national park and a World Heritage Site

Jurisdictions: The Boreal Plains Ecozone+ includes parts of Manitoba, Saskatchewan, Alberta, and British Columbia. The major Aboriginal groups that overlap the Boreal Plains Ecozone+ boundaries are the Cree, Denesuline, and Dunne-za.[12]

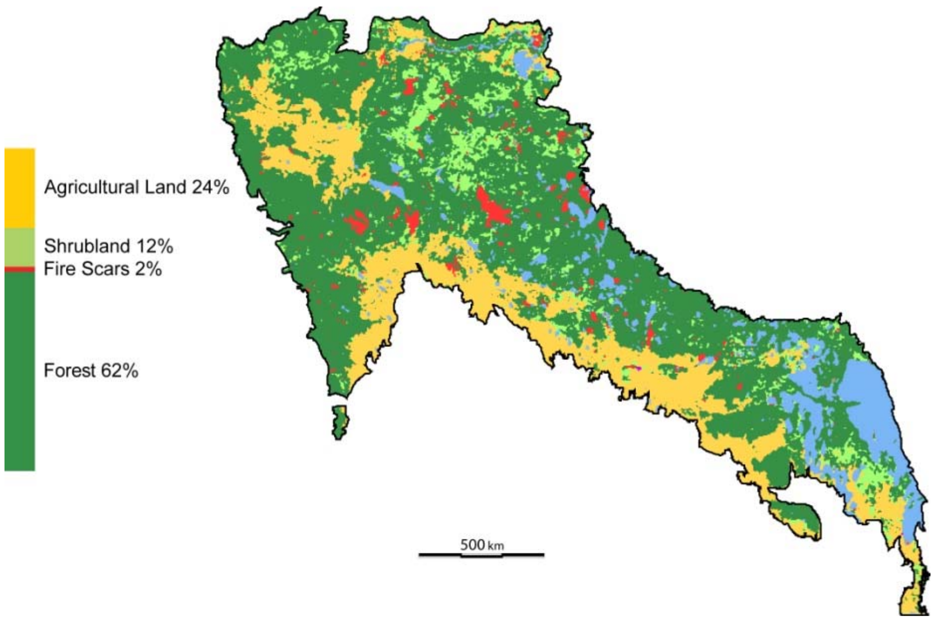


Figure 2. Broad (1 km resolution) landcover classification for the Boreal Plains Ecozone+, 2005. Source: data for ecozone+ provided by authors of Ahern et al., 2011[13]

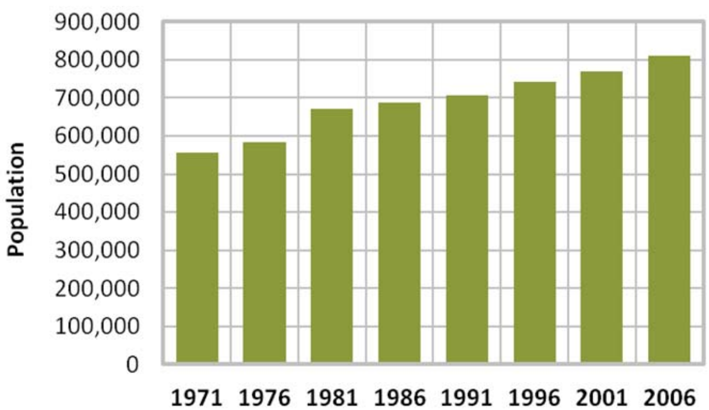


Figure 3.Human population trends, Boreal Plains Ecozone+ from 1971 to 2006. Source: Statistics Canada, 2000[14] and 2009[15]

The population of the Boreal Plains Ecozone+ has been steadily increasing and reached 809,169 in 2006 (Figure 3). Population growth is driven largely by the need for labour as resource development expands; for example the population of Fort McMurray expanded almost ten-fold between 1971 and 2007 (from 6,847 to 64,441).[16]

KEY FINDINGS AT A GLANCE: NATIONAL AND ECOZONE⁺ LEVEL

Table 2 presents the national key findings from Canadian Biodiversity: Ecosystem Status and Trends 2010[8] together with a summary of the corresponding trends in the Boreal 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 2. Key findings overview.

Themes and topics	Key findings: NATIONAL	Key findings: BOREAL 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.	Over 60% of the ecozone⁺ was classified as forest including conifer (42%), deciduous (37%), and mixed (20%). Between 1985 and 2005 there was a 3% decrease in forest cover largely due to an increase in fire. In the agricultural landscape, woodlots were also converted to cropland over this period. Approximately 37% of forests are intact, larger than 100 km^2. Forest fragmentation is the result of industrial development, such as: seismic lines, forest harvesting, access roads for oil and gas development, and forestry. Forest birds have remained stable between 1971 and 2006.
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.	There is little information on native grasslands; most native grassland in the ecozone⁺ has been converted to agriculture. From 1986 to 2002, 15% of grasslands and rangelands were lost in Manitoba's Boreal Plains.
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.	Few data were available for the status and trends for wetlands. Between 1986 and 2002, 15% of marshes and fens and 10% loss of treed and open bogs were lost in Manitoba's Boreal Plains.

Themes and topics	Key findings: NATIONAL	Key findings: BOREAL PLAINS ECOZONE+
4. Lakes and rivers	Trends over the past 40 years influencing biodiversity in lakes and rivers include seasonal changes in magnitude of stream flows, increases in river and lake temperatures, decreases in lake levels, and habitat loss and fragmentation.	Stream flows decreased, water levels lowered, and water withdrawals increased in the ecozone+. The main drivers of these trends were climate change and oil and gas development.
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
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.	The limited data available suggest later freeze-up and earlier break-up in some lakes and rivers, reflecting increased air temperature, particularly in the spring. Permafrost in peatlands in the northern portion of the ecozone+ have thawed and degraded.
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.	Total area protected increased from 4.0% in 1992 to 8.0% in 2009; 7.2% of the ecozone+ is protected under IUCN categories I–IV. Protected areas are threatened by habitat fragmentation and loss in areas surrounding parks, climate change, over use, and invasive species.

Themes and topics	Key findings: NATIONAL	Key findings: BOREAL PLAINS ECOZONE+
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.	Trends in stewardship initiatives are not well documented. Private organizations, such as the Nature Conservancy of Canada, have increased their holdings of privately owned protected areas over the past decade. There is increasing interest in the use of market-based instruments, such as conservation offsets, to mitigate impacts of industrial development, and to encourage stewardship of environmental values on private land.
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 no consistent long-term monitoring, ecozone+-wide lists or consistent control measures in place for invasive species. The Alberta Biodiversity Monitoring Institute have detected 75 invasive plant species in the Boreal Plains Ecozone+ in Alberta. Occurrences of invasive fish species appear to be increasing. Non-native earthworms are patchily distributed throughout much of the ecozone+ in Alberta and their range is expected to expand in the next 50 years with unknown consequences.
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.	Contaminant levels have exceeded toxic levels in the Athabasca oil sands area. Continued expansion of coal-combustion power plants near Wabamun Lake, AB has resulted in increased mercury and trace metal concentrations in the watershed.

Themes and topics	Key findings: NATIONAL	Key findings: BOREAL PLAINS ECOZONE$^+$
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.	Lakes in the Boreal Plains Ecozone$^+$ tend to be naturally eutrophic and shallow resulting in increased susceptibility to nutrient loading. Residual soil nitrogen on agricultural lands increased three-fold between 1981 and 2006, which represents a moderate risk. Phosphorus in Lake Winnipeg, MB increased by 30% from 1969 to 2007, resulting in a five-fold increase in average biomass of phytoplankton and a shift in species composition to blue-green algae. Increases in phosphorus are due to intensification of agriculture, land clearing, wetland drainage, and rapid growth of the human population.
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.	Although ecozone$^+$-wide data were not available, acid deposition is an emerging issue in this ecozone$^+$. Industrial expansion of oil and gas threatens to increase emissions and acid deposition, particularly in northwest Saskatchewan due to its downwind location and highly sensitive lakes.
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.	Temperature has increased significantly in the ecozone$^+$, especially in winter and spring. Snow depth and duration of snow cover has decreased since 1950. Changes in precipitation were variable. Broad-scale ecological impacts are projected based on continued warming related to changes in hydrological regimes, the forest biome, melting of frozen peatlands, and northward range expansions of species.

Themes and topics	Key findings: NATIONAL	Key findings: BOREAL PLAINS ECOZONE[+]
15. Ecosystem services	Canada is well endowed with a natural environment that provides ecosystem services upon which our quality of life depends. In some areas where stressors have impaired ecosystem function, the cost of maintaining ecosystem services is high and deterioration in quantity, quality, and access to ecosystem services is evident.	The ecozone[+] provides a number of provisioning services. Fresh water allocation is increasing although still very low in monitored river basins. Timber harvesting continues to increase. Populations of species that are hunted or trapped are generally stable with the exception of grizzly bear and wolverine. Overfishing has resulted in the collapse of commercial and sport fisheries in Alberta, but Lake Winnipeg, MB walleye commercial fisheries are at an unprecedented high. Agricultural land cover remains stable at 24% of the ecozone[+]. The ecozone[+] also supplies a number of regulating services. With increasing air temperature, the boreal forest could become a carbon source rather than a sink. Wetlands, which function to purify and store water, have declined. National Park visitation rates have remained steady, reflecting a human-use value for the ecozone[+]. Efforts to value ecological services in the Boreal Plains Ecozone[+] have increased.
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.	Agricultural land use, covering 21% of the ecozone[+], is continuing to expand and intensify. The conversion of natural land cover to agriculture has resulted in a decrease in wildlife habitat capacity.
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.	Grassland birds, certain duck species, boreal caribou, grizzly bears and bison have declined in geographic range and abundance across the ecozone[+]. Factors responsible for the declines included habitat alteration, disease, and changes in predator-prey dynamics.

Themes and topics	Key findings: NATIONAL	Key findings: BOREAL PLAINS ECOZONE[+]
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.	The Normalized Difference Vegetation Index increased for 20.8% of the land area between 1985 and 2006 as a result of increased agricultural production, climate change (particularly precipitation), and fire. Nutrient loading in Lake Winnipeg has also resulted in increased productivity. Productivity declined on less than 1% of the land base, which was attributed to industrial activity surrounding the Athabasca oil sands.
19. Natural disturbance	The dynamics of natural disturbance regimes, such as fire and native insect outbreaks, are changing and this is reshaping the landscape. The direction and degree of change vary.	Fire is an important natural disturbance in the ecozone[+]. The amount of area burned peaked in the 1980s and then decreased. Trends are heavily influenced by people through fire suppression and ignitions. Climate has also influenced trends in fire. Native insect outbreaks are also an important disturbance. Areas affected by spruce budworm may be increasing, although long-term data were lacking. Mountain pine beetles are also expanding their range into the Boreal Plains Ecozone[+].
20. Food webs	Fundamental changes in relationships among species have been observed in marine, freshwater, and terrestrial environments. The loss or reduction of important components of food webs has greatly altered some ecosystems.	Lynx-hare predator-prey population cycles are known to occur in the ecozone[+], but few data were available. Boreal caribou populations have declined due to habitat fragmentation. In particular, linear features such as roads and seismic lines associated with oil and gas development increased vulnerability of caribou to wolf predation.
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.	Cross-jurisdictional biodiversity monitoring is lacking in the Boreal Plains Ecozone[+]. Future reporting in the Alberta portion of the ecozone[+] will be improved by data collected through the Alberta Biodiversity Monitoring Institute. Spatial and taxonomic coverage were poor in the other provinces in the ecozone[+].

Themes and topics	Key findings: NATIONAL	Key findings: BOREAL 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 multiple stressors that may result in rapid, irreversible changes to ecosystems in the Boreal Plains, but few definitive examples. These include the outbreak of avian cholera in double-crested cormorants, the spread of mountain pine beetle to northern Alberta in 2005, the decline of boreal caribou and changes in their predator-prey dynamics due to industrial development, and the thawing of permafrost.

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.

Sixty-two percent of the Boreal Plains Ecozone+ was classified as forest.[13] Historically, frequent widespread natural disturbances such as fire, insect outbreaks, and wind shaped forest structure in this ecozone+. However, agricultural expansion, forest harvest, and an increase in industrial development have reduced the extent and increased fragmentation in Boreal Plains forests.

Forest type

According to Canada's 2001 National Forest Inventory, 42% of the forests of the Boreal Plains Ecozone+ forests were conifer, 37% were deciduous, and 20% were mixedwood.[17] Mixedwood forests are comprised of conifer species (e.g., black spruce, *Picea mariana*, white spruce, *P. glauca*, or jack pine, *Pinus banksiana*) and deciduous species (e.g., trembling aspen, *Populus tremuloides*). Mixedwood forests are species rich,[18] such as the Central Mixedwood in Alberta,[19] and productive for wildlife, such as Dry Mixedwood forests.[20]

Case study: trembling aspen health

Trembling aspen is the most abundant deciduous tree species in the Boreal Plains Ecozone+ and the most important tree in the transition zone between the boreal forest and grassland.[21] It is increasingly important commercially; in 2006, trembling aspen accounted for 86% of hardwood and 31% of total wood (m^3) harvested in British Columbia and Alberta.

Concern about climate change, recent aspen dieback (defined as progressive tree death, generally starting at the root, shoot, and branch tips), and reduced growth in aspen stands led to the Climate Change Impacts on Productivity and Health of Aspen research initiative.[22] To better understand trembling aspen health and productivity, researchers determined growth trends via tree ring analysis at 24 sites across Canada's western interior, 15 of which were in the Boreal Plains. They found that drought and insect defoliation resulted in two cycles of reduced growth between 1951 and 2000 (Figure 4). Dieback in a similar study of aspen near Grande Prairie, AB was caused by secondary wood-boring insects and fungal pathogens in trees already affected by insect defoliation and drought coupled with freeze-thaw cycles in years of light snow.[23] Future climate change will increase the frequency of drought and insect defoliation cycles, causing increased dieback, decreased productivity, and decreased CO_2 uptake.[23]

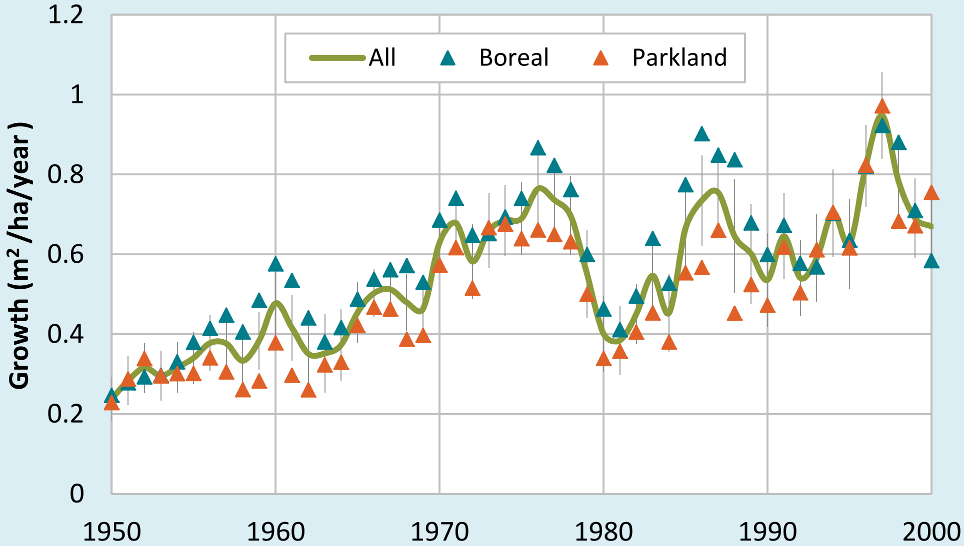


Figure 4.Trends in average stand-level aspen growth in the western Canadian interior from 1950 to 2000.
Based on tree-ring analysis of disks collected at 1.3 m from 432 stems adjacent to plots in the boreal and parkland zones (symbols show estimated average growth of 36 stands within the 12 study areas in each zone).
Error bars are 95% confidence intervals, based on the variation recorded among all 24 study areas. Growth is expressed as annual increment in stem cross-sectional area and is based only on aspen trees that were living in 2000 (growth is underestimated in the early years of the study).
Source: adapted from Hogg et al., 2005[22]

Extent

Forest cover is the most common land cover type (62%) in the Boreal Plains Ecozone⁺ (Figure 2, Figure 5).[13] However, forest cover declined by 3% (11,000 km^2) between 1985 and 2005 due to fire, forest conversion to agriculture, and oil and gas development.[13] From 1985 to 2005, the area of fire scars in the Boreal Plains Ecozone⁺ increased by 357%, from 2,099 to 9,590 km^2.[13] Natural regeneration should result in the successional recovery of these burned areas to forest cover.[13, 24] Nevertheless, forest conversion to other cover types is also occurring. Approximately 5,020 km^2 was converted from woodland to cropland, particularly along the southern periphery and in the Peace River region (Figure 6) (see Wildlife habitat capacity section on page 52 for information on the impact of this loss to biodiversity).[13] In more recent years, conventional oil and gas and bitumen exploration and development in Alberta and British Columbia have contributed to deforestation in the Boreal Plains Ecozone⁺.[25] For example, in a 3,906 km^2 area within the Athabasca oil sands area, 21% (810 km^2) of mostly forested vegetation has been cleared since 1984 for oil and gas development.[26]

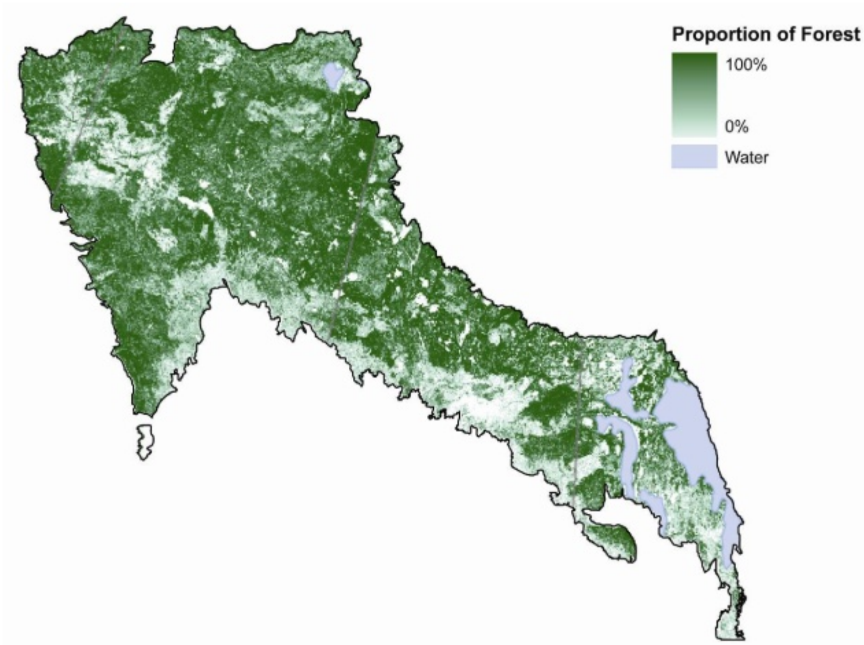


Figure 5.Forest density in the Boreal Plains Ecozone⁺ as determined by remote sensing, 2000.
Forest density calculated as the proportion of forested pixels (30 m resolution) within each 1 km² unit.
Forest is classified as >10% tree cover.
Source: adapted from Wulder et al., 2008[27] by Ahern, 2011[13]

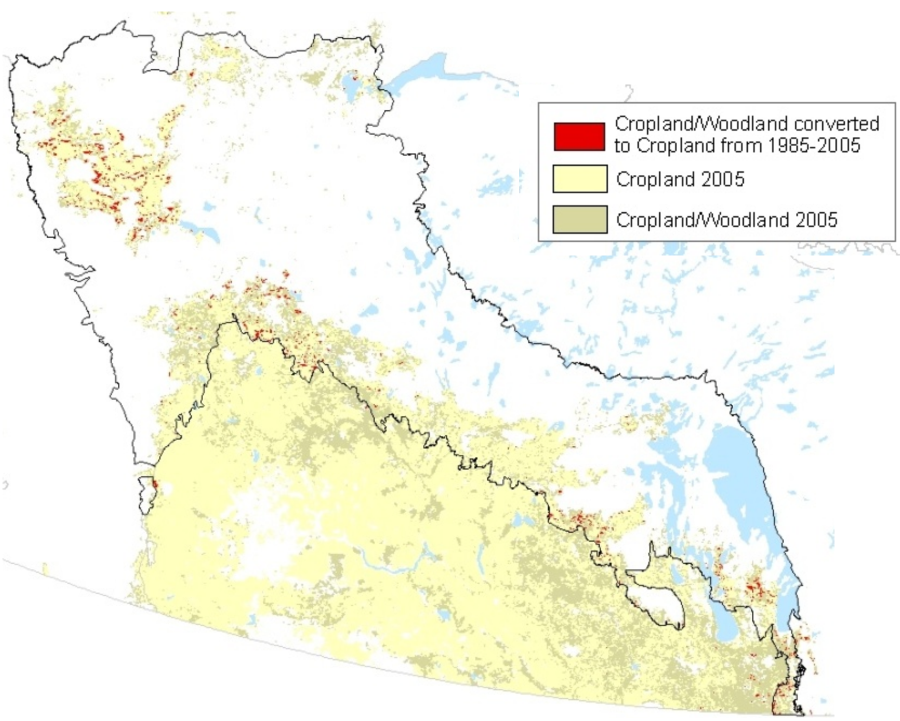


Figure 6. Conversion from cropland/woodland to cropland from 1985 to 2005 in the Boreal Plains Ecozone⁺.
Source: adapted from Latifovic and Pouliot, 2005[28] by Ahern, 2011[13]

Intactness

The intactness of forest ecosystems in the Boreal Plains Ecozone+ has been assessed in two different ways. Global Forest Watch measured the amount of undisturbed forest landscapes that were free from visible human impact, at least 50 km^2 in size, and at least 500 m from any known human disturbance (buffer width varied depending on the type of human disturbance).[29] By this definition, the extent of intact forest landscapes in the Boreal Plains Ecozone+ was 37% as of 2002 (Figure 7). The Alberta Biodiversity Monitoring Institute (ABMI) measured intactness for the Alberta portion of the Boreal Plains Ecozone+ by comparing the observed area covered by old-forest habitat versus the expected area of old-growth with no development. Overall, old-forest habitat was 92% intact (i.e., old-forest habitat covered 8% less area than expected).[30]

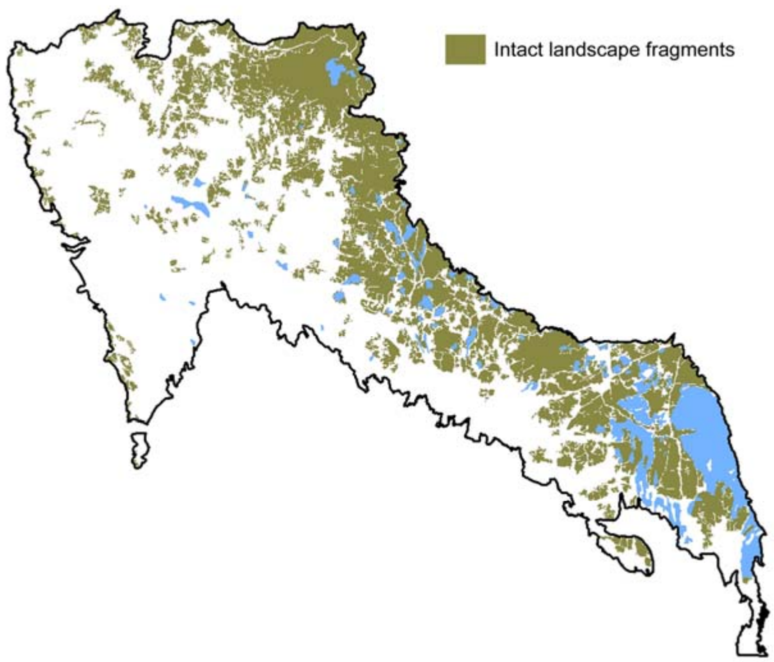


Figure 7. Intact forest landscape fragments larger than 100 km^2 in the Boreal Plains Ecozone+, 2006. A forest landscape fragment is defined as a contiguous mosaic, naturally occurring and essentially undisturbed by significant human influence. It is a mosaic of various natural ecosystem including forest, bog, water, tundra and rock outcrops.
Source: Lee et al., 2006[31]

Case study: intactness of old forest habitat in Alberta-Pacific Forest Management Area

The Alberta Biodiversity Monitoring Institute measured habitat intactness and the human footprint of the Alberta-Pacific Forest Management Area (Al-Pac FMA).This area encompasses 57,331 km^2,[30] and makes up 9.5% of the Boreal Plains Ecozone+ in northeastern Alberta.[32] Old-forest habitat in the Al-Pac FMA is 92% intact. That is, it occupies 92% of the area that it would be expected to occupy if there were no human impacts (Figure 8). The human footprint index shows that human influence is evident in 7% of the Al-Pac FMA. Most of the human footprint is due to forestry, energy, and transportation infrastructure. Half of the forestry footprint was created in the last 10 years.[30]

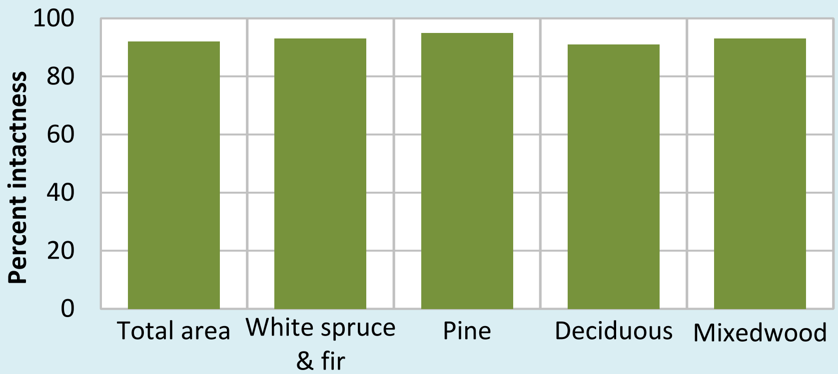


Figure 8. Intactness (percent deviation of observed conditions from intactness expected under undeveloped conditions) of old-forest habitats in the Alberta-Pacific Forest Industries Management Agreement Area.
Habitat type and intactness from 142 sites was determined using Provincial Alberta Vegetation Inventory GIS data.
Source: adapted from Alberta Biodiversity Monitoring Institute, 2009[30]

Shift from late-successional to early-successional forest

Similar to other ecozones+, there has been a shift in the forest age class structure from older to younger forests in the Boreal Plains Ecozone+.[33] For example, the percentage of Alberta's boreal forest that was over 120 years in age declined from 28% in 1991 to 17% in 1999.[24] Remote sensing data from the AMBI provides an indication of the current age-class distribution of managed and unmanaged forests in the Boreal Plains Ecozone+ in Alberta (Figure 9). Over 50% of unmanaged forests are at least 80 years old. In contrast, over 50% of managed forests are between 11 and 30 years old. The loss of older age classes, particularly spruce, is a concern for biodiversity.[24] For example, one third of all birds which breed in old boreal forests are specialized for old-growth habitat.[34] The loss of old-forest habitat negatively impacts these old growth specialists, particularly year-round residents which are less abundant than migrants and are often more sensitive to habitat loss.[34]

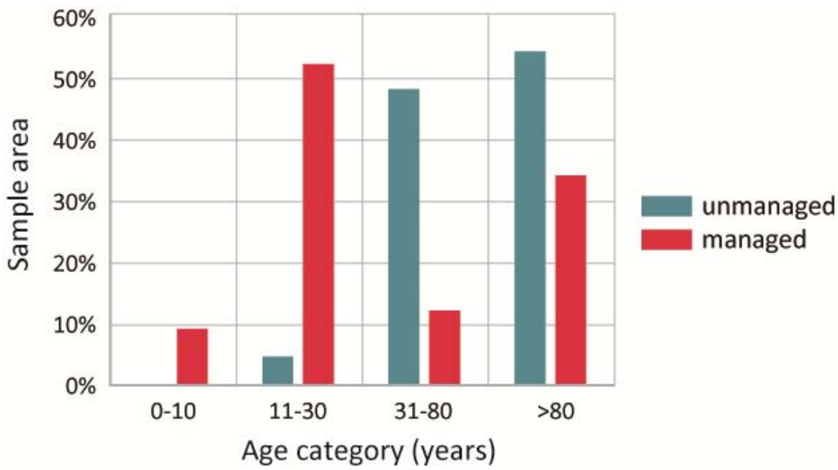


Figure 9. Current age class distribution of managed and unmanaged forests, 2008.
Summarized from 517 32 km^2 Alberta Biodiversity Monitoring Institute systematic landscape sample sites with complete coverage (coverage derived from the Alberta Vegetation Inventory). Unmanaged and managed areas totalled 7,963 km^2 and 62 km^2 respectively.
Source: adapted from Alberta Biodiversity Monitoring Institute by Haughland, 2008[33]

The corollary of intactness is fragmentation. Both anthropogenic (e.g., roads, seismic lines, forestry) and natural processes (e.g., fire, insect infestations) result in fragmentation in the Boreal Plains Ecozone+.[35, 36] Forests in the Boreal Forest Ecozone+ are becoming increasingly fragmented, particularly in the southern half of this ecozone+ where the majority of human activity is concentrated (Figure 7). Forest fragmentation affects forest patterns in three distinct ways: reducing forest area, increasing isolation of forest remnants, and creating edges.[13] The resulting impacts on biodiversity are complex and species dependent.[34, 37-42] Examples include declines in Neotropical migrant and resident birds requiring interior boreal forest habitat,[34, 43, 44] declines in species with large area requirements such as grizzly bear and caribou, increases in species that prefer to browse along forest edges such as moose, increased exposure of interior forest species to predators and parasites,[34] disruption of social structure of some species,[45] and barriers to dispersal.[46]

Key finding2 **Theme** Biomes

Grasslands

National key finding

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.

The Boreal Plains Ecozone+, though largely forested, does include dry native grassland ecosystems; however, little of these grasslands remain today. Historically, extensive native grasslands were located in the Boreal Transition ecoregion along the southern periphery of the ecozone+, and the Peace Lowland ecoregion in the west of the ecozone+. With settlement and agricultural development in the late 1800s and early 1900s, many of these areas were converted to agricultural use and are currently maintained primarily as cropland and improved range for grazing.[19]

Little data exist on the extent and trends of native grasslands in the Boreal Plains Ecozone+. In Manitoba, grassland and rangeland in the ecozone+ declined by 15% between 1986 and 2002.[47, 48] See Agricultural landscapes as habitat section on page 50.

Key finding 3 **Theme** Biomes

Wetlands

National key finding

High loss of wetlands has occurred in southern Canada; loss and degradation continue due to a wide range of stressors. Some wetlands have been or are being restored.

Wetlands include peatlands, like bogs and fens, and marshes and swamps. Together they covered 108,300 km^2 or approximately 15% of the total area of the Boreal Plains Ecozone+ in 2005.[17] While trend data are lacking for most of the ecozone+, wetlands have been lost across the region. For example, a comparison of Landsat imagery of land cover between 1986 and 1992 and 2000 and 2002 on a 46,975 km^2 region of Manitoba's boreal plains indicated a contraction of water bodies, marshes, and fens. This represented a loss of approximately 15% of marshes and fens and 10% of treed and open bogs in the area.[47] In Saskatchewan, wetlands within the Boreal transition zone declined by 5% from 1985 to 2001 with only 52% of wetlands observed as unused by humans.[49]

In the Alberta region of the ecozone+, wetland habitat is generally made up of peatlands (fens, bogs, and conifer swamps). Wetland loss and impairment in this region is a relatively recent phenomenon due to the establishment of conventional oil and gas activity, oil sands development, and operational forest harvesting.[50] While the extent of wetland loss is not well known, cumulative impacts may be high given the rate of industrial activity in the region.[51] As of March 2008, 244 km^2 of wetlands (0.2% of wetland cover in the ecozone+) were lost due to industrial activities in the Athabasca oil sands area.[52]

In addition to industrial development, climate change compounds impacts on this ecozone+. In general, temperatures have increased and snow precipitation decreased since 1950.[53] Wetlands are sensitive to increases in temperature and precipitation changes, particularly small and/or seasonal wetlands, as they are vulnerable to increased evaporation and reduce inputs through precipitation.

Peace–Athabasca Delta Case Study

The Peace–Athabasca Delta, at over 5,000 km^2, is one of the largest inland freshwater deltas in the world.[54] It is designated as a RAMSAR Wetland of International Importance and as an internationally Important Bird Area. Most of the delta lies within Wood Buffalo National Park, a World Heritage Site. Its water distribution is driven by many factors but depends strongly upon sporadic spring floods caused by ice-jams.[55, 56] Once the delta is recharged by these floods it can take many years to dry.[57] The delta's climate, hydrology, and vegetation history are highly variable.[58, 59] Many of the basins adjacent to lakes and rivers have a restricted connection, such as a perched channel entry or levee. Basins inland of the main flow system are hydraulically isolated. Restricted and isolated types are referred to as perched basins. Water level fluctuation of perched basins is independent of the main flow system except during episodic floods.[60]

The flow of the Peace River has been regulated since 1968 by the W.A.C. Bennett Dam in BC. Flow regulation has reduced the frequency, duration and magnitude of Peace River flow contributions to the delta in summer[61] and has reduced the frequency of ice-jam flooding in the spring.[62] Public concern following dam construction led to construction of outflow weirs to emulate high river stages, and dam outflow modification has been employed to augment ice-jam flooding of the delta.[63]

In addition to hydroelectric flow regulation, climate change and variability also influence the hydrology of the delta; warmer, drier conditions have led to earlier drying-out of the perched wetlands on the delta which then requires more frequent recharge from the Peace River and thick winter ice formation to cause the ice-jam floods.[59, 62, 64-66] There have only been four major ice-jam events on the Peace River post-regulation and the corresponding decrease of floods and increased drying-out has led to reductions in wetland habitat.[67] A continued reduction in ice-jam flood frequency, a shorter ice season, and a decrease in winter ice thickness are predicted over the next century.[66] In addition, the delta faces stress from multiple upstream developments, including forestry, agriculture, hydroelectric dams and the oil sands.[58] Contamination is both an ecological and human health concern in the delta and the community of Fort Chipewyan, where concentrations of contaminants such as arsenic, mercury, and PAHs appear to be rising.[68,69]

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.

The relatively flat Boreal Plains Ecozone⁺ region has several large river systems and thousands of interconnected lakes. The region flows into three major river drainage basins: eastward into the Nelson River, north-eastward into Hudson Bay, and northward to Great Slave Lake (Figure 20 in the Nutrient loading key finding). Large lakes that fall within the ecozone⁺ boundary include Lake Winnipegosis, Lake Winnipeg, and part of Lake Manitoba. Trends in lakes and rivers in the Boreal Plains Ecozone+ include decreased stream flow and water levels and an increase in water allocations. The main drivers of these trends are climate change and industrial development.

Climate change impacts: stream flows, temperature and water levels

The reduction of freshwater predicted by climate change models may be the most serious and imminent effect of climate warming.[70] Although increases in precipitation to the western Prairie provinces are predicted, these will not make up for the increase in evaporation forecasted with warming temperatures. Western Prairie provinces' rivers originate in the Rocky Mountains, including many rivers in the western portion of the Boreal Plains Ecozone+; these rivers rely on deep snowpack and glacial melt to maintain flow. As glaciers recede and snowpacks diminish, groundwater and surface runoff into these rivers will also subside and contribute to lower flows. Reduced volumes of water in rivers and lakes will result in less water for human use and in increased concentrations of nutrients. Nutrient loading can lead to larger algal blooms, and increases in waterborne pathogens which can be detrimental to the ecosystem and to drinking water.[71]

Streamflow monitoring from 1961 to 2003 at 21 hydrometric stations in the Boreal Plains indicate that many streams in the ecozone+ are experiencing decreasing flows.[58] For example, flows are lower in the Athabasca River and Beaver River (Figure 10) with a decrease of 30% relative to the median flow for all months but April. These decreased streamflows correspond with warmer temperatures and less precipitation over the same time period,[53, 72] and less precipitation fell in 2003 than in 1900 across the ecozone+. Shifts in the timing and magnitude of the spring freshet (inundation of water discharge due to spring melt) have occurred in the Beaver River, where discharge has peaked in April in the past and, although there is still a peak in April, another peak occurs mid-June (Figure 10). Other studies examining streamflow dynamics in the Peace–Athabasca river system corroborate these observed trends. The average summer (May to August) flows of the Athabasca River decreased by 20% between 1958 and 2003[73], and in contrast to the Beaver River, spring freshet occurred earlier in the Peace–Athabasca catchments over time (Figure 11).[63]

a) Athabasca River b) Beaver River

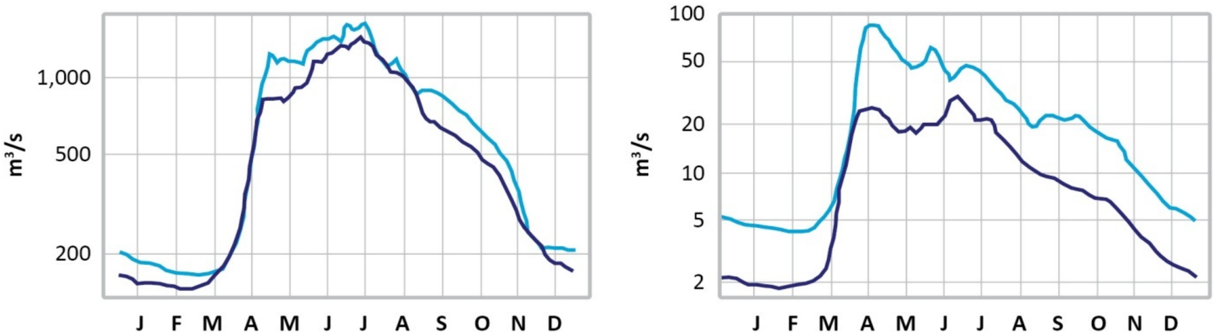


Figure 10. Streamflow by month for 1961–1982 (light blue) and 1983–2003 (dark blue) for two representative rivers in the Boreal Plains Ecozone+.
Source: Cannon et al., 2011[72]

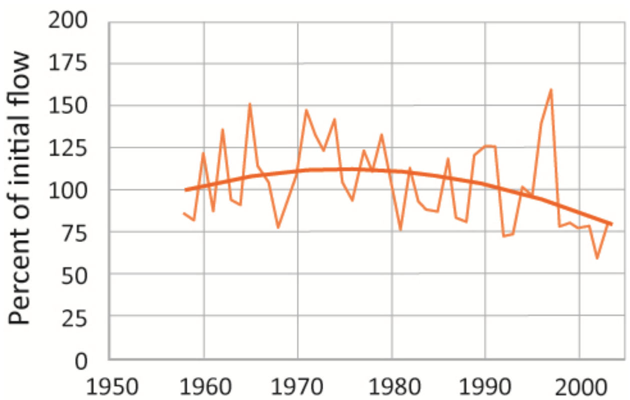


Figure 11. Long-term relative change in summer flow (May-August) in the Athabasca River downstream of Fort McMurray, AB from 1958 to 2003.
Source: Schindler and Donahue, 2006[71]

Temperature increases across the prairie provinces[53] have likely increased evaporation rates in prairie lakes, decreasing water levels and increasing salinity through evapoconcentration.[74] Water level and salinity changes can have large impacts on biological communities within lakes, particularly phytoplankton and zooplankton, which are sensitive to changes in salinity.[75] Although there are no available ecozone+-wide trends on water levels and salinity of lakes, there is evidence that changes are occurring. For example, increasing salinity, which is correlated with temperature increases (and associated evaporation) and precipitation decreases, has been shown in two lakes in central Saskatchewan over the past 75 years.[74] These salinity increases have likely caused a 30% loss of macrobenthos diversity over the same time period.[74] Water levels have decreased since the 1960s in several closed-basin lakes in the semi-arid Prairie region of Canada, three of which fall within the Boreal Plains Ecozone+ (Figure 12).[76] Although land-use changes play a role in lake levels, temperatures, particularly the increase in spring time temperatures, are the main driver of the declining water levels in this area.[76]

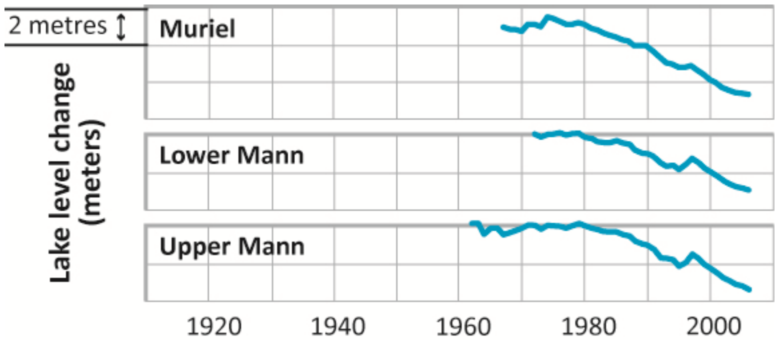


Figure 12. Water levels for Muriel, Lower Mann, and Upper Mann lakes, AB from the 1960s to 2006. Source: Van der Kamp et al. (2008).[77]

Water stresses

An increasing number of human activities pose threats to Canada's lakes and rivers,[78, 79] including: water control structures such as dams;[80] water use and allocation;[81] chemical contamination impacting water quality;[82] and climate change[1] (discussed above).

Dams

Water control structures are one of the greatest threats to freshwater ecosystems because they change the flow of water and lead to habitat discontinuity and fragmentation.[83, 84] There were 14 large dams (>10 m in height) built in this ecozone+ between 1950 and 1990.[85] The W.A.C. Bennett Dam on the Peace River is perhaps the most well-known and most controversial dam affecting this ecozone+. No summarized ecozone+-wide trend or status data were found on dams/river diversions; however, data from the provincial energy agencies on hydro projects could be compiled for future reports.

Water usage and allocation

In the Boreal Plains Ecozone+, the amount of water allocated for human use was increasing as of 2006, yet still below 1% of the average annual flow for the Peace/Slave, SK, North Saskatchewan, SK, and the Churchill, MB basins.[86, 87] In 2006, 4% of the Athabasca River Basin's average annual flow was allocated for human use, mainly for oil and gas and commercial developments (Figure 13).[87] Oil sands open pit mining, steam-assisted gravity drainage, and conventional oil production rely heavily on water inputs drawn from surface freshwater resources such as rivers.[88] Continued development in the oil sands region in Alberta combined with climate change could compromise water security in the Athabasca River Basin in the future.[89]

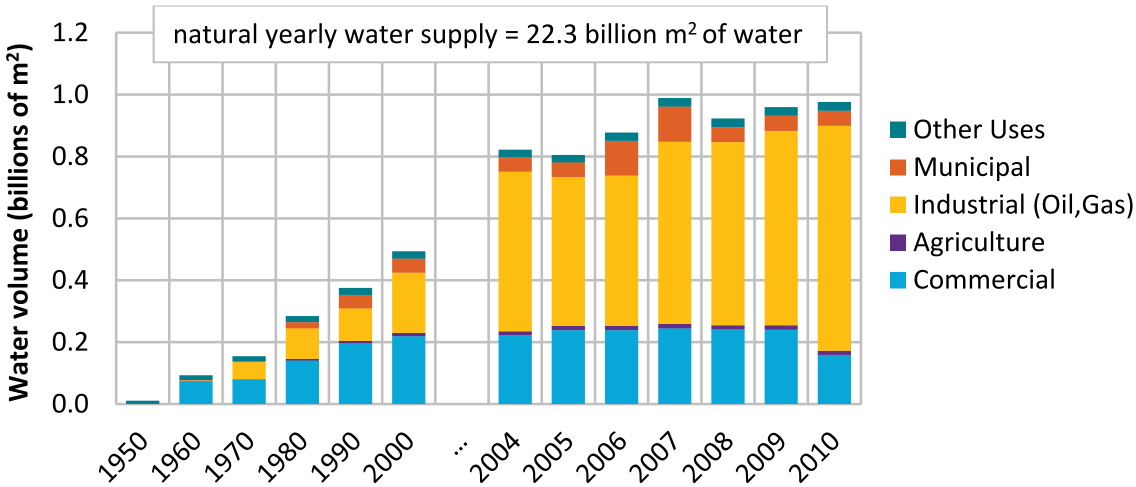


Figure 13. Sectoral water allocation of the Athabasca river basin, 1950 t0 2010. Source: Alberta Environment, 2006,[87] updated by M. Seneka (April 2012)

Water quality

Water quality in lakes and rivers can be measured by examining the amount of metals, nutrients, bacteria (fecal coliforms), and pesticides in a water body. Changes in water quality can occur when nutrients and/or pollutants are added through agricultural run-off, sewage effluent, air emissions that are later deposited on earth, and industrial waste. Ecozone+-wide status and trend data on water quality were unavailable; however, see Nutrient loading section on page 34 for impacts on nutrient loading and its effects on lakes and rivers in the Boreal Plains ecozone+. In general, nutrient inputs from agriculture are increasing, most notably in the Red River drainage, which is influencing the frequency of algal blooms in Lake Winnipeg, MB. The data for assessing trends in chemical contaminants in river and lake ecosystems in the ecozone+ are sparse.[90] Localized data suggest contaminants are increasing in some areas; a more detailed discussion of contaminants in the ecozone+ is covered in the Contaminants section on page 30.

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.

Ice cover plays a fundamental role in the structure of freshwater ecosystems,[91-95] and can cause both direct and indirect changes to the hydrological regime of lakes and rivers (for example see Peace–Athabasca Delta Case Study on page 18). Consequently, these changes impact biotic and abiotic processes in aquatic ecosystems.[96] Available data suggest the ice season is shortening in the Boreal Plains Ecozone+. Permafrost is also declining and has completely melted from the southern extent of its historical range.[84, 85]

Lake and river ice

Despite the importance of ice processes to freshwater ecosystems (reviewed in Prowse and Culp, 2003),[96] long-term biological monitoring data during the ice season were limited at the ecozone+-wide scale and few trends were available. Six lakes in the Boreal Plains Ecozone+ tended towards later freeze-up dates between 1970–2005, but this trend was significant only for Churchill Lake, SK. Freeze-up on Churchill Lake occurred 0.5 days later per year between 1970 and 1985, totalling 10 days later after 25 years.[97] Freeze-up occurred 12–13 days later on the Red River, MB, in the 20th century compared to the 19th century.[98, 99] Finally, freeze-up on Lake Athabasca in Alberta occurred 1.25 days per year later between 1965–1990, for difference of more than 30 days.[100]

The ice season is also changing because of trends towards earlier ice break-up. From 1961–1990, the timing of ice break-up occurred significantly earlier in Bear and Lesser Slave lakes, AB.[100] These tendencies towards earlier break-up continued, although not significantly, from 1971–2000.[100] Ice break-up occurred 10 days earlier in the Red River, MB, during the 20th century compared to the 19th century.[100] In Lake Winnipeg, MB, there were no significant trends prior to 1970 in ice break-up but since 1970, ice break up has occurred earlier in the year (Figure 14).[97] These trends are consistent with increasing annual temperatures since 1950, particularly in spring (see the Climate change section on page 41).

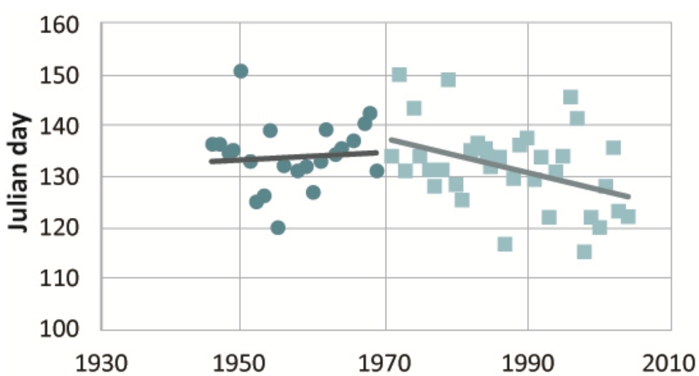


Figure 14. Trend in lake ice break-up dates before (dark blue circles) and after (light blue squares) 1970 for Lake Winnipeg, MB.
Source: Latifovic and Pouliot, 2007[101]

Permafrost

The northern reaches of the Boreal Plains Ecozone+ are within the sporadic permafrost zone in Canada (Figure 15). In 2003 it was estimated that 37.5% of land covered by bogs and 9.1% of land covered by fens have localized permafrost (frozen peatlands) in the Boreal Plains Ecozone+.[102] However, over the last century, permafrost has completely thawed or shrunk in some locations, especially at the southern limit of the permafrost zone.[102, 103] For example, 32–70% of the permafrost field sites in Alberta have degraded over the last 100–150 years.[102, 103] In northern Manitoba in the neighbouring Boreal Shield Ecozone+, tree ring analysis revealed that boreal peatland permafrost thaw accelerated significantly (200 to 300%) between 1995–2002 relative to rates from 1941–1991.[86]

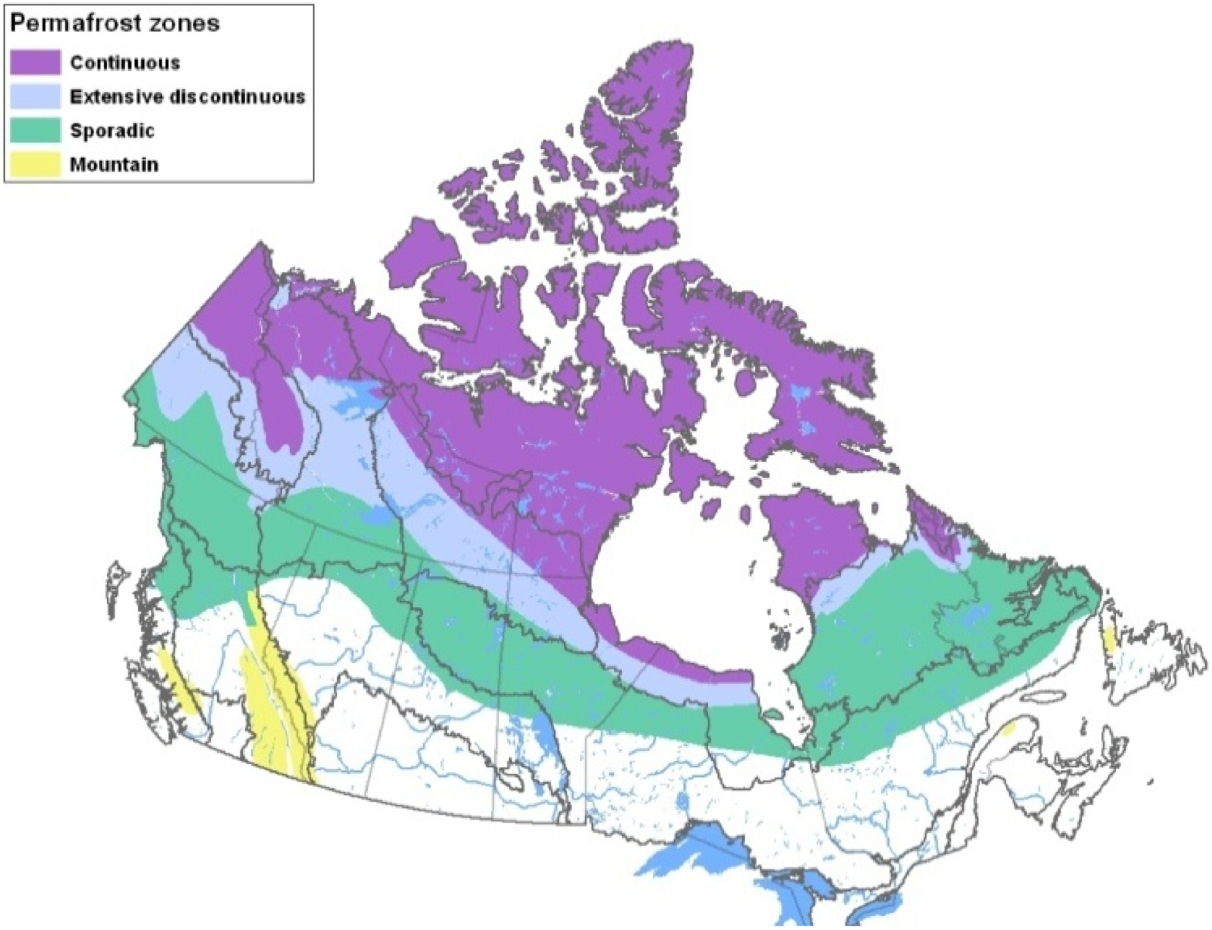


Figure 15. Permafrost map for Canada.
Source: adapted from Heginbottom, 1995[104]

Permafrost melting could have several severe ecological consequences. It is anticipated that permafrost thaw depth will continue to increase with increases in air temperature, further reducing the extent of permafrost throughout the Boreal Plains Ecozone+.[105] The predicted decrease in permafrost will result in increased methane emissions,[106] increased net carbon storage in peatmoss, and loss of wetland plant diversity where permafrost bogs produce some of the most bryologically diverse peatland ecosystem types in western Canada.[107] In addition, permafrost melting will result in large-scale changes in hydrological dynamics, changing the type and expression of wetlands across the northern boundary of the Boreal Plains Ecozone+.[108] Melting permafrost and collapse of frozen peatlands may flood the land, replacing forest ecosystems with wet sedge meadows, bogs, ponds and fens as is happening in northern Quebec.[109, 110]

THEME: HUMAN/ECOSYSTEM INTERACTIONS

Key finding8 **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.

As of May 2009, there were 546 protected areas in the Boreal Plains Ecozone+ (Figure 16). These protected areas are highly variable in size and shape. The southern half of the ecozone+ is characterised by many small parks, while protected areas become larger and more sparsely distributed to the north. This includes a portion of Wood Buffalo National Park, which is one of the world's largest national parks (44,807 km^2) and a UNESCO world heritage site.

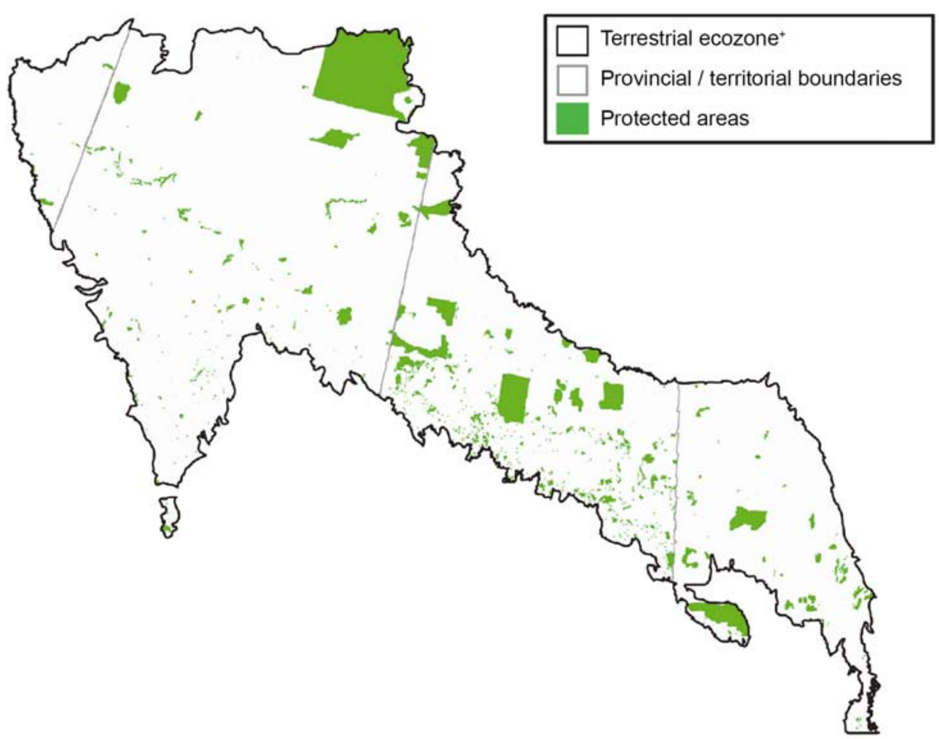


Figure 16. Distribution of protected areas in the Boreal Plains Ecozone+, May 2009.
Source: Environment Canada, 2009;[111] data from the Conservation Areas Reporting and Tracking System (CARTS), v.2009.05, 2009[112]

Prior to 1922, two small category II protected areas had been established totalling 4 km^2 (Figure 17). Prior to the 1992 signing of the Convention on Biological Diversity, 4.0%[i] of the Boreal Plains Ecozone+ was protected.[112] As of May 2009, protected areas increased to 8.0% of the ecozone+ (Figure 16 and Figure 17). These protected areas can be divided into two groups:

- 7.2% (423 protected areas) as IUCN categories I–IV. These categories include nature reserves, wilderness areas, and other parks and reserves managed for conservation of ecosystems and/or natural and cultural features, as well as those managed mainly for habitat and wildlife conservation[113]
- 0.7% (123 protected areas) as IUCN categories V–VI. These categories focus on sustainable use by established cultural tradition[113]

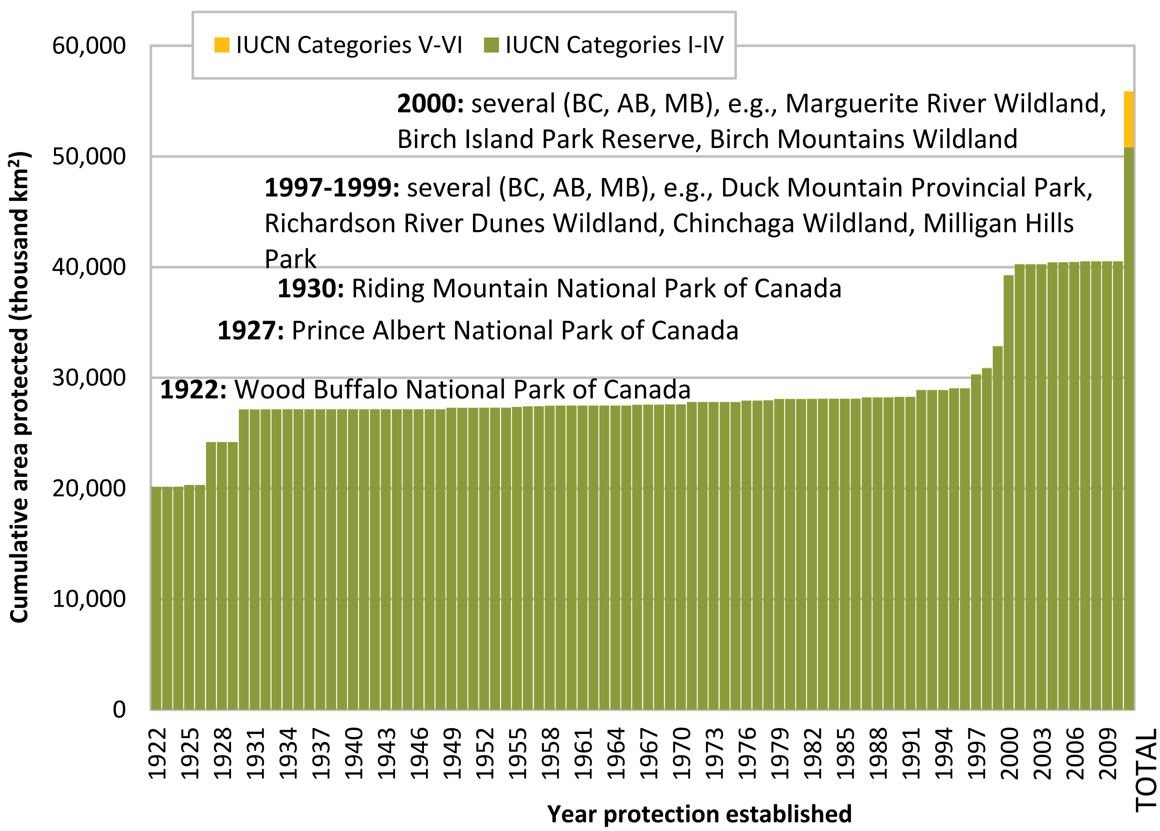


Figure 17. Growth of protected areas, Boreal Plains Ecozone+, 1922–2009.
Data provided by federal, provincial and territorial jurisdictions, updated to May 2009. Only legally protected areas are included. IUCN categories of protected areas are based on primary management objectives. Note: the last bar marked 'TOTAL' includes protected areas for which the year established was not provided.
Source: Environment Canada, 2009;[111] data from the Conservation Areas Reporting and Tracking System (CARTS), v.2009.05, 2009[112]

[i] Note that there is 15,340 km^2 of protected land in the Boreal Plains Ecozone+ with no information on the year of establishment. If all of this land was protected prior to 1992, then 6.2% of the ecozone+ was protected prior to 1992.

Most parks in the Boreal Plains Ecozone+, particularly southern parks, are threatened by both internal and external stressors such as: habitat fragmentation and loss in areas surrounding parks, climate change, over use, and invasive species.[114] For example, land cover changes for Prince Albert National Park, SK (centrally located in the Boreal Plains Ecozone+) and surrounding areas were analyzed from 1985 to 2001.[115] Forest cover changed little inside the park boundary but declined from 19 to 14% in the greater park ecosystem due to forest harvesting and fires.[115] Open water bodies declined in the park and surrounding areas as a result of drought, declining from 10 to 8% cover between 1985 and 2001.[115] Sustainable land management strategies in areas surrounding parks play a critical role in maintaining the ecological integrity of the parks themselves.[115]

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.

Information on stewardship activities in the Boreal Plains Ecozone+ was limited. Some stewardship areas in the Boreal Plains Ecozone+ are owned and managed by non-governmental organizations such as the Nature Conservancy of Canada. In addition, there has been growing interest in the use of market based approaches to conserve environmental values in the boreal forest, particularly in the oil sands region of Alberta,[116] and to enhance stewardship of environmental values on private land. The Governments of Alberta and Manitoba are exploring market based instruments (e.g., conservation offsets, conservation auctions) as tools to enhance the stewardship of ecosystem services.

Model Forests

Two Model Forests, part of the Canadian Model Forest Network, are located in the Boreal Plains Ecozone+. The Canadian Model Forest Network represents 14 non-profit member organizations nationwide to support resource-based communities overcome obstacles that affect their long-term social and economic well-being.[117] The 3,670 km^2 Prince Albert Model Forest (Saskatchewan) coordinates consultants, researchers, governments to work with First Nations on forest related projects.[118] The 330 km^2 Weberville Community Model Forest, located 25 km north of Peace River, Alberta, is comprised of privately-owned and crown land. The land managers collaborate on tree planting, recreational trail systems and woodlot inventories, and also future opportunities such as biomass energy projects and carbon credit trading.[119]

Conservation offsets

Conservation offsets are actions intended to compensate for the residual, unavoidable harm to ecosystems caused by development.[120] The Alberta Land Stewardship Act enables the implementation of a conservation offset program.[121] No formal offset program is in place in Alberta; however, the Alberta Conservation Association implemented a voluntary, terrestrial conservation offset program in 2003. From 2003 to 2011, the program secured 19.65 km^2 of private land for protection - to reduce the cumulative effects of oil sands development on ecosystems in the Boreal Plains Ecozone+.[122] Similarly, Alberta Agriculture and Development is coordinating the Southeast Alberta Conservation Offset Pilot to convert cropland into native pasture with wildlife habitat. Through this pilot, farmers and ranchers could be eligible for voluntary conservation offset payments from oil and gas firms with developments in southeastern Alberta. As of May 2014, however, no industrial partners had signed on.

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

Invasive non-native species

National key finding

Invasive non-native species are a significant stressor on ecosystem functions, processes, and structure in terrestrial, freshwater, and marine environments. This impact is increasing as numbers of invasive non-native species continue to rise and their distributions continue to expand.

Invasive non-native species are those that are naturalized to ecosystems outside of their natural range, and often are introduced intentionally or accidentally by humans.[123] Non-native species threaten native biodiversity and cost millions of dollars annually for management and control.[123] Invasive species compete with and/or displace native species, degrade habitat, alter ecosystem processes such as carbon sequestration, and introduce disease.[124] Climate change is expected to intensify invasive non-native species impacts in the boreal region as temperature barriers are removed.[125, 126] Broad-scale reporting on invasive non-native species trends is lacking for the Boreal Plains Ecozone+, but some information is available for non-native vascular plants, fish, and earthworms.

Terrestrial non-native invasive plants

The majority of known invasive non-native species in the Boreal Plains are vascular plants, typically of Eurasian origin.[17, 126, 127] As of 2008, 93 invasive non-native plant species have been documented in the Boreal Plains Ecozone.[128] Noxious weeds (i.e., plants designated as injurious to agricultural or natural habitats; often non-native) are spreading in northeastern Alberta[129] (Figure 18). The spread of invasive plants is likely to continue, however, surveys and treatment methods were rarely systematic and so trends were unknown.

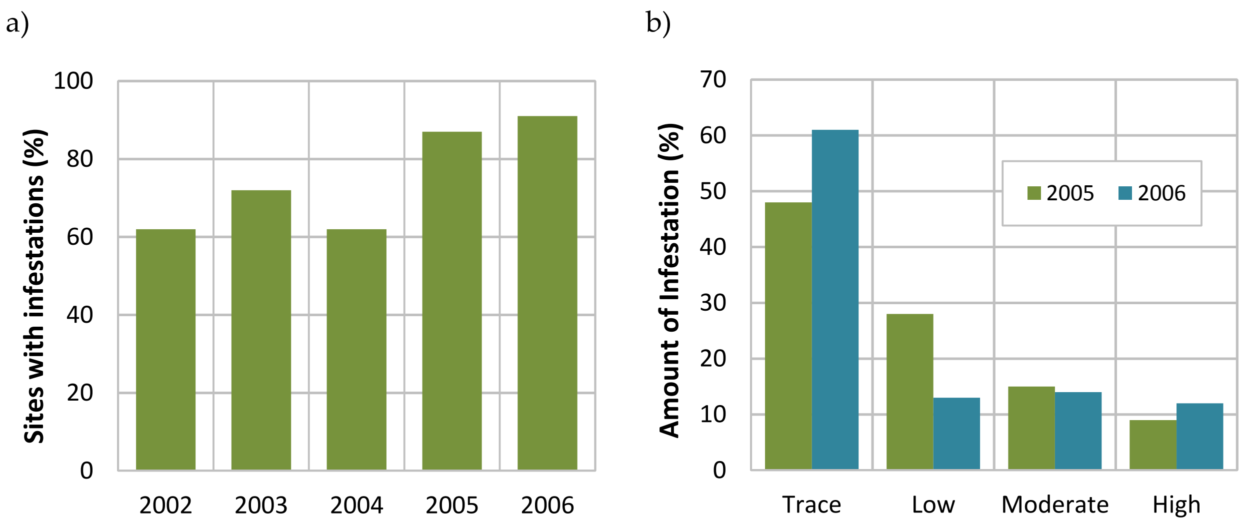


Figure 18. Of 217 sites surveyed, (a) the percentage of sites with infestations of noxious weeds, 2002-2006 and (b) the percentage of infestation in 2005 and 2006 in northeastern Alberta.
Source: Alberta Sustainable Resource Development, 2006[129]

The ABMI detected 75 non-native plant species within 343 monitoring sites surveyed from 2003–2011 in the Boreal Plains Ecozone+ in Alberta.[130] Non-native species were present at 48% of the sites surveyed with between two and three (average of 2.55) non-native plant species detected per site. The common dandelion (*Taraxacum officinale*) was almost twice as abundant as any other invasive plant (Table 3). Common dandelions were often found at sites without human influence, indicating that this species can colonize areas without human disturbance. Six of the 10 most abundant non-native invasive plants are commonly planted as forage crops for livestock and have become naturalized to the Boreal Plains Ecozone+.[131]

Table 3. The 10 most abundant non-native species detected in the Boreal Plains Ecozone+ in Alberta, the number of sites detected (out of 343), and the percent occurrence.

Common name	Scientific name	Number of sites	Percent occurrence (%)
Common dandelion[1]	*Taraxacum officinale*	134	39.1
Kentucky bluegrass[2]	*Poa pratensis*	81	23.6
Timothy[2]	*Phleum pratense*	68	19.8
Asike clover[2]	*Trifolium hybridum*	55	16.0
Canada thistle[1]	*Cirsium arvense*	40	11.7
White clover[2]	*Trifolium repens*	38	11.1
Smooth brome[2]	*Bromus inermis*	35	10.2
Red clover[2]	*Trifolium pratense*	33	9.6
Common plantain[1]	*Plantago major*	32	9.3
Quackgrass[1]	*Crepis tectorum*	22	6.4

[1]species listed in Alberta's Weed Control Act
[2]species planted as forage crops in Alberta
Source: Alberta Biodiversity Monitoring Institute 2009[131]

The ABMI also detected non-native plants at 32% of their sites in the Athabasca oil sands area. Common dandelion (*Taraxacum officinale*), found in 25% of the sites, was the most common of the 38 non-native species found – most occurred infrequently. When present at an ABMI site, an average of 2.1 non-native species were detected. Three plants listed as noxious weeds listed under the Alberta Weed Control Act, perennial sow-thistle (*Sonchus arvensis*), creeping thistle (*Cirsium arvense*), and tall buttercup (*Ranunculus acris*), were present on 6%, 5%, and 3% of the ABMI sites in the Athabasca oil sands area, respectively.

Other invasive non-native species of concern

Native fish species can be impacted through competition with and/or predation by invasive fish species. There is limited information on the distribution and abundance of invasive fish in the Boreal Plains Ecozone+. However, occurrences of non-native fish appear to be increasing in British Columbia's portion of the Boreal Plains Ecozone+; of 15 water bodies surveyed, non-native fish were present in one water body in 1950, one in 1975, and four in 2005.[132] Introduced rainbow smelt in Manitoba disrupt food webs, alter zooplankton communities, and compete with shortjaw cisco (*Coregonus zenithicus*) for food.[133]

Earthworms are not native to the Boreal Plains Ecozone+. Non-native earthworms are patchily distributed throughout much of the Boreal Plains Ecozone+ in Alberta and their range is expected to expand in the next 50 years.[134, 135] Earthworms are considered an ecosystem engineer that cause the loss of soil carbon, decrease soil organic content, and decrease the diversity and abundance of microarthropods and understorey plants.[135] Given that the earthworm invasion of the boreal forest is relatively recent, long-term consequences to ecosystem structure and function are unknown.[126, 134]

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.

Contaminants can harm species and ecosystems and impair ecosystem services. Contaminants were not monitored at the scale of the Boreal Plains Ecozone+. However, there is evidence that contaminants[ii] are increasing in certain parts of the ecozone+ and may be negatively affecting biodiversity and human settlements in those areas.[52] Two major sources of contaminants include surface mining in the oil sands and coal-fired power plants.

[ii] Emerging contaminants are newer chemicals, or substances that have been in use for some time but have only recently been detected in the environment –they are usually still in use and/or only partially regulated. Legacy contaminants (e.g., PCBs, DDT) have been banned or restricted but still may be widespread in the environment.

Oil sands development

The production of synthetic crude oil derived from bituminous sands in northeastern Alberta is energy intensive and results in the emission of toxic pollutants. The oil sands industry releases the 13 elements considered priority pollutants under the US Environmental Protection Agency's (EPA) Clean Water Act, via air and water, to the Athabasca River and its watershed.[136] The pollutants enter the environment through seepage from tailings ponds and discharge into the air.[52] These pollutants include polycyclic aromatic hydrocarbons (PAHs), naphthenic acids (NA), and other elements such as mercury (Hg), lead (Pb), and arsenic (As). In 2012, the governments of Canada and Alberta released an implementation plan for enhanced environmental monitoring in the oil sands region[137] (Figure 19).

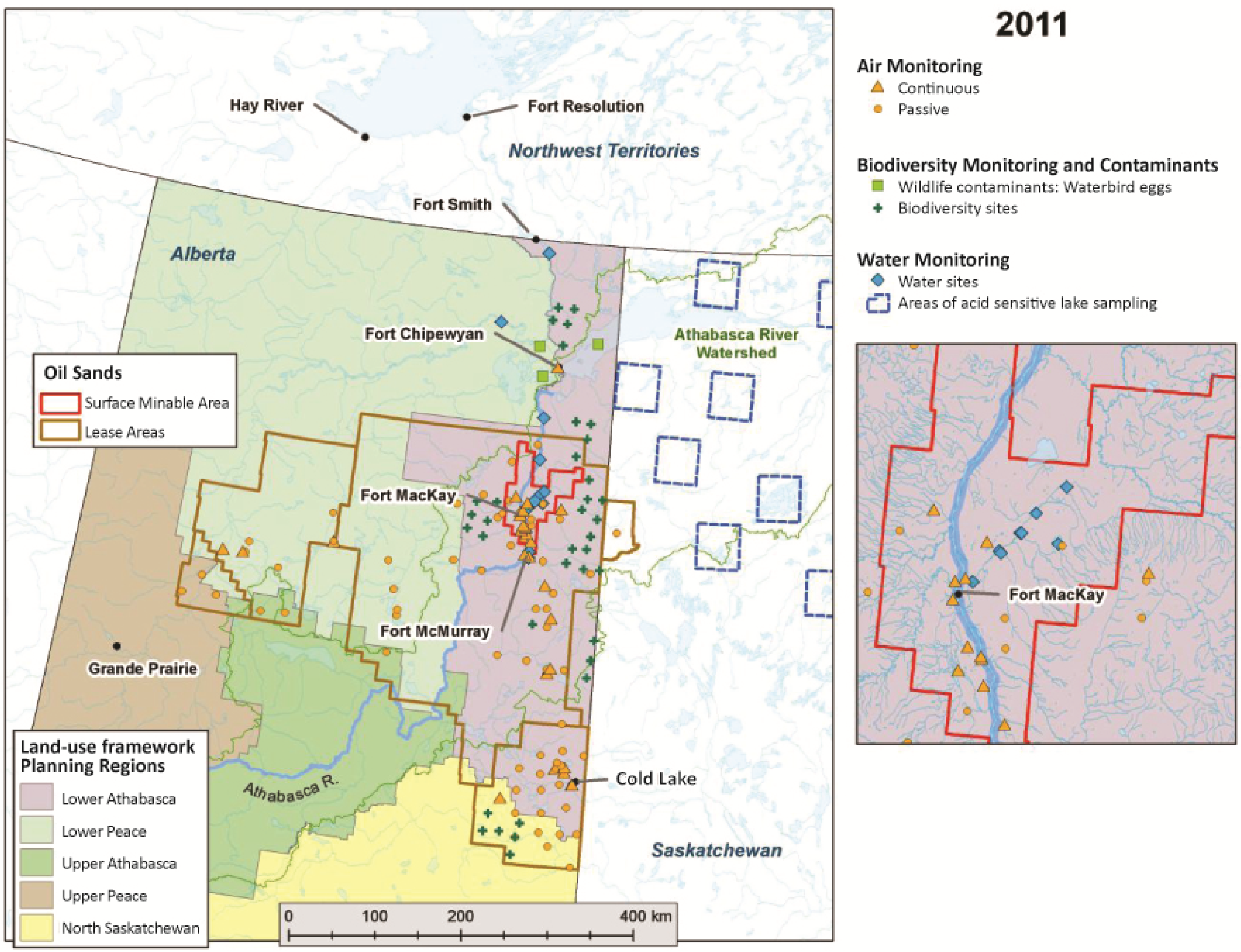


Figure 19. Existing monitoring during the 2010-11 baseline year in the Alberta and Saskatchewan oil sands areas.
Source: Government of Alberta and Government of Canada 2012[137]

Polycyclic aromatic hydrocarbons (PAHs)

Polycyclic aromatic hydrocarbons enter the environment via natural sources such as volcanoes and forest fires, or through anthropogenic sources, such as industrial development.[138] Oil sands development is increasing concentrations of PAHs through the emission of airborne particulates that are deposited on land, snow and surface water, or that enter water directly in dissolved forms.[136] The concentrations of these contaminants increase in the summer months and may be elevated further during snowmelt and heavy rains. In a study of six lakes north of Fort McMurray, PAH concentrations and fluxes from lake sediment records increased markedly since the ~1960–1970s, coinciding with over four decades of oil sands development in the Athabasca oil sands area.[139] Lakes that were closer and downstream/downwind of oil sands operations had the highest concentrations. Specifically, Canadian interim sediment quality guidelines (CISQGs), which are available for 13 specific PAHs (30), have been exceeded for seven compounds [i.e., phenanthrene, pyrene, benz(a)anthracene, chrysene, benzo(a)pyrene, dibenz(a,h)anthracene, 2-methylnaphthalene] at the site receiving the highest deposition of PAHs.[139] Sediments within oil sands deposits from downstream portions of the Athabasca, Ells, and Steepbank rivers, and a wastewater pond, were toxic to early developmental stages of common forage fish native to northern Alberta such as white sucker (*Catostomus commersoni*) and fathead minnow (*Pimephales promelas*).[139] Other native forage fish, such as yellow perch (*Perca flavescens*), slimy sculpin (*Cottus cognatus*), and pearl dace (*Semotilus margarita*), displayed lower levels of gonadal steroids at reference compared to exposed sites.[139]

In 2008, snow was collected from 12 sites along the Athabasca River and 19 sites along its tributaries. Dissolved PAH concentrations were sufficiently high to be toxic to minnow embryos at some of these sites.[136] Between 1999 and 2009, PAH concentrations increased in the sediment of the Athabasca River Delta.[138] The 2009 sediment levels in the lower Athabasca River were 1.72mg/kg, which exceed, by a factor of about 2-3, the threshold observed to induce liver cancers in fish.[138, 140] Fish exposed to PAHs found in Athabasca sediments have also exhibited hatching alterations, increased mortality, spinal malformations, reduced size, cardiac dysfunction, edema, and reductions in the size of the jaw and other craniofacial structures.[141-143] Although some linkages between PAH exposure and the health of sentinel fish species are evident, less is known regarding the potential effects of PAH exposure to other members of aquatic ecosystems.[139] The ultimate ecological consequences of decades-long increases in aquatic primary production, coupled with greater PAH loadings to lakes in the oil sands region, are unknown and require further assessment.[139]

Naphthenic acids

At high concentrations (~50–100 mg/L), NAs, a by-product of oil sands production, are toxic and reduce survival in mammals, fish, landbirds, water birds and amphibians.[144-150] Currently, oil and gas facilities are not required to report NA levels to the National Pollutant Release Inventory.[151] As a result, there are few data on the status and trends of NAs in the environment. Naphthenic acids have been found at concentrations of 1–2 mg/L in natural surface waters, ~60 mg/L in a wetland formed from tailings seepage effluent, and in excess of 100 mg/L in oil sands tailings ponds.[148, 152]

Mercury and other toxic elements

Guidelines for the protection of aquatic life were exceeded for seven priority pollutants—cadmium, copper, lead, mercury, nickel, silver, and zinc—in melted snow and/or water collected near or downstream of Athabasca oil sands area.[136] Concentrations of mercury, lead, and arsenic increased by 63%, 29%, and 28%, respectively, across all tailings ponds in the oil sands region between 2006 and 2009.[153] These increases were intentional (as part of reclamation strategy) and unintentional (e.g., tailing pond casing leakage or dyke breaches).[88, 154]

Mercury poisoning reduces reproductive success and affects brain and kidney function for birds[155] and mammals,[156] reduces the growth, behaviour, and survival of fish,[157] and has severe health impacts on humans.[158] Because of biomagnification, long-lived predatory fish such as walleye (*Sander vitreus*) and other top predators in aquatic food chains (e.g., mink (*Neovison vison*))[159] are at greatest risk of elevated dietary mercury exposure (in the form of methyl mercury). Between 1977 and 2009 mercury burdens in California gull (*Larsus californicus*) eggs from Lake Athabasca increased by 40%.[160]

Coal-fired power plants

Energy generation through coal combustion is increasing in Alberta, with the Wabamun region in the Boreal Plains Ecozone+ hosting power plants which are among the largest mercury emitters in Canada.[161] Over the last 150 years, mercury in Wabamun Lake has increased 7-fold, compared to 2–4 fold increases in remote lakes in North America.[161] Annual increases of mercury to Wabamun Lake before coal combustion began (1840–1956) was 1.6%; as industrial development increased (1956–2001), mercury increased annually by 3.9%.[161] Increased concentrations of other trace metals (Cu, Pb, As, Sb, Sr, Mo, and Se) also coincided with power plant and other industrial developments in the Wabamun Lake watershed. Although emission controls were implemented, the expansion of coal-burning in the Wabamun Lake region at the rate of one power plant per decade (1960–2000) means that collective emissions from this region will increase.[161]

Other sources of contaminants

Sewage effluent, pulp mill effluent, agricultural spraying and run-off, mineral exploration and mining activities (e.g., uranium mining in Northern Saskatchewan) reduce water quality in the Boreal Plains Ecozone+. The cumulative effects of these multiple contaminant sources are unknown.[162, 163]

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

Nutrient loading and algal blooms

National key finding
Inputs of nutrients to both freshwater and marine systems, particularly in urban and agriculture-dominated landscapes, have led to algal blooms that may be a nuisance and/or may be harmful. Nutrient inputs have been increasing in some places and decreasing in others.

Although spatial coverage data on nutrient loadings across the Boreal Plains Ecozone+ is incomplete, available data suggest that nutrient inputs from agriculture, industry, and urban development have increased. The Lake Winnipeg, MB watershed, in particular, receives high nutrient loads, and algal blooms occur annually in the lake.

Nutrient loading

Nutrient loading may result in algal blooms that can harm or even kill other aquatic organisms in two ways. First, algal blooms can deplete oxygen that other plants and animals need to survive. Second, toxic algal blooms (primarily blue-green algal species in freshwater systems) produce toxic compounds that can kill other organisms.[8] Because of their naturally high nutrient levels, many Boreal Plains lakes are highly susceptible to nutrient loading and algal blooms when additional nutrient inputs (e.g., nitrogen, phosphorus) from agriculture, human settlement, and logging are added.[164] For example, approximately 67% of lakes monitored across the province of Alberta are hypertrophic or eutrophic (hypertrophic lakes experience significant algal blooms), 26% are mesotrophic, and only 7% are oligotrophic.[87]

A national assessment of nutrients in Canada's watersheds documented their 2004–2006 trophic status and 1990–2006 trends in phosphorus.[165] Nutrient concentrations including total phosphorus (TP), total dissolved phosphorus (TDP), nitrate-nitrite (N-N), and total nitrogen, increased in 5 out of 10 rivers (Table 4). For example, the Athabasca River site downstream from Fort McMurray, AB, was eutrophic with increasing TDP, TP, and N-N, which increases the risk of high nutrient loads in the Peace–Athabasca Delta.[165] Two sites in the Nelson River drainage, which includes Lake Winnipeg, MB, also receive high nutrient loads and the two other sites with stable nutrient trends but a high risk of nutrient loading have already reached nutrient saturation (Table 4).

Table 4. Trophic status and nutrient trends by drainage area in the Boreal Plains Ecozone+ including: the Great Slave Lake drainage, the Western and Northern Hudson Bay drainage, and the Nelson River in 2004–2006.

Drainage	Sites in Boreal Plains* Ecozone+	Nutrients TDP	TP	N-N	TN	Status	At risk of nutrient loading
Great Slave Lake, NWT	Peace River at Peace Point, AB	—	—	↑	—	Eutrophic	✓
	Athabasca River 160 km downstream of Fort McMurray, AB	↑	↑	↑	—	Eutrophic	✓
	Athabasca River below Snaring River, AB	↓	—	—	—	Oligotrophic	
	Athabasca River at Athabasca Falls, AB	—	—	↑	↑	Oligotrophic	
Western and Northern Hudson's Bay, MB and NU	Beaver River at Beaver Crossing, AB	↓	—	—	—	Eutrophic	
	Cold River at outlet of Cold Lake, AB	—	—	—	—	Mesotrophic	
Nelson River, MB	Saskatchewan River above Carrot River, MB	—	—	—	—	Eutrophic	✓
	Carrot River near Tumberry, SK	↑	↑	—	—	Hyper-eutrophic	✓
	Red Deer River at Erwood, SK	↑	↑	—	—	Meso-eutrophic	✓
	Assiniboine River, SK	—	—	—	—	Hyper-eutrophic	✓

**Sites are arranged from north to south within each drainage area (see Figure 20).*
Nutrients: Total dissolved phosphorus (TDP); Total phosphorus (TP); nitrate-nitrite (N-N), and Total nitrogen (TN). Trends: stable (—); increased (↑); and decreased (↓). Checkmark: sites with a high risk of algal blooms
Source: data summarized from the Water Science and Technology Directorate, Environment Canada, 2011[165]

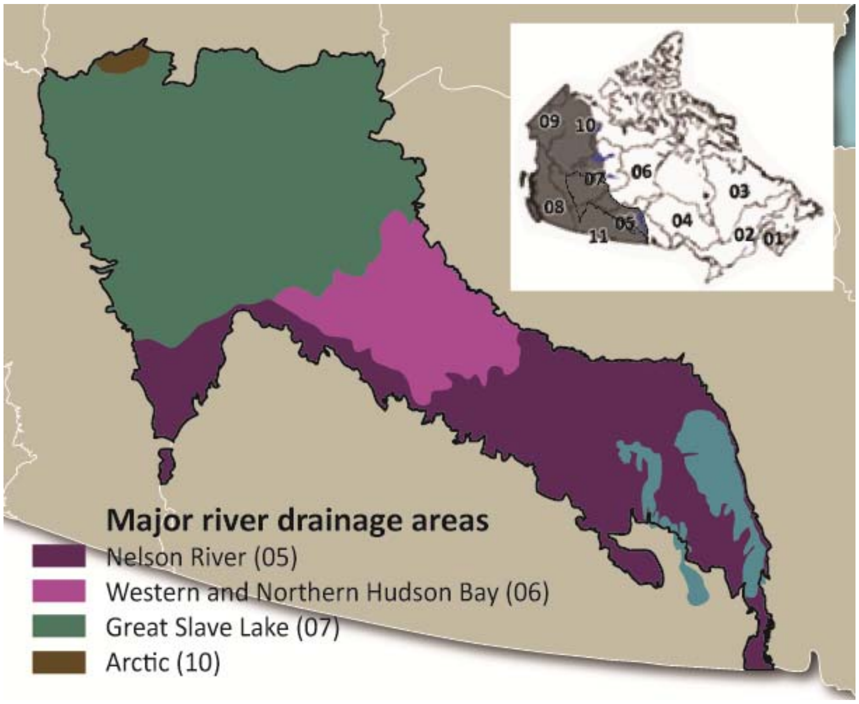


Figure 20. Boreal Plains Ecozone⁺ regions and Water Survey of Canada designated major drainage basins.
Three drainages partially within the Boreal Plains Ecozone⁺ are 07 (Great Slave Lake); 06 (Western and Northern Hudson Bay); and 05 (Nelson River).
Source: Water Survey of Canada, 2006

Nitrogen from agricultural land

Residual soil nitrogen (RSN; i.e., nitrogen left in the soil post-harvest) is used to identify the agronomic regions that are at medium to very high risk of accumulating nitrate. Residual soil nitrogen may accumulate in the soil as a result of inputs from nitrogen fertilizer and manure, legume nitrogen fixation, and atmospheric deposition. It may then leach into ground and surface waters which can be harmful to freshwater ecosystems and subsequently pose a health risk to humans. In the Boreal Plains Ecozone⁺, nitrogen inputs increased steadily over time from 40.8 kg/N/ha in 1981 to 69.3 kg/N/ha in 2006.[166] Risk of accumulation was very low (8.1 kg N/ha) in 1981, but this risk increased to medium (22.1 kg N/ha) by 2006; although this was a reduction from the maximum concentration of 26.4 kg N/ha in 2001.[166] As of 2006, there was an increased risk of residual soil nitrogen accumulation in almost all agricultural areas of the Boreal Plains Ecozone⁺ (Figure 21a); RSN risk levels were highest in the Alberta and Manitoba portions of the ecozone⁺ (Figure 21b).

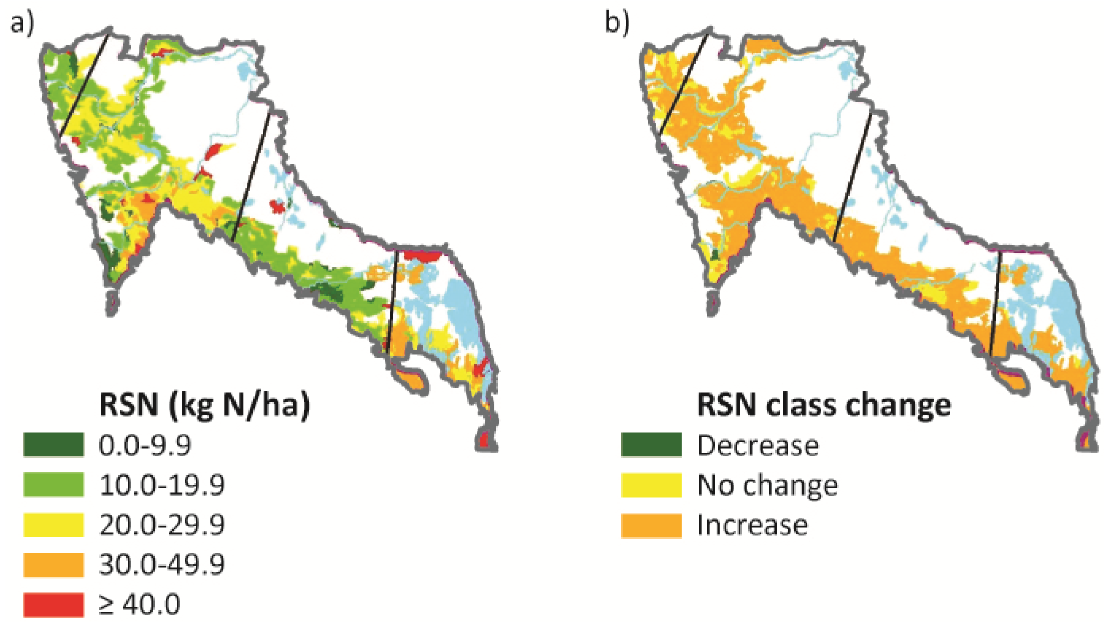


Figure 21.Map of a) residual soil nitrogen risk classes assigned to farmland in 2006 and b) change in risk class between 1981 and 2006.
a) Residual Soil Nitrogen (RSN) risk values correspond to the following risk classes: very low <10kgN/ha; low= 10–19.9kgN/ha, medium=20–29.9kgN/ha; high = 30–39.9kgN/ha; very high >40kgN/ha
b) Green represents a decrease from a higher to a lower risk class, yellow represents no change, and orange represents an increase from a lower to a higher risk class.
Source: Drury et al., 2011[166]

Algal blooms in Lake Winnipeg, MB

The eastern shoreline of Lake Winnipeg, MB, is the Boreal Plains Ecozone+'s eastern boundary. The Lake Winnipeg watershed is home to 6.6 million people and 20 million livestock, with 68% of the watershed as cropland and pastureland.[2] Intensification of agriculture, land clearing, wetland drainage, and rapid growth of human populations has led to an overall 30% increase in phosphorus in the lake from 1969 to 2007; most (73%) of the phosphorus load to Lake Winnipeg comes from the Red River, MB.[3] Nitrogen is also increasing, but at a more variable rate.[5, 6] Concentrations of both nitrogen and phosphorus vary depending upon the location of the sampling site but, in general, nutrient concentrations are highest in the southern basin of the lake (Figure 22 and Figure 23).

Figure 22. Average annual total phosphorus concentrations in 1969 and from 1992-2007 in Lake Winnipeg, MB[5] and b) spatial trends in average total phosphorus concentrations at 14 long-term monitoring stations on Lake Winnipeg, MB (data are averages from 1999- 2007 at each station).[6]
Source: Brunskill et al., 1969[5] and Manitoba Water Stewardship, 2008[6]

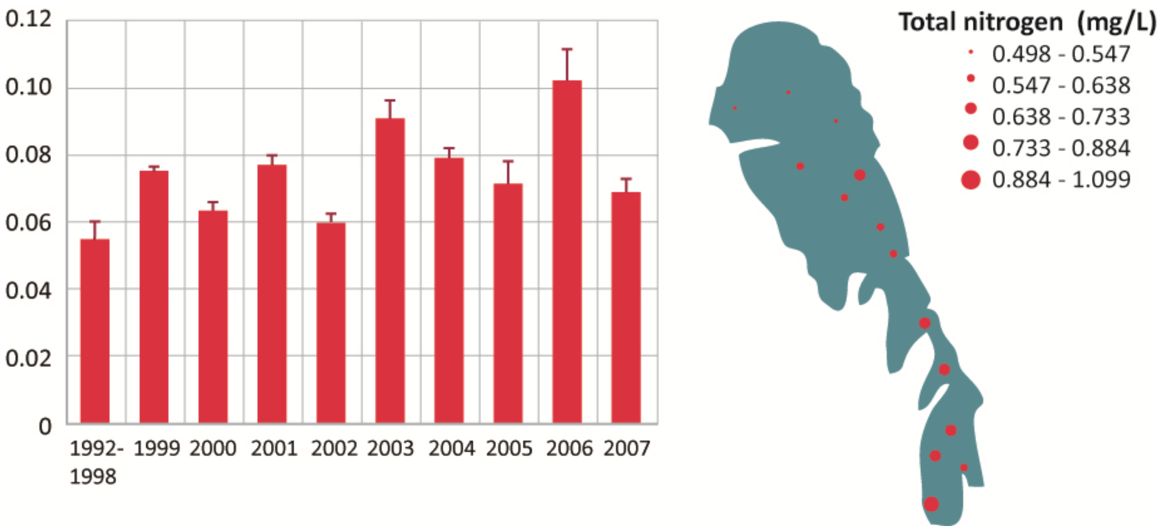


Figure 23. Average annual total nitrogen concentrations from 1992-2007 in Lake Winnipeg, MB and b) spatial trends in average total phosphorus concentrations at 14 long-term monitoring stations on Lake Winnipeg, MB (data are averages from 1999-2007 at each station).
Source: Manitoba Water Stewardship, 2008[6]

One effect of nutrient loading in Lake Winnipeg has been the development of large surface algae blooms comprised mostly of blue-green algae. Between 1969 and 2003, the average biomass of phytoplankton increased five-fold (Figure 24). The increase in algal blooms, and shift in species composition towards blue-green algae, has been occurring since the 1940s but has been particularly pronounced since the mid-1990s. Algal blooms have been as large as 10,000 km^2, covering much of the north basin of the lake.[6] Toxic blooms of blue-green algae in August 2010 prompted public health advisories to be posted at beaches, as water from Lake Winnipeg was not safe to drink.[167]

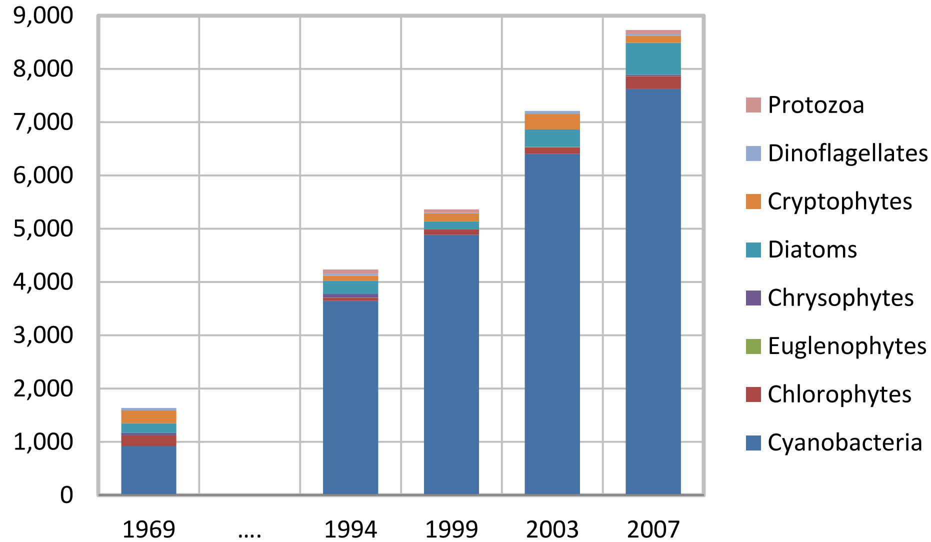


Figure 24. Average phytoplankton biomass and species composition (mg/m^3) from late July and early September in Lake Winnipeg, MB, in 1969, 1994, 1999, 2003 and 2007.
Source: Brunskill et al., 1969[5], Kling et al., 2011[168]

Key finding 13 **Theme** Human/ecosystem interactions

Acid deposition

National key finding

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.

Acid deposition is produced when sulphur and nitrogen-based pollutants react with water in the atmosphere and are deposited on earth.[169] The pollutants originate from industrial processes and can travel thousands of kilometres. It is the combination of acid deposition and the sensitivity of the land, water, flora, and fauna to acid that determines the severity of the impact on biodiversity. There were no data for acid deposition across the Boreal Plains Ecozone+; however, the north-central regions of the ecozone+ are sensitive to acid due to their geology and soil type (Figure 25).

Critical Load is the maximum level of acid deposition that terrain can absorb without experiencing impairment; it differs across ecosystems depending on geology and soil type.[170] Acid sensitive terrain, which has less buffering capacity, is generally underlain by slightly soluble bedrock and overlain by thin, glacially-derived soil.[171] The northern boundary of the Boreal Plains Ecozone+, from northwestern Saskatchewan east to central Manitoba is fairly sensitive to acid deposition with a critical load of <300 (Figure 25).

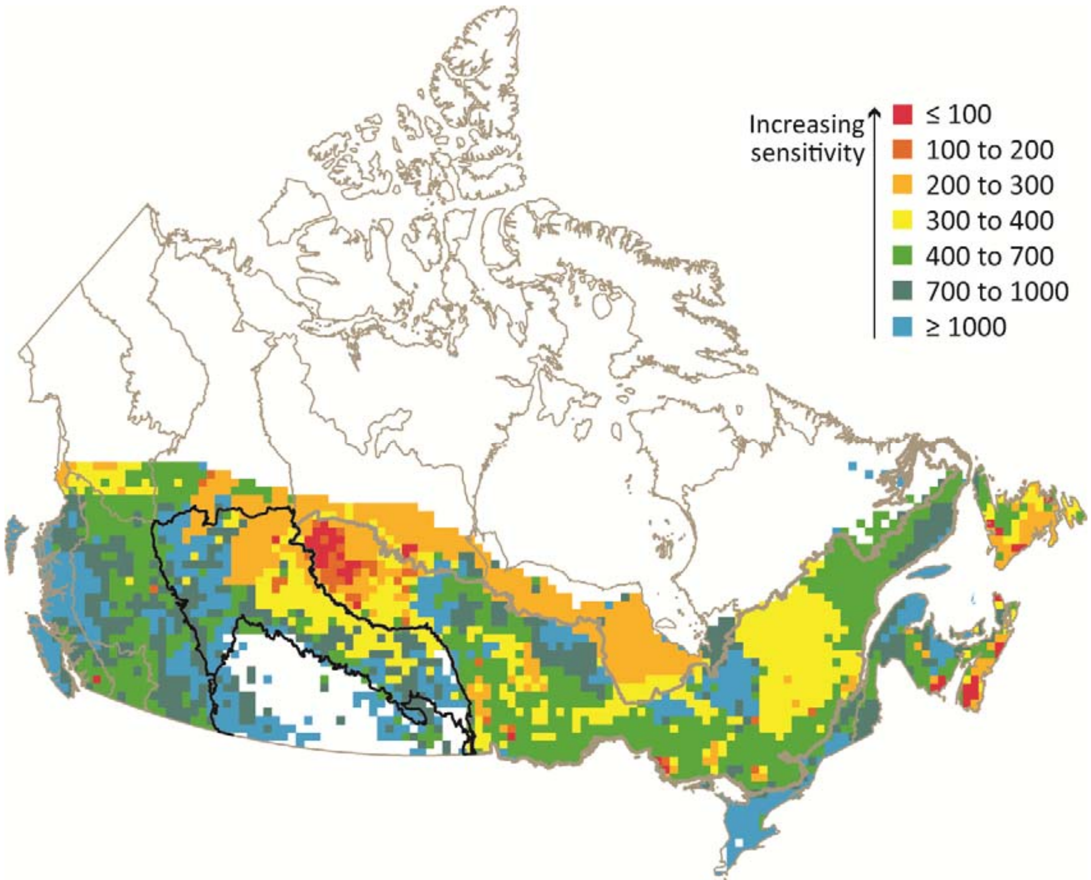


Figure 25. Combined aquatic and terrestrial critical loads, 2008.
<400 indicates acid sensitive terrain.
Source: adapted from Jeffries et al., 2010[172]

In aquatic communities, algae, invertebrates, fish, amphibians, and waterbirds are affected by increased acidity through direct effects such as reduced survival, growth and reproductive success, and indirect effects such as loss or alteration of prey species.[169, 173-177] Acidification of aquatic systems can also lead to increases in methylmercury, which bioaccumulates and reduces survival in embryos and young animals.[178-181] Biodiversity is impacted when critical loads are exceeded. This happens when acid is deposited on sensitive terrain or when acid deposition is high on less-sensitive terrain. The risk of exceedance of critical loads is high in northwest Saskatchewan because 68% of the 259 lakes assessed in 2007–2008 were highly sensitive to acid and are located downwind of acidifying emissions from energy developments.[182] Similar concerns exist for other areas on sensitive terrain near these developments making this an emerging issue in the ecozone+.[183]

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.

The Boreal Plains Ecozone+ has experienced an increase in temperature, decrease in snow depth, and decrease in the duration of snow cover since the start of detailed record keeping in 1950. Broad-scale ecological impacts are projected as the climate continues to change, including: changes to the forest biome, melting of frozen peatlands, and shifts in species' phenology and ranges. Climate trends from 1950 to 2007 are summarized in Table 5.

Table 5. Trends in climate variables from 1950–2007 in the Boreal Plains Ecozone+ (temperatures represent changes in average temperature across the ecozone+.

Climate variable	Ecozone+ wide trend (1950–2007)	Comments on regional variation
Temperature	Spring: 2.3°C ↑ Summer: 0.7°C ↑ Fall: no trend Winter: 3.5°C ↑	Temperatures ↑ in spring and summer at stations but magnitude of increases variable across the ecozone+, particularly in the summer Temperatures ↑ in winter at stations throughout ecozone+
Growing season	No ecozone+-wide trend in timing of start or finish of the growing season, or length	
Annual precipitation (rain and snow) amount (33 stations)	No trend in any season	Precipitation ↓ at majority of sites except for an ↑ at one site near the southeast boundary of the ecozone+
Palmer drought severity index (12 stations in ecozone+)	No significant ecozone+-wide trend	↓ trend (becoming significantly drier) in southwestern region of the ecozone+
Snow cover duration (# of days with >2cm of snow cover)	February to July: significant 16.7 day ↓ in duration August to January: no trend	
Maximum annual snow depth (7 stations)	11.3 cm ↓ in snow depth	↓ of >40 cm near northeastern boundary of ecozone+ at the SK/MB border
Snow to total precipitation ratio (33 stations)	No significant trend	↓ decrease in the proportion of precipitation falling as snow at 5 stations in the west and central areas of the ecozone+

Unless otherwise indicated, data from 15 weather stations across ecozone+. Also refer to Figure 26 and Figure 27.
Only significant ($p<0.05$) trends were reported.
Source: Zhang et al., 2011[53] and supplementary data provided by the authors.

Between 1948 and 2007, the average annual temperature increased by 1.7°C across the Boreal Plains Ecozone+.[184] The most significant temperature increases were observed in the winter and spring (Figure 26). Since 1950, precipitation has generally been increasing across Canada; however, precipitation did not change in the Boreal Plains Ecozone+ in any season (Figure 27). It is possible that no trend in precipitation was observed because the Boreal Plains Ecozone+ is located between the Prairies Ecozone+, where precipitation declined, and northern Canada, where precipitation increased. There were, however, regional changes in precipitation. Precipitation increased in the eastern section, particularly in Manitoba, and decreased in west central Alberta.[185]

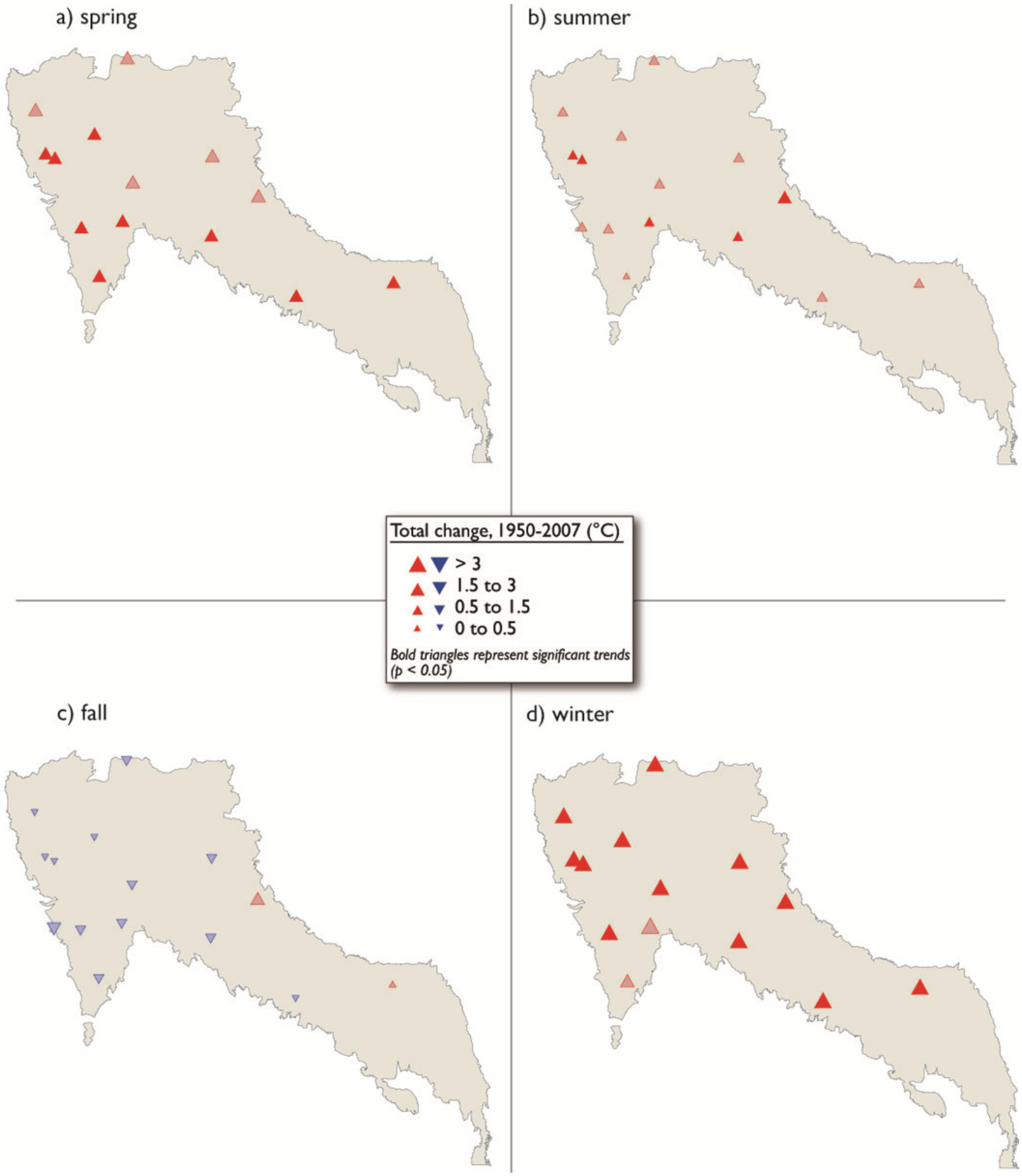


Figure 26. Change in average temperature, 1950–2007.
Seasons: spring=March–May; summer=June–Aug; fall=Sept–Nov; winter=Dec–Feb. Significant (p<0.05) trends in bold.
Source: Zhang et al., 2011[53] and supplementary data provided by the authors.

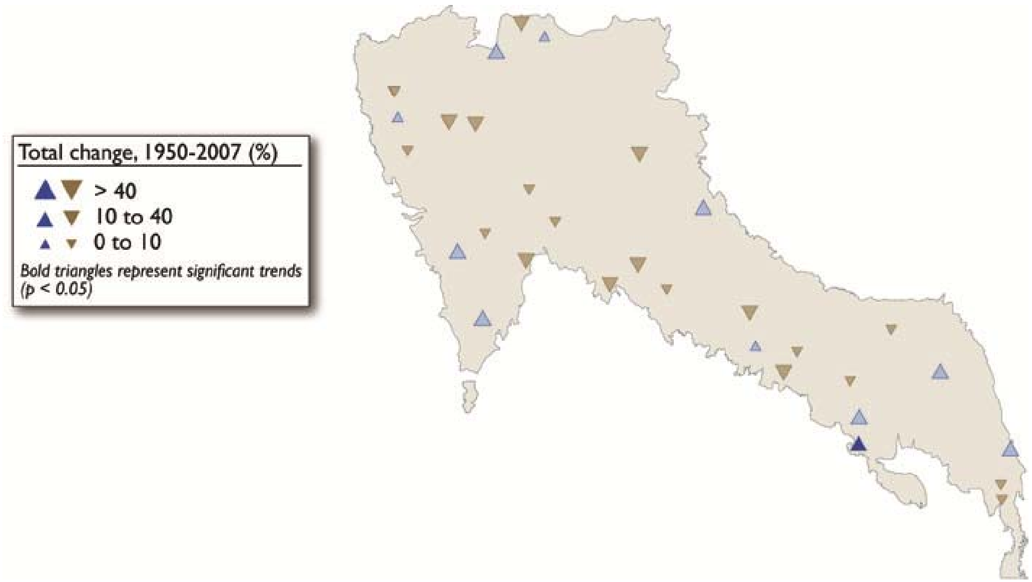


Figure 27. Change in the amount of annual precipitation, 1950–2007.
Expressed as a percentage of the 1961–1990 average.
Source: Zhang et al. 2011[53] and supplementary data provided by the authors

Climate change impacts on ecosystems

Changes to major biomes in the Boreal Plains Ecozone+ are predicted under continued climate change. Over the next 50 years, 12–50% of Alberta's boreal forests may be converted to parkland (that is, fewer trees) coupled with a northward shift of grasslands into existing parkland.[186] Although large burns presently regenerate into mixedwood forest, changes to the bioclimatic envelope will result in parkland as trees fail to regenerate.[186] In the southern portion of the ecozone+, massive tree die offs related to drought have already been documented.[23, 187-189] Tree mortality in the western regions of the boreal forest increased by 4.9% per year from 1963 to 2008, mainly as a result of water stress created by regional drought.[190]

Changes to climate in the Boreal Plains Ecozone+ have already affected physical and biological processes across the region. For example, although permafrost has always been patchily distributed in the Boreal Plains Ecozone+,[108] the southern edge of the permafrost zone has completely thawed over the last 100 to 150 years as a result of increasing temperatures (see the Climate change section on page 41).[103] This results in the release of methane hydrates (a greenhouse gas) and changes wetland hydrology.[108, 191-194] Warmer temperatures and decreasing snow pack have affected streamflow dynamics[61,62] and lake levels,[74, 76] altering the salinity and changing the composition of aquatic communities (see the Climate change impacts: stream flows, temperature and water levels section on page 19). Finally, much like the rest of the country, species have responded to climate change through northward range shifts and changes in phenology.[195, 196] All of these effects are predicted to continue under future climate change as are the frequency and/or severity of fire and increases in the incidence of forest insect infestation, fungus, and disease infection.[23, 24]

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.

The Boreal Plains Ecozone+ provides an abundance of ecosystem services. Provisioning services, such as forest harvesting, hunting, fishing, trapping, and agriculture, are activities in the Boreal Plains which provide economic benefits. The boreal forest as a whole (including the Boreal Plains Ecozone+) provides a range of other ecosystem services (e.g., water as well as regulation and cultural services) that have not been quantified or valued to date; most notable of these services is the globally important role of the boreal forest as a carbon sink.[197]

Provisioning services

Fresh water

In the Boreal Plains Ecozone+, the amount of water allocated for human use was increasing as of 2006 yet still remains below 1% of the average annual flow for four of the five river basins monitored, including[86, 87] Peace/Slave, Saskatchewan, North Saskatchewan, and the Churchill basins. In 2006, 4% of the Athabasca River Basin's average annual flow was allocated for human use, mainly for oil and gas and commercial developments (see Figure 13 in the Water stresses section on page 21). However, there is concern that continued development in the oil sands region in Alberta, combined with climate change, will compromise water security in the Athabasca River Basin in the future.[89]

Timber

Timber harvesting within the Boreal Plains Ecozone+ has continued to increase since softwoods were first extensively harvested in the 1950s. Up until the past 20 years, the majority of harvested forest was spruce for lumber and pulp production; however, the harvest of hardwoods, such as trembling aspen, has increased significantly since the late 1980s.[21, 58] See the Forests section on page 11 for more information on forest trends.

Subsistence benefits

There is limited information on the trends of subsistence benefits of the Boreal Plains Ecozone+ including hunting, trapping, and fishing. In general, populations of hunted species appear to be stable in the Boreal Plains Ecozone+,[198, 199] with the exception of grizzly bear. Grizzly bears are "at risk" in Alberta, and some populations are probably declining.[200]

Most fur-bearing species are considered stable in Alberta having recovered from intensive trapping in the early part of the 1900s.[198] The exception to this is the wolverine which is listed as "may be at risk" in Alberta, and is thought to be declining.[201] Furbearer pelt harvests by trappers has been variable but declining in recent years, mainly as a result of lower fur prices, weather, and declining trapper interest (Figure 28).[202]

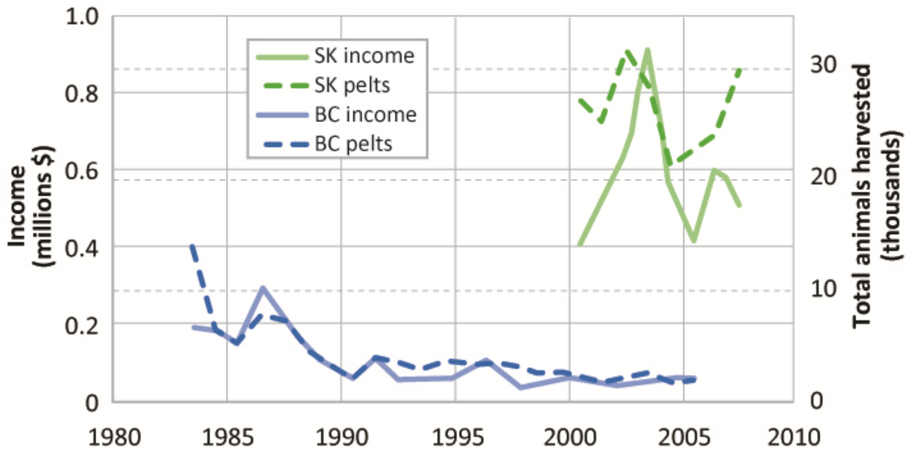


Figure 28. Total income ($) and number of animals harvested in the Boreal Plains Ecozone+ of British Columbia, 1984- 2006 and Saskatchewan, 2000- 2007.
Source: annual returns compiled from BC Ministry of Environment, 2008,[203] Saskatchewan Environment, 2008,[204-211] and Haughland, 2008[212]

Fishing and commercial fisheries harvests likewise have variable information with inconsistent reporting among jurisdictions in the Boreal Plains Ecozone+. In Alberta, there has been unsustainable harvesting pressure in many fish-bearing lakes where access has increased dramatically over the last 50 years.[198] Since the 1960s, overfishing has resulted in the collapse of commercial fisheries, such as the goldeye (*Hiodon alosoides*) (Figure 29).[213, 214] Similarly, sport fishing has also contributed to declines in fish populations in some lakes; for example, walleye populations were significantly reduced in several lakes in northern Alberta as a result of overfishing.[215] In contrast, commercial catches of walleye in Lake Winnipeg are high (Figure 30), suggesting that this species is abundant in the lake (see Lake Winnipeg fishery section below).[216] The Lake Winnipeg sauger (*Sander canadensis*) commercial fishery, however, has declined since the 1980s and population trends for the 2000s are unknown (Figure 30).[216] See the Fish section on page 58 for more information on fisheries.

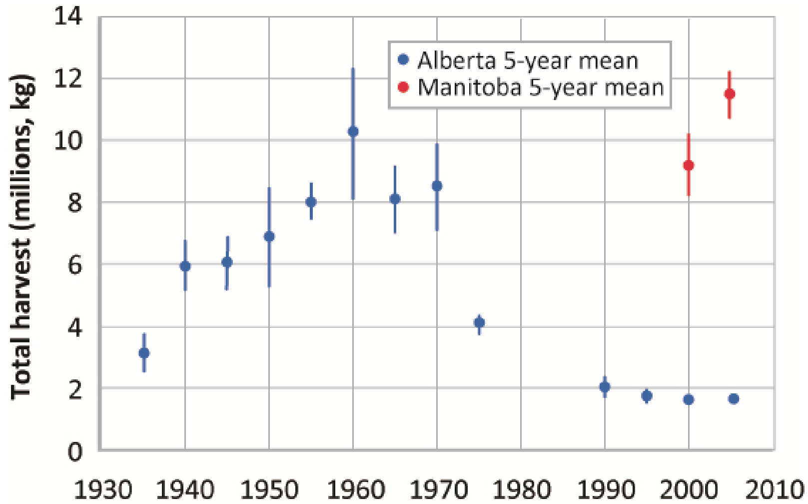


Figure 29. Total commercial fisheries harvest in the Boreal Plains Ecozone+ of Alberta and Manitoba. Circles depict 5-year averages and whiskers are 95% confidence intervals. Temporal extent of data varies by region according to data availability.
Alberta provincial values 1931–1975 are used and corrected downwards using a conversion factor (84%) derived from a comparison of total harvests to Boreal Plains-specific data from 1987–2007.
Source: Haughland, 2008[217] from Alberta Recreation Parks and Wildlife, 1976,[214] Bodden, 2008,[218] Department of Justice, 2007[219] Manitoba Water Stewardship, 2006[220]

Lake Winnipeg fishery

Lake Winnipeg supports the largest commercial fishery in the Boreal Plains Ecozone+. It represents 40% of the total fish production in the province of Manitoba and is an important component of Manitoba's economy (the Lake Winnipeg fishery annual landed value is approaching $25 million[1]). The three most commercially valuable species harvested from Lake Winnipeg are walleye, lake whitefish (*Coregonus clupeaformis*), and sauger. Commercial catches of walleye are at unprecedented highs, sauger catches have declined since the late 1980s and lake whitefish catches show no trend in either direction (Figure 30).

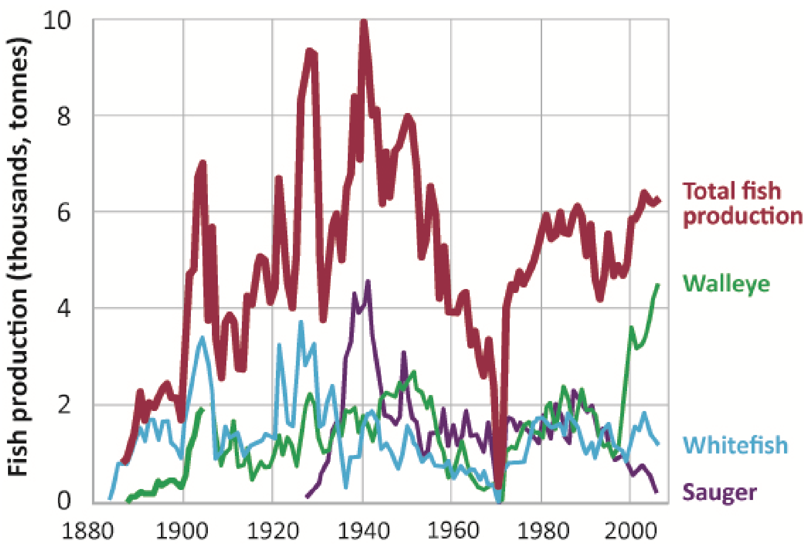


Figure 30. Fish production (kg) of the Lake Winnipeg commercial fishery, 1883–2006.
Source: adapted from Manitoba Water Stewardship Fisheries Branch as cited in Kling et al., 2011[168]

Agricultural

Agriculture including grain farming, production of forage crops, and livestock production, has dominated the economy of some areas of the Boreal Plains Ecozone⁺. In the Peace River region, agricultural land cover increased from 23 to 46% between 1961 and 1986.[198] Between 1985 and 2005, agricultural land cover remained stable at 24% for the Boreal Plains Ecozone⁺ as a whole. See the Agricultural land cover section on page 51.

Regulating services

Carbon storage

Boreal forest carbon storage is globally significant.[197] Much of this carbon is held within peat deposits and organic forest floor material.[221, 222] However, the status of the boreal forest as a net sink in a given year is affected by other factors, such as forest fires which increase carbon release and decrease carbon uptake.[106, 223] For example, forests in the Boreal Plains Ecozone⁺ acted as a net source of carbon from 2001 to 2007 (Figure 31). Future trends of climate warming and permafrost thaw due to increased air temperature could perpetuate a trend of atmospheric carbon release in the coming years.[224] See the Permafrost section on page 23.

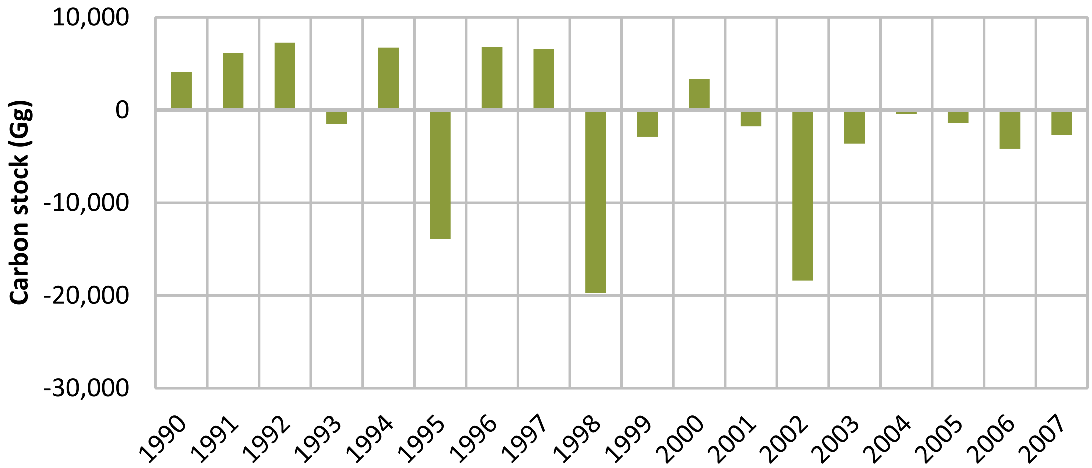


Figure 31. Cumulative change in carbon stocks from the land use, land-use change, and forestry sector in the Boreal Plains Ecozone+, 1990–2007.
Source: Environment Canada, 2009[225]

Water purification and regulation

Wetlands in the Boreal Plains Ecozone+ provide numerous environmental and human benefits, including[197] water purification, flood control, and carbon storage. In addition, wetlands provide critical habitat for many components of biodiversity, such as: migratory birds (e.g., American white pelican, *Pelecanus erythrorhynchos*);[226] fish (e.g., shortjaw cisco and lake sturgeon, *Acipenser fulvescens*);[227] and mammals (e.g., American beaver, *Castor canadensis*).[228-231]Wetlands (peatlands, marshes, and fens) covered approximately 15% of the total area of the Boreal Plains Ecozone+ in 2005[17] (see the Wetlands section on page 17).

Cultural services

Human use, enjoyment and valuation of natural systems are difficult to quantify, but the creation, maintenance and visitation rates of parks and protected areas are often used as surrogates for these values. Of the three national parks in the ecozone+, data was only available for Prince Albert National Park, SK, where the number of visitors increased from 1987 to 2007 (Figure 32).[232] The number of protected areas in the Boreal Plains Ecozone+ also increased, from 4 to 8% between 1992 and 2009.[112]

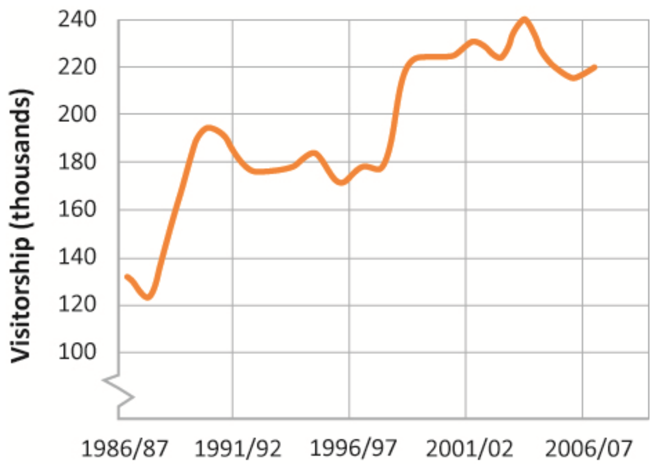


Figure 32. Total visitorship to Prince Albert National Park, SK.
Source: Corrigal, 2008[232]

Valuation of ecosystem services

Efforts to value ecological services in the Boreal Plains Ecozone+ have increased in recent years,[233, 234] as has the interest in the use of market based approaches to conserve the boreal forest, particularly in the oil sands region of Alberta.[116] Alberta and Manitoba are exploring market based instruments as tools to enhance the stewardship of ecological services. Ecosystem services, goods and assets were identified and qualitatively ranked for southern Alberta,[235] which included parts of the Boreal Plains Ecozone+. Manitoba applies the ecological goods and services concept in the development of future agri-environment policy through the Manitoba Ecological Goods and Services Initiative Working Group. For example, Growing Assurance – Ecological Goods and Services[236] provides financial assistance to local Conservation Districts to help implement best management practices on farms to restore, conserve and enhance ecological goods and services on the agricultural landscape.

THEME: HABITAT, WILDLIFE, AND ECOSYSTEM PROCESSES

Key finding 16 **Theme** Habitat, wildlife, and ecosystem processes

Agricultural landscapes as habitat

National key finding

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.

The Boreal Plains Ecozone+ is second only to the Prairie Ecozone+ in area of agriculture land. Agricultural landscapes comprise a mosaic of wildlife habitats and support many components of biodiversity. However, the wildlife habitat capacity of agricultural lands declined in the Boreal Plains Ecozone+ from 1986 to 2006 mainly due to the loss of natural land cover.[237]

Agricultural land cover

Agricultural land in the Boreal Plains Ecozone+ expanded from 1986 to 2006 (130,000 to 135,000 km^2) to comprise approximately 21% of the ecozone+[238] (Figure 33). This increase was mainly the result of forest conversion to pasture and cropland (see the Forests section on page 11). Most of the agricultural land (~75%) is concentrated in the Boreal Transition and Peace Lowlands Ecoregions. The two dominant land cover types, Unimproved Pasture and Cereals, declined between 1986 and 2006 from 27 to 24% and from 26 to 19%, respectively. Tame Hay (6 to 16%), Improved Pasture (8 to 12%) and Oilseeds (10 to 11%) gained a greater share of farmland while Summerfallow (10 to 3%) and All Other Land[iii] (14 to 13%) decreased.

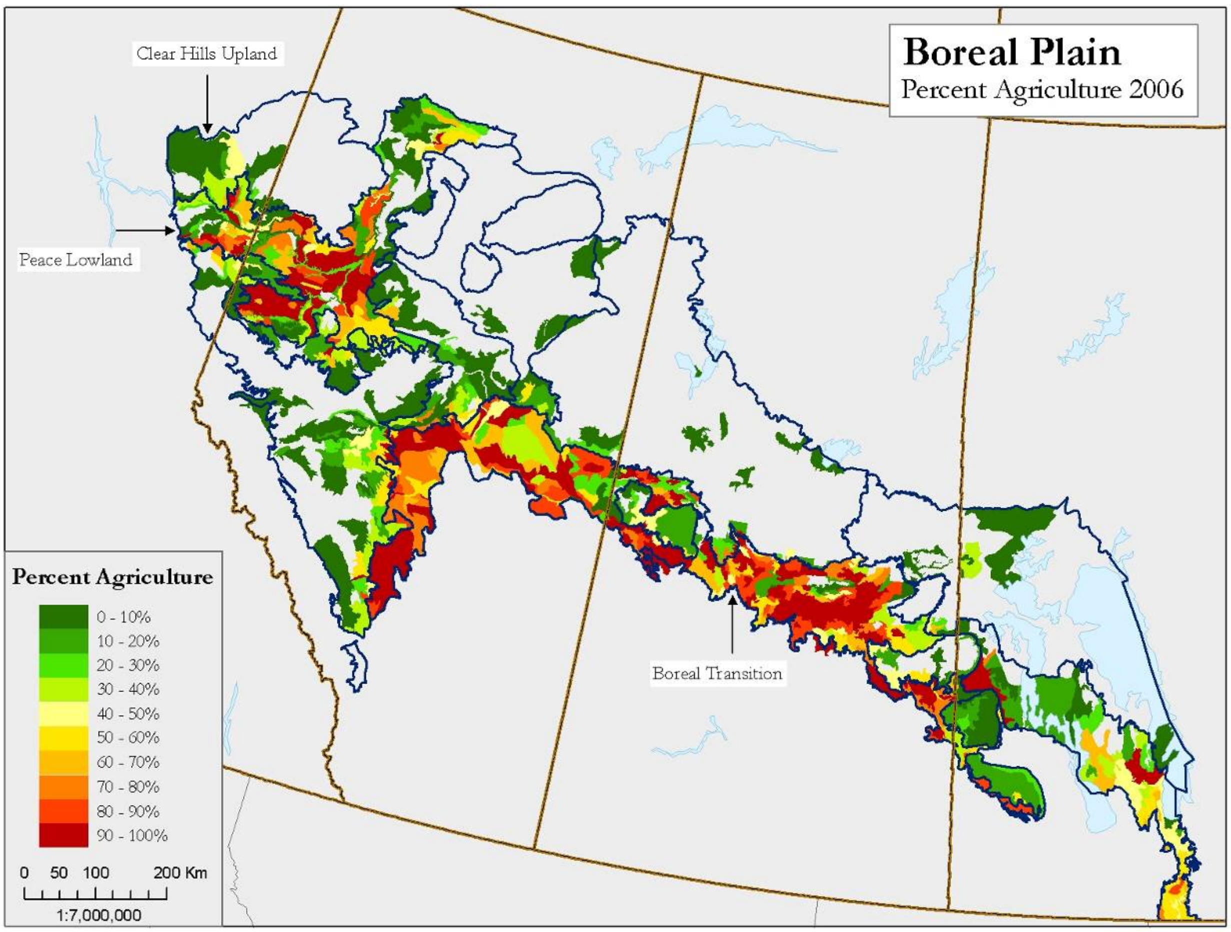


Figure 33.The percentage of agricultural land cover in the Boreal Plains Ecozone+.
Source: Javorek and Grant, 2011[237]

[iii] The agricultural landscape (or agricultural land) includes the "All Other Land" category from the Census of Agriculture, which is made up of areas such as wetlands, riparian zones, shelterbelts, woodlands, idle land/old fields, and anthropogenic areas (farm buildings, green houses, and lanes).

Potential wildlife use of agricultural lands

A total of 314 species (235 birds, 63 mammals, 6 reptiles, and 9 amphibians) potentially use agricultural land in the Boreal Plains Ecozone+.[237] However, not all agricultural land cover types meet all life requisites for these species; further, the value of agricultural habitat is affected by the ability of adjacent habitats to provide required resources. Of all the land cover categories within the agricultural landscape, the "All Other Land" category, which includes wetlands, riparian zones, and forests, was the most valuable cover type for wildlife; it accommodated both breeding and foraging requirements for 280 (89%) species.[237] The next most valuable cover type was Unimproved Pasture which provided breeding and foraging requirements for 62 (20%) species; this percentage was improved to 40% when requisite breeding habitat was nearby. Only 11 (4%) species met breeding and feeding requirements entirely on cropland (e.g., Tame Hay, Cereals, Oilseed land cover categories). However, when other breeding habitat was present, 90 (29%) species were able to use cropland as feeding habitat.

Wildlife habitat capacity

The dynamic nature of agricultural practices in the Boreal Plains Ecozone+ resulted in concurrent changes in beneficial and detrimental landuses to wildlife. As a result, there was no change in wildlife habitat capacity on 78% of farmland in the ecozone+ between 1986 and 2006 (Figure 34). However, there was a significant decrease in capacity on 13.4% of farmland and only an 8.6% increase, resulting in an overall decline in wildlife habitat capacity for the Boreal Plains Ecozone+ (Figure 35).[237] As the wildlife habitat capacity was stable in the Boreal Transition Ecoregion, the primary reason for the decline was due to the reduction in the preferred cover type All Other Lands (17 to 13%) in the Peace Lowlands (Figure 35). As it relates to bird populations, the decline of natural cover types (i.e., All Other Land and Unimproved Pasture), and the intensification of agricultural systems have reduced the availability and quality of habitat for grassland and open bird species assemblages in agricultural landscapes in the Boreal Plains Ecozone+ (Figure 36).[237, 239]

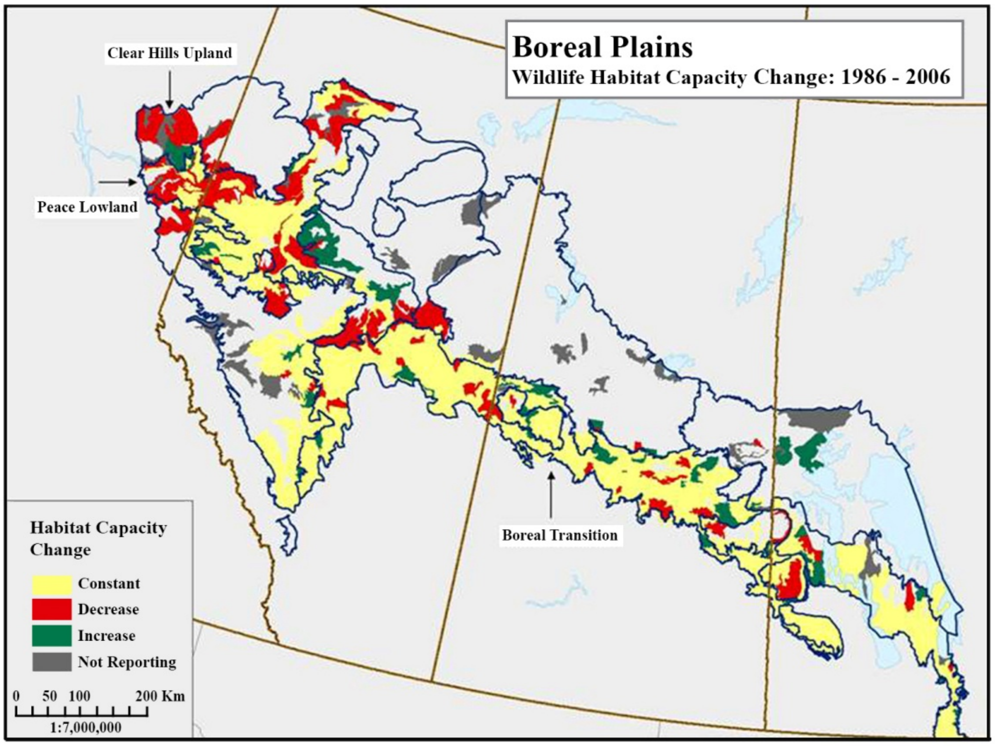
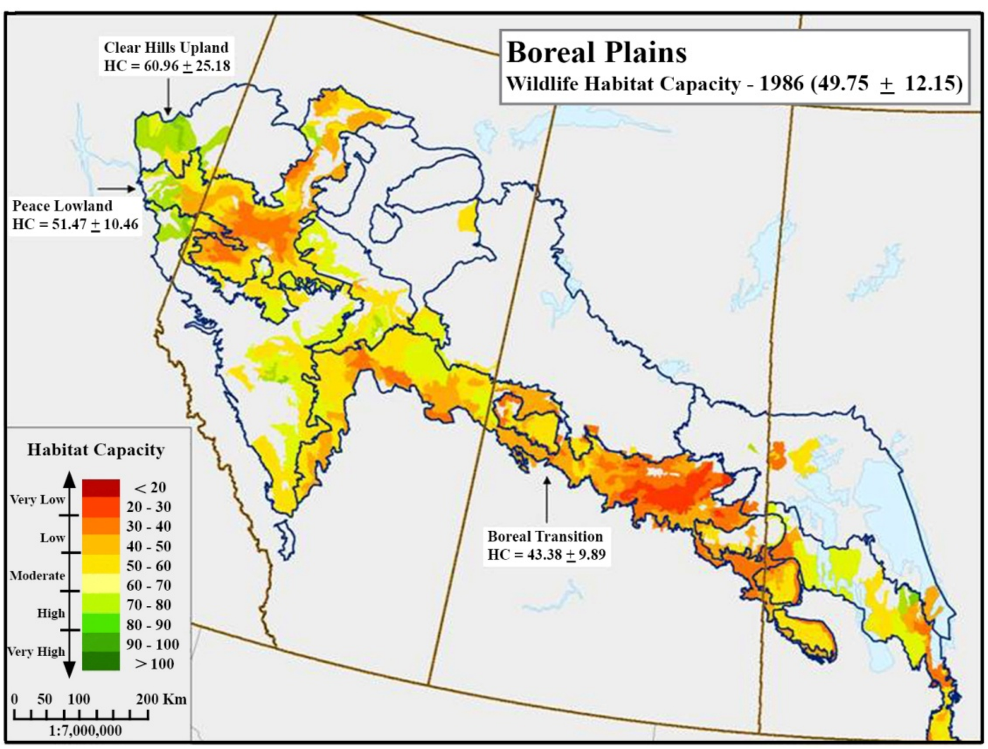


Figure 34. Changes in wildlife habitat capacity on farmland in the Boreal Plains Ecozone+ between 1986 and 2006.
Source: Javorek and Grant, 2011[237]

a)



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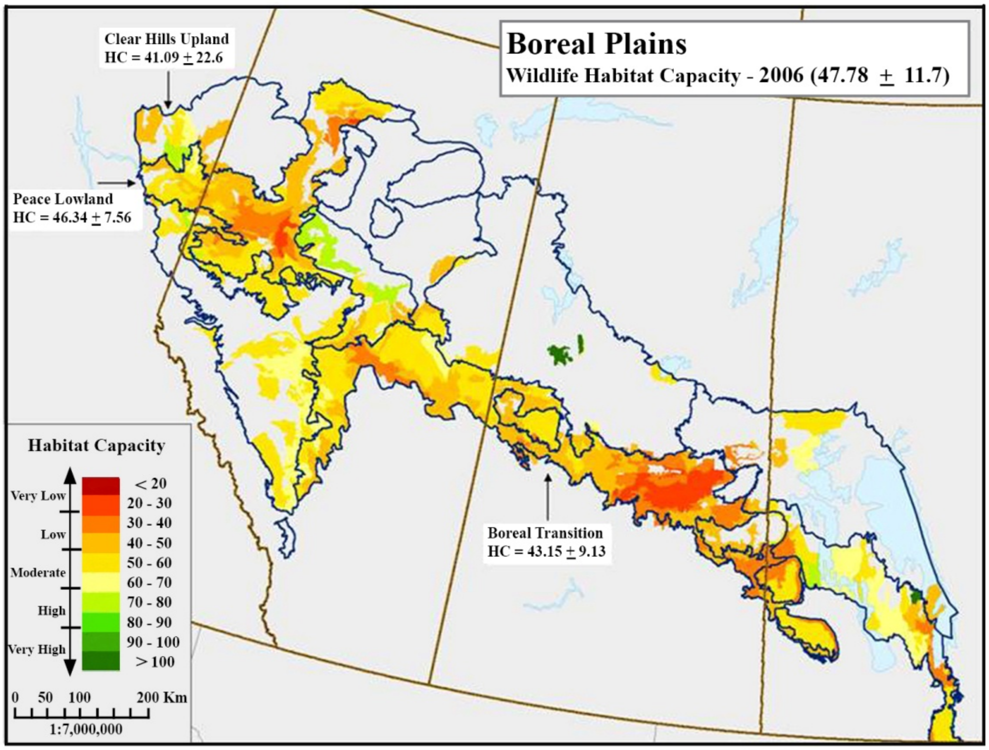

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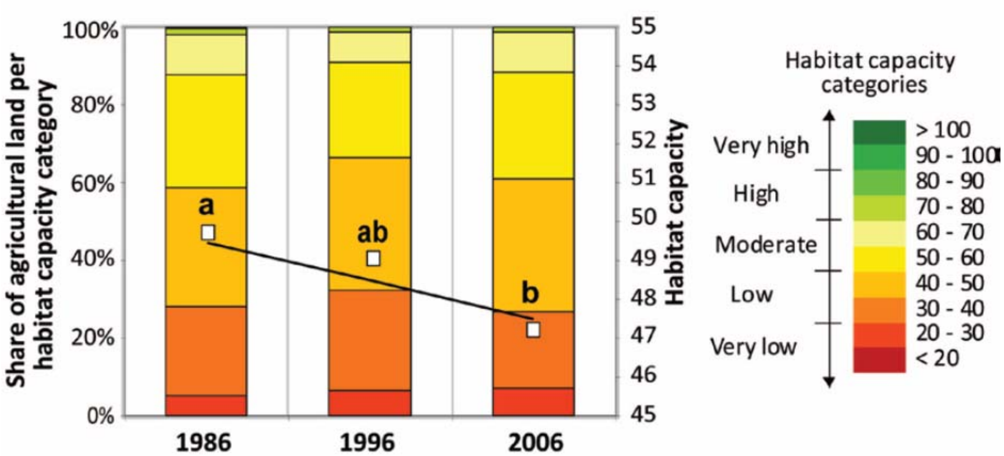

Figure 35. Wildlife habitat capacity on farmland in the Boreal Plains Ecozone+ in a) 1986 and b) 2006 and c) The share of agricultural land in each habitat capacity category (bars, left axis) and the average habitat capacity for the Boreal Plains Ecozone+ in 1986, 1996, and 2006 (points and line, right axis). Years with different letters differed significantly (ANOVA: F = 4.25, Tukey HSD p<0.05).
Source: Javorek and Grant, 2011[237]

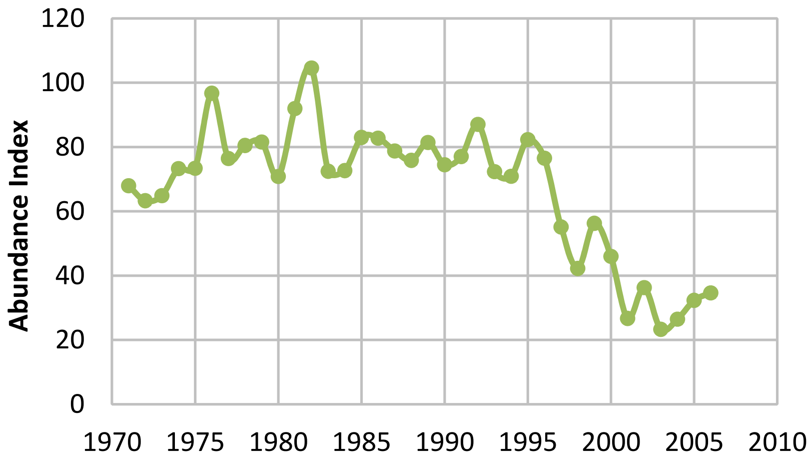

Figure 36. Annual indices of population change in open/agricultural birds in the Boreal Plains Ecozone+, 1971-2006.
Based on data from the Breeding Bird Survey.
Source: Downes et al., 2011[239]

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.

Human activity in the Boreal Plains Ecozone+ has both positive and negative effects on wildlife populations. Biodiversity population sizes are most greatly impacted by habitat loss that is most often the outcome of industrial activity; however, disease and predation also play important roles in biodiversity population fluctuations. The oil sands in Alberta present a potential threat to biodiversity and the ABMI[240] (see the Alberta Biodiversity Monitoring Institute section on page 76) works with federal and provincial agencies to implement scientifically credible monitoring systems for the Athabasca oil sands area.

The Athabasca oil sands area is within the Boreal Plains Ecozone+ and comprises 14% of Alberta. Human footprint covered 6.8% of the Athabasca oil sands area and 9% is protected.[241] The ABMI assessed the status of 386 common species in the Athabasca oil sands area between 2003 and 2012. They found higher-than-expected abundances of species that thrive in areas with human development and lower-than-expected abundances of species that thrive in old-forest habitat.[241] Half (12 of 24) old-forest birds were less abundant than expected if there were no human footprint. Old-forest birds that were less abundant than expected included brown creeper (*Certhia americana*), black-throated green warbler (*Setophaga virens*), boreal chickadee (*Poecile hudsonicus*), Cape May warbler (*Setophaga tigrina*), and least flycatcher (*Empidonax minimus*). However, pileated woodpecker (*Dryocopus pileatus*), winter wren (*Troglodytes hiemalis*), and warbling vireo (*Vireo gilvus*) were more abundant than expected.[241]

Of 13 mammal taxa, three (American marten, (*Martes americana* and fisher, (*Martes pennant*), mice and voles, (*Rodentia*), and red squirrels, (*Tamiascirus hudsonicus*)) were less abundant and red fox (*Vulpes vulpes*), mink, and wolf (*Canis lupus*) were more abundant than expected if there were no human footprint.[241]

The ABMI also measured "intactness", statistical models that describe the relationship between the relative abundance of individual species, habitat, and human footprint for the Boreal Forest Natural Region. Six-dimpled northern mites (*Tectocepheus sarekensis*) were detected at 5% of the sites in the Athabasca oil sands area, and were found to be 90% intact (Table 6). The presence and abundance of species in this species' family (Tectocepheidae) often indicate recent habitat disturbance.[242]

Of 23 berry-producing vascular plants, 20 were less abundant than expected than would be expected if there was no human footprint. Wild red raspberry (*Rubus idaeus*), which grows in open and disturbed sites such as burns, recently logged forest, and road edges, was more abundant than would be expected if there were no human footprint.[241]

Table 6. Intactness for different components of biodiversity in the Athabasca oil sands area of Alberta. Source: Alberta Biodiversity Monitoring Institute[241]

Biodiversity Component	Number of Species	Intactness
Native birds	71	92%
Winter-active mammals	13	95%
Armoured mites	62	95%
Native plants	165	93%
Moss	75	96%
Overall intactness	**386**	**94%**

Source: Alberta Biodiversity Monitoring Institute[241]

The ABMI tracks 14 of the 28 species considered at risk in this Athabasca oil sands area. This includes 6 species listed as provincially or/or federally threatened (Table 7).

Table 7. Summary of species at risk in the Athabasca oil sands area, arrows indicate whether the species is increasing or decreasing.

Species	Designation*	ABMI Assessment	Abundance	% Sites detected
Bay-breasted warbler (*Setophaga castanea*)	Sensitive - ESRD In Process - AB ESCC 2010-	97% Intact	↑	15
Black-throated green warbler (*Setophaga virens*)	Sensitive - ESRD Species of Special Concern -AB ESCC 2010	85% Intact	↓	4
Brown creeper (*Certhia americana*)	Sensitive – ESRD	81% Intact	↓	10
Canada warbler (*Wilsonia canadensis*)	Sensitive - ESRD Threatened - COSEWIC Threatened - SARA	99% Intact	↓	10
Cape May warbler (*Setophaga tigrina*)	Sensitive - ESRD In Process - AB ESCC 2010	96% Intact	↓	26
Common yellowthroat (*Geothlypis trichas*)	Sensitive – ESRD	95% Intact	↑	36
Least flycatcher (*Empidonax minimus*)	Sensitive – ESRD	93% Intact	↓	44
Olive-sided flycatcher (*Contopus cooperi*)	ESRD - May Be at Risk Threatened - COSEWIC Threatened - SARA	99% Intact	↑	17
Pileated woodpecker (*Dryocopus pileatus*)	Sensitive – ESRD	87% Intact	↑	22
Rusty blackbird (*Contopus cooperi*)	Sensitive - ESRD | Special Concern - COSEWIC Special Concern - SARA	99% Intact	↑	6
Sora (*Porzana carolina*)	Sensitive – ESRD	95% Intact	↑	11
Western tanager (*Piranga ludoviciana*)	Sensitive – ESRD	96% Intact	↓	36
Western wood pewee (*Contopus sordidulus*)	Sensitive – ESRD	90% Intact		14
Yellow-bellied flycatcher (*Empidonax flaviventris*)	Undetermined - ESRD	91% Intact	↓	10

**Threat categories for species at risk as identified by the Government of Canada and/or the Government of Alberta. This assessment includes species and sub-species identified by Canada's Committee on the Status of Endangered Wildlife in Canada (COSEWIC), listed under Canada's Species at Risk Act (SARA), recognized by Alberta's Ministry of Environment and Sustainable Resource Development (ESRD), and/or identified by Alberta's Endangered Species Conservation Committee (AB ESCC)*
Source: Alberta Biodiversity Monitoring Institute[241]

The majority of imperilled species in the entire Boreal Plains Ecozone+ are vascular plants and plant communities; amphibians have the highest proportion of species at risk (Figure 37).[243-245]

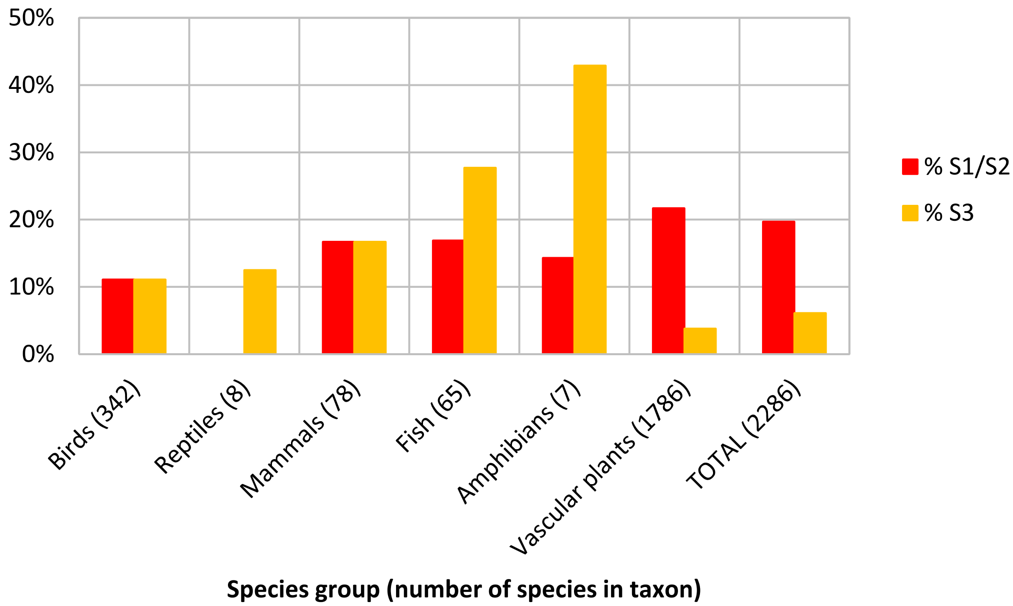

Figure 37: Percentage of known taxa ranked as S1/S2 (at risk) and S3 (may be at risk) as of 2008. Ranked taxa were compiled from sub-region/ecoregion tracking lists from the provinces.[243, 246-248] The total known species in each group was estimated from summing species from tracking lists and field guides in AB[249, 250] and SK.[246] For species with multiple rankings, the most at risk ranking was used. Any listed subspecies and variants were included in the totals.
Source: Haughland, 2008[251]

Fish

The Boreal Plains Ecozone+ has two economically important fish classified as at risk by COSEWIC: lake sturgeon, Endangered, and shortjaw cisco, Threatened).[133, 252] Historically, overexploitation was the cause of large declines in lake sturgeon populations; more recently, dams, habitat degradation, and contaminants from agricultural run-off are among the most critical threats.[227] Historical declines in shortjaw cisco were also caused by overexploitation; current threats include habitat degradation and introduced fish such as rainbow smelt (*Osmerus mordax*) which compete with, and predate on, the cisco.[101] Within the Boreal Plains Ecozone+, the statuses of populations that persist in smaller lakes in Alberta, Saskatchewan, and Manitoba are unknown.

Walleye, northern pike (*Esox lucius*) and yellow perch (*Perca flevescens*) are three popular game fish species in the ecozone+. Walleye are a popular fish for anglers in Alberta's relatively sparse but heavily-fished boreal lakes.[215] Due to passive management and overharvest, many walleye fisheries collapsed between the 1950s and 1980s and have yet to recover.[215] Despite the potential for recovery if released from threats, walleye continue to be harvested due to societal and economic pressures (Figure 38).[215, 253]

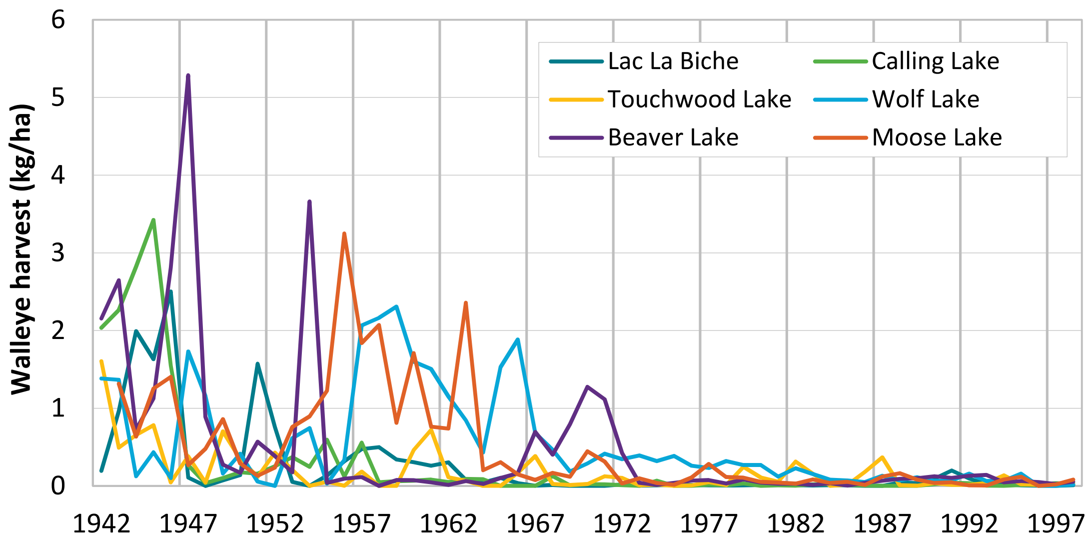

Figure 38. Commercial harvests of walleye (kg/ha) from lakes in Alberta's Boreal Plains Ecozone+, 1942-1998.
Source: Sullivan 2003[215] with data from the author

Birds

Landbirds

The southern boreal forest of western Canada, including the Boreal Plains Ecozone+, encompasses the breeding ranges of more than 200 bird species;[254] nearly half of these are neotropical migrants. Similar to trends across Canada, four of five bird habitat assemblages have declined significantly since the 1970s. Shrub/successional birds declined by 1.2%/year, urban/suburban birds declined by 1.3%/year, open/agricultural birds declined by 2.6%/year, grassland birds declined by 1.7%/year and forest birds were stable (Figure 39).[239] These estimates were derived from the Breeding Bird Survey (BBS). The BBS is a long-term, large-scale, international avian monitoring program initiated in 1966 to track the status and trends of North American bird populations. Each year, thousands of birders volunteer to collect bird population data along roadside survey routes during the height of the avian breeding season. The reliance on roadside habitats, which facilitate accessibility for observers, reduces reliability of trends for bird species that use other habitats. Many landbird species (irruptive species, nomadic species, primary cavity nesters/woodpeckers, grouse, diurnal raptors, nocturnal raptors, species at risk), almost all waterbird and shorebird species, and cavity-nesting waterfowl species are not adequately monitored.[255] Variation in observer abilities and incomplete geographic coverage are other sources of bias.[256] In particular, trends with low reliability should be interpreted with caution.

The Boreal Plains Ecozone+ coincides with Bird Conservation Route 6 (Boreal Taiga Plains). Although BCR 6 also includes the Taiga Shield Ecozone+, the active survey routes are concentrated in the southern two-thirds of the Boreal Plains Ecozone+. This is also the region where the most rapid habitat alteration and loss is occurring.

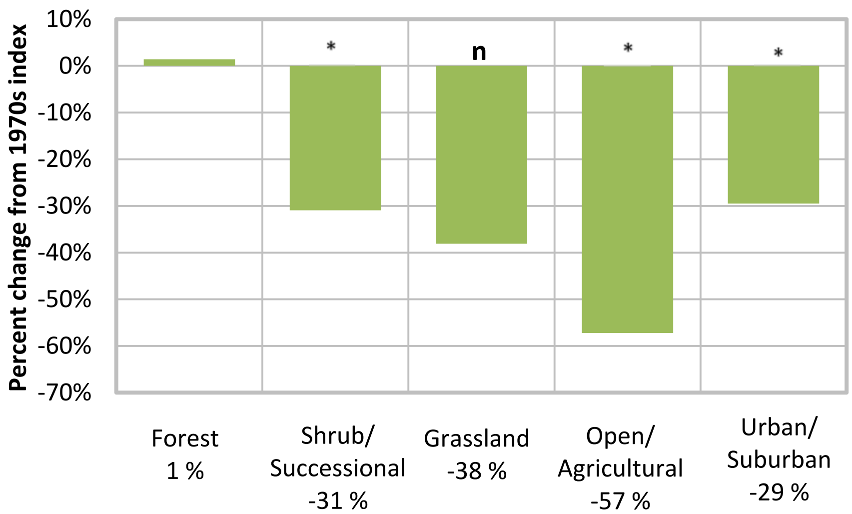

Figure 39. Trends in abundance of landbirds from the Boreal Plains Ecozone+.
The y-axis represents the percent change in the average index of abundance between the first decade for which there were data (1970s) and the 2000s (2000–2006).
** indicates p <0.05; n indicates 0.05<p<0.1; no value indicates not significant.*
Source: adapted from data in Downes et al., 2011[239] based on data from the Breeding Bird Survey[257]

Estimates of bird assemblages were based on an earlier analysis (1970s-2007) of the North American Breeding Bird Survey.[239] Species-specific trends for birds are based on updated data and analyses. Since 2011, the results have been produced using a Bayesian hierarchical analysis. This new approach provides more precise trend estimates that are less sensitive to sampling error, and provides more intuitive measures of uncertainty. In addition, the estimates of geographic coverage were recalculated using updated species range-maps. Users should note that changes in coverage estimates between the 2012 and the 2011 analyses reflect the updated range maps and not a major change in the geographic scope of the survey.[258]

Overall, species in the forest bird assemblage were stable; however, ruffed grouse (*Bonasa umbellus*) and Townsend's solitaires (*Myadestes townsendi*) declined whereas pileated woodpeckers and chestnut-sided warblers (*Setophaga pensylvanica*) increased (Table 8).[239]

Table 8. Trends in the abundance (% change/year) and reliability of the trend for forest bird species of the Boreal Plains Ecozone+ from the 1970s and 1989 to 2012.

Species	Year	Annual Trend	Reliability
American three-toed woodpecker (*Picoides dorsalis*)	1973-2012	1.44	Low
Black-backed woodpecker (*Picoides arcticus*)	1978-2012	-4.15	Low
Blackburnian warbler (*Setophaga fusca*)	1970-2012	0.51	Low
Black-throated green warbler (*Setophaga virens*)	1970-2012	-2.91	Low
Brown creeper (*Certhia americana*)	1977-2012	0.2	Low
Canada warbler (*Cardellina canadensis*)	1970-2012	-3.3	Low
Chestnut-sided warbler (*Setophaga pensylvanica*)	1970-2012	4.91	Low
Downy woodpecker (*Picoides pubescens*)	1970-2012	0.73	Medium
Eastern wood-pewee (*Contopus virens*)	1970-2012	-3.61	Low
Evening grosbeak (*Coccothraustes vespertinus*)	1972-2012	-3.62	Low
Golden-crowned kinglet (*Regulus satrapa*)	1972-2012	1.21	Low
Nashville warbler (*Oreothlypis ruficapilla*)	1970-2012	-0.69	Medium
Philadelphia vireo (*Vireo philadelphicus*)	1970-2012	0.14	Low
Pileated woodpecker (*Dryocopus pileatus*)	1970-2012	4.91	Medium
Pine grosbeak (*Pinicola enucleator*)	1989-2012	-13.1	Low
Red crossbill (*Loxia curvirostra*)	1970-2012	-5.29	Low
Red-headed woodpecker (*Melanerpes erythrocephalus*)	1970-2012	-2.2	Low
Ruffed grouse (*Bonasa umbellus*)	1970-2012	-1.4	Low
Spotted towhee (*Pipilo maculatus*)	1976-2012	-1.43	Low
Townsend's solitaire (*Myadestes townsendi*)	1989-2012	-4.43	Low
Veery (*Catharus fuscescens*)	1970-2012	-4.75	Low
White-breasted nuthatch (*Sitta carolinensis*)	1970-2012	5.25	Low
Winter wren (*Troglodytes hiemalis*)	1972-2012	0.48	Low
Yellow-throated vireo (*Vireo flavifrons*)	1970-2012	1.53	Low

Source: Environment Canada 2014[258]

In contrast to the forest bird assemblage, most species in the shrubland/early successional assemblage declined (Figure 40),[167] some by over 40% (Table 9). As shrub habitat matured into young forests, populations of shrub birds (e.g., mourning warbler, *Geothlypis philadelphia*) declined along with their preferred habitat.[167]

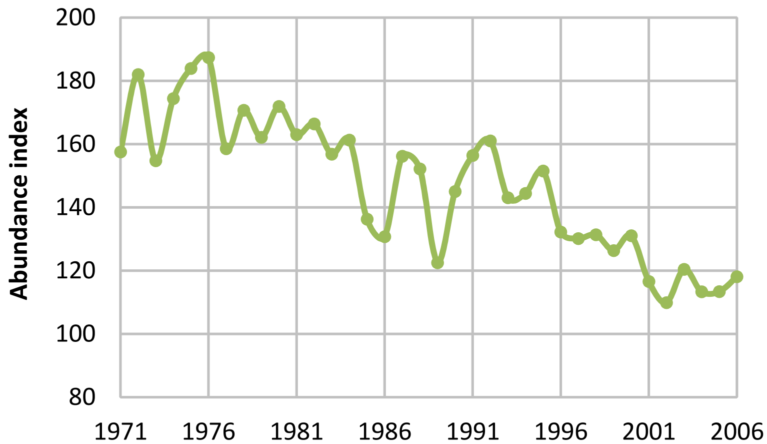

Figure 40. Annual indices of population change in birds of shrub/early successional in the Boreal Plains Ecozone+, 1971-2006.
Source: adapted from Downes et al., 2011[239] based on data from the Breeding Bird Survey[257]

Table 9. Trends in abundance (% change/year) and reliability of the trend of selected species of shrub/early successional birds that are characteristic of the Boreal Plains Ecozone+ , 1970-2012.

Species	Annual Trend (1970-2012)	Reliability
American goldfinch (*Spinus tristis*)	-1.62	Medium
Connecticut warbler (*Oporornis agilis*)	-1.43	Medium
Grasshopper sparrow (*Ammodramus savannarum*)	-9.5	Low
Gray catbird (*Dumetella carolinensis*)	-0.59	High
Gray partridge (*Perdix perdix*)	1.55	Low
House wren (*Troglodytes aedon*)	-0.67	Medium
Mourning warbler (*Geothlypis philadelphia*)	-2.32	Medium
Song sparrow (*Melospiza melodia*)	-1.54	Medium
Spotted towhee (*Pipilo maculatus*)	-1.43 (1976-2012)	Low

Source: Environment Canada 2014[258]

Shorebirds

As with the Taiga and other northern ecozones+, shorebirds are not adequately monitored in the Boreal Plains Ecozone+. However, the available information on boreal-breeding shorebirds suggests that several species have declined (Table 10).[258] These trends are relevant to shorebird populations across the boreal forest including the Boreal Plains, Boreal Shield, Boreal Cordillera, Taiga Shield, Taiga Plains, and Taiga Cordillera ecozones+.

Table 10. Trends in abundance (% change/year) and reliability of the trend for shorebirds of the Boreal Plains Ecozone+ from the 1970s to 2012.

Species	Year	Annual Trend	Reliability
American avocet (*Recurvirostra americana*)	1973-2012	4.83	Low
Greater yellowlegs (*Tringa melanoleuca*)	1970-2012	2.6	Low
Killdeer (*Charadrius vociferus*)	1970-2012	-4.67	Medium
Marbled godwit (*Limosa fedoa*)	1970-2012	2.59	Medium
Upland sandpiper (*Bartramia longicauda*)	1970-2012	-9.3	Low
Willet (*Tringa semipalmata*)	1970-2012	-1.22	Low
Wilson's phalarope (*Phalaropus tricolor*)	1970-2012	-5.62	Low

Source: Environment Canada 2014[258]

Waterbirds

Because many species of waterbirds are piscivorous, and therefore at the top of the aquatic food web,[183] water and marsh birds have been used as indicators of ecosystem health for many years.[259] Monitoring of waterbirds in the Boreal Plains Ecozone+ has been inconsistent; however, local data were available for western grebes (*Aechmophorus occidentalis*) and American white pelicans (*Pelecanus erythrorhynchos*).[260] In Alberta, western grebes declined and have low reproductive success.[261] Threats to grebes, and waterbirds in general, include habitat degradation (oil spills, pollution, and reduction of prey) and human disturbance/development.[260] White pelicans increased in Saskatchewan between 1976–1991 and are no longer listed as Threatened in that province.[260] In Alberta, the number of breeding white pelicans is low and they are listed as Sensitive in the province.[226] Observations from Aboriginal communities around Fairford Dam and Lake St. Marin in Manitoba suggest that pelicans have been expanding their range northwards.[262] Although the reliability is low, the North American Breeding Bird Survey suggests that pelican populations are increasing in the ecozone+ (Table 11).[258] However, the North American Breeding Bird Survey is generally poor for the census of colonial waterbirds.[260]

Table 11. Trends in abundance (% change/year) and reliability of the trend for waterbirds of the Boreal Plains Ecozone⁺ from the 1970s to 2012.

Species	Annual Trend	Reliability
American white pelican (*Pelecanus erythrorhynchos*)	3.59	Low
Black tern (*Chlidonias niger*)	-4.2	Low
Caspian tern (*Hydroprogne caspia*)	-1.69	Low
Common loon (*Gavia immer*)	1.85	Medium
Common tern (*Sterna hirundo*)	-2.41	Low
Double-crested cormorant (*Phalacrocorax auritus*)	6.44	Low
Eared grebe (*Podiceps nigricollis*)	-0.36	Low
Forster's tern (*Sterna forsteri*)	-2.13	Low
Horned grebe (*Podiceps auritus*)	-1.83	Medium
Red-necked grebe (*Podiceps grisegena*)	-0.14	Medium
Western grebe (Clark's/Western) (*Aechmophorus* sp.)	0.06	Low

Source: Environment Canada 2014[258]

Waterfowl

The Boreal Plains Ecozone⁺ is one of the most important regions for breeding waterfowl in North America.[263] Species such as white-winged scoter (*Melanitta fusca*) and northern pintail (*Anas acuta*) have declined (Table 12) due, in part, to the cumulative impacts from anthropogenic activities such as conversion to agriculture, forestry, and oil and gas development.[264] Similar to other regions, populations of temperate nesting Canada geese (*Branta canadensis*) increased in the Boreal Plains Ecozone⁺ (Table 12), likely due to conversion of forest to cultivated land and expansion of urban areas.[265]

Table 12. Trends in abundance (% change/year) and reliability of the trend for waterfowl of the Boreal Plains Ecozone+ from 1970 to 2012.

Species	Annual Trend	Reliability
American wigeon (*Anas americana*)	-4.27	Medium
Blue-winged teal (*Anas discors*)	-0.59	Medium
Canada Goose (*Branta canadensis*)	12.3	Low
Canvasback (*Aythya valisineria*)	-0.99	Low
Common merganser (*Mergus merganser*)	-0.38	Low
Gadwall (*Anas strepera*)	0.22	Medium
Green-winged teal (*Anas crecca*)	0.74	Medium
Northern pintail (*Anas acuta*)	-4.67	Low
Northern shoveler (*Anas clypeata*)	2.05	Medium
Ruddy duck (*Oxyura jamaicensis*)	-1.34	Low
White-winged scoter (*Melanitta fusca*)	-19.6	Low
Wood duck (*Aix sponsa*)	3.99	Low
Redhead (*Aythya americana*)	2.02	Low

Source: Environment Canada 2014[258]

Mammals

Boreal Plains Ecozone+ mammals have been affected by landscape changes due to habitat loss and human disturbance.

Bison

Wood Buffalo National Park contains the largest free-roaming herd of bison (Plains *Bison bison bison* and Wood *B. b. athabascae*) left in Canada.[266, 267] This population declined from 1971 to 1999 (Figure 41).

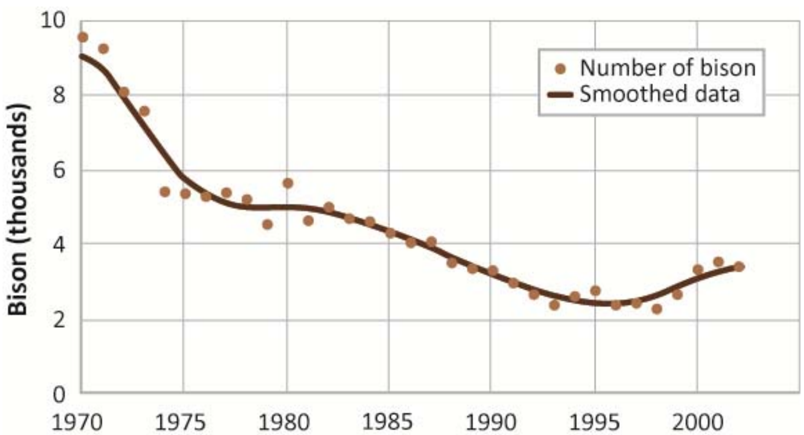

Figure 41. Number of bison in Wood Buffalo National Park, 1971-2003.
Source: after Bradley and Wilmshurst, 2005[267]

There are competing explanations for the population decline:

- decreased survival and reproduction due to tuberculosis, brucellosis (introduced with the plains bison in 1925/1926), and sporadic anthrax outbreaks[268, 269]
- increased predation by wolves[268, 270]
- altered habitat use in the Peace–Athabasca Delta[271]

Population models suggest that wolf predation on juvenile bison, and not just disease, drive these declines, particularly for the Peace–Athabasca Delta subpopulation (Figure 42).[184]

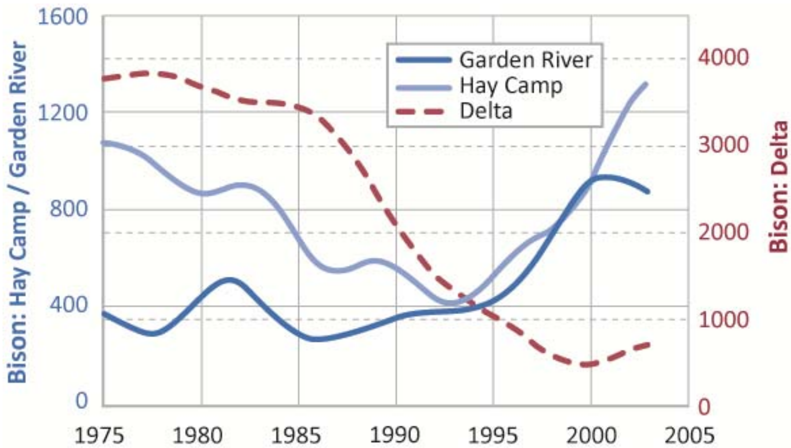

Figure 42. Number of bison in the Delta, Hay Camp, and Garden River subpopulations, 1975-2003. Source: after Bradley and Wilmshurst, 2005[267]

Caribou

Woodland caribou, boreal population (i.e., boreal caribou) was listed as Threatened under the *Species at Risk Act* (SARA) in 2003.[272] The classification of caribou used in this report follows the current *Species at Risk Act* (SARA) classification system. In 2011, COSEWIC adopted 12 designatable units for caribou in Canada that will be used in caribou assessments and subsequent listing decisions under SARA beginning in 2014. This section on boreal caribou is based on the *2011 Scientific Assessment to Inform the Identification of Critical Habitat*[273] and the *2012 Recovery Strategy for the Woodland Caribou* (Rangifer tarandus caribou), *boreal population in Canada*.[274] The information in this report has been updated since the release of the ESTR national thematic report, *Woodland caribou, boreal population, trends in Canada.*[275]

Habitat for boreal caribou in the Boreal Plains Ecozone+ included late seral-stage (> 50 years old) conifer forest (jack pine, black spruce, tamarack, *Larix laricina*), treed peat lands, muskegs and bogs with some elevation (~1135 m).[274] Caribou also selected old (>40 years) burns.[274] Bogs and mature forests were selected for calving, as well as islands and small lakes, which provide protection from predators.[275-280] Boreal caribou in the Boreal Plains Ecozone+ are declining and at risk of local extirpation in some areas of their distribution (Figure 43). Of the 19 local caribou populations in the Boreal Plains Ecozone+, 16 were considered not self-sustaining or as likely as not self-sustaining in 2012 (Table 13).[274] Like bison, boreal caribou have declined in response to increased predation facilitated by human disturbance.[275] Increased industrial disturbance and expansion of linear elements (roads and seismic cut-lines) provide easier access for predators like wolves.[275-280]

Table 13. Boreal caribou local population condition and habitat condition in the Boreal Plains Ecozone+.

Range Name	Range Type	Population Size Estimate	Population Trend	Disturbed Habitat (%)	Risk Assessment*
Chinchaga	LP	250	Declining	76	NSS
Caribou Mountains	LP	315-394	Declining	57	NSS
Little Smoky	LP	78	Declining	95	NSS
Red Earth	LP	172-206	Declining	62	NSS
West Side Athabasca River	LP	204-272	Declining	69	NSS
Richardson	LP	150	Not available	82	NSS
East Side Athabasca River	LP	90-150	Declining	81	NSS
Cold Lake	LP	150	Declining	85	NSS
Nipisi	LP	55	Not available	68	NSS
Slave Lake	LP	65	Not available	80	NSS
Boreal Plain	CU	Not available	Not available	42	NSS/SS
The Bog[1]	ICU	50-75	Stable	16	NSS/SS
Naosap[1]	ICU	100-200	Stable	50	NSS
Reed[1]	ICU	100-150	Stable	26	SS
North Interlake[1]	ICU	50-75	Stable	17	NSS/SS
William Lake[1]	ICU	25-40	Stable	31	NSS
Wabowden[1]	ICU	200-225	Stable	28	SS
Manitoba North[1]	CU	Not available	Not available	37	NSS/SS
Manitoba South[1]	CU	Not available	Not available	17	SS

*Self-sustaining (SS), Not self-sustaining (NSS)

[1]The Government of Manitoba is in the process of updating their range boundaries. This will result in an update to current range delineations, as well as a revision of their self-sustainability status following integrated risk assessment of any new range boundaries.

The Range Type lists the different classification of local populations based on updated range boundaries for boreal caribou provided by jurisdictions, which were subsequently classified into three types reflecting the level of certainty in range boundaries: Local Population (LP – high certainty), Improved Conservation Units (ICU – medium certainty), and Conservation Units (CU – low certainty).

Disturbed habitat includes both anthropogenic disturbance (to which a 500m buffer is applied to all linear and polygonal differences) and fire disturbance (any area where a fire has occurred in the past 40 years; no buffer applied). Anthropogenic and fire disturbances that overlap are not counted twice in the total disturbance.

Source: Environment Canada 2012[274]

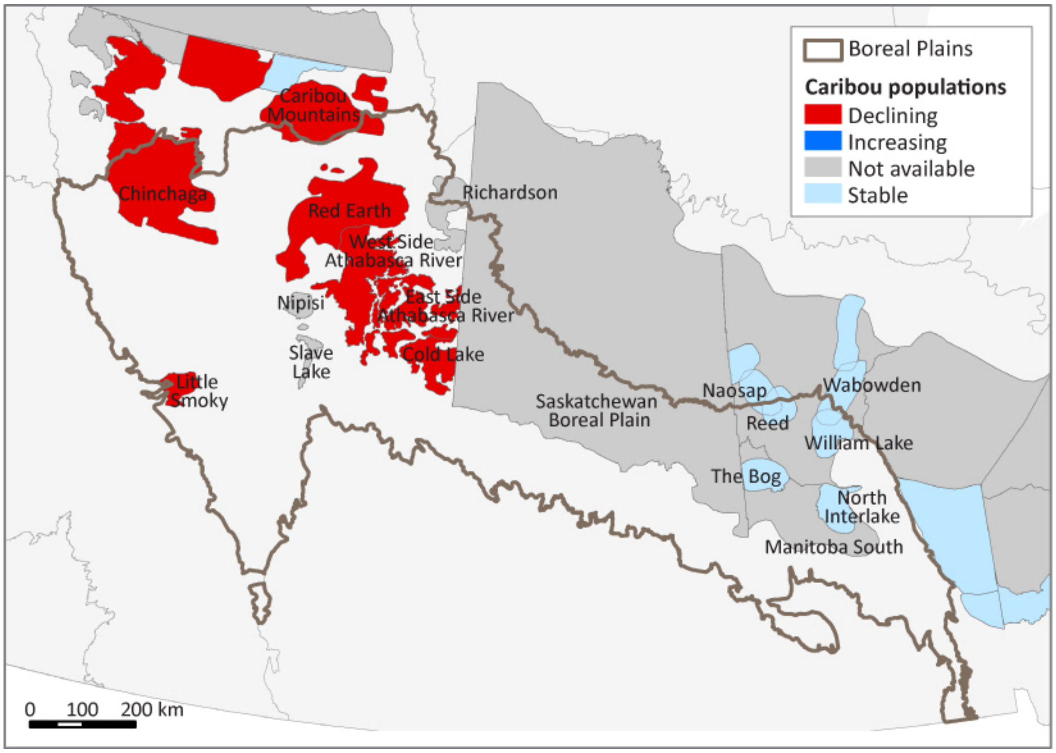

Figure 43. Status of boreal caribou local populations in the Boreal Plains Ecozone+.
Source: updated from Callaghan et al., 2011[275] based on Environment Canada, 2012[274]

In the Athabasca oil sands area, human footprint for the six woodland boreal caribou sub-population ranges in 2010 varied from <1% to >7%.[241]

Grizzly bears

Grizzly bears once ranged across the boreal region of Canada as well as the grasslands of Alberta, Saskatchewan, and Manitoba[281] (Figure 44). Grizzly bear populations are now restricted to British Columbia and the western foothills and plains of Alberta because of human settlement and land conversion.

Figure 44. Reduction in the range of grizzly bear in North America.
Source: after Hummel and Ray, 2008[282]

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.

Primary productivity is the basis of food webs in most ecosystems. Remote sensing of green vegetation provides a useful means to assess primary productivity and changes in productivity due to disturbance.[283] The status and trends in primary productivity for the Boreal Plains Ecozone+ were assessed using two remote sensing indices, the Normalized Difference Vegetation Index (NDVI) and the Dynamic Habitat Index (DHI). Overall, trends indicate primary productivity is increasing more than decreasing across the ecozone+ with the increases mainly driven by increased agricultural production.[8] Agricultural land also has the highest seasonal variation in primary productivity as do areas that have recently burned (Table 14).[283]

Normalized Difference Vegetation Index

The NDVI, a remote-sensing based measurement of photosynthetic activity, measures the amount and vigour of green vegetation.[8] Primary productivity increased on 20.8% of the Boreal Plains Ecozone+ between 1985 and 2006, and decreased on less than 1% (Figure 45). These trends were scattered throughout the ecozone+, although increased primary productivity was detected most often in agricultural areas. Two patches of strong negative NDVI trends appear to be associated with the Athabasca oil sands development in Alberta (Figure 45).

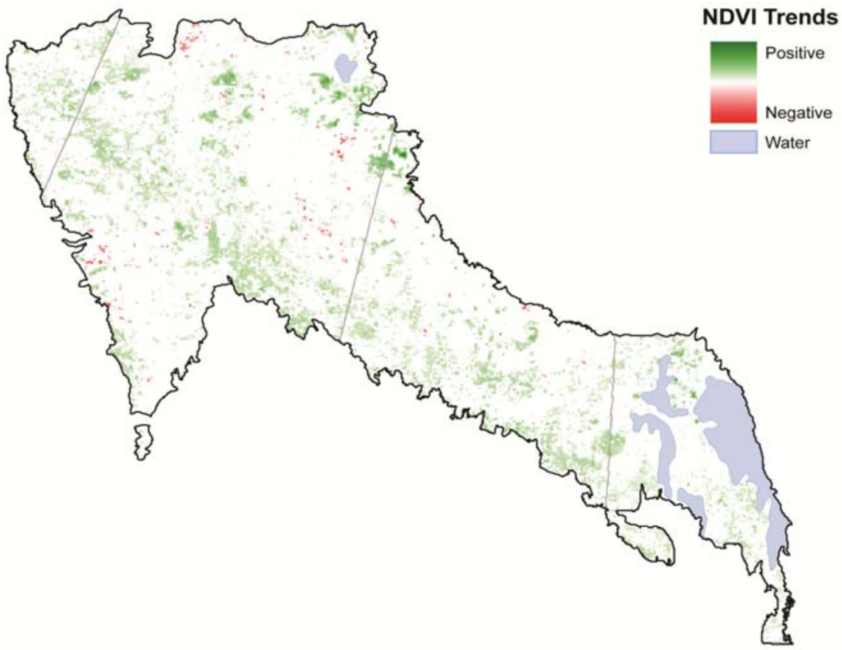

Figure 45. Normalized Difference Vegetation Index (NDVI) trends for the Boreal Plains Ecozone+ from 1985–2006.
Trends are in annual peak NDVI, measured as the average of the 3 highest values from 10-day composite images taken during July and August of each year. Spatial resolution is 1 km, averaged to 3 km for analysis. Only significant (p<0.05) trends are reported.
Source: adapted from Pouliot et al., 2009[284] by Ahern, 2011[13]

Although NDVI trends in the northern regions of Canada have been conclusively attributed to climate change, trends in the Boreal Plains Ecozone+ and other regions in the southern part of the country are likely responding to multiple factors[284] such as: increased agricultural production;[13] the natural cycle of fire and succession (which reduced primary productivity in recently burned areas but increased productivity in regenerating forests);[284, 285] climate change (especially precipitation changes);[284] and forestry operations (for example, early-succession broadleaf vegetation has higher primary productivity than late-succession conifers).[284]

Dynamic Habitat Index

The Canadian Dynamic Habitat Index (DHI), also an index derived from remote sensing, can also be used to examine the primary productivity of a region. The DHI (developed using the fraction of photosynthetically active radiation or fPAR) is more directly related to photosynthesis than NDVI as it is calculated from a physically based model of the propagation of light in plant canopies.[283] The DHI is a composite of three indicators of vegetation change:

1) cumulative annual greenness (measure of primary productivity);
2) annual minimum vegetation cover (the lowest level of perennial cover); and
3) seasonal variation in greenness (vegetation seasonality).[8, 283]

The Boreal Plains Ecozone+ transitions from an urban and agriculture dominated landscape in the south to a forested landscape in the north resulting in high variation in the DHI from 2000–2006 (Table 14).[283] Although this time period is too short to analyze trends, it does provide a baseline upon which future changes can be compared. As plant communities move further north and/or to higher altitudes as the climate warms, the seasonal variation in greenness could serve as an indicator of the effects of climate change on vegetation.[8]

Table 14. Summary of vegetation characteristics measured by Dynamic Habitat Index (DHI) indicators of vegetation change in the Boreal Plains Ecozone+ (average over 2000–2006).

Annual cumulative greenness (primary productivity)	Average annual minimum vegetation cover (lowest level of cover)	Average degree of vegetation seasonality (vegetation seasonality
Variable; lowest in agricultural areas*	Variable, lower in agricultural areas; lowest in patches that are likely fire scars	Variable, higher in agricultural areas and in patches that are likely fire scars

**This result appears to contradict NDVI results but this is not the case. The increasing trend in primary productivity in the ecozone+ as indicated by the NDVI is due to increased agricultural production. By comparison, the DHI measure of cumulative annual greenness indicates that when averaged over the year, agricultural areas have lower annual primary productivity when compared with other vegetation types across the ecozone+ (e.g., forests).*
Source: Ahern et al., 2011[8]

Primary productivity in freshwater

Primary productivity has also increased in aquatic ecosystems in the Boreal Plains Ecozone+; the frequency of algal blooms is on the rise as a result of increased nutrient loading in lakes and rivers. For example, the Nelson River drainage in the southeastern region of ecozone+ has been particularly impacted by nutrient loading. As a result, large algal blooms have been occurring with increasing frequency in Lake Winnipeg since the mid-1990s (see the Nutrient loading section on page 34).

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

Natural disturbance

National key finding
The dynamics of natural disturbance regimes, such as fire and native insect outbreaks, are changing and this is reshaping the landscape. The direction and degree of change vary.

Natural disturbance is a primary driver of ecosystem variability and processes in the Boreal Plains Ecozone+ with both fire and native insect outbreaks serving as important agents of change. Fire season duration and seasonality have remained relatively unchanged in the Boreal Plains Ecozone+, but other fire characteristics (e.g., frequency, size) are more variable. Native insect outbreaks are regionally common throughout the Boreal Plains. The mountain pine beetle (*Dendroctonus ponderosae*) is of particular concern as it is expanding its range in the ecozone+.

Fire

Fire is an important natural disturbance in the Boreal Plains Ecozone$^+$. On average, 2,214 km^2 of the forested area in this ecozone$^+$ burns each year, but this can range from less than 200 km^2 to over 6,000 km^2.[286] The area burned in the Boreal Plains represents 11% of the total area burned annually in Canada but only 0.47% of the ecozone$^+$. The proportional area burned is comparable to neighbouring ecozones$^+$ the Boreal Shield (0.49%) and Taiga Cordillera (0.47%) and lower than the Taiga Shield (0.77%) and Taiga Plains (0.71%).[286] Approximately 90% of this ecozone$^+$ is protected by fire suppression activities, the highest of all the ecozones$^+$.[287] Fires are actively suppressed in the ecozone$^+$ due to the abundance of high value elements including populated communities, forestry resources, and infrastructure.[288] The low proportion of fires may also be due to the abundance of deciduous or mixedwood forest (24% of the ecozone$^+$)[27] which are less prone to burning.[289] Humans were also responsible for 57% of ignitions of large fires in this ecozone$^+$ over the last 40 years. Lightning-caused fires, however, were the dominant cause of fires in the 1990s.[286]

Based on 40 years of available data, both fire season duration and seasonality have remained relatively unchanged during this time period.[286] At 5 months, the Boreal Plains Ecozone$^+$ had the longest fire season of all the ecozones$^+$ primarily due to human-caused fires which prolonged the fire season.[286] Human-caused fires were most common during the spring fire season, lightning-caused fires predominated in the summer, and humans were generally responsible for the infrequent fires that occurred in the fall. Although the Boreal Plains Ecozone$^+$ has severe fire weather, this did not translate into severe fires.[287, 289, 290]

In the Boreal Plains Ecozone$^+$, trends in area burned were also related to differences in monitoring and detection over the past five decades.[286] The area burned was relatively low in the 1960s and 1970s, peaked during the 1980s, and then declined (Figure 46). The amount of burned area was likely underestimated during the 1960s and 70s due to poor monitoring and detection. The declines in the past 20 years may be attributed, in part, to improvements in detection and firefighting techniques and/or increased prevention efforts, as well as changes in fire weather.[291-294]

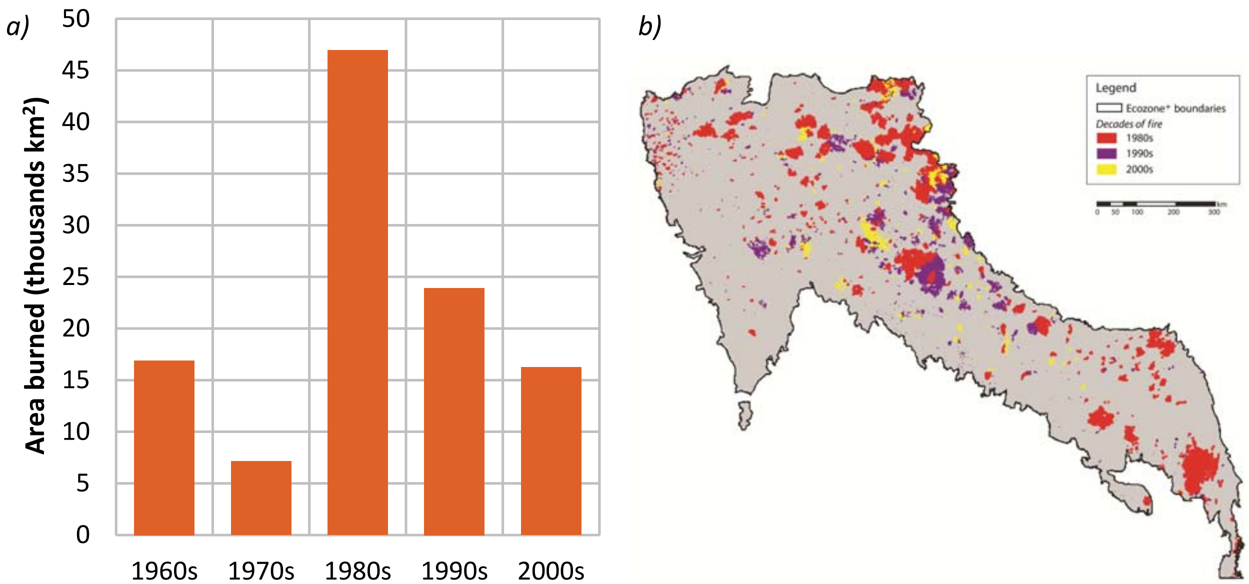

Figure 46. Trend in a) total area burned per decade and b) distribution of large fires (>2 km^2) by decade for the Boreal Plains Ecozone+.
The value for the 2000s decade was pro-rated over 10 years based on the average from 2000–2007.
Source: Krezek-Hanes et al., 2011[286]

Insect outbreaks

Insect defoliators are the other major natural disturbance in the Boreal Plains Ecozone+, including several deciduous defoliators, spruce budworm (*Choristoneura fumiferana*), and mountain pine beetle.

Data on insect defoliators are typically available at the province-wide scale. Alberta values were extracted using GIS or through a downwards correction using a conversion factor based on comparisons between Boreal Plains Ecozone+-specific and provincial data. Province-wide data was presented for Saskatchewan[295] because most surveys for forest insects occurred in the Boreal Plains Ecozone+.[296]

Deciduous defoliators

Important deciduous defoliators in the Boreal Plains Ecozone+ include forest tent caterpillar (*Malacosoma disstria*), large aspen tortrix (*Choristoneura conflictana*), bruce spanworm (*Operophtera bruceata*), aspen twoleaf tier (*Enargia decolour*), and aspen leafroller (*Pseudecenterra oregonana*). Forest tent caterpillars are the most important defoliators of trembling aspen, the dominant deciduous tree in the ecozone+. Outbreaks do not occur in synchrony across the Boreal Plains Ecozone+. Defoliation appears to be cyclical in Alberta, following a 10-year outbreak cycle with peak values heightened in more recent years.[297] In Saskatchewan, peak-cycle annual defoliation has diminished since a recorded high of 36% in 1979. At a regional scale, insect defoliation leads to reduced growth in trembling aspen.[22]

Spruce budworm

Spruce budworm is considered the most destructive forest defoliator in North America leading to reduced tree growth and increased tree mortality during severe outbreaks.[298] While it is most damaging to older, denser forest stands, all host stands are vulnerable when spruce budworm populations are high. Defoliation in the Boreal Plains Ecozone+ peaked during 1992–2003 in Alberta and Saskatchewan, and then declined in most areas. The temporal extent of these data was too short to examine trends in spruce budworm population cycles, as the length of time between peaks is approximately 30–35 years.[298]

Mountain pine beetle

Until recently, the Boreal Plains Ecozone+ was outside the range of mountain pine beetles.[299] Only two mountain pine beetle outbreaks have occurred in Alberta in the past, and both were restricted to areas south of the Boreal Plains.[300] However, mountain pine beetles have expanded their range significantly in recent years.[299] Warmer winters, fire suppression, and continued dispersal increase the probability of range expansion. Since 2005, mountain pine beetles have spread eastward across the Rocky Mountains affecting tens of thousands of square kilometres of lodgepole pine and lodgepole pine x jack pine hybrid forests in western portions of the Boreal Plains Ecozone+ (Figure 47).[301, 302] Alberta has responded with an aggressive management strategy aimed at preventing the further spread of beetles.[303]

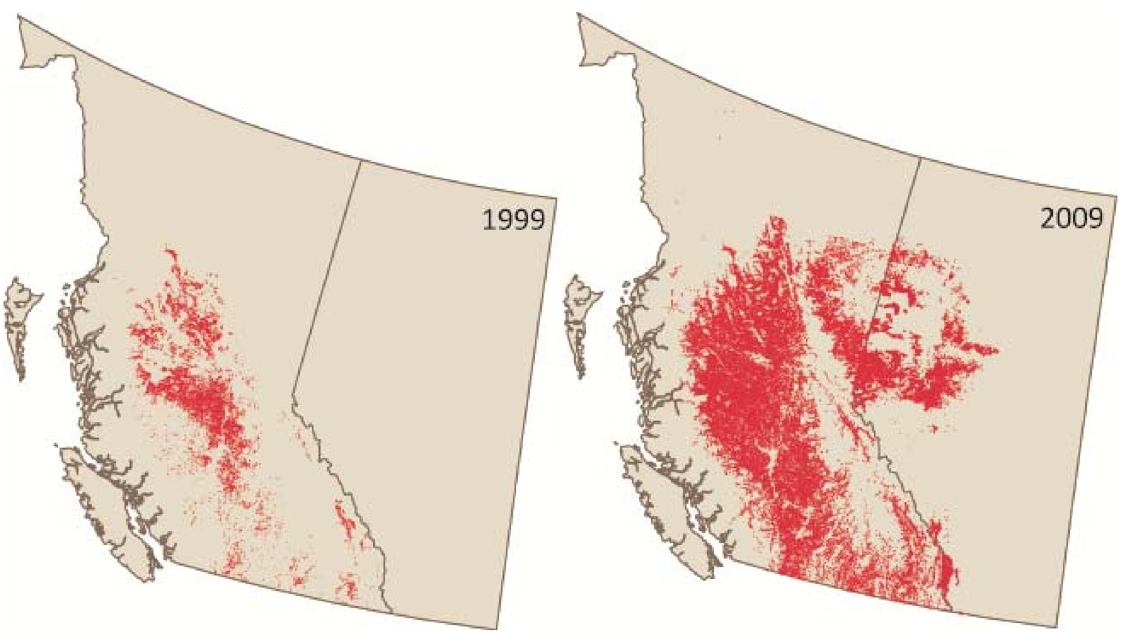

Figure 47. Area affected by mountain pine beetle increased eastward from 1999 (left) to 2009 (right). Source: BC Ministry of Forests and Range, 2010[304] and Alberta Sustainable Resource Development, 2010[303]

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.

Food webs and population cycles are important because they shape the structure and function of ecosystems. In the Boreal Plains Ecozone+, trophic dynamics appear to be changing in terrestrial and likely freshwater ecosystems, facilitated by factors such as industrial development and a warming climate. As elsewhere in the boreal forest, pronounced cycles in the abundance of predator-prey populations are also known to occur in the Boreal Plains Ecozone+.

Food webs

Trophic dynamics and its impact on caribou

Predator-prey interactions have changed with increasing fragmentation and linear disturbance from industrial development in northeastern Alberta. Predation on caribou has increased due to linear features and human disturbance, which have given grey wolves greater access to caribou habitat.[305-308] In addition, the abundance of deer has increased and resulted in increased wolf densities and consequently higher incidental predation on caribou.[309] The increases in wolf population coupled with increasing predation risk for caribou due to increasing fragmentation, have likely worked synergistically to cause the extensive declines in caribou over the past several decades.

Potential impacts of climate change on freshwater food webs

Climate change can cause changes to food webs because interacting species respond differently to shifting environmental conditions; these changes may be especially dramatic in aquatic ecosystems where trophic interactions are typically strong.[310] Aquatic food webs in certain lakes in the Boreal Plains Ecozone+ are somewhat resilient to disturbances like forest harvesting and fires,[311, 312] however, information is lacking on the impacts of climate change on aquatic food webs in the region. Even slight changes in climate and drought are known to cause complex and unpredictable changes in boreal lakes and streams.[313] Warmer spring temperatures, as observed in this ecozone+ (see the Climate change section, Table 5 on page 42) disrupt trophic linkages between phytoplankton and zooplankton in temperate lakes because of differing sensitivity to the warming; this changes the flow of resources to upper trophic levels in pelagic ecosystems.[314] In general, warmer temperatures and associated changes in precipitation, evaporation, salinity, and shorter ice seasons affect aquatic organisms in the ecozone+,[74, 162] with corollary effects on aquatic food webs. Given that the Boreal Plains Ecozone+ is home to thousands of lakes and river systems, the impacts of climate change on aquatic food webs may be an emerging issue for the ecozone+. In addition, aquatic food webs can be altered by a number of other disturbances including increased nutrients, invasive species, and overfishing.[315, 316] The cumulative effects of these disturbances on aquatic food webs in the Boreal Plains Ecozone+ are unknown.

Population cycles

Long-term fur trapping records from Hudson's Bay posts identified cycles in the abundance of certain predator-prey populations, such as the ten-year cycle of lynx and snowshoe hare.[317, 318] The lynx-hare cycle did not change significantly from 1821 to 2000;[318] however, Peace, Athabasca, and Slave River Basin Aboriginal Peoples suggest that the length of time between high and low population peaks in the cycle may be increasing.[319]

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.

The Boreal Plains Ecozone+ does not have a harmonized framework for biodiversity monitoring, research, information management, or reporting. Although many monitoring and research initiatives are operational within the Boreal Plains Ecozone+, spatial and thematic coverage is compartmentalized. Steps to harmonize biodiversity monitoring and research are underway through the Joint Canada-Alberta Implementation Plan for Oil Sands Monitoring in the western portion of the ecozone+.

Alberta Biodiversity Monitoring Institute

The ABMI is an arm's length, not-for-profit scientific organization that measures and reports on the state of biodiversity and human footprint across Alberta.[240] To do this, the ABMI has 1,656 monitoring sites systematically distributed every 20 km where this ecozone+ overlaps with provincial boundaries (Figure 48).[240] Approximately 58% of the Boreal Plains Ecozone+ is monitored by the ABMI. The ABMI is designed to operate in perpetuity and throughout the Boreal Plains Ecozone+ of Alberta; however, it is presently operating at only about 50% of its designed capacity in this ecozone+.

The ABMI is designed to measure and report on the state of land, water, and wildlife in Alberta using a suite of indicators including human land use, species, and habitats. This monitoring framework includes the integrated collection and management of data for many species of mammals, birds, plants, moss, lichen, soil mites, aquatic invertebrates, and fish. Data generated by the ABMI are value-neutral, independent, and most are publicly accessible. The ABMI works with federal and provincial agencies to implement scientifically credible monitoring for biodiversity in the oil sands areas of Alberta. This includes the Athabasca, Peace River, and Cold Lake oil sands areas.

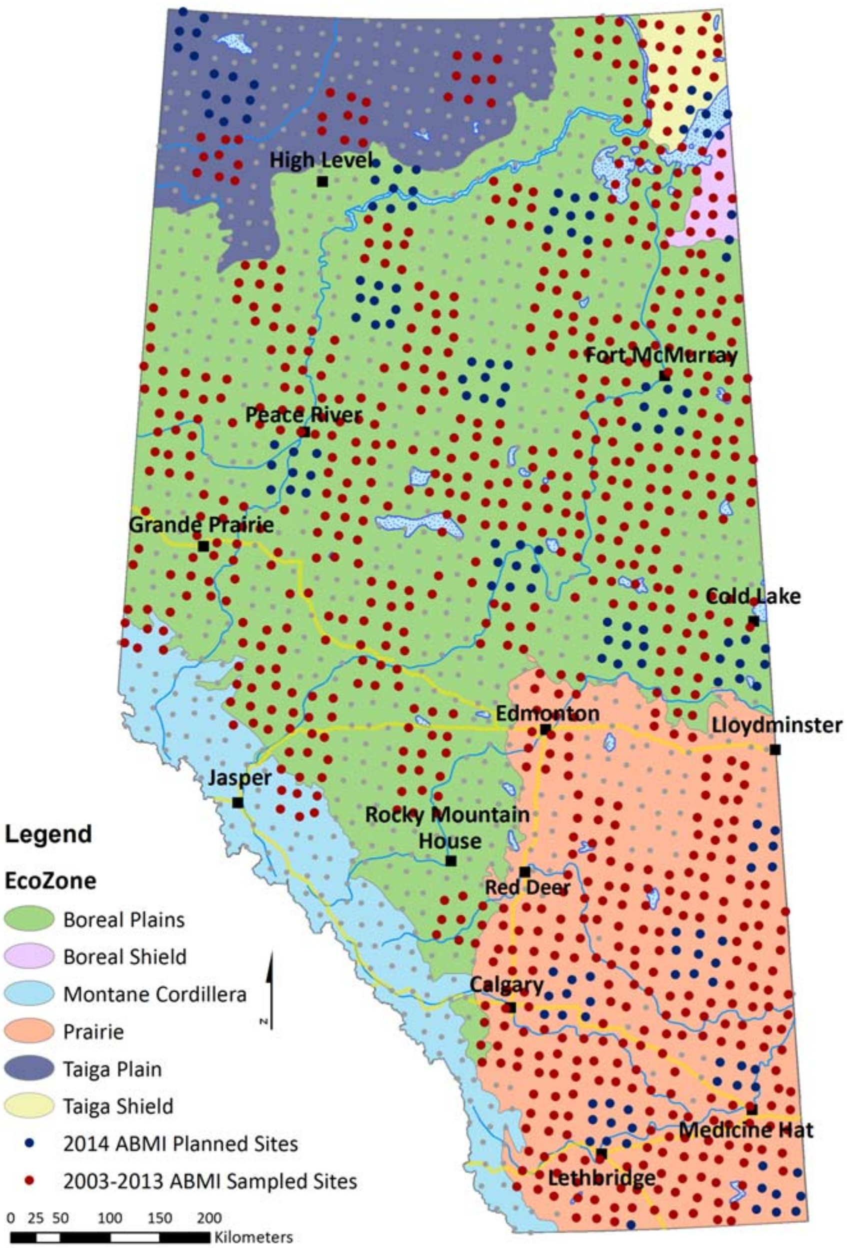

Figure 48. The Alberta Biodiversity Monitoring Institute's core sampling sites across Alberta. Source: Alberta Biodiversity Monitoring Institute, 2013[240]

Joint Canada-Alberta Implementation Plan for Oil Sands Monitoring

The Joint Canada-Alberta Implementation Plan for Oil Sands Monitoring is an environmental monitoring program designed to monitor the long-term cumulative effects of oil sands development on water, air, land, and biodiversity. The three-year implementation plan, which began in 2012, extends over 140,000 km^2. The primary objective of Terrestrial Biodiversity (toxics) monitoring is to assess the levels and effects of oil sands-related contaminants and their influence on the health of individual wildlife and wildlife populations proximal to and at varying distances from oil sands operations. Some of the components of the monitoring plan include:

1. Monitoring the effects of oil sands activities on breeding waterbird populations, diet, and egg contaminants downstream from the oil sands on the Athabasca River and Lake Athabasca
2. Monitoring the impacts of contaminants associated with oil sands processing on the health and development of amphibian (i.e., wood frog) indicator species
3. Monitoring the effects of oil sands contaminants on avian health using non-lethal measures of stress and physiological response
4. Toxicological assessments of hunter/trapper-harvested wildlife (waterfowl and mammals), and dead and moribund birds in oil sands impacted areas and lower reaches of the Athabasca River
5. Use of native plants to monitor the condition of oil sands-associated wetlands

The plan also includes monitoring the impact of habitat disturbance and mitigation on terrestrial biodiversity. Data from the program will be made publicly available from a portal (www.JointOilSandsMonitoring.ca).

Boreal Avian Modelling Project

The Boreal Avian Modelling Project (BAM)[320] is a land-bird data management and research initiative that aggregates data from across North American boreal forests including all of the Boreal Plains Ecozone+. Using quantitative modelling techniques, BAM derives information on abundance, distribution, and habitats of boreal birds, and uses this to evaluate and predict the effects of human activity. Biophysical data is also being assembled from remote-sensing and forest resource inventories including climate, land cover, and forest productivity indices. Several regional songbird monitoring initiatives are conducted under BAM through collaboration with university researchers.

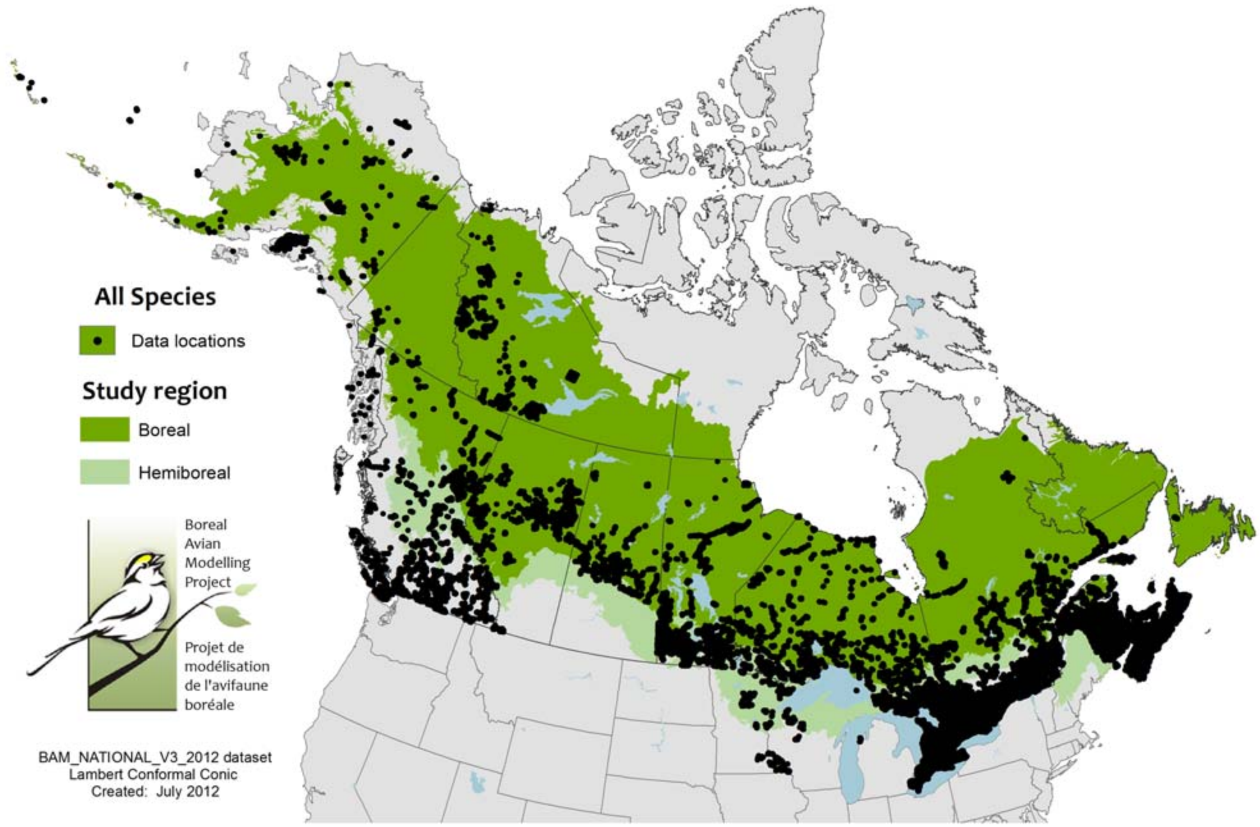

Figure 49. Bird point-count sites compiled by the Boreal Avian Modeling Project.
Source: Boreal Avian Modelling Project, 2014[320]

Waterfowl Breeding Population and Habitat Survey

The Waterfowl Breeding Population and Habitat Survey is a collaborative initiative between the United States Fish and Wildlife Service and the Canadian Wildlife Service that was initiated in 1955. The primary purpose of the survey is to provide information on spring population size and trends for certain North American duck species (with particular focus on mallards). Data from these surveys are used extensively in the annual establishment of hunting regulations in the United States and Canada and provide long-term time series critical to effective conservation planning for waterfowl.[321]

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.

In the Boreal Plains Ecozone+, forest fragmentation, fire and insect disturbances, invasive species, contamination, climate change, acidification, and food web perturbations are all stressors that may be causing rapid, irreversible changes to the ecozone+. However, detecting rapid change or breached ecological thresholds requires more spatially and temporally comprehensive data than is available for the ecozone+. Given available data, rapid change in the Boreal Plains Ecozone+ may have been caused by insect outbreaks, habitat loss and fragmentation, melting permafrost, and invasive species.

Insect outbreaks

Mountain pine beetle

British Columbia has experienced unprecedented mountain pine beetle infestations over the last decade and infestations have recently spread to Alberta. Since 2005, the mountain pine beetle has spread eastward across the Rocky Mountains affecting tens of thousands of square kilometres of lodgepole pine and lodgepole pine x jack pine forests in western portions of the Boreal Plains Ecozone+.[301, 302] If left unchecked, it is possible that mountain pine beetle could expand its range further eastward through the Boreal Plains Ecozone+ and beyond.[299, 300] Warmer winters, fire suppression, and continued dispersal increase the probability of range expansion (see the Mountain pine beetle section on page 74).

Forest fragmentation and loss

Woodland caribou, boreal population (i.e., boreal caribou) are classified as threatened by COSEWIC,[272] and are declining and at risk of local extirpation in some areas of their range (see the Caribou section on page 66).The decline of boreal caribou in the Boreal Plains Ecozone+ has been linked to two factors that have altered predator-prey dynamics in the area. First, habitat loss and fragmentation, specifically linear disturbances (roads and seismic lines) associated with oil and gas development, has increased grey wolf access to caribou habitat.[193] Second, white-tailed deer (*Odocoileus virginianus*) populations have increased, likely in response to warmer temperatures and habitat disturbance, which has created more habitat favouring deer.[309, 322] More deer increases available prey for grey wolves.[309] These two factors likely caused the extensive declines in caribou over the past several decades.

There is a threshold of habitat required to sustain populations of forest-dependent species, particularly old-forest specialists.[323] Most of the Boreal Plains Ecozone+ remains intact for most species,[241] however, habitat thresholds have been breached in some areas. For example, American marten require complex habitat structure (e.g., coarse woody debris) and forest cover. Marten could not persist in parts of the west Boreal Plains of Alberta where >36% of the area is developed by forestry, mining, and/or other industrial activities.[324]

Although populations of forest birds have not declined to date, the expected future landscape condition is not expected to support current populations of bird species that prefer mature and old boreal forests.[43] Species such as black-throated green warbler, boreal chickadee, and western tanager prefer unfragmented, mature forest types. These forests are being lost, subdivided, and perforated by logging, oil sands development, and an expanding network of seismic lines, pipelines, production and exploration wellsites, power/utility lines and access roads.[43] Climate change-induced forest fires are expected to increase, thus causing further population declines for mature and old forest-associated landbird species because the increased fire rate could lead to earlier and more substantial declines in old forest types.[43]

Thawing of permafrost

Permafrost is melting along the northern perimeter of the ecozone$^+$ in response to increases in average air temperature.[53] Changes in biodiversity, landscape and hydrology are expected in the Boreal Plains Ecozone$^+$ but the actual impacts are unknown (see Permafrost section on page 23 for more details).

Invasive species

Currently there is limited information on the distribution and abundance of invasive species across the Boreal Plains Ecozone$^+$.[126] Further, the threshold level of disturbance and/or fragmentation in the boreal forest that could enhance invasive species spread is unknown. However, continued industrial development may present windows of opportunity for non-native species to establish and spread. The populations of non-native species that are present in the ecozone$^+$ may serve as nascent sources for a much wider invasion once a particular disturbance threshold has been reached.[325, 326]

CONCLUSION: HUMAN WELL-BEING AND BIODIVERSITY

The Boreal Plains Ecozone$^+$ acts as a transition zone between agricultural areas in the south and forested areas in the north of the ecozone$^+$. Historically, frequent wide-spread natural disturbances including fire, insect outbreaks and wind, created a heterogeneous landscape supporting a diversity of ecosystems, habitats and wildlife species. However, the Boreal Plains is also rich in renewable and non-renewable resources such as agriculture, forestry, and oil and gas deposits. These activities are now impacting ecosystems in a variety of ways, putting increasing pressure on ecosystem services across the ecozone$^+$. In addition, climate change is a large-scale phenomenon that is predicted to impact all ecosystems in the Boreal Plains Ecozone$^+$.

A large number of ecosystem services are provided by the Boreal Plains Ecozone$^+$; for example, provisioning services, such as forest harvesting and agriculture, are important economic drivers in the Boreal Plains. Forests dominate the landscape of the Boreal Plains Ecozone$^+$. Forest extent and intactness have declined due to forest harvesting, agricultural expansion, and increased industrial development (see the Forests section on page 11). The mountain pine beetle is of particular concern to boreal forests as it expands it range in the ecozone+ (see the Insect outbreaks section on page 73). Agriculture has driven human settlement in the Boreal Plains Ecozone+ and continues to expand; however, the potential of agricultural land to support wildlife has declined mainly due to the loss of natural land cover (see the Potential wildlife use of agricultural lands section on page 52).

The Boreal Plains also provides a range of other ecosystem services (e.g., water supply and regulation, biodiversity, cultural) that are under pressure from continued human and industrial activity. For example, water allocation of the Athabasca River for oil sands processing, and reduced flow due to climate change, could reduce available habitat for fish and other wildlife (see the Water stresses section on page 21). In addition, inputs of contaminants and nutrients from a variety of sources (e.g., oil sands development, forestry, agriculture) have reduced water quality across the ecozone+ (see the Water quality section on page 22 and the Contaminants section on page 30).

Climate change has impacted stream hydrology, lowered lake water levels, and altered flood regimes across the ecozone+ (see the Climate change impacts: stream flows, temperature and water levels section on page 19, the Water stresses section on page 21, and the Climate change impacts on ecosystems section on page 44). In addition, warming has resulted in a shorter ice season and has melted permafrost from the southern extent of its historical range (see the Permafrost section on page 23). Combined, these effects could result in large-scale changes to hydrological dynamics across the ecozone+ in the future.

Human activities in the Boreal Plains Ecozone+ are also impacting wildlife populations and food web dynamics (see the Species of special economic, cultural, or ecological interest section on page 55 and the Food webs section on page 75). Caribou have declined in response to increased wolf predation facilitated by human disturbance. Several commercial and sport fisheries have collapsed in boreal lakes as a result of overfishing. With the exception of the forest bird assemblage, all other bird habitat guilds are declining in the Boreal Plains Ecozone+ and the high rate of resource development further threatens bird populations (see the Birds section on page 59).[255] However, other species, like Canada geese and white-tailed deer, are experiencing increases in their range and are likely benefiting from human disturbance and climate change.

Biodiversity and ecological integrity maintain the quality of life for humans.[327] The steady visitation rates to national parks (see the Cultural services section on page 49) and the increase in protected areas in the ecozone+ (see the Protected areas section on page 25) indicate the value that people in this region place on preservation of the natural environment. Understanding ecosystem functions, monitoring ecosystem status and trends, and taking action to mediate negative impacts and preserve the natural legacy of the area, will ensure that the environment and the services it provides will be sustained for future generations.

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