Boreal Shield and Newfoundland Boreal ecozones⁺ evidence for key findings summary

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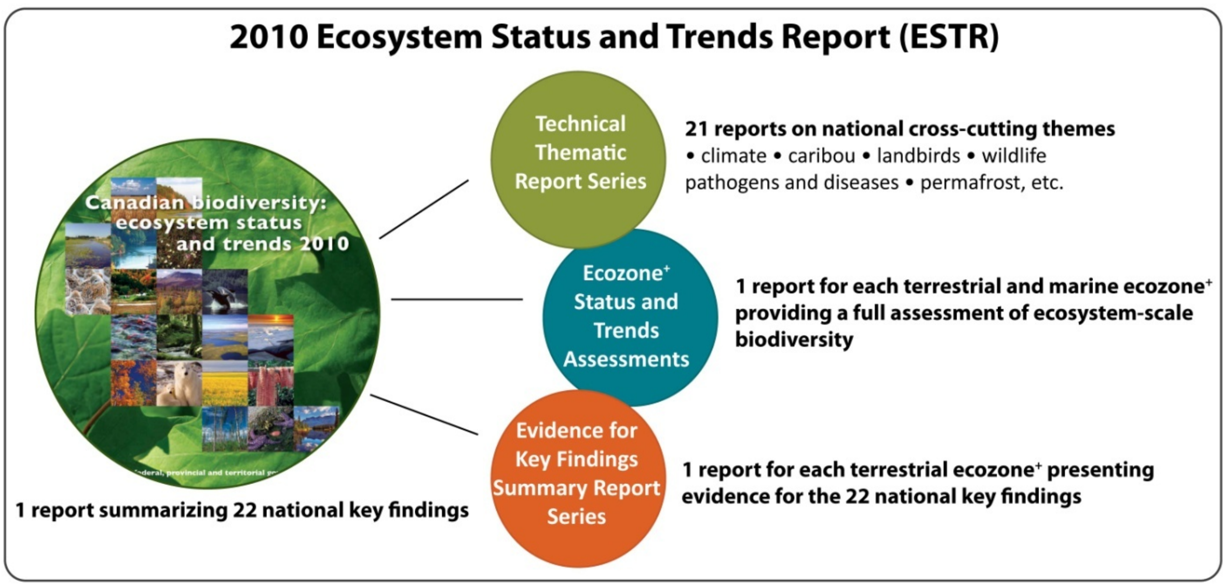
PREFACE

The Canadian Councils of Resource Ministers developed a Biodiversity Outcomes Framework [2] in 2006 to focus conservation and restoration actions under the *Canadian Biodiversity Strategy*.[5] *Canadian Biodiversity: Ecosystem Status and Trends 2010*[6] 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 Assessment Report Series). 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).

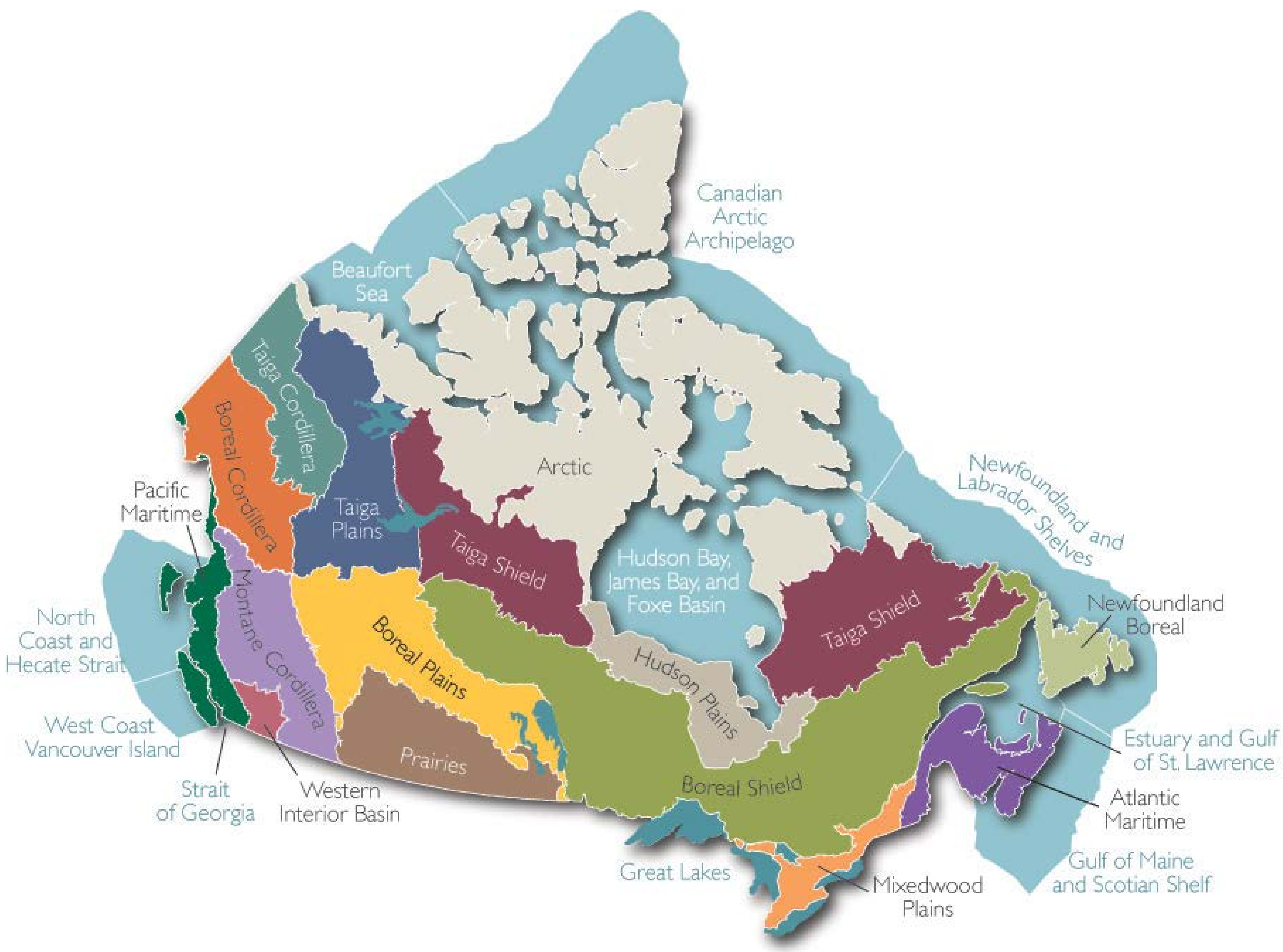


This report, *Boreal Shield and Newfoundland Boreal ecozones⁺ Evidence for Key Findings Summary*, presents evidence from the Boreal Shield and Newfoundland Boreal ecozones⁺ related to the 22 national key findings and highlights important trends specific to these ecozones⁺. This summary report draws from the *Boreal Shield Ecozone⁺ Status and Trends Assessment*[7] and the draft *Newfoundland Boreal Ecozone⁺ Status and Trends Assessment*, as well as the national Technical Thematic Report series that were part of the Ecosystem Status and Trends Report program. 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.

Although the Boreal Shield and Newfoundland Boreal ecozones+ were treated in separate reports in the Status and Trends Assessments, they were combined for this Evidence for Key Findings Summary because some of the Technical Thematic reports combined these ecozones+ and because the original framework[8] combined these areas into one Boreal ecozone. Whenever possible, information for the two ecozones+ was distinguished for this report.

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.[8] For the Boreal Shield, the boundary between the Hudson Plains and Boreal Shield ecozones was updated within Ontario, and Newfoundland is treated as a separate ecozone+, the Newfoundland Boreal Ecozone+.



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The ESTR Secretariat acknowledges Gregg Sheehy, Shelley Pardy Moores, and Isabelle Turcotte for the preparation of various drafts of the report. This report was overseen and edited by Emily Gonzales. Kelly Badger was the lead graphics designer. Additional support was provided by Ellorie McKnight, Michelle Connolly, Eric Jacobsen, Clementine Hiltner, and others. It is based on the draft *Boreal Shield Ecozone$^+$ Status and Trends Assessment*[7] and the draft *Newfoundland Boreal 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.

Boreal Shield Ecozone$^+$

Boreal Shield Ecozone$^+$ Status and Trends Assessment acknowledgements

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Large-scale climate oscillations influencing Canada, 1900–2008: B. Bonsal, and A. Shabbar
Canadian climate trends, 1950–2007: X. Zhang, R. Brown, L. Vincent, W. Skinner, Y. Feng, and E. Mekis
Trends in large fires in Canada, 1959–2007: C.C. Krezek-Hanes, F. Ahern, A. Cantin, and M.D. Flannigan
Wildlife pathogens and diseases in Canada: F.A. Leighton. Contributors: I.K. Barker, D. Campbell, P.-Y. Daoust, Z. Lucus, J. Lumsden, D. Schock, H. Schwantje, K. Taylor, and G. Wobeser
Trends in breeding waterfowl in Canada: M. Fast, B. Collins, and M. Gendron
Trends in permafrost conditions and ecology in northern Canada: S. Smith
Northern caribou population trends in Canada: A. Gunn, D. Russell, and J. Eamer
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Trends in wildlife habitat capacity on agricultural land in Canada, 1986–2006: S.K. Javorek and M.C. Grant
Trends in residual soil nitrogen for agricultural land in Canada, 1981–2006: C.F. Drury, J.Y. Yang, and R. De Jong
Soil erosion on cropland: introduction and trends for Canada: B.G. McConkey, D.A. Lobb, S. Li, J.M.W. Black, and P.M. Krug
Monitoring ecosystems remotely: a selection of trends measured from satellite observations of Canada: F. Ahern, J. Frisk, R. Latifovic, and D. Pouliot
Inland colonial waterbird and marsh bird trends for Canada: D.V.C. Weseloh. Contributors: G. Beyersbergen, S. Boyd, A. Breault, P. Brousseau, S.G. Gilliland, B. Jobin, B. Johns, V. Johnston, S. Meyer, C. Pekarik, J. Rausch, and S.I. Wilhelm
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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 administered by the ESTR Steering Committee. Additional reviews of specific sections were conducted by university researchers in their field of expertise at the request of the authors.

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

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

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

Newfoundland Boreal Ecozone+

Draft Newfoundland Boreal Ecozone+ Status and Trends Assessment acknowledgements

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Large-scale climate oscillations influencing Canada, 1900–2008: B. Bonsal and A. Shabbar
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ECOZONE+ BASICS

Boreal Shield Ecozone+

The Boreal Shield Ecozone+ (Figure 1, Table 1) is Canada's largest ecozone+, representing 18.2% of the country's land surface.[10] It contains one of the world's largest remaining intact forest ecosystems and is rich in forests, freshwater, and wildlife. Development is concentrated in the southern portion; the northern portion remains relatively undeveloped.[11] Humans have modified this ecozone+ directly through natural resource development, including mining, forestry, and hydroelectric power generation, and indirectly through acid deposition, mercury contamination, and climate change.

The Boreal Shield Ecozone+ spans five provinces: Alberta, Saskatchewan, Manitoba, Ontario, and Quebec as well as parts of Labrador. Given the large expanse of this ecozone+, ecosystem function, composition, structure, disturbances, and processes vary regionally. When possible, this report used the most detailed data available that were specific to and covered the whole ecozone+ with results broken down by province. For example, Bird Conservation Region (BCR) 8 and the northern half of BCR 12 fall within the ecozone+'s boundaries. For other key findings, data were available only for a portion of the ecozone+ or data from different provinces were not comparable or compatible across the ecozone+. Also, for some topics, data were only available for whole provinces and, thus, reported data exceed the boundaries of the ecozone+. With the exception of specific discussions of Lake Athabasca in Alberta, the Alberta and Labrador portions of the Boreal Shield Ecozone+ were generally excluded due to their small contributions.

Table 1. Boreal Shield Ecozone+ overview.

Area	1,781,391 km^2 (18.2% of Canada)
Topography	Low and rolling, interspersed with lakes and wetlands.
Climate	Annual precipitation ranges from 400 mm in the west to 1600 mm on the eastern coast.[12] Average summer (June to August) temperatures were highest in the south (17.6°C) and average winter (December to February) temperatures were lowest in the northwest (-24.2°C).[13]
River basins	Southeastern streams are tributaries of the St. Lawrence; streams draining north feed into Hudson Bay. Watersheds in the west are part of the Nelson River and Great Slave Lake drainage basins.[14] Watersheds account for nearly 25% of Canada's freshwater.[15]
Geology	Shaped by the glacier retreat, over 60% of surficial materials are glacial till.[15] In the northcentral region, fine materials form what is known as the 'clay belt'.[15]
Permafrost	Permafrost has a sporadic distribution over the northeastern and western ecozone and is largely confined to organic terrain.[16]
Settlement	Thunder Bay, Sudbury, and Saguenay are the largest settlements.[17]
Economy	Resource industries (forestry, mining, and hydroelectricity) are major employers. Cultivated areas are small and contribute little to the economy of the ecozone+.[18]
Development	In addition to small cities, logging roads and hydroelectric projects account for most of the development.[11] Urban settlements are encroaching northwards from the Mixedwood Plains Ecozone+.[17]
National/global Significance	Important Bird Areas (IBAs) of global, continental, and national importance are located along the north shore of the St. Lawrence Gulf and Estuary.[19] The Georgian Bay Littoral and Manicouagan–Uapishka sites are UNESCO Biosphere Reserves.[20] The forests in this ecozone+ are some of the largest intact forest ecosystems in the world; they sequester a substantial amount of carbon dioxide. The ecozone+ contains a large portion of critical habitat for the Threatened boreal population of forest-dwelling woodland caribou. Along with the Taiga Shield Ecozone+, the Boreal Shield Ecozone+ provides breeding habitat for more than half of the world's populations of 40 common bird species.

Jurisdictions: The Boreal Shield Ecozone+ includes portions of Labrador, Quebec, Ontario, Manitoba, Saskatchewan, and Alberta. The First Nations of the ecozone+ include the Dene (Athapascan), Anishnaabe (Ojibwa, Ojibwe), Cree, Algonquin, Attikamek, Huron–Wendat, and Innu (Montagnais).[21]

The Boreal Shield, consisting of 97% forest and shrubland (Figure 2), is largely undeveloped with a small but steadily growing human population (Figure 3). Population growth is concentrated in the suburban areas on the southern border adjacent to the Mixedwood Plains

Ecozone+.[17] However, some of the fastest population declines in Canada are also occurring in the Boreal Shield Ecozone+ with populations in many mid-sized urban areas declining between 2001 and 2006.[17, 22]

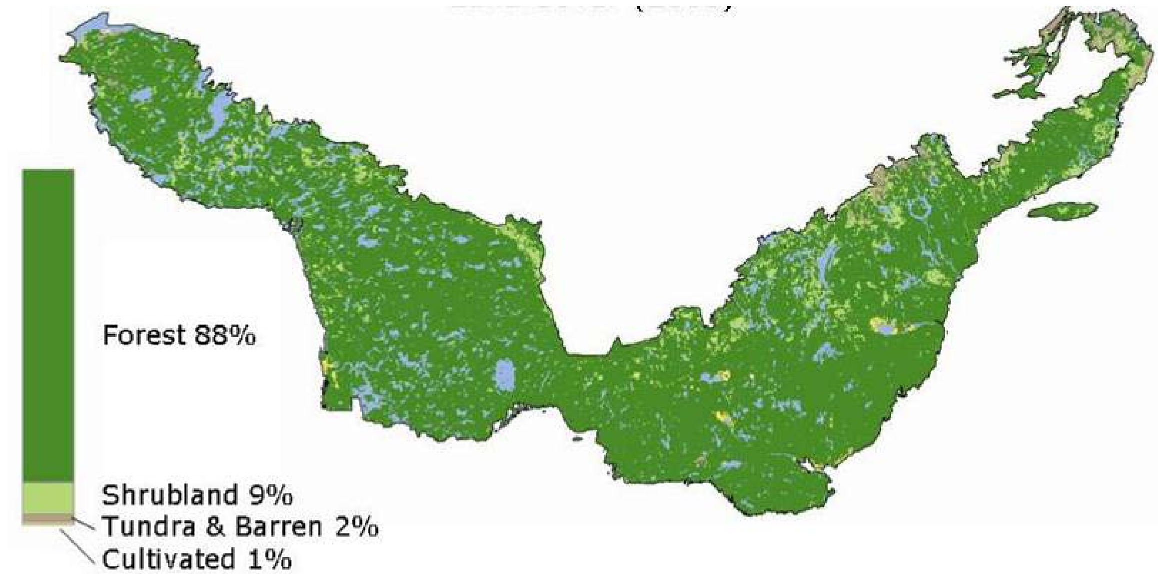


Figure 2. Land cover of the Boreal Shield Ecozone+, 2005.
Source: Ahern, 2011[23] using data from Latifovic and Pouliot, 2005[24]

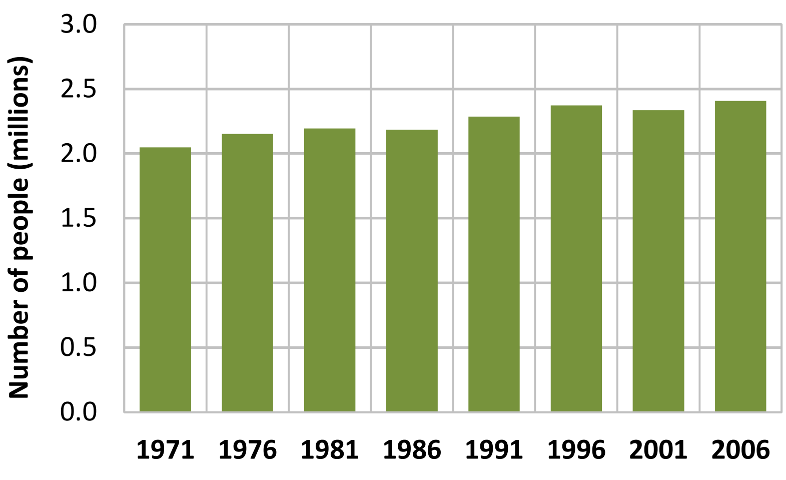


Figure 3. Human population of the Boreal Shield Ecozone+, 1971-2006.
Source: Statistics Canada, 2008[25]

Images of typical ecosystems found in the Boreal Shield Ecozone[+26]
Photos: Francine Bérubé, Canadian Forest Service's Forests of Canada Collection

Newfoundland Boreal Ecozone+

The Newfoundland Boreal Ecozone+ (Figure 1; Table 2) consists of the greater island of Newfoundland and smaller islands off its coast. At 112,134 km^2, Newfoundland is the 16th largest island in the world. The island has endemic species, subspecies, as well as species with unusual life history traits. The ecozone+ is dominated by shrubland (51.4%) and forest (44%) (Figure 4). Newfoundland was first inhabited by many groups of native peoples, including the Maritime Archaic Indians (9000–2400 years before present (BP)), Paleo-Eskimo and Dorset peoples (3850–1300 BP), and the Beothuk, Micmac, Naskapi-Montagnais, and Inuit (1200–200 BP).[27] The island was first visited by Norsemen from Greenland as early as AD 1001 at L'Anse aux Meadows.[28] European settlers and their descendants introduced a number of species not native to Newfoundland. Human settlements are located predominantly along the coast and the people and culture of Newfoundland are intimately connected with the sea.[29] Populations rose from the 1970s to the 1980s but declined in the 2000s (Figure 5).

Table 2. Newfoundland Boreal Ecozone+ overview.

Area	112,134 km^2 (1.1% of Canada)
Topography	Tilted plateau located at the northeastern-most limit of the Appalachian mountain chain.[30, 31] Characterized by deep valleys alternating with long, high ridges, and a coastline that has numerous bays, fjords, peninsulas, islands, and harbours.[32] Lakes, ponds, rivers, and peatlands are ubiquitous and extensive, with approximately 10% of the ecozone+ covered by water.[32]
Climate	Climate is driven by the cold Labrador Current, the North Atlantic Oscillation, and the island's cold ocean location.[33] High average cloudiness, abundant fog and precipitation, and frequent high winds Summers are short and cool; winters are relatively mild. Average annual temperatures are cool for this latitude and precipitation levels vary across the ecozone+ with changes in latitude and topography.
River basins	Major rivers include the Exploits, Gander, Humber, and Main.[34]
Geology	Most of the ecozone+ was glaciated 7000–1000 BP[35, 36]; therefore, most of the island is covered by glacial deposits.[32] Major rock types include sedimentary, intrusive and volcanic igneous, and metamorphic.[30]
Settlement	Major urban centres include St. John's and Mount Pearl on the east coast, Gander and Grand Falls–Windsor in central Newfoundland, Corner Brook on the west coast, and St. Anthony on the Great Northern Peninsula.
Economy	Service and resource industries (forestry, mining, oil and gas, and fishing) are major employers.
Development	Development is primarily in coastal areas with a few settlements in the interior.
National/global significance	The Main and Bay du Nord are Canadian Heritage Rivers. There are 25 Important Bird Areas. There are approximately 20,000 km^2 of heath, comprising the largest tract of this type of vegetation in North America.

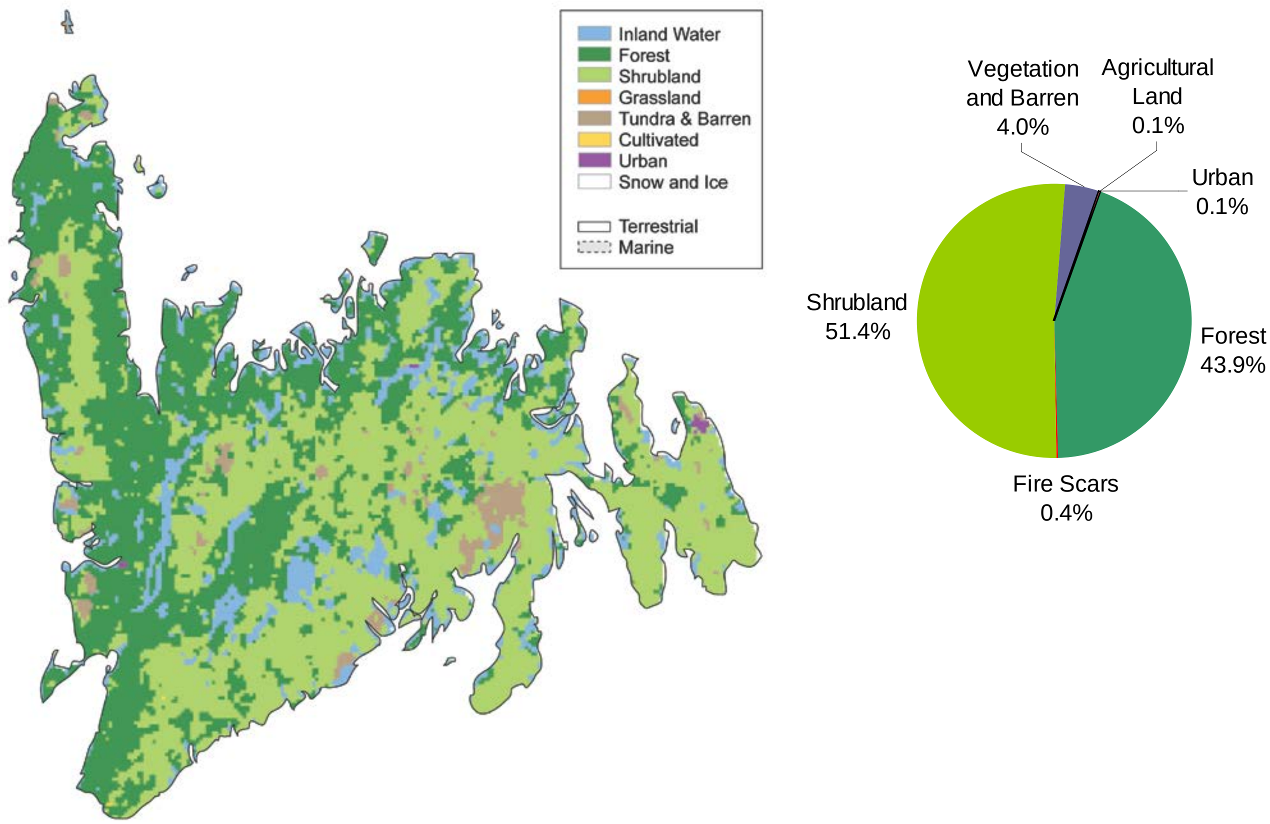


Figure 4. Land cover in 2005 for the Newfoundland Boreal Ecozone⁺.
Source: Ahern, 2011[23] using data from Latifovic and Pouliot, 2005[24]

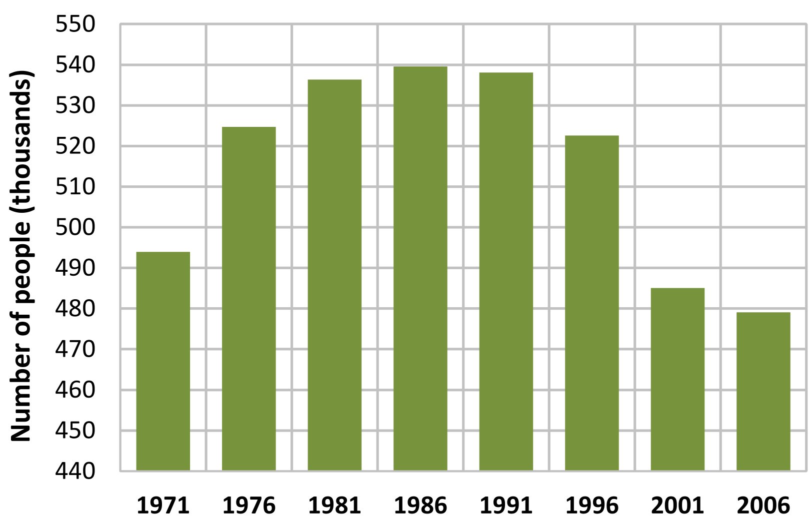


Figure 5. Human population of the Newfoundland Boreal Ecozone⁺, 1971-2006.
Source: Statistics Canada, 2008[25]

Wetland in Carmanville, NL
Photo: Shelley Pardy Moores

Sandy coastline
Photo: Shelley Pardy Moores

KEY FINDINGS AT A GLANCE: NATIONAL AND ECOZONE+ LEVEL

Table 3 and Table 4 present the national key findings from *Canadian Biodiversity: Ecosystem Status and Trends 2010*[6] together with a summary of the corresponding trends in the Boreal Shield and Newfoundland Boreal ecozones+, respectively. Topic numbers refer to the national key findings in *Canadian Biodiversity: Ecosystem Status and Trends 2010*. Topics that are greyed out were key findings at the 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 ii.

Boreal Shield Ecozone+

Table 3. Key findings overview for the Boreal Shield Ecozone+.

Themes and topics	Key findings: NATIONAL	Key findings: BOREAL SHIELD ECOZONE+
THEME: BIOMES		
1. Forests	At a national level, the extent of forests has changed little since 1990; at a regional level, loss of forest extent is significant in some places. The structure of some Canadian forests, including species composition, age classes, and size of intact patches of forest, has changed over longer time frames.	In 2005, forests covered 88% of the Boreal Shield Ecozone+. Although coverage was stable from 1985 to 2005 in managed forests, mixed and deciduous-dominated stands have replaced conifer-dominated stands as a result of natural regeneration after harvesting. Logging has replaced fire as the dominant forest disturbance; however, the forest industry has slowed since 2004.
2. Grasslands	Native grasslands have been reduced to a fraction of their original extent. Although at a slower pace, declines continue in some areas. The health of many existing grasslands has also been compromised by a variety of stressors.	Not relevant

Themes and topics	Key findings: NATIONAL	Key findings: BOREAL SHIELD ECOZONE[+]
3. Wetlands	High loss of wetlands has occurred in southern Canada; loss and degradation continue due to a wide range of stressors. Some wetlands have been or are being restored.	Over 320,000 km^2 of wetlands are located in this ecozone[+]. Between 1960 and 2000, 9,000 km^2 of wetlands were flooded for hydroelectric developments. Between 1980 and 2000, 250 km^2 of peatlands were drained for forestry.
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.	Conditions in lakes and rivers vary across the ecozone[+]. Dominant patterns include declining annual flows, earlier maximum flows, decreasing rates of water level rise, and increasing water level fall rates.
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.	Rates of erosion increased between 1990 and 2004, especially for sandy coastlines and low clayey cliffs.
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.	Break-up of lake ice has shifted earlier and become faster, and lake ice freeze-up has shifted later in the southern part of the ecozone[+]. Thawing and peatland collapse has occurred over the last 50 to 100 years in northern Saskatchewan and Manitoba.

Themes and topics	Key findings: NATIONAL	Key findings: BOREAL SHIELD ECOZONE+
THEME: HUMAN/ECOSYSTEM INTERACTIONS		
8. Protected areas	Both the extent and representativeness of the protected areas network have increased in recent years. In many places, the area protected is well above the United Nations 10% target. It is below the target in highly developed areas and the oceans.	In 2009, 8.1% (143,491 km^2) of the ecozone+ was protected and 7.9% in protected areas classified as IUCN categories I–IV, areas protected for natural and cultural conservation rather than sustainable use by established cultural tradition. In 1992, only 3% of the ecozone+ was protected. The rate of protection has increased since the 1970s.
9. Stewardship	Stewardship activity in Canada is increasing, both in number and types of initiatives and in participation rates. The overall effectiveness of these activities in conserving and improving biodiversity and ecosystem health has not been fully assessed.	Stewardship activities in the ecozone+ are coordinated among larger conservation, First Nations, and industry networks. Examples include the Canadian Boreal Forest Agreement, the Boreal Leadership Council, the Oil Sands Leadership Initiative in Alberta, the Boreal Peatlands Stewardship Strategy in Manitoba, Ontario's Safe Harbour Agreement, and Ducks Unlimited projects.
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.	Invasive species have spread from southern Quebec eastward and from Ontario westward. Species of particular concern include rusty crayfish, spiny water flea, and purple loosestrife.
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.	Acid deposition, forestry, and hydroelectric projects increase mercury concentrations. Mercury concentrations in aquatic environments rise, and then decline in the years to decades after reservoir creation. Air mercury measurements within or near the Boreal Shield Ecozone+ indicate that concentrations are low and near global background levels. Species that eat fish have elevated mercury levels.

Themes and topics	Key findings: NATIONAL	Key findings: BOREAL SHIELD 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.	The Boreal Shield Ecozone+ contains a relatively small amount of agricultural land given its size. From 1981 to 2006, nitrogen inputs increased from 82.4 to 107 kg N/ha. From 1981 to 2006, nitrogen outputs increased from 62.6 to 74.0 kg N/ha. Residual soil nitrogen increased from 19.8 kg N/ha in 1981 to 33.0 kg N/ha in 2006. The number of lakes and rivers affected by blue-green algae in the eastern ecozone+ increased from fewer than 10 in 2004 to over 80 in 2008.
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.	Acid-sensitive terrain occurs throughout the ecozone+. Areas of maximum acid deposition are concentrated in the southeastern part of the ecozone+ in Quebec and near metal smelters in the western portion in Ontario. Lakes in Quebec and Ontario are sensitive to acid deposition. Following peaks in lake acidity in the 1970s, conditions have improved where point sources of acid deposition were strictly controlled.
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.	From 1950 to 2007, temperature increased in the spring (by 1.7°C), summer (by 1.3°C), and winter (by 1.8°C) and precipitation increased by 17% in the fall. The ratio of snow to total precipitation decreased by 3.3%. Maximum annual snow depth declined by 13.7 cm. The duration of snow cover declined for the second half of the snow season, February–July, but did not change for the first half of the snow season, August to January.

Themes and topics	Key findings: NATIONAL	Key findings: BOREAL SHIELD 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.	In 2009, the net market value of products extracted from the boreal forest annually was $50.9 billion. Non-marketable ecosystem goods and services were valued at $703.2 billion. Aboriginal people have reported some deterioration in provisioning of blueberries, wild rice, and fish within the ecozone+.
THEME: HABITAT, WILDLIFE, AND ECOSYSTEM PROCESSES		
Intact landscapes and waterscapes*	Intact landscapes and waterscapes was initially identified as a nationally recurring key finding and information was subsequently compiled and assessed for the Boreal Shield Ecozone+. In the final version of the national report,[6] information related to intact landscapes and waterscapes was incorporated into other key findings. This information was maintained as a separate key finding for the Boreal Shield Ecozone+.	As of 2006, 64% of the ecozone was composed of intact natural areas including forests and wetlands >100 km^2 in size. The southern portion of the ecozone+ is significantly more modified and fragmented than the northern portion.
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.	Within the small agricultural portion of the ecozone+, wildlife habitat capacity declined by 71% from 1986 to 2006.

* This key finding is not numbered because it does not correspond to a key finding in the national report.[6]

Themes and topics	Key findings: NATIONAL	Key findings: BOREAL SHIELD ECOZONE+
17. Species of special economic, cultural, or ecological interest	Many species of amphibians, fish, birds, and large mammals are of special economic, cultural, or ecological interest to Canadians. Some of these are declining in number and distribution, some are stable, and others are healthy or recovering.	The boreal population of woodland caribou was designated as Threatened by the *Species at Risk Act (SARA)* in 2003. The distribution of caribou has shrunk substantially from its historic range. The number of imperilled freshwater and diadromous fish species increased from 7 to 14 from 1979 to 2008; but the status of two of these species also improved. The main threats included habitat degradation and loss, over-exploitation, invasive species, and competition. The range of wolves, cougars, and wolverine declined in the 1800s to 1900s, although observations of wolves, cougars, and fisher have increased since the 1990s. Populations of three out of four focal shorebird species declined. All landbird groups declined except for forest birds.
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.	Net primary productivity, inferred from the Normalized-Difference Vegetation Index (NDVI), increased for 21% of the ecozone+ from 1985 to 2006. This increase was concentrated in the northeastern part of the ecozone+. Decreases occurred in 0.9% of the area, mainly in the western portion; these were attributed to fire.

Themes and topics	Key findings: NATIONAL	Key findings: BOREAL SHIELD ECOZONE+
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.	Higher wildfire risk, earlier fire occurrence, and increased insect defoliation in the northeastern portion of the ecozone+ replaced closed-crown boreal forest stands with lichen-spruce woodlands. In the western part of the ecozone+, increased wildfire risk and mountain pine beetle invasion could lead to decreased ecosystem productivity and significant releases of stored carbon. Lower intensity fires were more abundant and occurred earlier in the season in dense, mature conifer forests. The annual area burned by large fires from 1959 to 2007 ranged from 109 km^2 to 27,863 km^2. Hemlock looper outbreaks moved north to Labrador and jack pine budworm moved east. The severity of spruce budworm outbreaks increased over the past 100 years.
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.	Food webs in the ecozone+ are largely intact and include the Canada lynx and snowshoe hare cycle and caribou/moose and wolf population dynamics. Wildlife diseases also affect bird and ungulate populations. Aquatic food webs were simplified by acidification and mercury contamination and, despite improvements in water quality, species composition has not always recovered.
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.	Long-term data at the ecozone+ level were rarely available for the Boreal Shield. Wetlands, in particular, were poorly monitored. Data for fish, reptiles, and amphibians were lacking relative to data for birds and mammals. Forest birds offer the best available biodiversity information because of existing long-term standardized surveys and monitoring including the Breeding Bird Survey.

Themes and topics	Key findings: NATIONAL	Key findings: BOREAL SHIELD 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 was no clear evidence of rapid changes or thresholds being crossed. However, in the western part of the ecozone+, increased wildfire risk and potential mountain pine beetle invasion could decrease ecosystem productivity and release stored carbon. These changes are gradual but may be irreversible. Anthropogenic activities tripled the amount of mercury in the environment compared to global background levels, although concentrations decline in the decades following disturbance.

Newfoundland Boreal Ecozone+

Table 4. Key findings overview for the Newfoundland Boreal Ecozone+.

Themes and topics	Key findings: NATIONAL	Key findings: NEWFOUNDLAND BOREAL 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.	Forests cover 44% of the Newfoundland Boreal Ecozone+. Abundant populations of introduced moose are a major driver of forest change. Insect defoliators, fire suppression, and logging also affect forest structure and composition.
2. Grasslands	Native grasslands have been reduced to a fraction of their original extent. Although at a slower pace, declines continue in some areas. The health of many existing grasslands has also been compromised by a variety of stressors.	Not applicable
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.	Many productive coastal wetlands occur in areas of intensive settlement. Development of wetlands through drainage, infilling, and channelization has detrimental effects on the quality and quantity of water. Little information is available on the trends in wetlands for the 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.	Streamflow increased in the spring by 10–40% and decreased in the summer by 20–70%, both influenced by a rise in spring and summer temperatures. Contrary to national trends, however, temperature decreased in January. Hydrologic changes may also be the result of interior forest losses dues to harvest, fire, and insect outbreaks.

Themes and topics	Key findings: NATIONAL	Key findings: NEWFOUNDLAND BOREAL ECOZONE+
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.	Human settlement is concentrated along the 11,550 km long coastline of Newfoundland. Coastal erosion is occurring along the southwest, west, and eastern coasts, accelerated by rising sea levels, increased residential and tourism use, and changing offshore winter ice conditions. The vulnerability of most coastal communities to erosion was "moderately-high" or greater.
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 applicable
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.	Freeze-up shifted 0.5 days/yr earlier for Deadman's pond (in the north-central part of the ecozone+) from 1961–1990.
THEME: HUMAN/ECOSYSTEM INTERACTIONS		
8. Protected areas	Both the extent and representativeness of the protected areas network have increased in recent years. In many places, the area protected is well above the United Nations 10% target. It is below the target in highly developed areas and the oceans.	In 2009, 6.3% (7,098 km^2) of the ecozone+ was protected, an increase from 4.5% in 1992. This was comprised of 45 protected areas in IUCN categories I–III. Additionally, five category VI protected areas covered 1.2% of the ecozone+, a category that focuses on sustainable use by established cultural tradition.

Themes and topics	Key findings: NATIONAL	Key findings: NEWFOUNDLAND BOREAL 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.	Partners with the Eastern Habitat Joint Venture Program collaborate to secure and improve wetland habitat for waterfowl. The provincial government and 33 municipalities have conserved and restored 142 km^2 of wetland habitat.
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.	Twelve mammals including moose, mink, snowshoe hare, coyote, and squirrels have been introduced to Newfoundland. Moose hinder forest regeneration after disturbance and preferential browsing is changing plant species composition. Red squirrels predate nests of native birds and reduce regeneration due to cone predation. Over 35% of the plants in the ecozone+ are non-native.
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.	Sewage is a serious form of pollution in many coastal environments.
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.	Residual soil nitrogen on agricultural land increased from 20.1 kg N/ha in 1981 to 53.6 kg N/ha in 2006. Nitrogen inputs doubled from 50.7 kg N/ha in 1981 to 102 kg N/ha in 2006. Manure was the greatest source of nitrogen in 1981 at 23.8 kg N/ha compared to 11.3 kg N/ha for fertilizer and 13.6 kg N/ha for legume nitrogen fixation. By 2006, legume fixation was 37.7 kg N/ha, manure addition was 34.5 kg N/ha, and fertilizer was 28.1 kg N/ha. Nitrogen output increased from 30.6 kg N/ha in 1981 to 48.4 kg N/ha in 2006.

Themes and topics	Key findings: NATIONAL	Key findings: NEWFOUNDLAND BOREAL ECOZONE+
13. Acid deposition	Thresholds related to ecological impact of acid deposition, including acid rain, are exceeded in some areas, acidifying emissions are increasing in some areas, and biological recovery has not kept pace with emission reductions in other areas.	Spatial variation characterizes the deposition of sulphates and nitrates across the ecozone+. From 1983 to 2000, depositions were greatest on the southwest corner of the island and diminished to the north and east. Deposition of sulphate declined since 1990, but nitrate increased. Declining trends of sulphate may be related to emission abatement measures, but could also result from changes in weather patterns.
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.	From 1950 to 2007, temperatures increased in the summer (by 1.7 °C) and fall (by 1.0 °C); there were no changes to the growing season. Spring, fall, and winter precipitation increased by 0.2%. Maximum annual snow depth increased (32.5 cm), however, the ratio of total precipitation to snow and the duration of snow cover did not change.
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.	Ecosystem services have not been systematically estimated in the ecozone+. Hunting revenues and other tourist activities related to moose contribute more than $100 million annually to the Newfoundland economy.
Intact landscapes and waterscapes*	Intact landscapes and waterscapes was initially identified as a nationally recurring key finding and information was subsequently compiled and assessed for the Newfoundland Boreal Ecozone+. In the final version of the national report,[6] information related to intact landscapes and waterscapes was incorporated into other key findings. This information was maintained as a separate key finding for the Newfoundland Boreal Ecozone+.	In 2006, 57% of the ecozone+ was composed of intact natural areas, contiguous blocks of forest, bog, water, tundra, and rock outcrops of more than 10 km^2.

Themes and topics	Key findings: NATIONAL	Key findings: NEWFOUNDLAND BOREAL ECOZONE+
16. Agricultural landscapes as habitat	The potential capacity of agricultural landscapes to support wildlife in Canada has declined over the past 20 years, largely due to the intensification of agriculture and the loss of natural and semi-natural land cover.	Not applicable
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.	Caribou populations declined from a peak of 95,000 in 1997 to 32,000 in 2008. Newfoundland marten were downlisted from Endangered to Threatened in 2007. Newfoundland has the largest tract of heath in North America including rare and endemic species such as Long's braya and Fernald's braya.
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.	Net primary productivity, as measured by the NDVI, increased on nearly 41% of the land in the ecozone+ from 1985 to 2006. This is the largest proportion of land with a positive trend among Canadian ecozones+. A warming climate, forest harvest, or moose, which impede forest regeneration, could be responsible for observed trends.
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 not a significant natural disturbance in this ecozone+. Balsam fir sawfly, eastern spruce budworm, and hemlock looper were the three main insect defoliators. Major outbreaks were primarily restricted to west and central regions. Balsam fir sawfly outbreaks have increased in duration, severity, and extent.
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.	Introductions of several non-native species into the ecozone+ have affected native species' population cycles. The introduction of coyotes may have affected caribou, Arctic hare, and marten populations. Seals have increased residence times in several rivers and estuaries and are now present during the salmon smolt run.

Themes and topics	Key findings: NATIONAL	Key findings: NEWFOUNDLAND BOREAL ECOZONE+
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.	Very little quantitative information was available for this 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.	The shift in tree species composition and lack of forest regeneration for decades following disturbance suggests that moose and insect defoliators have shifted ecosystems in Newfoundland Boreal Ecozone+ to a new state. Given the limited data available, it is unknown if other thresholds have been reached.

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.

Boreal Shield Ecozone+

Most of the Boreal Shield Ecozone+ is boreal forest, but the ecozone+ also includes temperate forests in the south. As of 2005, 88% of the ecozone was covered by forest. Forest composition, age structure, and both biotic and abiotic drivers vary widely across the vast expanse of the ecozone+. For example, fire is a major disturbance and driver of both forest composition and age class in the Boreal Shield Ecozone+ as a whole, but fire return intervals vary from 125 to 600 years between the west and the east.[37] Forestry is also a major industry in Ontario and Quebec, and less so in Saskatchewan and Manitoba. Forests were converted to cropland in the southwestern portion of the ecozone+ between 1985 and 2006.[23] These changes were insignificant at the ecozone+ scale and the general extent of forested ecosystems was unchanged, however, the composition and structure of managed forests has changed.[38-40]

The shift from conifer to broad-leaved deciduous forest and shrub may have been facilitated by natural regeneration.[40-42] Natural regeneration of cutovers was standard practice in central Canada from the 1920s to the mid-1970s and continues to be a common approach.[43] The failure of natural regeneration resulted in re-planting programs from the 1970s until 2009.[44, 45]

Forest composition and structure is tracked by provincial natural resource and environment departments; therefore, the following data and discussion are based on provincial divisions with additional ecozone+- and ecoregion-level summaries where possible. Figure 6 and Figure 7 illustrate the areas of forests that are managed in the Boreal Shield Ecozone+, as well as the ecoregion boundaries that were defined from the National Ecological Framework for Canada.[9]

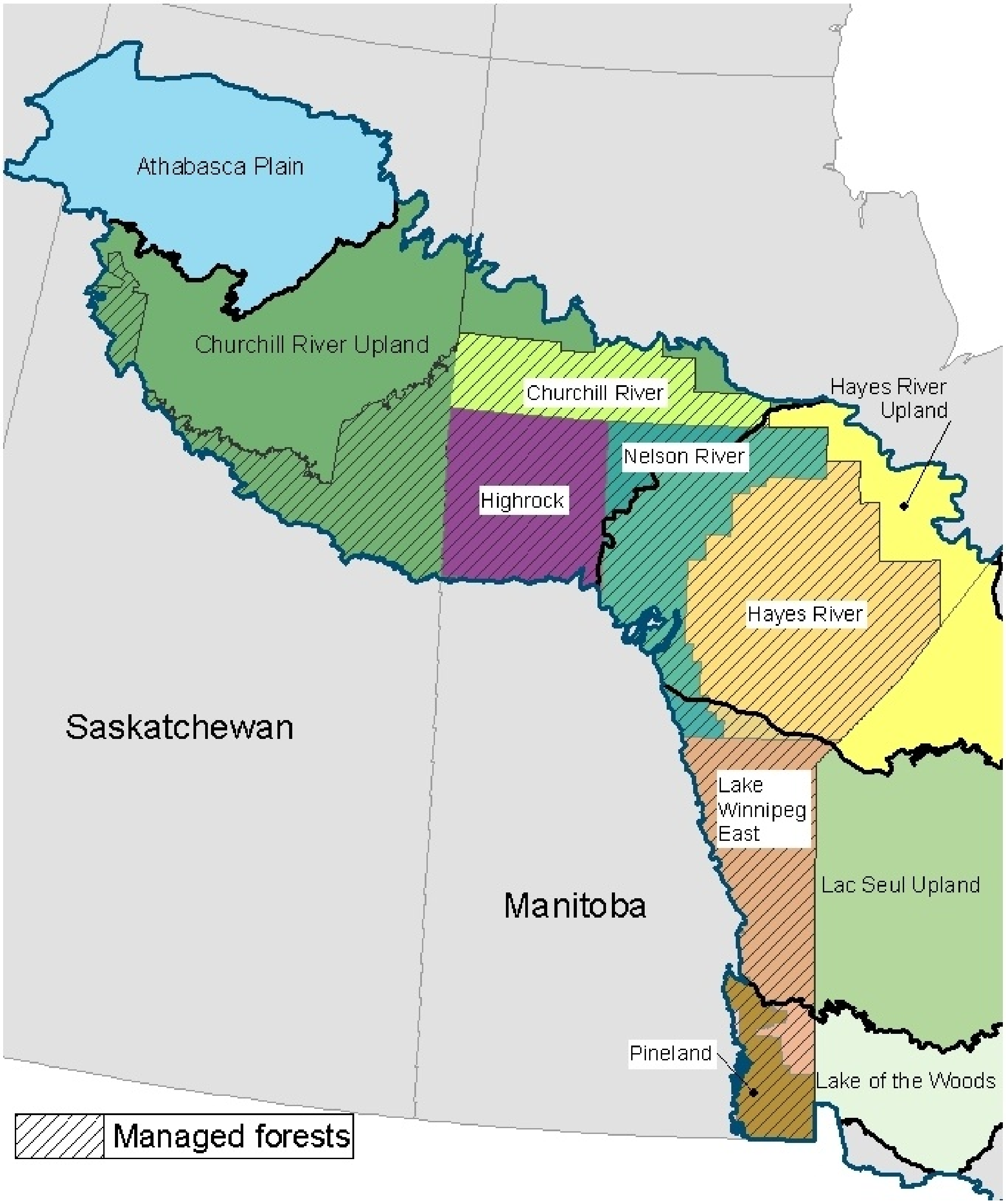


Figure 6. Map of managed forests in the Saskatchewan and Manitoba portions of the Boreal Shield Ecozone+.
Manitoba areas shown are forest management units. Managed forests in Saskatchewan include forests south of the northern reconnaissance area for which inventory data exist. Ecoregion boundaries are shown for context.
Source: Saskatchewan Ministry of Environment – Forestry Service Branch, unpublished data and Manitoba Conservation, Forestry Branch, Forest Management Licenses, unpublished data[38]

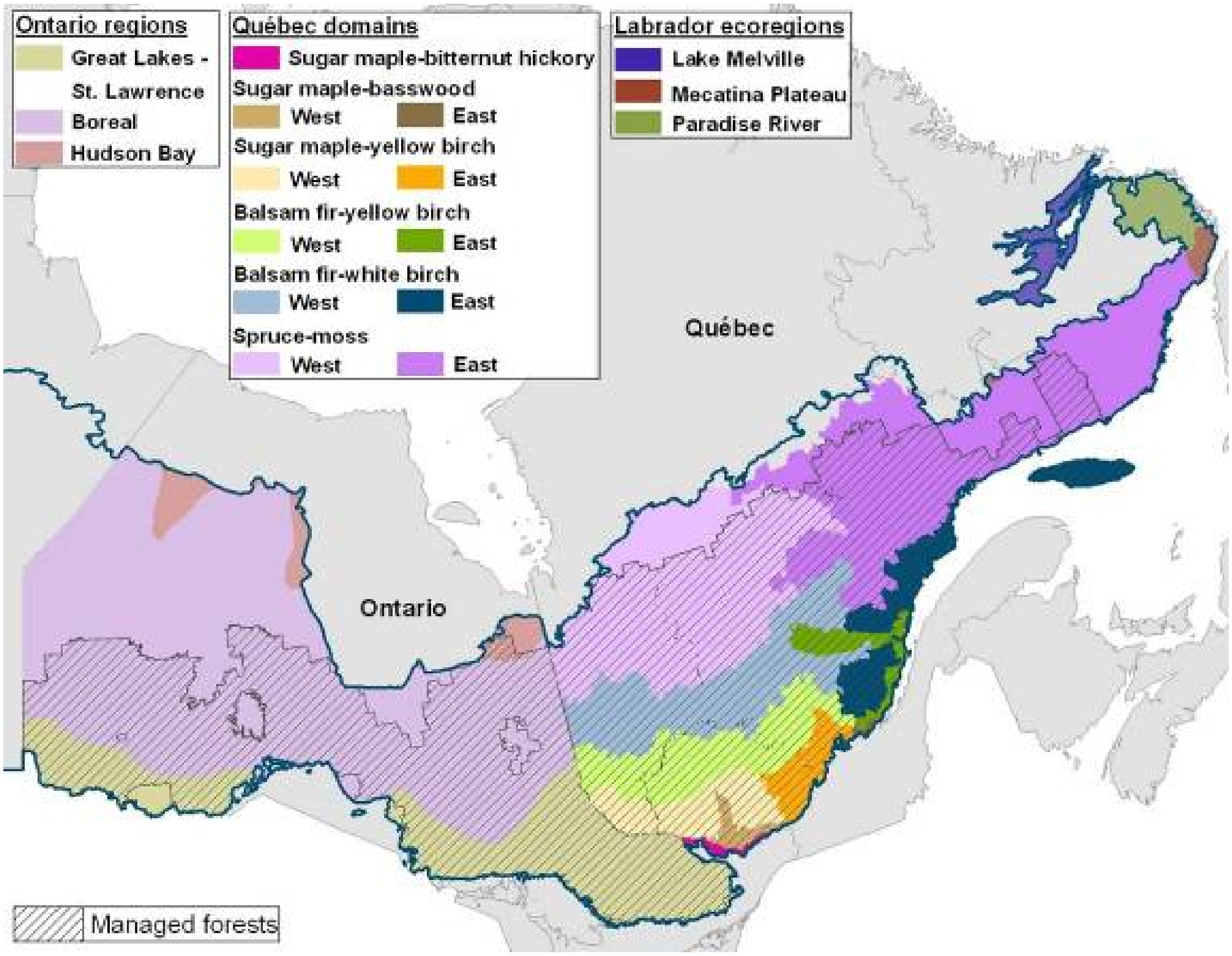


Figure 7. Map of managed forests in Ontario and Quebec portions of the Boreal Shield Ecozone+.
The term"managed forests" refers to areas where inventory data exist. Ontario forest regions and Quebec forest domains are shown for context.
Source: Ministère des Ressources naturelles, 2005[46]

The most common natural disturbance in the western Boreal Shield Ecozone+ is fire. The lack of fire suppression has resulted in a relatively natural fire regime, especially in the Saskatchewan portion of the ecozone+ where there are few anthropogenic stressors on the system.[47] Forestry operations are limited to 340,000 km^2 along the southern boundary of the Churchill River Upland Ecoregion[48] and less than 10 km^2 per year is harvested.[49] Approximately 76% of the Boreal Shield Ecozone+ in Saskatchewan is forested.[50] In Manitoba, forest management has resulted in a decrease in jack pine (Pinus banksiana), black spruce (Picea mariana), and white spruce (Picea glauca) and an increase in other pines, balsam fir (Abies balsamea), other conifers and other hardwoods from the 1970s to the 1990s (e.g., Figure 8).

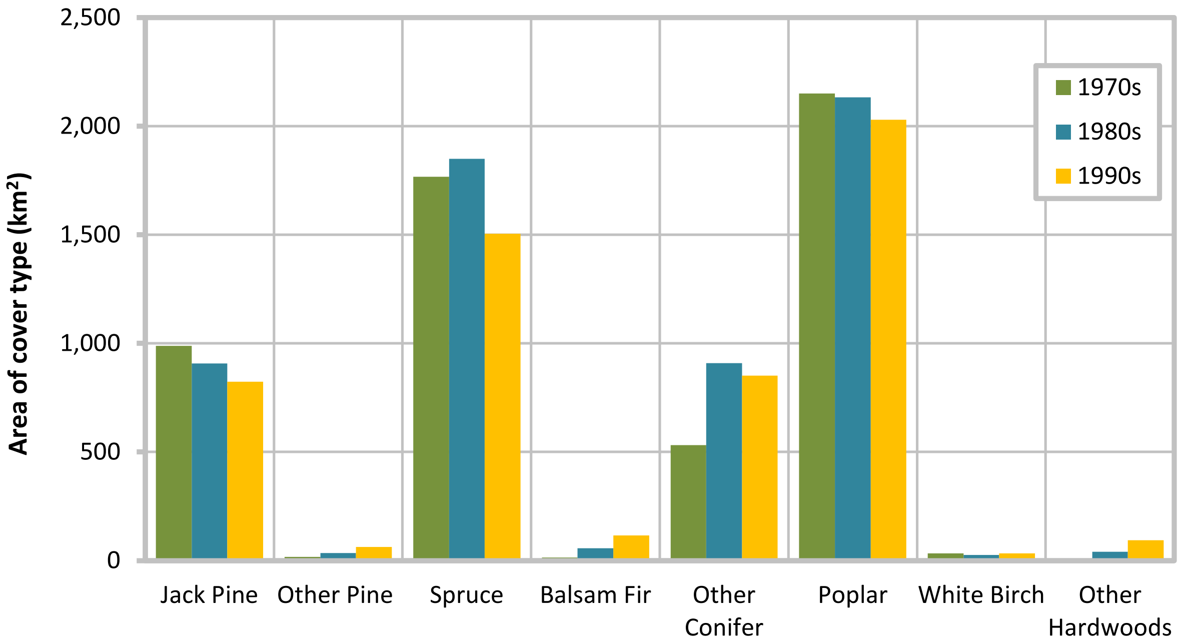


Figure 8. Area of tree species cover type within the Pineland forest section in the 1970s-1990s. Source: Manitoba Conservation - Forestry Branch, Manitoba Forest Inventory, unpublished data[38]

Natural disturbances of the eastern boreal forest of Canada include fire,[47, 51] insect outbreaks,[52] and windthrow,[53] with fire having the most widespread influence at regional scales.[54] Fire regimes (frequency, size, intensity, seasonality, fire type, and severity) have a significant influence on the age structure of boreal landscapes and the structure and composition of stands.[55-58] In the eastern Boreal Shield Ecozone+, 30% of the forested area is dominated by dense coniferous forests, 13% is mixed conifer and deciduous forests, and 35% is considered sparse forest.[59] There is relatively little human disturbance, but these forests are likely to be affected by climate change with potential increases in fire frequency and extent and changes in species distributions.[59]

The Ontario boreal forest region covers approximately 500,000 km^2, 82% of which is forested.[60] Conifer-dominated stands, especially stands dominated by spruce, have been converted to mixed and deciduous-dominated stands post-harvest in Ontario (Figure 9) and Quebec (Figure 10).[39, 40, 61] Spruce regeneration is fire-dependent, hence, the absence of fire leads to reduced regeneration of spruce and increases in hardwood species or other conifers.[62] Although conifers are planted post-harvest, softwood regeneration is not always successful.[39, 42, 44, 63]

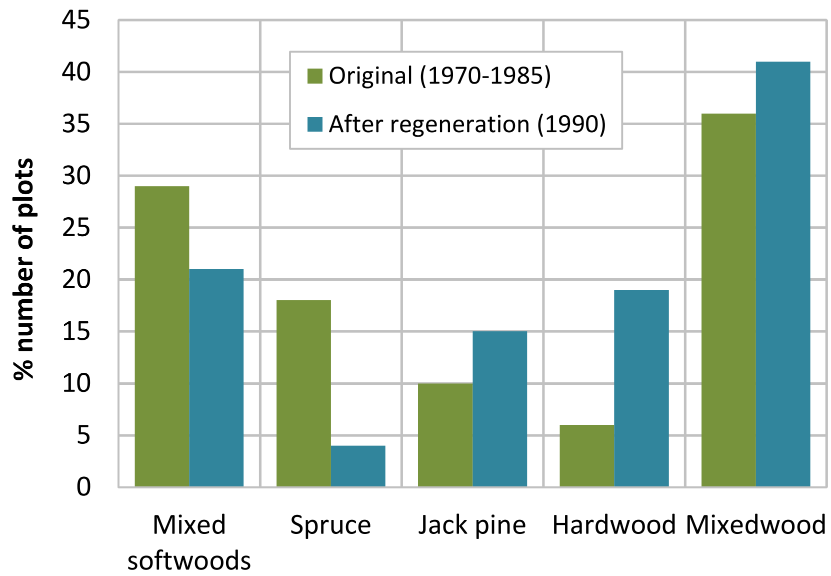


Figure 9. Change in proportions of tree species composition groups after harvest in 1522 plots throughout the Boreal Forest Region of Ontario between 1970–1985 and 1990 (5 to 20 years after cutting).
Source: adapted from Hearden et al., 1992[40]

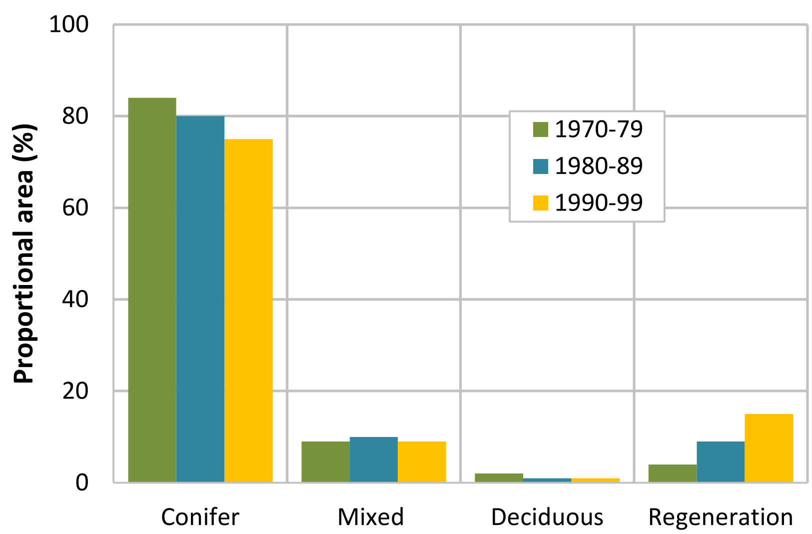


Figure 10. Proportional area by cover types of the spruce-moss east subdomain in Quebec.
Source: Ministère des Ressources naturelles, 2002[61]

The majority of harvesting activities on Ontario's Crown forest takes place in the Boreal and the Great Lakes-St. Lawrence forest regions.[45] In 2009–2010, there were 852 active clearcut harvest areas in the Boreal Forest Region (Figure 7). Of these clearcuts, 826 (97%) were less than 2.6 km^2. The average clearcut size was 0.6 km^2 and the maximum clearcut was 14.2 km^2.[45] The age class distribution of the forest is an important indicator of changing ecosystem processes. Forest stands are recorded in the 0–20 age class until a renewal treatment has been prescribed. This includes the activities of site preparation and regeneration to promote the establishment of desired forest stands, and the stand has been declared free-to-grow, meaning that the stands meet growth criteria and are essentially free from competing vegetation. High levels of fire disturbance, delayed or failed regeneration, delayed reporting of successful regeneration and gaps in time between the disturbance and when the stand is declared free-to-grow may have contributed to the high frequency of the 0–20 age class reported for Ontario (Figure 11). Similarly, the age class distribution of forests in Manitoba are weighted toward younger trees.[64]

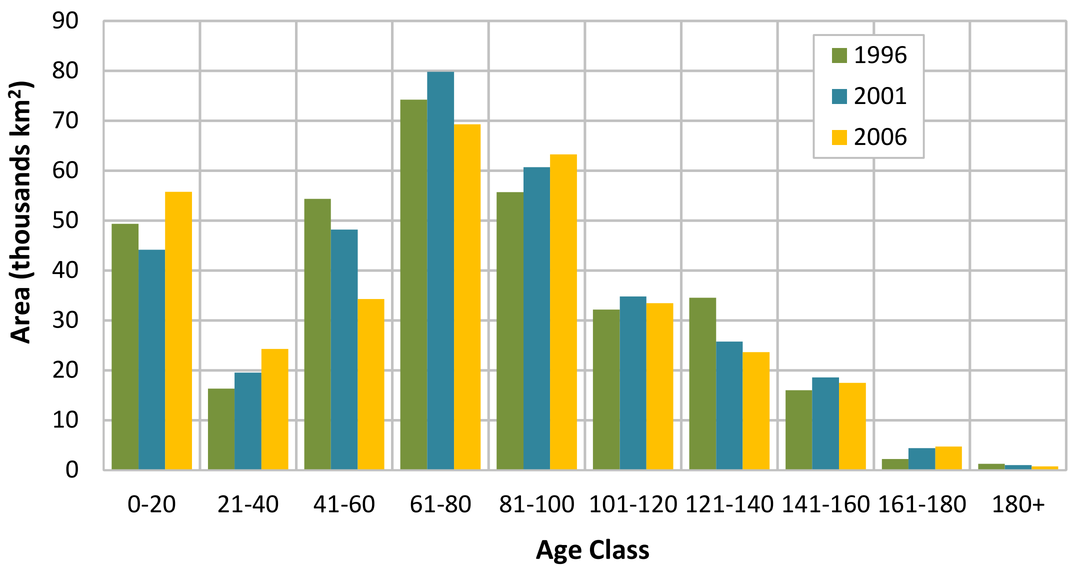
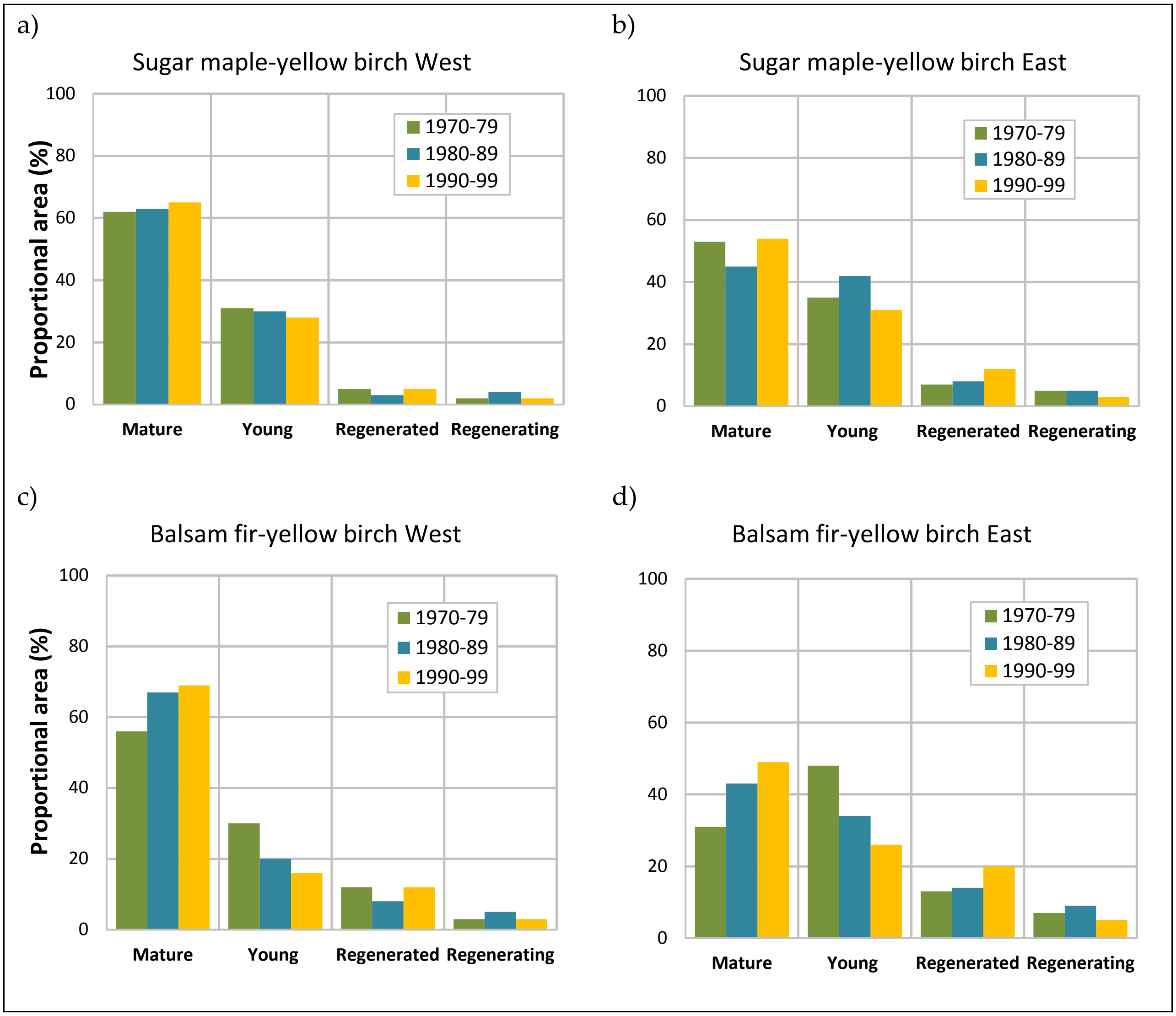


Figure 11. Area (thousands of km^2) of the age class distribution for the managed forests of Ontario for all forest types for 1996, 2001, and 2006.
Source: data from Ontario Ministry of Natural Resources, 2007[39]

The Quebec portion of the Boreal Shield Ecozone+ includes approximately 433,000 km^2 of forest, 424,000 km^2 of which are productive (forests capable of producing 30 m^3 or more of wood per hectare (0.01 km^2) within 120 years, and having <41% slope).[63] Fire history reconstruction records from the past 300 years from northeastern Ontario to eastern Quebec's north shore show that, historically, more than 50% of the forest was over 100 years old.[58, 65] In Quebec, current forest management practices have resulted in an increase in the proportion of early-seral habitats and decreases in late-seral habitats as forestry moves towards the east and north (e.g., Figure 12).[55, 66] Harvesting targets older age classes, hence, the shift to younger seral stages after harvest occurs more frequently than what would be expected by natural disturbance alone.


a)
Sugar maple-yellow birch West
Proportional area (%)
100
80
60
40
20
0
1970-79
1980-89
1990-99
Mature
Young
Regenerated
Regenerating
b)
Sugar maple-yellow birch East
100
80
60
40
20
0
1970-79
1980-89
1990-99
Mature
Young
Regenerated
Regenerating
c)
Balsam fir-yellow birch West
Proportional area (%)
100
80
60
40
20
0
1970-79
1980-89
1990-99
Mature
Young
Regenerated
Regenerating
d)
Balsam fir-yellow birch East
100
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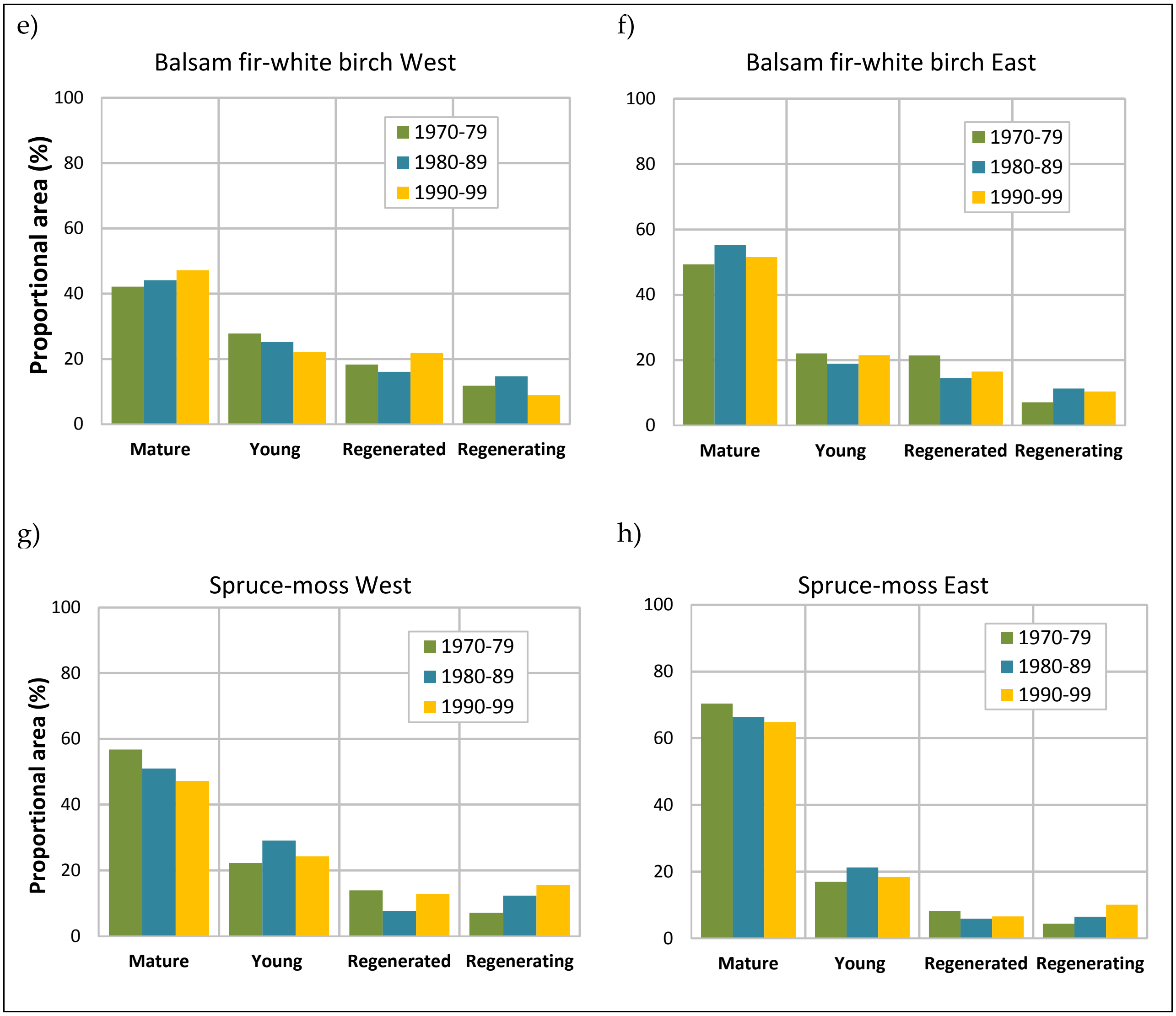


Figure 12. Proportional area of the most common subdomains by developmental stage in the Quebec portion of the Boreal Shield Ecozone⁺.
Data includes private and public forests.
Source: Ministère des Ressources naturelles et Faune, 2009[67], Statistiques forestières, unpublished data, updated from Ministère des Ressources naturelles 2002)[61]

The Quebec government is exploring the viability of fibre production in the north (between the 49th and the 52nd latitudes). The three potential zones would include "northern development" with some fragile areas but overall good growth and potential for forestry, "fire-driven development" with short fire intervals that would have to be considered during harvest planning, and "limited development" furthest north for limited forestry.[68]

Areas north of the managed forests are rarely monitored and changes across these regions are generally unknown. However, dense, mature conifer (spruce-dominated) stands were replaced with lichen woodlands over nine percent of the landscape between 1950 and 2002, causing a shift in ecosystem types in the northeast Boreal Shield Ecozone⁺. These shifts were attributed to increased fire frequency, earlier and lighter fires, and fire events that shortly followed insect outbreaks.[69, 70]

A small amount of the Boreal Shield Ecozone+ extends into Labrador. Based on Landsat imagery from 1987–1990, 87% of the region is forested and includes all of the Paradise River and Lake Melville ecoregions (Figure 7). Commercially viable forests of black spruce and balsam fir comprise 52.6% of the total forested area and non-commercial forest includes other black spruce forest (24.3%), lichen woodland (6.7%), and smaller amounts of hardwood scrub and mixed forest.[71] Burned areas comprise 15% of the forested area, typically dominated by birch, aspen, and black spruce. No trends can be reported for Labrador because these forests are not monitored regularly. Permanent sample plots were established in the 1990s but few have been re-measured.[72, 72]

Forest harvest increased in the Boreal Shield from the early 1900s until it peaked in the mid-1990s.[73] As of 2004, forest harvesting activities had declined sharply to their early 1980s levels. Many factors led to these declines, including high costs of fuels and electricity, trade restrictions, the relatively high value of the Canadian dollar, global competition, and, most importantly, the collapse of the US housing market, which depressed demand for lumber.[74]

Forest birds

Given that forest habitat dominates the Boreal Shield Ecozone+, this ecozone+ supports a substantial proportion of Canada's forest birds.[75, 76] Eighteen species have 30% or more of their Canadian range in the Boreal Shield Ecozone+ and 17 of these are neotropical migrants (Table 5). The Boreal Shield Ecozone+ has year-round resident landbirds such as boreal chickadees (*Poecile hudsonicus*) and gray jays (*Perisoreus canadensis*) as well as many migratory species that breed in boreal forests each summer then migrate southward each year. Sparrows, warblers, and thrushes account for more than half of all boreal landbirds. Boreal landbirds are highly migratory: an estimated 93% of these birds leave the boreal each fall to overwinter in the United States, Mexico, the West Indies, and Central and South America and return the following year to breed.[77] For the few bird species that are year-round residents in this ecozone+, populations are difficult to monitor because of the timing of their breeding season (April to May when there is still snow cover) and their low densities.[76]

Overall, trends in forest birds are stable or increasing in the Boreal Shield Ecozone+ (Table 6). Boreal chickadees, endemic to the spruce-fir forests of the North American boreal region, are declining Canada-wide according to the Christmas Bird Count (CBC)[78] but not the Breeding Bird Survey (BBS) (Table 6).[79] The decline of olive-sided flycatchers (*Contopus cooperi*) (Table 6), listed as Threatened by the Committee on the Status of Endangered Wildlife in Canada (COSEWIC) in 2007,[80] was consistent with reduced numbers of all the aerial insectivores over the same period.[81] In 2008, Canada warblers (*Cardellina canadensis*) were also listed as Threatened by COSEWIC. These and other neotropical migrants are affected by changes to their tropical wintering grounds.[82] Similarly, populations of short-distance migrant forest birds (e.g. winter wrens (*Troglodytes hiemalis*), blue-headed vireos (*Vireo solitarius*), ruby-crowned kinglets (*Regulus calendula*) are affected by the degradation of their winter habitat, even though their breeding grounds remain unchanged in the Boreal Shield Ecozone+.[83]

Estimates for species-specific trends were drawn 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.[84] Variation in observer abilities and incomplete geographic coverage are other sources of bias.[85] In particular, trends with low reliability should be interpreted with caution.

The trends reported here are not representative at the ecozone+-scale. The Boreal Shield Ecozone+ coincides with Bird Conservation Region 8 (BCR 8 - Boreal Softwood Shield) and the northern half of Bird Conservation Region 12 (BCR 12 - Boreal Hardwood Transition). Trends for all of BCR 12, which includes the Mixedwood Plains Ecozone+, are reported here. The more active survey routes are concentrated in the southern part of the Boreal Shield Ecozone+, which increases the reliability of the trends in BCR 12 compared to BCR 8 (e.g., Table 6). Ontario and Quebec also have better coverage than other provinces in the Boreal Shield Ecozone+.

Populations of forest birds respond to the availability of food resources. Populations of several species, including purple finch (Haemorphous purpureus), exhibit substantial natural fluctuations due to changes in seed supply, fire, and insect infestations, particularly those in more northern coniferous forests.[76] Global climate change may also affect birds by advancing arrival times on breeding grounds and/or nestling hatch times, causing a mismatch with peaks in prey abundance.[87] This leads to decreased productivity, changes to predator communities, and reduced or shifted ranges.[88] For example, declines in gray jay in Algonquin Park have been attributed, at least in part, to higher winter temperatures that spoil this resident species' winter food stores.[89]

Table 5. Neotropical migrant bird species with more than 30% of their Canadian range within the Boreal Shield Ecozone+.

Common name	North American (NA) breeding population within the Ecozone+ (%)	Range within the Ecozone+ (%) relative to NA range	Range within the Ecozone+ (%) relative to Canadian range	Significant (p) decline from 1970 to 2012 (BBS)[a]
Bay-breasted warbler (*Setophaga castanea*)	84	61	63	
Black-and-white warbler (*Mniotilta varia*)	61	3	47	
Blackburnian warbler (*Setophaga fusca*)	77	51	65	
Black-throated blue warbler (*Setophaga caerulescens*)	59	40	60	
Black-throated green warbler (*Setophaga virens*)	62	54	66	
Canada warbler (*Cardellina canadensis*)	67	55	61	nBCR 8
Cape May warbler (*Setophaga tigrina*)	79	51	53	
Chestnut-sided warbler (*Setophaga pensylvanica*)	79	47	62	*BCR 8
Connecticut warbler (*Oporornis agilis*)	61	61	55	nBCR 8 and *BCR 12
Golden-winged warbler (*Vermivora chrysoptera*)	76	25	56	
Magnolia warbler (*Setophaga magnolia*)	60	45	47	
Mourning warbler (*Geothlypis philadelphia*)	83	47	51	*BCR 8 and *BCR 12
Nashville warbler (*Oreothlypis ruficapilla*)	82	46	59	
Ovenbird (*Seiurus aurocapilla*)	61	26	46	
Philadelphia vireo (*Vireo philadelphicus*)	79	38	45	
Veery (*Catharus fuscescens*)	64	25	36	*BCR 12
Yellow-bellied flycatcher (*Empidonax flaviventris*)	86	39	52	

These estimates are based on North American Breeding Bird Survey (BBS) data housed at the National Wildlife Research Centre (Canadian Wildlife Service) or Patuxent Wildlife Research Center (US Geological Survey). This table includes forest and shrubland birds.

p is the statistical significance: * indicates $p < 0.05$; n indicates $0.05 < p < 0.1$; no value indicates not significant. Bird Conservation Regions (BCRs) that overlap the Boreal Shield Ecozone+ are BCR 8, which includes the Newfoundland Boreal Ecozone+, and the northern half of BCR 12.[86, 86] The declines reported here include all of BCR 12 and exceed the Boreal Shield Ecozone+'s boundaries.

Source: data from Rich et al., 2004[83]*, [a](Environment Canada, 2014)*[79]

Table 6. Trends in abundance (% change/year) and reliability of the trend for selected species of forest birds characteristic of the Boreal Shield Ecozone+ from 1970–2012.

Forest Birds	BCR 8 Trend	BCR 8 Reliability	BCR 12 Trend	BCR 12 Reliability
American redstart (*Setophaga ruticilla*)	-0.01	Low	-0.49	High
Bay-breasted warbler (*Setophaga castanea*)	1.47	Low	-3.64	Medium
Black-and-white warbler (*Mniotilta varia*)	0.68	Low	-0.53	High
Blackburnian warbler (*Setophaga fusca*)	1.55	Low	0.88	High
Black-throated blue warbler (*Setophaga caerulescens*)	5.29	Low	2.10	High
Black-throated green warbler (*Setophaga virens*)	0.60	Low	1.07	High
Blue-headed vireo (*Vireo solitarius*)	5.99	Low	3.83	High
Boreal chickadee (*Poecile hudsonicus*)	3.25	Low	0.78	Medium
Broad-winged hawk (*Buteo platypterus*)	3.07	Low	0.40	High
Canada warbler (*Cardellina canadensis*)	-1.54	Low	-3.62	High
Cape May warbler (*Setophaga tigrina*)	0.91	Low	-1.08	Medium
Evening grosbeak* (*Coccothraustes vespertinus*)	-5.84	Medium	-3.5	Medium
Gray jay (*Perisoreus canadensis*)	0.63	Low	-0.16	High
Least flycatcher (*Empidonax minimus*)	-1.07	Low	-2.47	High
Magnolia warbler (*Setophaga magnolia*)	1.85	Low	1.89	High
Olive-sided flycatcher (*Contopus cooperi*)	-1.44	Low	-5.37	High
Ovenbird (*Seiurus aurocapilla*)	0.21	Medium	-0.22	High
Philadelphia vireo (*Vireo philadelphicus*)	0.47	Low	2.14	High
Purple finch (*Haemorphous purpureus*)	-0.70	Low	-2.89	High
Red-eyed vireo (*Vireo olivaceus*)	0.90	Medium	0.99	Medium
Rose-breasted grosbeak (*Pheucticus ludovicianus*)	-1.87	Low	-2.61	High
Ruby-crowned kinglet (*Regulus calendula*)	1.45	Low	-3.20	High
Ruffed grouse(*Bonasa umbellus*)	2.68	Low	-1.78	High
Swainson's thrush (*Catharus ustulatus*)	-0.31	Low	-0.29	High
Tennessee warbler (*Oreothlypis peregrina*)	0.98	Low	-3.57	Medium
Veery (*Catharus fuscescens*)	2.00	Medium	-1.05	High
Winter wren (*Troglodytes hiemalis*)	1.22	Low	0.94	High
Yellow-rumped warbler (*Setophaga coronata*)	2.64	Low	0.64	High

Shrubland bird species*

These data include the Ontario and Quebec portions of Bird Conservation Region 8 and 12. Only the northern half of BCR 12 falls within the ecozone+, so these data exceed the boundaries of the ecozone+ to the south and underrepresent the ecozone+ in the prairie provinces and Labrador.[86]

Source: Environment Canada, 2014[79]

Eastern wild turkeys (*Meleagris gallopavo*) were extirpated in early 1900s and reintroduced to their native range in southern Ontario and the southern edge of Boreal Shield Ecozone+.[90] Turkeys are naturally expanding their range northward into the Boreal Shield Ecozone+ in Algonquin Provincial Park, along Georgian Bay, and near the Ottawa River.[90]

Cavity nesters

Cavity nesters are birds that nest in cavities they make themselves (primary cavity nesters) or in cavities made by other species (secondary cavity nesters). As primary cavity nesters, woodpeckers are good indicators of overall forest health because they occupy various habitat types and seral stages[91] and are "habitat engineers" that provide nests for other species. Reductions in old-growth forest habitat and fire suppression in some areas reduce the number of cavity nesters,[76] however, woodpeckers were generally stable or increasing in the Ontario and Quebec parts of the Boreal Shield Ecozone+ (Table 7).

Table 7. Trends in abundance (% change/year) and reliability of the trend for woodpeckers in the Ontario and Quebec portions of the Boreal Shield Ecozone+ from 1970 to 2012.

Cavity nesters	BCR 8 Trend	BCR 8 Reliability	BCR 12 Trend	BCR 12 Reliability
Black-backed woodpecker (*Picoides arcticus*)			-1.79	Medium
Downy woodpecker *(Picoides pubescens)*	1.31	Low	0.33	High
Hairy woodpecker *(Picoides villosus)*	1.80	Low	2.16	High
Northern flicker *(Colaptes auratus)*	0.04	Low	-0.66	High

These data include the Ontario and Quebec portions of Bird Conservation Region 8 and 12. Only the northern half of BCR 12 falls within the ecozone+, so these data exceed the boundaries of the ecozone+ to the south and underrepresent the ecozone+ in the prairie provinces and Labrador.[86]
Source: Environment Canada, 2014[79]

Newfoundland Boreal Ecozone+

Approximately 5,000 km^2 (44%) of the Newfoundland Boreal Ecozone+ is forested (including productive forest, forested fens, forested bogs, thickets and swamps).[92, 93] Productive forests are producing or capable of producing commercial forest products. As of 2009, productive forests were dominated by trees 81 years and older, with lower but fairly even densities of trees in the 0–20, 21–40, 41–60, and 61–80 age classes (Figure 13).[23]

In Newfoundland, black-backed woodpeckers (*Picoides arcticus*) were almost exclusively found in >80-year-old forests.[94] Downy woodpeckers (*Picoides pubescens*) were common and similarly distributed among all forest age classes, and hairy woodpeckers (*Picoides villosus*) were uncommon and only observed in the 40- and 60-year age classes.[94] A reduction in the amount of forest in the oldest age class could be responsible for the decline in black-backed woodpeckers in western Newfoundland (Table 8).[79]

Table 8. Trends in abundance (% change/year) and reliability of the trend in cavity nesters in the Newfoundland Boreal Ecozone+ from 1980 to 2012.

Species	Annual Trend	Reliability
Black-backed woodpecker (*Picoides arcticus*)	-1.76	Low
Downy woodpecker (*Picoides pubescens*)	2.07	Low
Hairy woodpecker (*Picoides villosus*)	1.43	Low
Northern flicker (*Colaptes auratus*)	-1.80	Medium

Source: Environment Canada, 2014[79]

Black spruce is the dominant tree species in about one-third of the forests on the island. It is common on both very dry and very wet sites due to its high tolerance for unfavourable conditions. Repeated fires over the centuries have established black spruce as a dominant species in much of the central Newfoundland Boreal Ecozone+.[93] Balsam fir is the most abundant tree species in the ecozone+.[93] Forest stands in the west of the ecozone+ are commonly pure balsam fir. These areas are usually moist, with well-drained soils where trees can attain heights of 24 m at 100 years. White birch (*Betula papyrifera*) and trembling aspen (*Populus tremuloides*) make up significant components of mixed wood and minor hardwood stands on better forest sites. Hardwoods can reach a height of 22 m at 80 years in fertile areas. There are no major hardwood stands in the Newfoundland Boreal Ecozone+.[93]

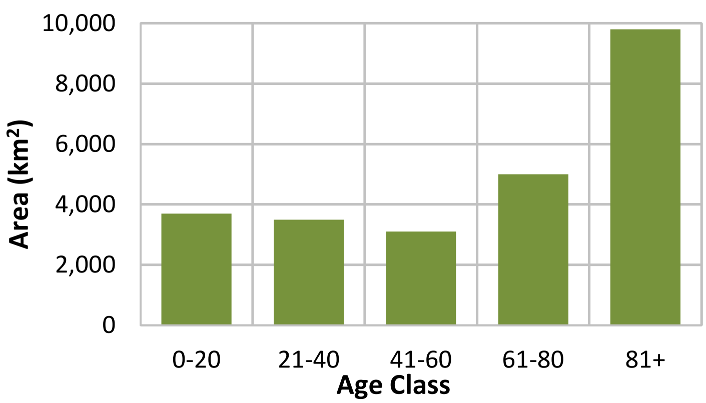


Figure 13. Area of each forest age class in the Newfoundland Boreal Ecozone+, 2009.
This represents all productive forested stands. It does not reflect scrub types nor forests in national parks.
Source: Newfoundland and Labrador Department of Natural Resources, 2009[95]

Moose (*Alces alces*), initially introduced in 1878, are a major driver of forest change in the ecozone+.[96-98] Browsing pressure has reduced the abundance of native trees and shrubs and caused the community composition to shift.[96-98] Balsam fir has failed to regenerate in many areas and, where browsed, has become a low, bush-shaped tree. Unpalatable white spruce and black spruce are avoided by moose and are likely to replace fir as the dominant trees.[99] Many hardwoods, including white birch, have disappeared from the canopy.[99] Declines have been observed in other native species such as Canada yew (*Taxus canadensis*), mountain maple (*Acer spicatum*), serviceberry (*Amelanchier* spp.), Northern wild raisin (*Viburnum cassinoides*), pin cherry (*Prunus pensylvanica*), red maple (*Acer rubrum*) and American mountain-ash (*Sorbus americana*), also preferentially browsed by moose.[97, 99-101]

Sustained browsing pressure by overabundant moose populations has converted forests within Terra Nova National Park, NL (Figure 14) and Gros Morne National Park, NL. In these protected areas, forest gaps formed in the late 1970s as a result of natural (i.e., insect outbreaks) or anthropogenic disturbances have not returned to a closed canopy forest.[96, 97, 99, 100] After disturbance occurs, moose concentrate their browsing activities in these early successional communities because the seed bank contains highly palatable species.[99, 102, 103] Consequently, many sites have transitioned from closed boreal forest to an open landscape (Figure 14) dominated by unpalatable species[97, 99, 100, 104] and invasive non-native herbs.[104] Where balsam fir does occur, it is highly stunted from sustained browsing and unable to reach adult reproductive stages or form a canopy.[99, 104] Declines in balsam fir as well as hardwoods and overall forest structure could have cascading effects on numerous dependent native species, including forest birds,[105] specialist epiphytic tree lichens,[106] and insects.[99]

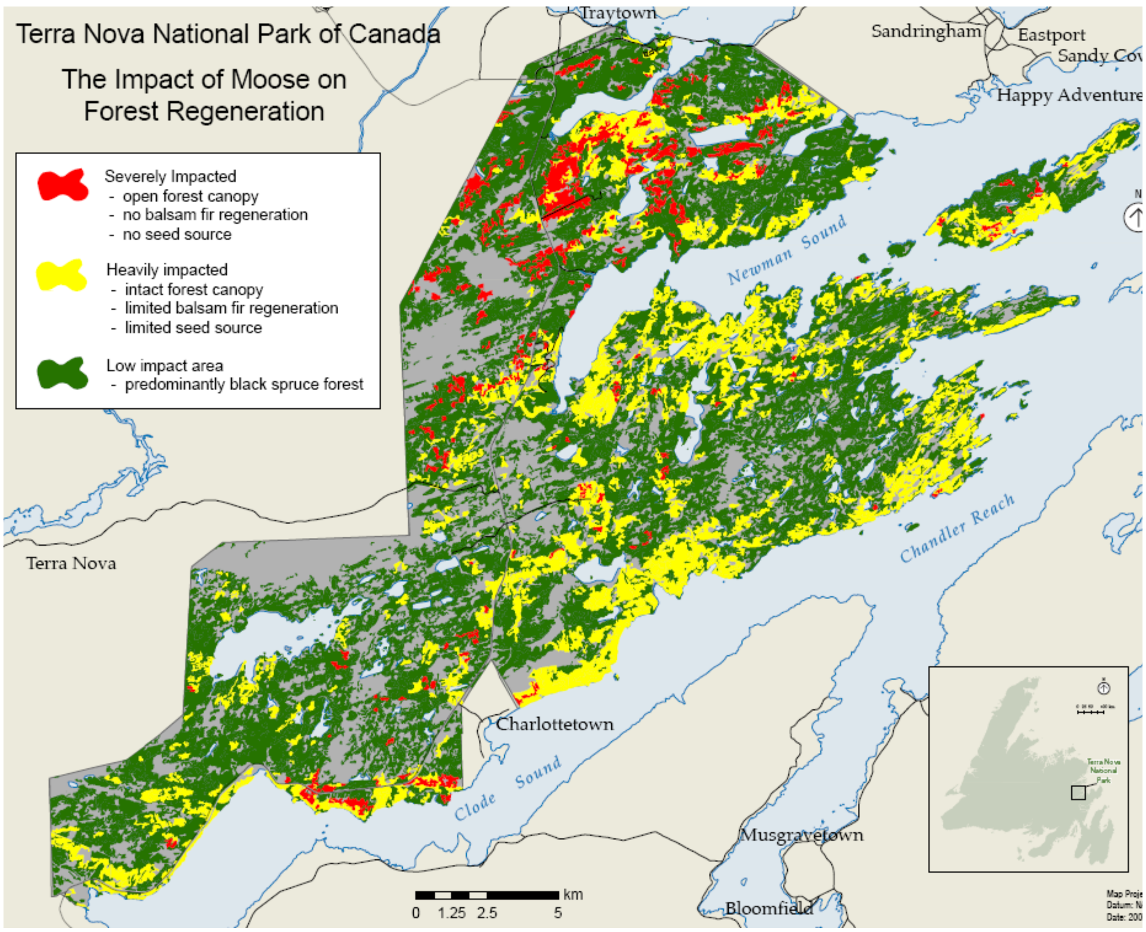


Figure 14. Impact of moose on forest regeneration in Terra Nova National Park, NL. Areas in grey are non-forest.
Source: Parks Canada, 2007[107]

Insect defoliators are another major stressor on forests in the Newfoundland Boreal Ecozone+ and are discussed in the Large scale native insect outbreaks section on page 142.

Forest birds

The Newfoundland Boreal Ecozone+ is part of BCR 8 and is easily distinguished in the BBS dataset by province. Most forest (Table 9) and shrubland (Table 10) birds in the Newfoundland Boreal Ecozone+ are increasing or stable, however some species such as red crossbill (*Loxia curvirostra*) and gray-cheeked thrush (*Catharus minimus*) declined substantially from 1980 to 2012 (Table 9).

Table 9. Trends in forest birds from 1980 to 2012 in the Newfoundland Boreal Ecozone+.

Species	Trend	Reliability
Black-and-white warbler (*Mniotilta varia*)	-0.72	High
Black-capped chickadee (*Poecile atricapillus*)	4.62	Medium
Blackpoll warbler (*Setophaga striata*)	-5.90	Medium
Black-throated green warbler (*Setophaga virens*)	0.48	Medium
Blue-headed vireo (*Vireo solitarius*)	5.19	Low
Cedar waxwing (*Bombycilla cedrorum*)	3.74	Low
Common redpoll (*Acanthis flammea*)	-9.01	Low
Dark-eyed junco (*Junco hyemalis*)	4.93	Medium
Golden-crowned kinglet (*Regulus satrapa*)	5.71	Low
Gray jay (*Perisoreus canadensis*)	1.98	Medium
Gray-cheeked thrush (*Catharus minimus*)	-12.80	Medium
Hermit thrush (*Catharus guttatus*)	2.38	Medium
Least Flycatcher (*Empidonax minimus*)	10.70	Low
Magnolia warbler (*Setophaga magnolia*)	0.42	Medium
Ovenbird (*Seiurus aurocapilla*)	-6.95	Medium
Pine grosbeak (*Pinicola enucleator*)	-0.33	Medium
Pine siskin (*Spinus pinus*)	-1.15	Low
Purple finch (*Haemorhous purpureus*)	-0.17	Medium
Red crossbill (*Loxia curvirostra*)	-16.30	Low
Red-breasted nuthatch (*Sitta canadensis*)	19.90	Low
Red-eyed vireo (*Vireo olivaceus*)	15.60	Low
Ruby-crowned kinglet (*Regulus calendula*)	-0.20	High
Swainson's thrush (*Catharus ustulatus*)	1.37	Medium
Tennessee warbler (*Oreothlypis peregrina*)	-1.57	Low
White-winged crossbill (*Loxia leucoptera*)	7.78	Low
Wilson's warbler (*Cardellina pusilla*)	-3.69	Medium
Winter wren (*Troglodytes hiemalis*)	-0.72	Low
Yellow-bellied flycatcher (*Empidonax flaviventris*)	-1.63	Medium
Yellow-rumped warbler (*Setophaga coronata*)	-0.37	High

Source: Environment Canada, 2014[79]

Table 10. Trends in shrubland birds between 1980 and 2012 in the Newfoundland Boreal Ecozone+.

Species	Trend	Reliability
Evening grosbeak (*Coccothraustes vespertinus*)	3.38	Low
Fox sparrow (*Passerella iliaca*)	-1.42	High
Lincoln's sparrow (*Melospiza lincolnii*)	-1.34	Medium
Mourning warbler (*Geothlypis philadelphia*)	-5.76	Medium
Palm warbler (*Setophaga palmarum*)	3.38	Low
Song sparrow (*Melospiza melodia*)	3.60	Low
White-crowned sparrow (*Zonotrichia leucophrys*)	1.58	Low
White-throated sparrow (*Zonotrichia albicollis*)	-1.67	Medium
Yellow warbler (*Setophaga petechia*)	0.16	Medium

Source: Environment Canada, 2014[79]

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.

Boreal Shield Ecozone+

Wetlands are defined as those land areas that have the water table at, near, or above the soil surface for a major portion, or all, of the growing season.[92] Up to 26% (320,000 km²) of the 1,240,368 km² of wetlands in Canada may be found in the Boreal Shield Ecozone+. Hydroelectric dams and reservoirs have been the primary causes of wetland losses. Between 1960 and 2000, 9,000 km² of wetlands were flooded for hydroelectric developments in the Boreal Shield Ecozone+.[12, 108] Peatlands (also called muskeg) are wetlands with a thick water-logged organic soil layer (peat) made up of dead and decaying plant material. Ditching and draining of peatlands for forestry or agriculture modifies the water balance[109] and can increase erosion and siltation of surface waters.[110] Between 1980 and 2000, 250 km² of peatlands were drained for forestry in the ecozone+.[12] In Quebec, 110 km² of peatlands were converted to agriculture by 2001.[110] Between the 46th and 49th parallels, peatlands in the Boreal Shield Ecozone+ are also used for cranberry cultivation.[110] Climate change could make more northern areas available for cultivation, further promoting drainage of peatlands.[111]

As well as direct loss of wetlands, road construction threatens wetlands through wildlife mortality from construction and vehicle collisions, modification of animal behaviour, alteration of the physical and chemical environment, facilitation of the spread of non-native species, and changes to predator-prey relationships.[112] Predation on artificial bird nests, for example, was highest in boreal forest-highway ecotones (an ecotone is a transition area between two biomes), intermediate in riparian boreal forest strips along lakes and forest-logging road ecotones, and lowest in riparian boreal forest buffers along rivers.[113] Road construction and use increases sedimentation and alters the water balance of wetlands.[112, 114] Laws governing road construction differ among provinces in the ecozone+. Several provinces now regulate the construction of logging roads to maintain water quality for fish habitat.[114-116]

Disturbances such as forestry and road construction create opportunities for the invasion of non-native species in the Boreal Shield. For example, purple loosestrife (*Lythrum salicaria*) exploits disturbances[117] and has spread into wetlands across Manitoba, Ontario, and Quebec.[118] Although the Boreal Shield is less invaded than more southern ecozones+, climate change could facilitate the spread of non-native species to regions where they are presently absent due to climate barriers.

Intensive cottage construction and recreation since the 1930s, particularly along the southern and northwestern lakes in the Boreal Shield Ecozone+, has altered riparian vegetation and led to eutrophication in aquatic environments as a result of sewage discharge. Grass mowing, shoreline clearing, and road construction alter riparian habitats, decreasing their function for fish and wildlife. For example, removing 50% of the macrophytes from lake shorelines reduced northern pike (*Esox lucius*) by 50%.[119] Clark et al. (1984)[120] found that ovenbirds (*Seiurus aurocapilla*) were found primarily along undeveloped lake shores whereas eastern phoebes (*Sayornis phoebe*) were found in highly developed habitats.

Undeveloped wetlands intercept and sequester nitrate entering catchments from precipitation, whether the origins were natural or anthropogenic.[121] With the increase in deposition of nitrate observed throughout developed areas of the world,[122] wetlands may help protect downstream waters from the full effects of nitric acid.[121] Effects of acid deposition on aquatic ecosystems of the Boreal Shield Ecozone+ are discussed in the Acid deposition key finding on page 100.

Waterfowl

Overall, waterfowl densities are relatively low in the Boreal Shield Ecozone+. However, waterfowl from the Atlantic, Mississippi, and central migratory flyways breed and stage in this ecozone+.[123] Areas of very high waterfowl densities can be found in the boreal forest in parts of Ontario and in Quebec's Abitibi region.[124]

To optimize the use of existing data, this ecozone+ was divided into eastern and western sections, along the 86°W meridian (dividing Ontario approximately in half). The western area is covered by the CWS/USFWS Waterfowl Breeding Survey (WBS)[125] and the eastern area is covered by the USFWS Airplane/Transect survey (USFWS A/TS) and the CWS Boreal Helicopter Plot Survey (CWSBHPS) (CWS, unpublished data)[126] (Table 11). For more on the surveys and related analyses, see Fast et al. (2011)[126]

Table 11. Abundance trends for selected waterfowl species in the western[a] and eastern[b] Boreal Shield Ecozone+ by decade, 1970s-2000s and the Breeding Bird Survey[c] between 1970 and 2012.

	Western Annual Index (in 1000s)[a]						**Eastern Annual Index (in 1000s)[b]**				**Breeding Bird Survey (BBS)[c]**	
Species	Trend (p)	1970s	1980s	1990s	2000s	% Change	Trend (p)	1990s	2000s	% Change	BCR 8 Trend	BCR 12 Trend
American black duck (*Anas rubripes)*							1.32*	141.6	162.4	14.7	2.1	-3.55
American wigeon (*Anas americana*)	-2.04*	152.1	127.8	115.6	79.6	-47.6						0.62
Bufflehead (*Bucephala albeola*)	0.59	64	55.7	73.6	79	23.5	-2.17	9.6	9	-6.2		
Canada goose (*Branta canadensis*)	3.66*	68.6	100	130.7	165.1	140.6	6.75*	27.1	47.4	75.4	18.3	21.5
Goldeneye (*Bucephala* sp.*)*	1.54*	170	174.6	268.7	272.3	60.2	2.16	86.7	107.1	23.5	-1.05	0.48
Green-winged teal (*Anas crecca*)	1.79*	101	101.8	152.2	140.6	39.2	-1.65	34	32.2	-5.1		-4.35
Mallard (*Anas platyrhynchos)*	-0.45	635.8	599.8	649.4	555.3	-12.7	3.9*	64.4	88.2	36.8		1.98
Ring-necked duck *(Aythya collaris*)	3.46*	153.5	199.9	337.7	433.9	182.7	2.39*	95.7	119.7	25	-2.64	1.67
Scaup (*Aythya* sp.)	-1.92*	236.7	202.8	200.8	133.7	-43.5						
Scoter (*Melanitta* sp.)	-1	50.7	56.6	47.1	44.1	-13.1						

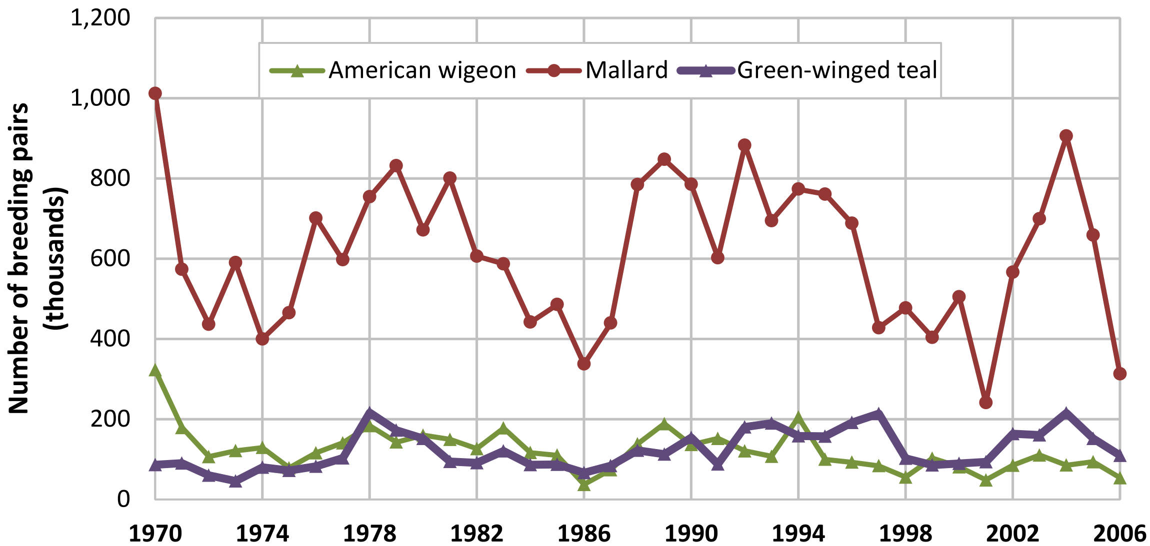
*p is the statistical significance: * indicates p <0.05; no value indicates not significant. The BBS data include portions of Bird Conservation Region 8 and 12. Only the northern half of BCR 12 falls within the ecozone+, so these data exceed the boundaries of the ecozone+ to the south and may underrepresent the ecozone+ in the prairie provinces and Labrador.[86]*

Sources: [a]CWS and USFWS WBS; [b]USFWS A/TS, the CWS BHPS and the Southern Ontario Waterfowl Survey (SOWS) in Fast et al. 2010[126] and [c]Environment Canada[79]

Waterfowl trends differed for each species in the western and eastern Boreal Shield Ecozone+ and among the different datasets. For example, green-winged teal (*Anas crecca*) increased in the west (Figure 15a), were stable in the east (Figure 16a), and declined in Bird Conservation Region 12 (Table 11). Scaup [combined lesser scaup (*Aythya affinis*) and greater scaup (*A. marila*)] have declined (Figure 15b). These species have also declined in neighbouring ecozones+ (i.e. Boreal Plain, Taiga Plain, Taiga Shield, and Prairie ecozones+), which suggests common factors operate within or beyond these breeding areas. The northern boreal region was less productive for scaup recruitment than more southern biomes, even though there were more breeding adults in the north.[127] Scaup at the northern limits of their range must migrate farther and have shorter overall breeding seasons than those nesting further south. These constraints may make these birds more susceptible to mechanisms of population regulation associated with female body condition, timing of breeding, quality of fledging juveniles,[127] changes in food resources,[128] and climate change.[129]

The population trends of scoters [combined white-winged (*Melanitta fusca*) and surf (*M. perspicillata*) scoters] and buffleheads (*Bucephala albeola*) (Table 11 and Figure 15b) were stable.

a)



b)

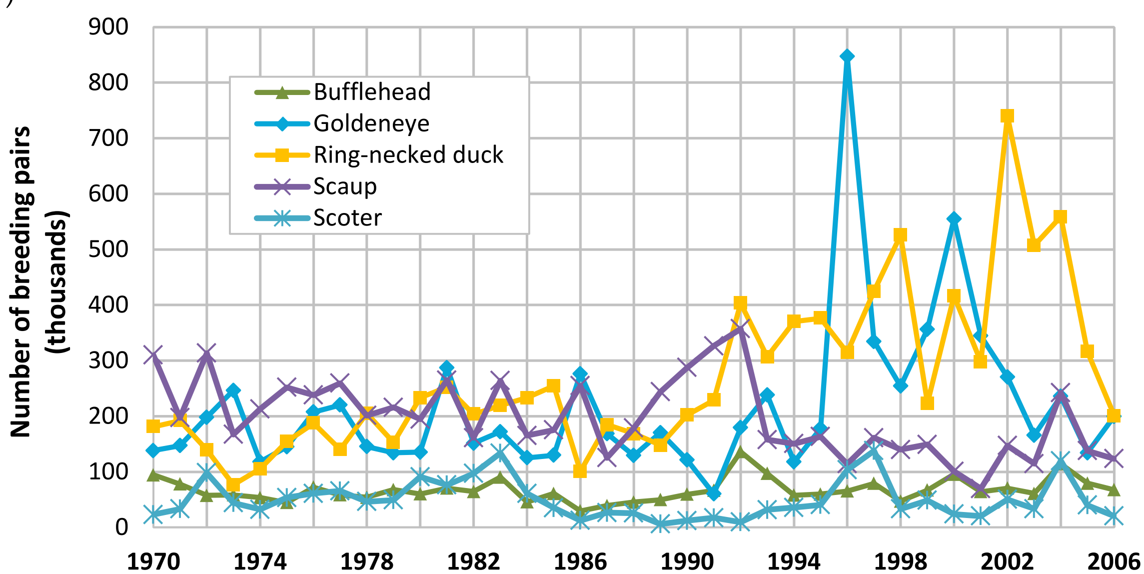
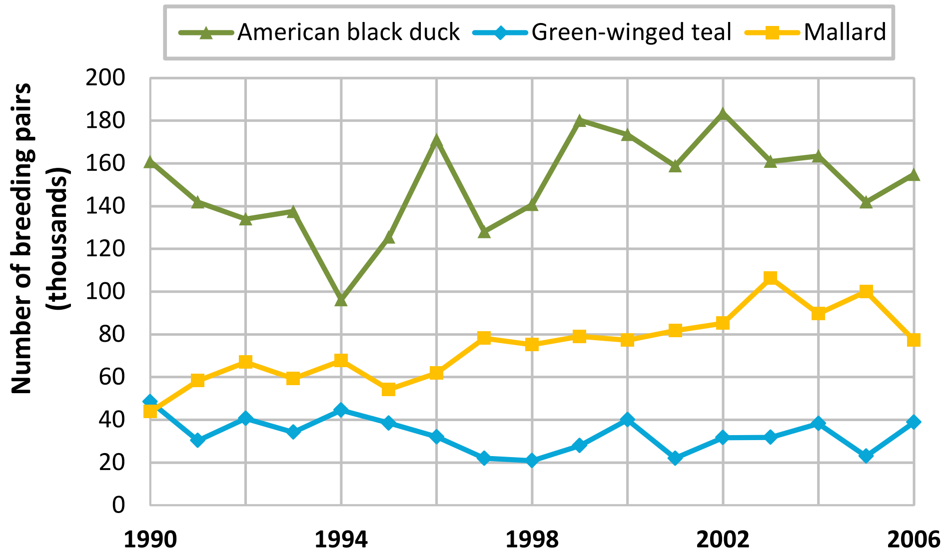


Figure 15. Number of breeding pairs for a) selected dabbling ducks: American wigeon, mallard, and green-winged teal and b) selected diving and sea ducks: bufflehead, goldeneye, ring-necked duck, scaup, and scoter in the western Boreal Shield Ecozone+, 1970-2006.
Source: based on data from CWS/USFWS WBS (WBS)[126]

Waterfowl trends in the eastern Boreal Shield Ecozone+ were similar to those observed the west; ring-necked ducks increased and bufflehead populations were stable (Figure 16b). Other species such as green-winged teal (Figure 16a) and goldeneye (Figure 16b) that were increasing in the west were stable in the east.

a)



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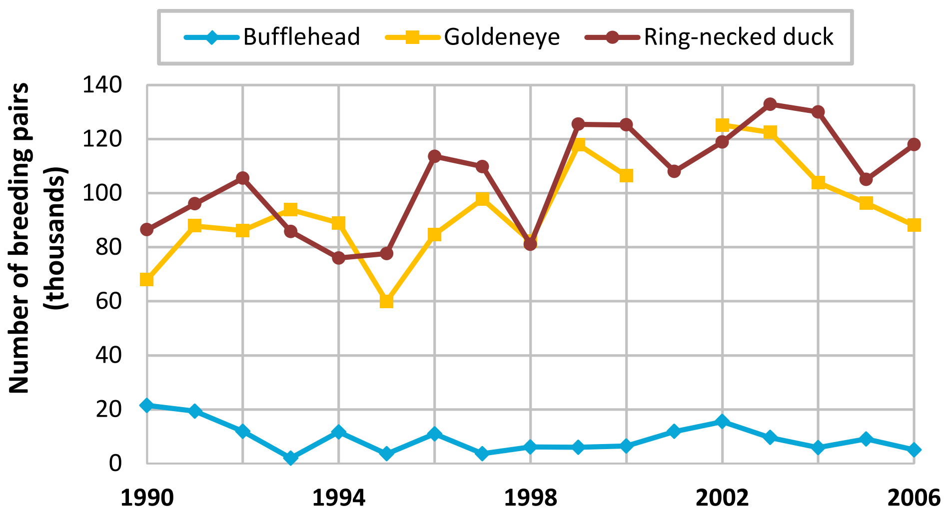


Figure 16. Number of breeding pairs of a) selected dabbling ducks: American black duck, green-winged teal, and mallard and b) selected diving and sea ducks: bufflehead, goldeneye, and ring-necked duck in the eastern Boreal Shield Ecozone+, 1990-2006.
Source: based on data from the USFWS A/TS, the CWS BHPS, and the SOWS[126]

The eastern population of Barrow's goldeneye was classified as Special Concern by COSEWIC in November 2000.[130] These cavity-nesting ducks breed in eastern Quebec and winter along the Gulf of St. Lawrence and the St. Lawrence Estuary.[131] Potential threats to this species include accumulation of heavy metals in prey, recreational development on breeding lakes, loss of nesting habitat due to logging, introduced fish, and oil spills in wintering areas.[131] Logging destroys nests, reduces the number of potential nest sites, exposes young to predation, and increases disturbance by making lakes more accessible.[130] Lakes that were originally fishless have now been stocked with brook trout (*Salvelinus fontinalis*) in some areas, and the presence of these fish could reduce habitat quality for Barrow's goldeneye.[130] Fish compete with ducklings, forcing them to feed in riparian sites that are less accessible to fish.[132]

Half of North America's American black duck (*Anas rubripes*) population breeds in boreal forest ecosystems. Logging, hydroelectric development, transmission lines, agriculture, and urbanization threaten American black duck breeding and staging habitats in Quebec.[133] Mallard populations have increased in the eastern Boreal Shield Ecozone+ (Figure 16a), a trend common to other eastern ecozones+ and consistent with their range expansion in the east. This expansion has also encroached on the range of American black ducks in southern Quebec.[133] American black ducks have been the focus of special conservation effort because their population in the United States decreased by almost 50% between 1955 and 1985.[133] This prompted the creation of the Black Duck Joint Venture under the North American Waterfowl Management Plan to guide black duck conservation and management decisions. Hunting restrictions in Canada and the United States may be helping American black ducks recover because their populations have been increasing in the eastern Boreal Shield Ecozone+ since 1994.[134]

Canada goose (*Branta canadensis*) populations increased in the Boreal Shield Ecozone+ (Table 11 and Figure 17), similar to other ecozones+ that have temperate nesting populations. Temperate nesting Canada geese have likely benefited from the large scale conversion of deciduous forest and natural prairie to cultivated land and urban areas that provide cereal grain, planted forage, and turf grass as food sources.[135]

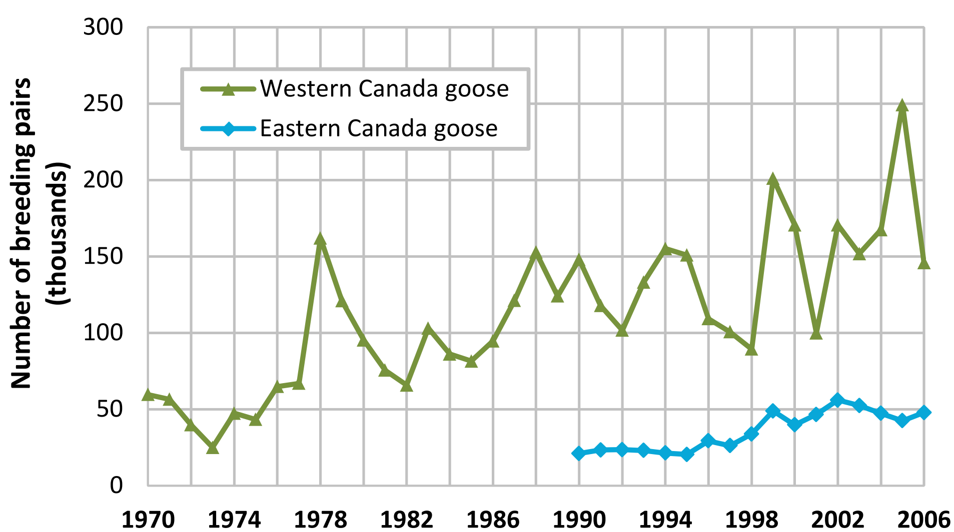


Figure 17. Number of breeding pairs of Canada geese over time in the western (1970-2006) and eastern (1990-2006) portions of the Boreal Shield Ecozone+.
Source: Western Canada goose based on data from the CWS/USFWS WBS. Eastern Canada goose based on data from USFWS A/TS, the CWS BHS, and the SOWS.[126]

Rusty blackbird (*Euphagus carolinus*) has declined steeply in the surveyed portions of this region, according to BBS data. Rusty blackbird was designated a Species of Special Concern by COSEWIC in 2006.[136] Trends for other wetland landbirds were not calculated because the BBS does not cover wetland habitat well.

Shorebirds

Shorebirds are migratory and rely on wetlands during breeding, migration, and on their wintering grounds.[137-139] Monitoring shorebirds in the Boreal Shield Ecozone+ is challenging because they breed in habitats that are difficult and expensive to access and because they use a variety of habitats in multiple ecozones+.[140] The populations of several shorebird species in the ecozone+ are declining (Table 12). The draining of wetlands, pollution, habitat loss, and disturbance on the nesting grounds, wintering grounds, and during migration all cause shorebird declines. Species will respond differently to these stressors depending on their life history and migratory pathways.[141]

Table 12. Trends in abundance (% change/year) and reliability of the trend in shorebirds in parts of the Boreal Shield Ecozone+.

Species	Year	BCR 8 Annual Trend	BCR 8 Reliability	BCR 12 Annual Trend	BCR 12 Reliability
Lesser yellowlegs (*Tringa flavipes*)	1991–2012	-3.07	Low		
Spotted sandpiper (*Actitis macularius*)	1970–2012	-1.83	Low	-5.01	High
Wilson's snipe (*Gallinago delicata*)	1970–2012	-0.52	Medium		
Killdeer (*Charadrius vociferus*)	1970–2012	-5.19	Medium	-5.43	Medium
Solitary sandpiper (*Tringa solitaria*)	1989–2012			8.32	Low

Only the northern half of BCR 12 falls within the ecozone+, so these data exceed the boundaries of the ecozone+ to the south and may underrepresent other parts of the ecozone+.[86]
Source: Environment Canada, 2014[79]

Newfoundland Boreal Ecozone+

Peatlands (bogs and fens) are the most common wetland type in the Newfoundland Boreal Ecozone+. They have been classified into six morphological types: domed bog, blanket bog, slope bog, basins bog, ribbed fen, and slope fen.[142] Despite the extensive wetland area, there is little documentation of wetland conditions or trends.

Wetlands of the Newfoundland Boreal Ecozone+ are increasingly being altered from their natural state to support alternative land uses such as agriculture, urbanization, industrial development, and recreation.[143] Development of wetlands through drainage, infilling, and channelization has detrimental effects on the quality and quantity of water downstream as well as within the wetlands themselves.[143] The loss of habitat impacts terrestrial and aquatic flora and fauna.[143] The potential consequences of impacts on water resources include structural damage to bridges and culverts from increased flood flows; river bed erosion causing siltation; and detrimental impacts on fish resources, drinking water quality, and recreational uses of water bodies.[143] In urban areas, development on former wetlands and floodplains can contribute both to lower water levels during summers and to flooding following rainstorms.[144-146]

Perhaps the greatest problem facing wetland management is that the ecological and socio-economic benefits of these ecosystems are usually not directly measurable and in many instances are not recognized until the wetland has been altered.[143] In the Newfoundland Boreal Ecozone+, many of the most productive coastal wetland habitats were located in the only bays and coves which are suitable for human settlement.[147] Many of the productive freshwater wetlands are within municipalities or under the jurisdiction of forest companies.[147] Legislation under the Newfoundland and Labrador *Water Resources Act* provides a degree of protection against wetland development which could aggravate flooding problems or have immitigable adverse effects on water quality or hydrology.[143] As well, uses and developments of wetlands resulting in potentially adverse changes to the hydrologic characteristics or functions of the wetlands require that appropriate mitigative measures be implemented in order to receive environmental approval.[143] Much of the stewardship activity in wetlands is carried out through the Eastern Habitat Joint Venture (EHJV) Program.[147] Many municipalities have committed to protecting and enhancing wetlands in their area by signing goodwill agreements (see the Newfoundland Boreal Ecozone+ key finding on page 72).

Wetland birds

Compared to other ecozones+, the Newfoundland Boreal is moderately important for breeding waterfowl. Inland and coastal wetlands in this ecozone+ are used by waterfowl for breeding and during the spring and fall migration.[123] The harlequin duck (*Histrionicus histrionicus*), designated as a Species of Special Concern by COSEWIC,[130] moults along the Newfoundland coast[148] and American black duck, king eider (*Somateria spectabilis*), long-tailed duck (*Clangula hyemalis*), and especially, common eider (*Somateria mollissima borealis/dresseri*) regularly over-winter in the open waters surrounding Newfoundland.[149]

Six species of wetland birds, some of which are declining in other ecozones+, increased in the Newfoundland Boreal Ecozone+ between 1980 and 2012 (Table 13). These birds may be increasing because they have fewer nest predators; Newfoundland lacks striped skunks (*Mephitis mephitis*) and raccoons (*Procyon lotor*), which are common in other regions.[150]

Table 13. Trends in abundance (% change/year) and reliability of the trend for selected waterfowl and other bird species that use wetlands in the Newfoundland Boreal Ecozone+ from 1980 to 2012.

Species	Annual Trend	Reliability
American bittern (*Botaurus lentiginosus*)	-1.38	Low
American black duck (*Anas rubripes*)	3.42	Low
Canada goose (*Branta canadensis*)	4.23	Low
Common goldeneye (*Bucephala clangula*)	4.04	Low
Greater scaup (*Aythya marila*)	4.76	Low
Green-winged teal (*Anas crecca*)	5.24	Low
Northern pintail (*Anas acuta*)	1.45	Low
Northern waterthrush (*Parkesia noveboracensis*)	-2.51	High
Red-breasted merganser (*Mergus serrator*)	-5.62	Low
Rusty blackbird (*Euphagus carolinus*)	-7.25	Low
Swamp sparrow (*Melospiza georgiana*)	-2.25	Medium

Source: Environment Canada, 2014[79]

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.

Boreal Shield Ecozone+

The boreal contains half of the world's lakes that are larger than 1 km², five of the world's 50 largest rivers, and more than 800,000 km² of surface water.[151] Hydrological conditions have direct effects on river and lake ecosystems, including the physical nature of river channels, sediment regimes, water quality, and key processes that sustain aquatic communities. Hydrological variability influences the structure of instream habitats and the composition of ecological communities, including plankton, benthic macroinvertebrates,[152] and fish. Hydrological conditions are highly variable geographically across the ecozone+, but there have been significant changes over recent decades.

From 1970 to 2005, Monk and Baird (2014)[14] found that monthly runoff significantly ($p<0.1$) increased or decreased at only a few of the 31 monitoring sites in the Boreal Shield Ecozone+ for which hydrometric data were available (Figure 18). An exception was late summer runoff: 10 out of 31 sites and 9 out of 31 sites declined for August and September runoff, respectively. More typical were variations in directional trends. For example, between November and March, average monthly runoff decreased, on average, at 14 sites but increased at 11 sites. This directional variation could reflect the large east to west extent of this ecozone+. Except for baseflow, a greater number of sites decreased in both minimum and maximum runoff variables (Figure 18).[14]

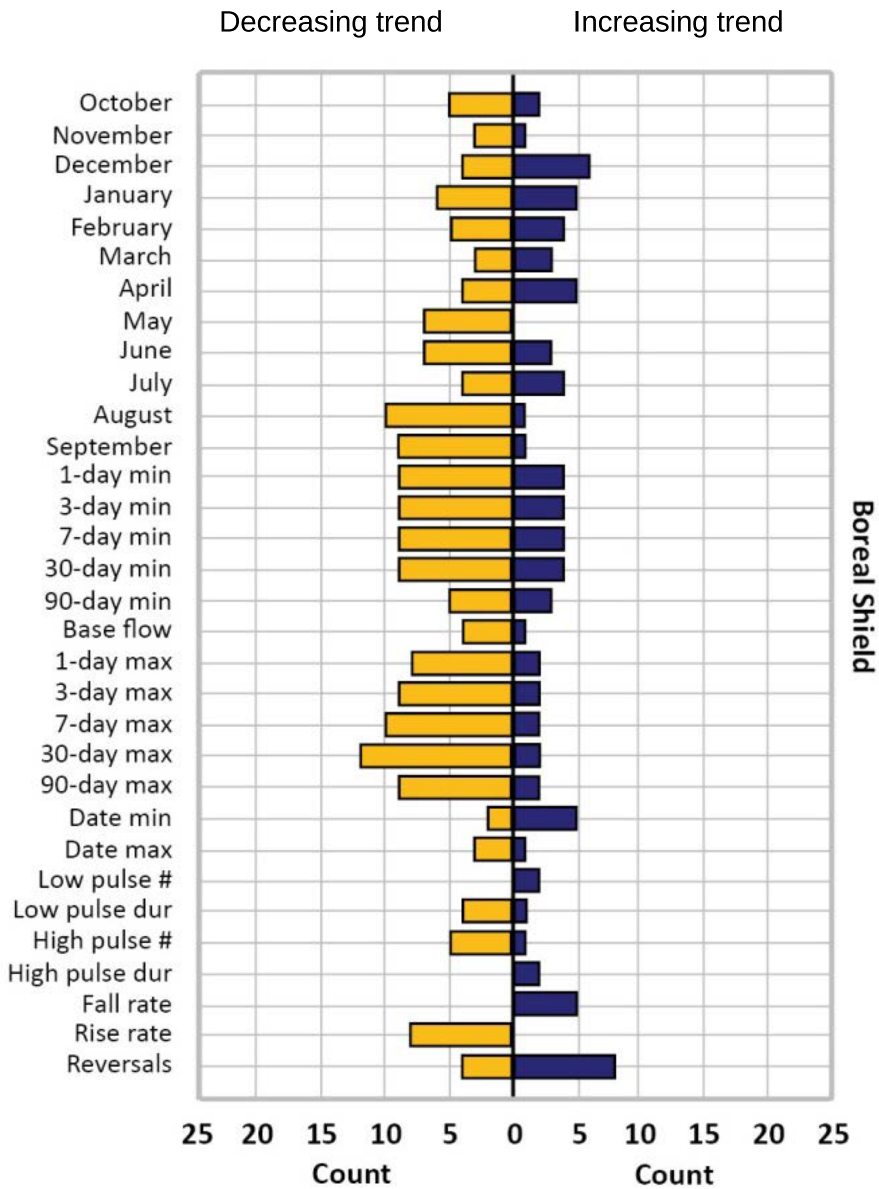


Figure 18. The number of sites with significant (p<0.1) increasing or decreasing trends for each Indicator of Hydrologic Alteration variable for the Boreal Shield Ecozone[+] from 1970 to 2005.
Source: Monk and Baird, 2014[14]

Annual flows generally decreased, and minimum and maximum flows declined. There was a trend toward earlier maximum flow events, decreasing water level rise, and increasing water level fall rates. There were significant changes in flashiness (changes in flashiness stress aquatic communities regardless of the direction of change)[14] and the pattern of flow pulse occurrences. Changes in flow coincided with warmer winters and springs, which explains earlier maximum flow events and lower summer flow.[153] Decreased precipitation as snow in winter may also result in lower flow throughout spring and summer months.[154]

Hydroclimatology is the analysis of how the climate system causes temporal and spatial variations in the hydrologic cycle. Changes in the relationship between the climate system and the hydrologic cycle underlie floods, drought, and influences of climate change on water resources. Cannon *et al.*(2011)[153] looked at patterns of intra-seasonal trends in streamflow and organized stations into six groups of similar hydrologic trends across Canada. Trends in monthly temperature and monthly precipitation were combined with the six hydrologic clusters (labelled 1 through 6) to identify the main processes driving the shifts in streamflow. Due to the size of the ecozone+, most of the classifications (18 of the 24) were represented in the Boreal Shield Ecozone+. Seven stations were Group 3, four were Group 1, three were Group 6, two were Group 5, and one each for Groups 2 and 4 (Figure 19).

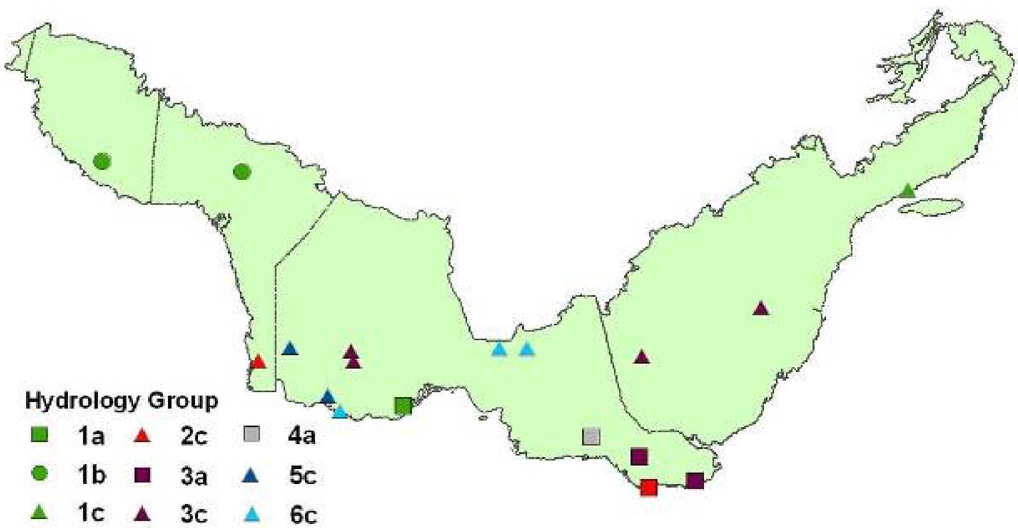


Figure 19. Natural streamflow stations in the Boreal Shield Ecozone+ by Hydrology Group (1–6) and streamflow driver (a–c).
Hydrograph type a rivers are driven by mixed rain and snow processes and types b and c describe rivers dominated by snowmelt runoff.
Source: Cannon et al., 2011[153]

Given the diversity of Hydrology Groups, there were few general conclusions about changes in streamflow for the entire ecozone+. Nevertheless, two shifts were apparent, one each in Groups 1 and 3. These two groups represented the majority of stations (11 of 18). During most of the year, flows decreased in Group 1 stations (Figure 20) located in the eastern and western edges of the ecozone+, as well as one north of Lake Superior. Among Group 3 stations, located closer to the centre of the ecozone+, flows increased in the winter and spring but decreased in the summer and fall (Figure 21). Local shifts were also observed, but were not representative of the Boreal Shield Ecozone+ at larger scales.[153]

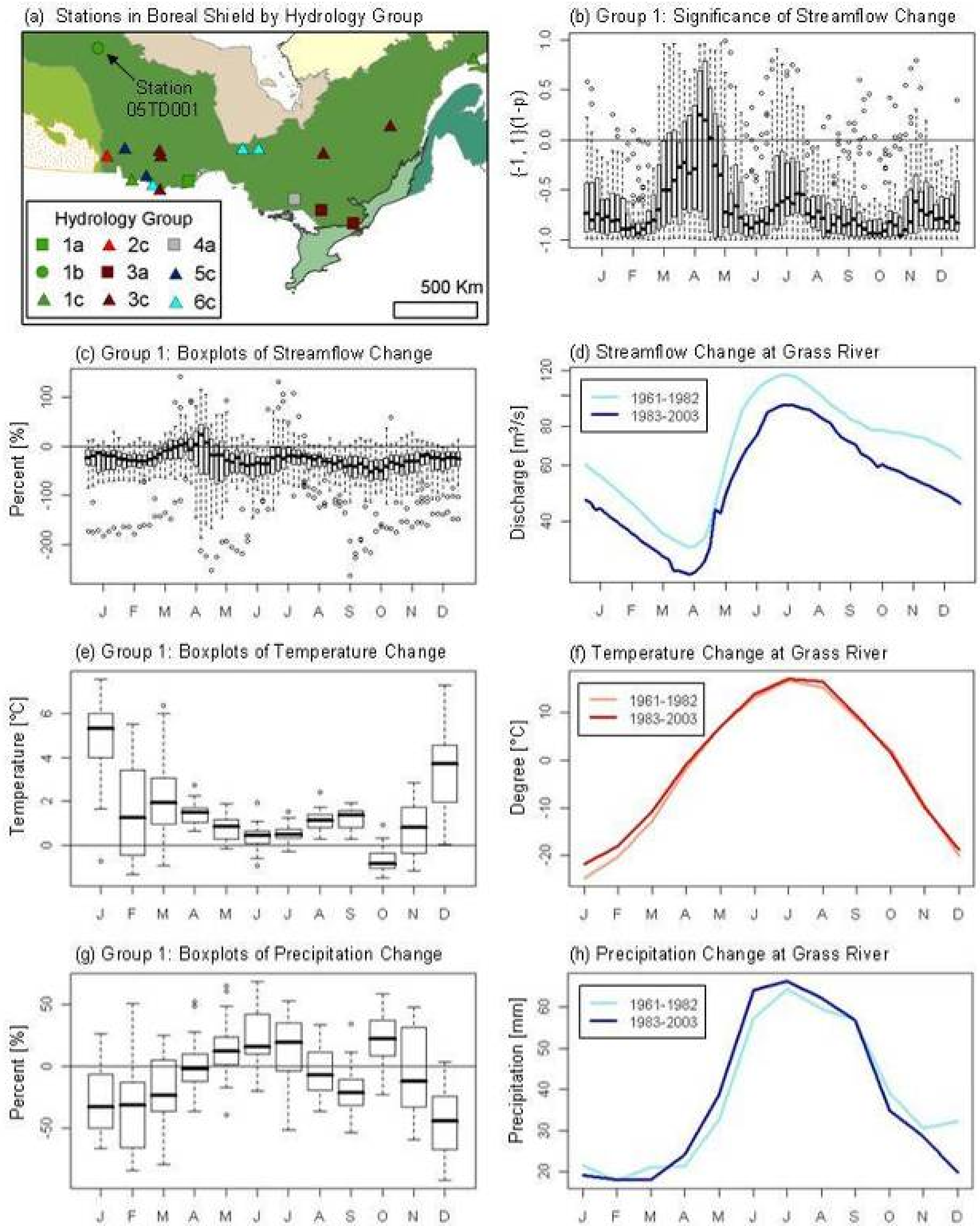


Figure 20. Changes in streamflow, temperature, and precipitation between 1961–1982 and 1983–2003 in the Boreal Shield Ecozone+ Hydrology Group 1, with an example of Grass River representing Group 1b. Source: Cannon et al., 2011[153]

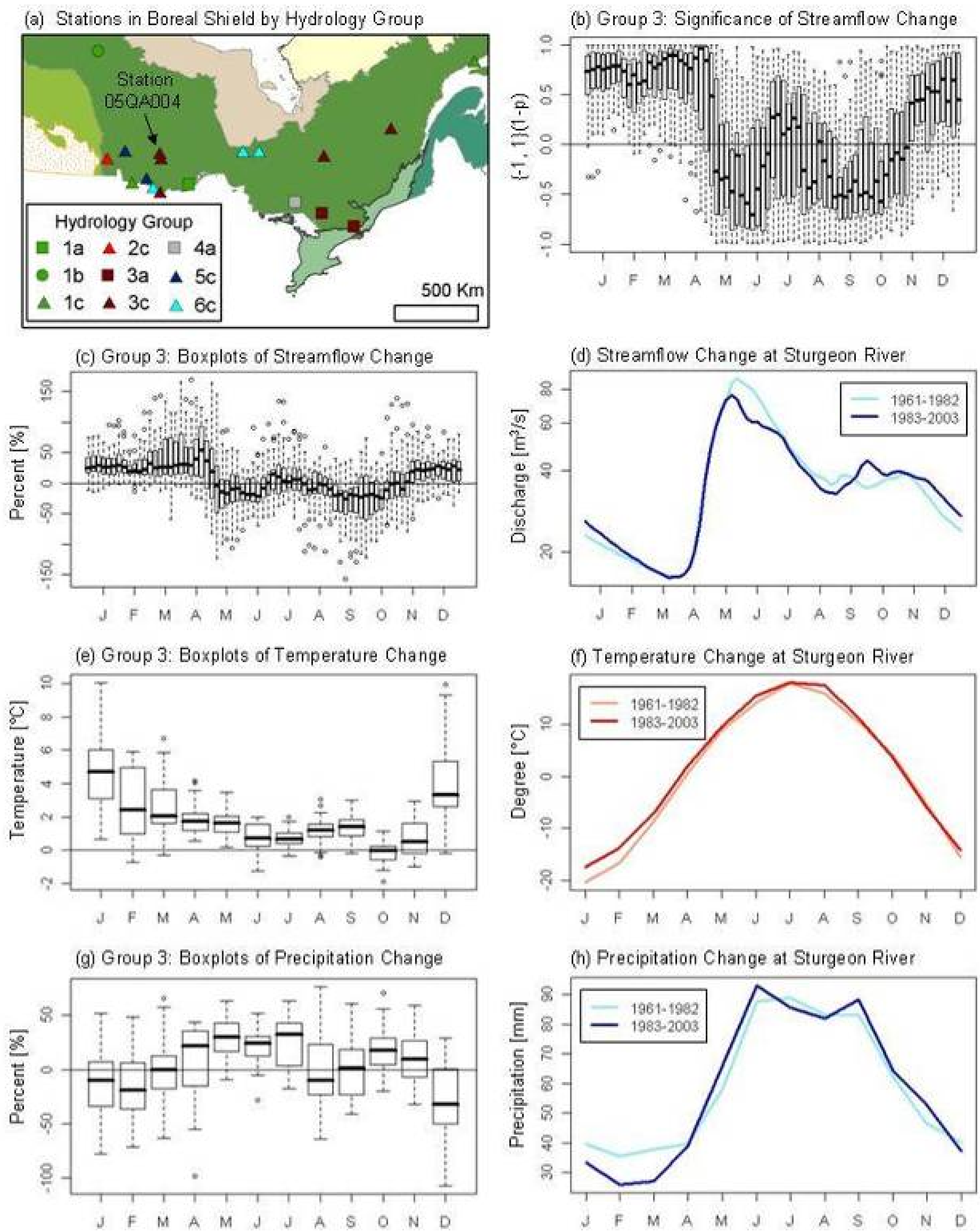


Figure 21. Changes in streamflow, temperature, and precipitation between 1961–1982 and 1983–2003 in the Boreal Shield Ecozone+ Hydrology Group 3, with an example of Sturgeon River representing Group 3c.
Source: Cannon et al., 2011[153]

River Flows in the Winnipeg River Basin

A Geological Survey of Canada study[1] examining river flows over the past century in the Winnipeg River basin illustrated the significant variation at the local scale for hydrological trends in the Boreal Shield Ecozone[+]. In this region specifically, average annual flows have increased by 58% since 1924. This differs from the more general pattern of decreasing flows observed northeast and northwest of this region, except for a higher and maybe earlier spring freshet (Figure 22). Winter discharge and streamflow have increased by 60 to 110% over the entire basin, likely caused by climatic factors. This shows that hydrological trends in the Winnipeg River basin during the last century differ from those observed for many other Canadian watersheds. Therefore, projections about decreasing surface flows and availability of water may not be valid for the Winnipeg River watershed.[3] However, the latest half of the 20th century saw increases in winter temperatures (Zhang et al., 2011[154] and supplementary data provided by the authors) and decreased winter precipitation in the east and west (Zhang et al., 2011[154] and supplementary data provided by the authors). Cree elders from Shoal Lake, Manitoba observed that there is less rain and snow than in the past. When it rains, they say that the land does not saturate and that this appears to be associated with warmer temperatures.[4] Trends observed for the Winnipeg River basin appeared to depend on the timeline examined, where increased streamflow in the 20th century may be due to climatic trends that occurred prior to 1950. The rest of the ecozone[+], in contrast, saw decreased flows and the main concerns were related to shifts in fish migration patterns, the availability of riparian habitat, and water quality.

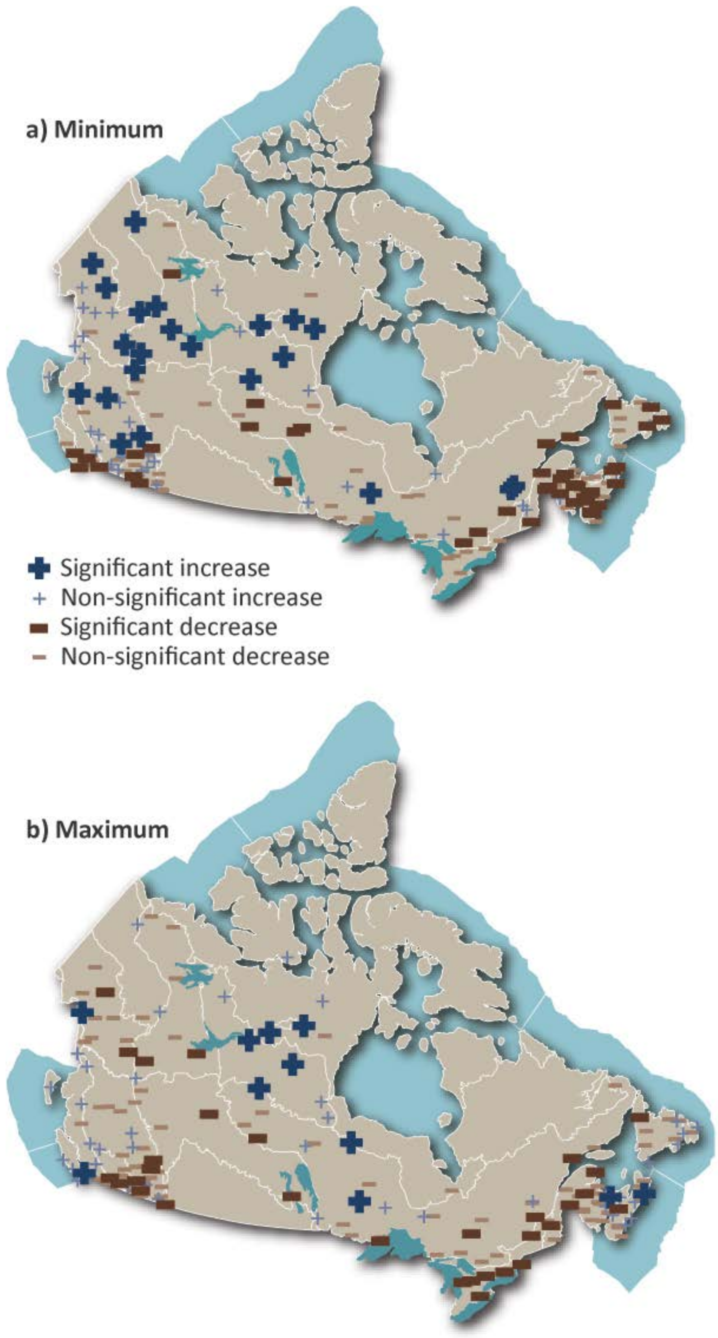


Figure 22. Map showing trends in the a) 1-day minimum and b) 1-day maximum river flow in natural rivers across Canada, 1970–2005.
Source: Monk and Baird, 2014[14]

Other key findings relevant to freshwater ecosystems include Intact landscapes and waterscapes on page 119, Fish on page 131, Aquatic Invasive non-native invertebrates on page 77, Boreal Shield Ecozone⁺ on page 90, Boreal Shield Ecozone⁺ on page 95, and Acid deposition on page 100.

Regulated streams and rivers

Dams and reservoirs alter the physical landscape, interrupt hydrological regimes, and the process of impoundment introduces contaminants that can accumulate along the food chain. More specifically, dams interrupt fish migration, increase sedimentation, flood or reduce habitat, and change water levels and water chemistry.[155] The degree of impact depends on the size of the dams, their operation, and the ecosystems' biophysical characteristics.[156, 157] However, dams can be operated to emulate natural hydrological regimes and mitigate adverse effects on ecosystems.[158]

Dams are more common in the southeastern portion of the ecozone+ (Figure 23).[159] The 1950s were the most productive decade for building dams in the ecozone+ and many of these dams are approaching the end of their productive lives (Figure 24).[12]

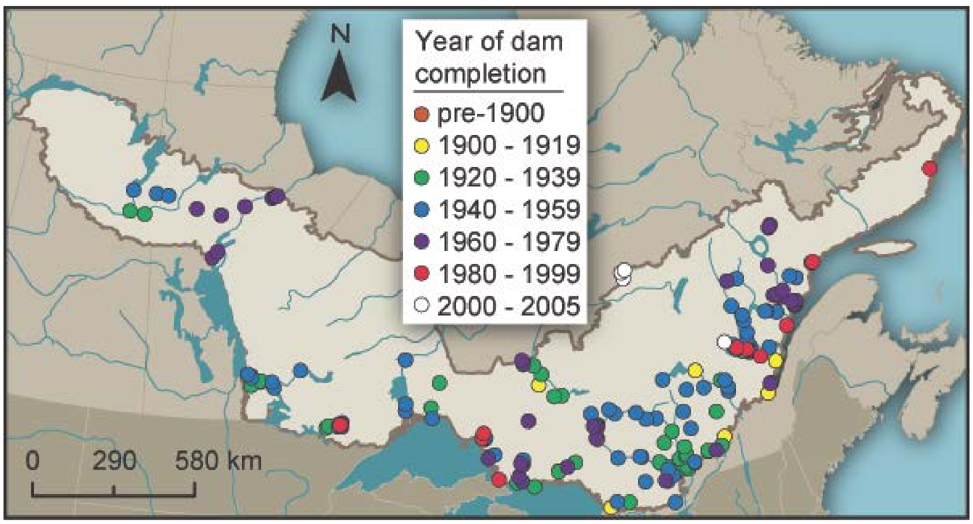


Figure 23. Distribution of dams greater than 10 m in height within the Boreal Shield Ecozone+ grouped by year of completion from 1830 to 2005.
Source: data from Canadian Dam Association, 2003[159]

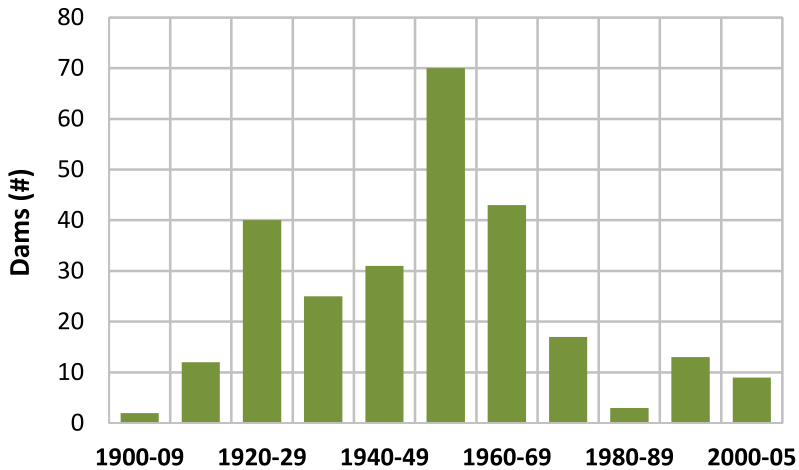


Figure 24. Number of dams greater than 10 m in height constructed in the Boreal Shield Ecozone+ per decade, 1900s-2000s (except for 2000–2005).
Source: data from Canadian Dam Association, 2003[159]

Newfoundland Boreal Ecozone+

Eight out of nine stations in the Newfoundland Boreal Ecozone+ were classified as Hydrology Group 4 (Figure 25).[153] Rivers in this ecozone+ can further be divided by their hydrologic regime. The easternmost part of the island is dominated by rainfall driven systems (type d) and the four remaining stations are either driven by mixed rain and snow processes (type a) or dominated by snowmelt runoff (type c).

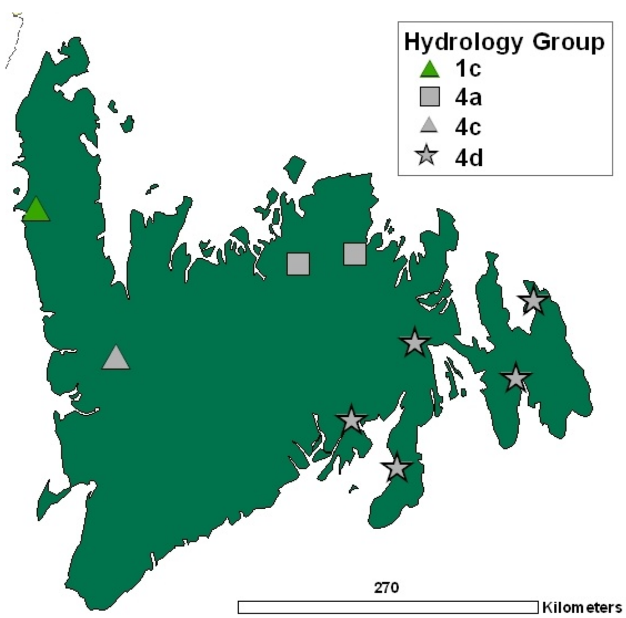


Figure 25. Natural streamflow stations in the Newfoundland Boreal Ecozone+ by Hydrology Group (1 or 4) and streamflow driver (a, c, or d).
Hydrograph type a rivers are driven by mixed rain and snow processes, type c describes rivers dominated by snowmelt runoff, and type d describes rivers exhibiting a rainfall driven pattern.
Source: Cannon et al., 2011[153]

The main pattern shift detected in the Newfoundland Boreal Ecozone+ was associated with Hydrology Group 4. Streamflow in this group increased in the spring by 10 to 40% relative to the median and decreased by 20 to 70% relative to the median during the summer low flow season (Figure 26a). Canada-wide, half of the stations classified as Hydrology Group 4 had temperature increases of up to 4°C during winter months (Figure 26b); however, this warming did not occur in the Newfoundland Boreal Ecozone+. A decrease in temperature was found in all stations in the ecozone+ in January. The Newfoundland Boreal Ecozone+ experienced cooler winters and warmer springs and summers (up to a 1°C increase), with no change detected in the fall. Precipitation in the Newfoundland Boreal Ecozone+ increased on average by 10 to 30% relative to the median for all months except August, November, and December (Figure 26c). For months where precipitation decreased, the average drop was approximately 10% relative to the median.

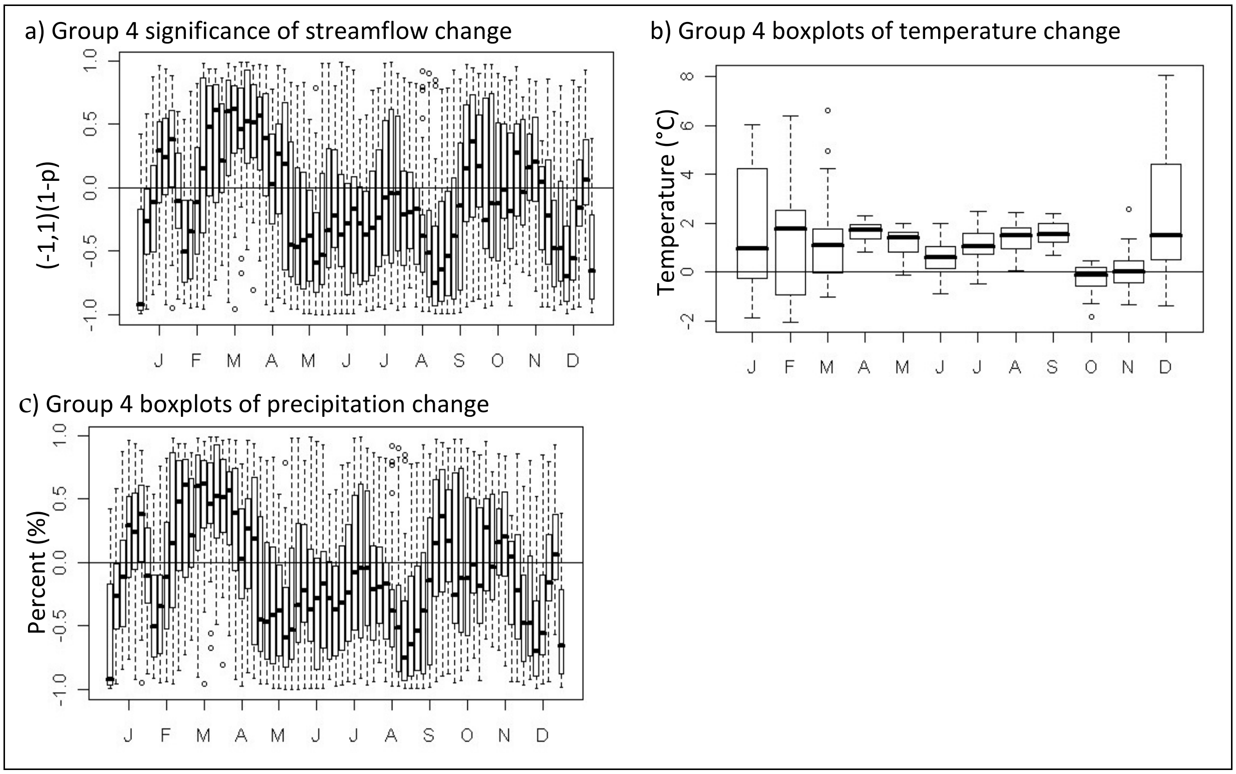


Figure 26. Changes in a) streamflow, b) temperature, and c) precipitation for Hydrology Group 4 in the Newfoundland Boreal Ecozone+, 1961–2003.
Source: Cannon et al., 2011[153]

Rainfall driven hydrologic regimes dominate the easternmost portion of the ecozone+, while the rest of the island is dominated by mixed rain and snow or snowmelt driven regimes (Figure 25).[153] Table 14 summarizes trends in unmanaged rivers from 1961 to 2003. Stream flow increases in the spring were attributed to a combination of higher precipitation and earlier snowmelt due to higher temperatures (see the Climate change key finding on page 106).[153] Decreases in summer discharge may be caused by higher temperatures, offsetting the effects of increased precipitation earlier in the season.[153] Hydrologic changes may also be the result of interior forest losses dues to harvest, fire, and insect outbreaks.[160]

Table 14. Summary of hydrologic trends in rivers with minimal regulation or impact upstream.

Period analyzed	Stations analyzed	Parameter	Significant Trends
1970–2005[14]		Total monthly runoff	↑ ↓
		Minimum 1, 3, 7, 30, 90 day runoff	↓
		Maximum 1, 3, 7, 30, 90 day runoff	↓
1961–2003[153]		Spring discharge	↑
		Summer discharge	↓

Sources: Monk and Baird, 2014[14] and Cannon et al., 2011[153]

The Bay du Nord River, a characteristic rainfall driven system (Figure 25), has displayed clear increases in spring flow and decreases in summer flow (Figure 27a). Hydrologic changes are also evident in the Gander River, a characteristic mixed rain and snow driven system.[153] Peak flows occurred earlier, with higher flows before the peak flow, and lower flows after the peak flow (Figure 27b).

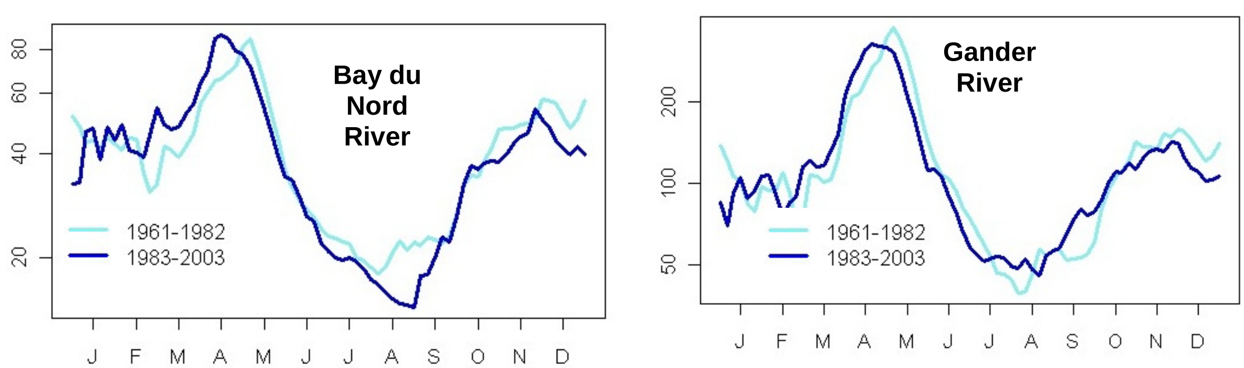


Figure 27. Changes in streamflow comparing 1961–1982 and 1983–2003 for the Bay du Nord River (left) and the Gander River (right).
Source: Cannon et al., 2011[153]

Regulated streams and rivers

Most dams in Newfoundland were built in the 1980s. Figure 28 shows locations of large dams completed in the Newfoundland Boreal Ecozone+ from 1895 to 2005.

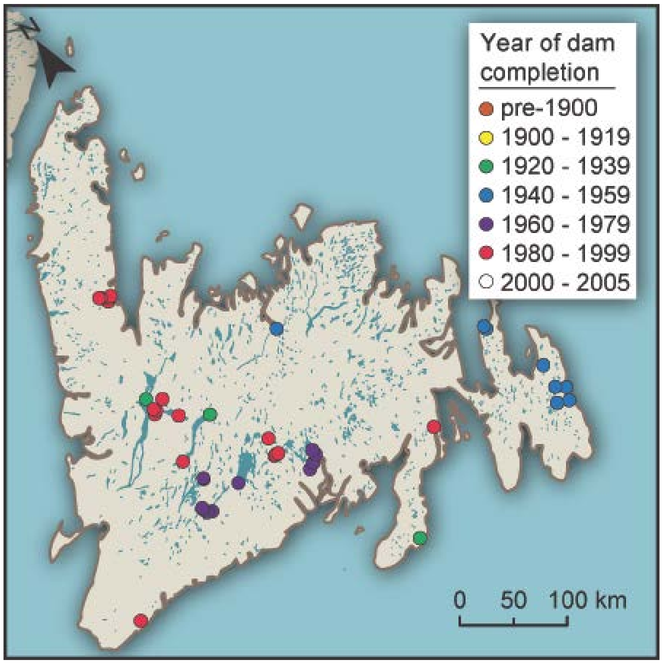


Figure 28. Distribution of dams greater than 10 m in height within the Newfoundland Boreal Ecozone+ grouped by year of completion from 1830 to 2005.
Source: data from Canadian Dam Association, 2003[159]

Key finding 5 **Theme** Biomes

Coastal

National key finding
Coastal ecosystems, such as estuaries, salt marshes, and mud flats, are believed to be healthy in less-developed coastal areas, although there are exceptions. In developed areas, extent and quality of coastal ecosystems are declining as a result of habitat modification, erosion, and sea-level rise.

Boreal Shield Ecozone+

Coastal ecosystems within the Boreal Shield Ecozone+ are located along the Gulf of St. Lawrence, Lake Superior, and the Labrador Sea. The most sensitive areas within the Boreal Shield Ecozone+ are on the north shore of the St. Lawrence and Anticosti Island, located at the mouth of the St. Lawrence River into the Gulf of St. Lawrence. Two-thirds of this 1,825 km of coast are classified as moderately to very sensitive to erosion.[161] In very sensitive areas, coastal loss can reach 10 m per year.

Accelerated coastal erosion is correlated with changes in climatic variables such as increased storm frequency,[162, 163] shorter ice season, more freeze/thaw cycles and winter rain events,[164] and increased sea level rise.[165] Temperatures in the maritime region of eastern Quebec increased by 0.9°C over the past century[163] with a concurrent 17 cm increase in sea level.[166, 167] The rate of erosion increased in the Laurentian maritime of Quebec between 1990 and 2004 as compared to pre–1990 studies.[168] This was especially true for low sandy coastlines and low clayey cliffs (Figure 29).

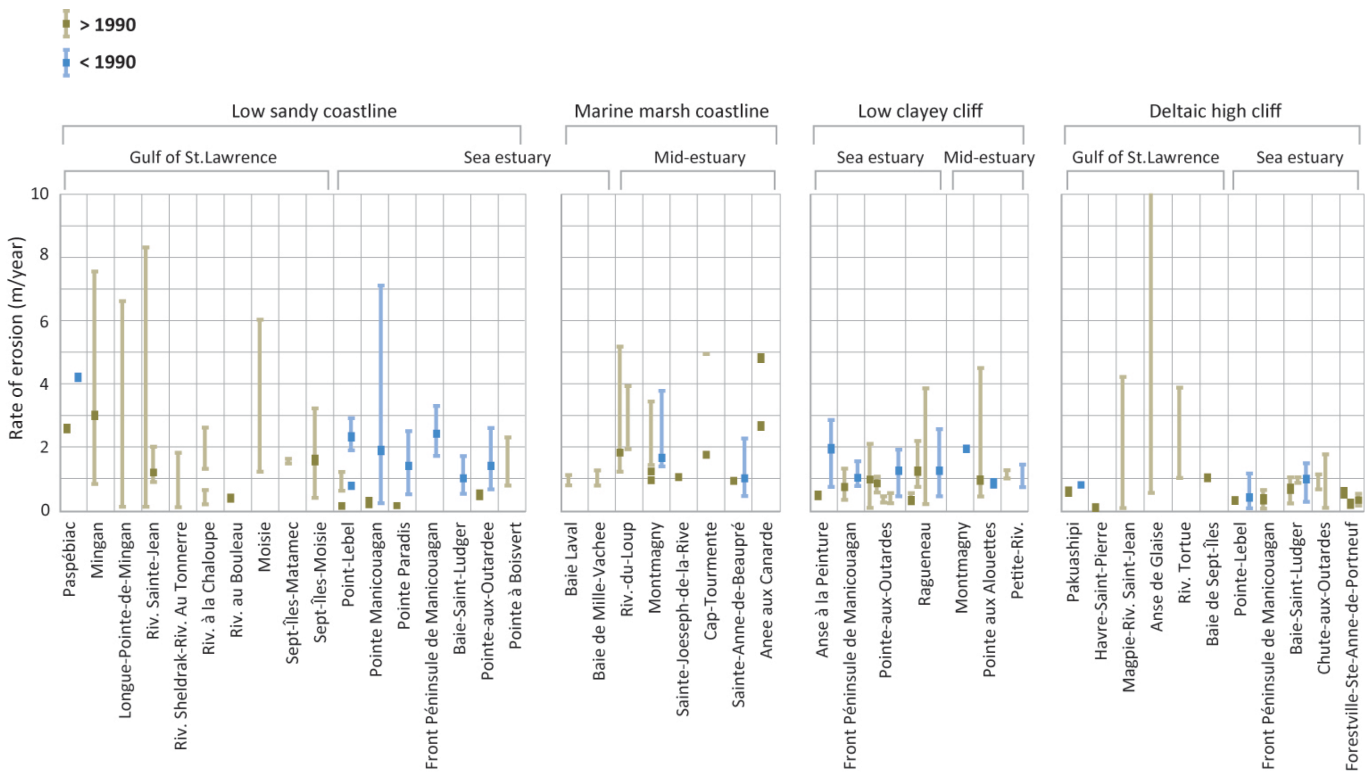


Figure 29. Sensitivity to coastal erosion of the four major types of coastal systems of the Laurentian maritime of Quebec according to historical and recent erosion rates.
Source: adapted from Bernatchez and Dubois, 2004[168]

Changes in ice dynamics due to warmer temperature likely contributed to increased erosion on the north shore of the St. Lawrence gulf and estuary.[169] Lake ice broke-up earlier on inland lakes of the ecozone+ from 1970 to 2004 (Figure 36).[170] See the Boreal Shield Ecozone+ key finding on page 65 for more information.

Double-crested cormorants (*Phalacrocorax auritus*) were first noted to be breeding in western Lake Superior in 1913.[171] From 1913 to 1945, they spread eastward across the Great Lakes, colonizing Lakes Huron and Michigan, then Lakes Erie and Ontario, and finally the Upper St. Lawrence River.[172] The population of double-crested cormorants is surveyed by Canadian Wildlife Service on a five-year rotation in the migratory bird sanctuaries of the north shore of the Gulf of St. Lawrence. Although cormorant populations increased during the 1980s and 1990s (Figure 30),[173] this trend may not be representative of the whole ecozone+. Major impacts of the increasing populations of double-crested cormorants include destruction of vegetation, impacts on other colonial waterbirds such as black-crowned night-herons (*Nycticorax nycticorax*), and impacts on fisheries.[172] To reduce cormorant populations, culling, destruction of nests and eggs, and harassment of birds began in the 1990s in the Great Lakes and along the St. Lawrence River.[172]

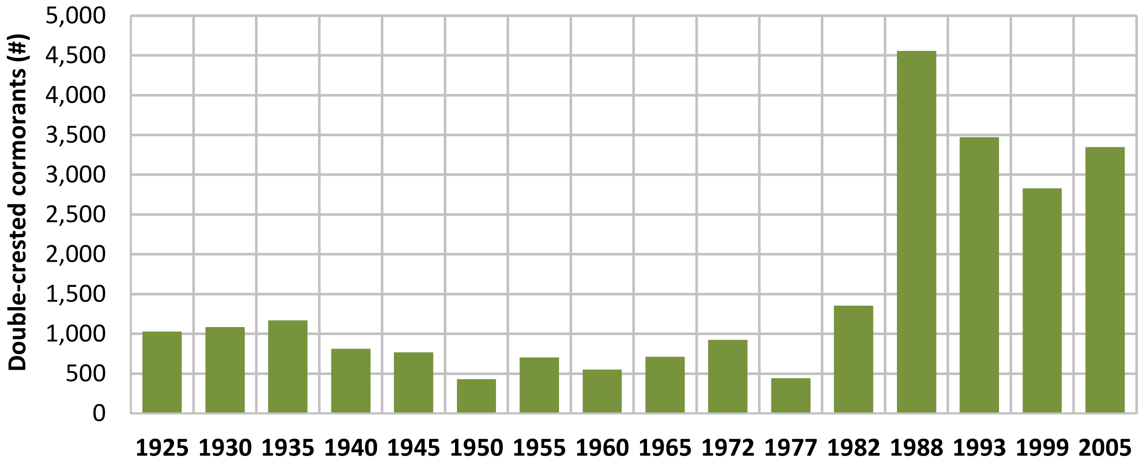


Figure 30. Number of double-crested cormorants in sanctuaries on the north shore of the Gulf of St. Lawrence, 1925-2005.
Source: Weseloh, 2011[173] adapted from Savard, 2008[174]

Newfoundland Boreal Ecozone+

The coastline of the Newfoundland Boreal Ecozone+ is approximately 11,550 km long, not including the many islands scattered along the coast.[175] The coastline is dotted with bays, inlets, sandy beaches, capes, and fjords, supporting habitats including salt marshes, eelgrass (*Zostera*) assemblages, rockweed (*Fucus anceps*) surf zone shores, capelin (*Mallotus villosus*) spawning beaches, temporary intertidal communities, and periwinkle (*Littorina littorea*) shores.[176] Human settlement is concentrated in coastal areas.[29]

Coastal dunes

Sand dunes are found along much of the coast of the Newfoundland Boreal Ecozone+ (Figure 31). Promotion of the dunes for tourism has resulted in increased recreation, including all-terrain vehicle use, that has accelerated coastal erosion and degradation of the dunes.[177] Erosion is further exacerbated by limited offshore winter ice and onshore snow cover. Replenishment of eroded sand is insufficient to maintain the dunes in the long term. Consequently, the coastal dunes of southwest Newfoundland, and perhaps other areas, will not regenerate following disturbance.[177]

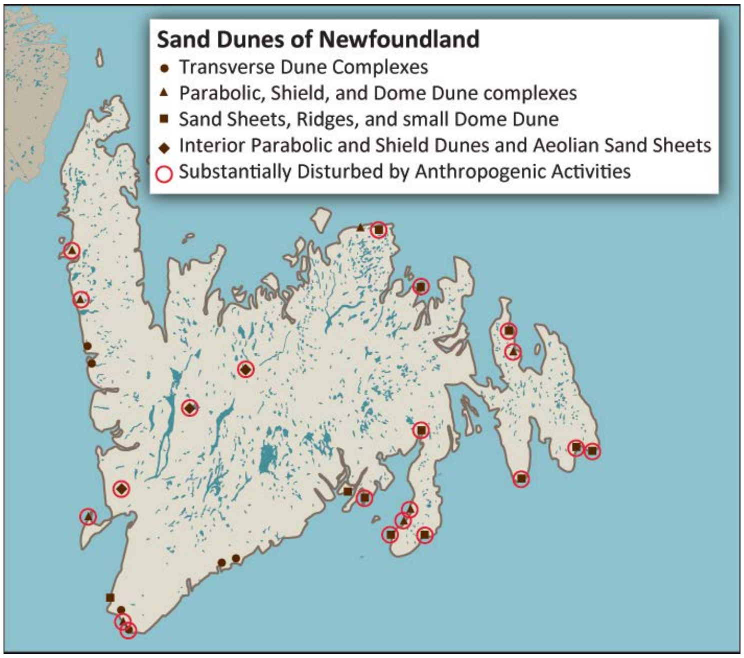


Figure 31. Sand dunes in the Newfoundland Boreal Ecozone+.
Source: adapted from Catto, 2002[177]

Sea-level rise and erosion

The effects of sea-level rise since the time of human occupation are evident at archaeological sites such as The Beaches, Bonavista Bay, Fort Frederick, Placentia Bay, and Ferryland.[160] Multiple factors including relief, rock type, land form, sea level change, and anthropogenic activities contribute to coastal erosion.[178] For example, along the southwestern, western, and eastern coasts of the ecozone+, the combination of rising sea levels, increased residential and tourism use, and changing offshore winter ice conditions have intensified erosion and degradation of dunes and shores.[144, 177, 179, 180] Figure 32 and Figure 33 provide evidence of accelerated beach erosion on the Avalon Peninsula. Of 405 coastal communities, the vulnerability of most communities was "moderately high"; Northern Bay Sands, Salmon Cove, and Point Lance Cove were ranked as "extremely high" (Figure 34).

Figure 32. Coastal erosion at Admiral's Beach, Avalon Peninsula, undercut this transportation route.
Source: Batterson and Liverman, 2010 [181]

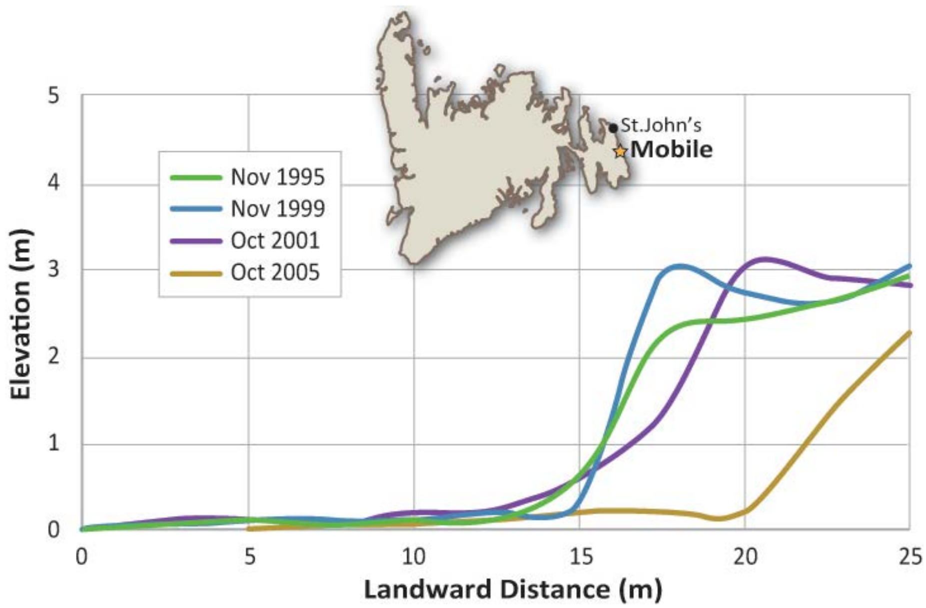


Figure 33. Elevation along a beach transect in Mobile, NL, showing erosion in the upper portion of the beach system, 1995-2005.
Source: Catto, 2006[182]

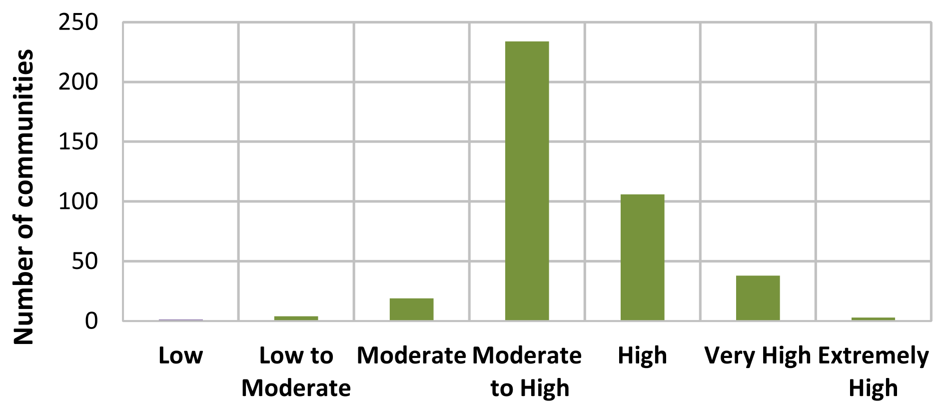


Figure 34. Number of communities in eastern Newfoundland experiencing various levels of sensitivity to sea-level rise.
Source: Catto, 2003[160]

Eelgrass

Eelgrass (*Zostera marina*) is a flowering marine plant that forms extensive subtidal beds in sand and mud along coastlines. It traps particulate matter and plankton and provides habitat for invertebrates, fish, and marine mammals. Eelgrass is an important food for migrating and wintering waterfowl, and provides foraging areas for other birds.[183-185] Eelgrass meadows are among the most productive ecosystems in the world,[186] and also among the most threatened.[187] Eelgrass assemblages in the Newfoundland Boreal Ecozone[+] are found in sandy, relatively sheltered lowshore locations. Based on local knowledge and in contrast to other areas on the Atlantic coast, eelgrass populations off the coast of Newfoundland are increasing in abundance, possibly due to milder temperatures and changes in sea ice.[186]

Coastal birds

The fall migration of 14 species of shorebirds was monitored for 12 sites in insular Newfoundland between 1980 and 2005, including six years of data collected by the Newfoundland and Labrador Shorebird Survey (NLSS) volunteers. Population levels fluctuated widely between years and decades. Most species increased in the 1980s, declined in the 1990s, and continued to decline from 2000 to 2005 although these rates were not significant (Table 15).[188]

Many species which have declined across the Maritimes [189] were species that increased in Newfoundland, possibly indicating a shift in preferred migration stop over areas within the Atlantic region.[188]

Table 15. Population trends for common shorebird species on southern migration during the 1980s, 1990s and 2000–2005 in the Newfoundland Boreal Ecozone+.

	1980–1989			1990–1999			2000–2005		
Species	Trend	Annual change (%)	P	Trend	Annual change (%)	P	Trend	Annual change (%)	**P**
Greater yellowlegs (*Tringa melanoleuca*)	0.02	1.47		0.108	11.4	n	0.06	6.08	
White-rumped sandpiper (*Calidris fuscicollis*)	0.21	23.0	*	-0.14	-13.2	n	-0.07	-7.01	
Semipalmated plover (*Charadrius semipalmatus*)	0.15	16.0	*	-0.02	-2.21		-0.03	-2.99	
Semipalmated sandpiper (*Calidris pusilla*)	0.16	17.2	*	-0.16	-14.6	*	-0.02	-2.36	
Sanderling (*Calidris alba*)	0.06	6.01	*	-0.11	-10.2	*	-0.18	-16.6	*****
Black-bellied plover (*Pluvialis squatarola*)	0.17	18.4	*	-0.24	-20.9	*	-0.10	-9.17	**n**
Ruddy turnstone (*Arenaria interpres*)	0.13	13.5	*	-0.15	-14.0	*	-0.07	-6.70	**n**
American golden-plover (*Pluvialis dominica*)	0.04	3.75	*	-0.09	8.42	*	-0.05	-4.74	*****
Whimbrel (*Numenius phaeopus*)	-0.005	-0.51		-0.12	-11.3	*	-0.04	-4.35	**n**
Least sandpiper (*Caldiris minutilla*)	0.07	7.57	*	-0.06	-5.98		-0.02	-2.27	
Dunlin (*Calidris alpine*)	0.04	3.40	*	-0.09	-8.46	*	0.02	2.18	
Spotted sandpiper (*Actitis macularius*)	-0.04	-3.49		0.14	15.0	*	-0.02	-2.14	
Lesser yellowlegs (*Tringa flavipes*)	0.09	9.15	*	-0.104	-9.90	*	0.016	1.59	
Short-billed dowitcher (*Limnodromus griseus*)	0.08	8.15	*	-0.05	-4.55		-0.06	-5.38	n

*P is the statistical significance: * indicates p <0.05; n indicates 0.05<p<0.1; no value indicates not significant.*
Source: Goulet and Robertson, 2007 [188]

On the Atlantic Seaboard, in the Estuary and Gulf of St. Lawrence, Gulf of Maine and Scotian Shelf and Newfoundland and Labrador Shelves marine ecozones+, the sharp discontinuity in oceanography and food webs that occurred in the early 1990s caused some marine bird populations, especially gulls, to shift from positive to negative trends. However, the northern gannet (*Morus bassanus*) (Table 16) and razorbill (*Alca torda*) continued to increase from the 1970s onwards, as have most auk (family *Alcidae*) populations within the Gulf of St. Lawrence and Atlantic puffins (*Fratercula arctica*) in southeast Newfoundland. Conversely, common terns (*Sterna hirundo*) generally decreased throughout the period in these ecozones+ (Table 16), probably as a result of human influences on their terrestrial breeding habitat. Decreases in large gulls and black-legged kittiwakes (*Rissa tridactyla*) (Table 16) may be related to the reduction in inshore fisheries activity (which provided fish offal and discards) following the groundfish moratorium of 1992. Overall positive trends in seabird populations prior to 1990 may reflect continuing recovery from egging and plumage harvesting prevalent before the institution of the *Migratory Bird Protection Act* in the early twentieth century, or in Newfoundland, after amalgamation with Canada in 1949. Some harvesting activities continued to affect seabirds on the north shore of the Gulf of St. Lawrence as late as the 1960s and 1970s.[190] In addition, the groundfish moratorium off eastern Newfoundland caused the closure of gill-net fisheries that were drowning many auks. Removal of this source of mortality may have had positive consequences for some populations of underwater divers.

Table 16. Trends in the abundance and reliability of the trend for coastal birds in the Newfoundland Boreal Ecozone+ from 1980–2012.

Species	Annual Trend	Reliability
Black-legged kittiwake (*Rissa tridactyla*)	-13.8	Low
Caspian tern (*Hydroprogne caspia*)	6.57	Low
Common tern (*Sterna hirundo*)	-2.75	Low
Double-crested cormorant (*Phalacrocorax auritus*)	20.3	Low
Great black-backed gull (*Larus marinus*)	-4.44	Medium
Northern gannet (*Morus bassanus*)	12	Low
Ring-billed gull (*Larus delawarensis*)	7.52	Low

Source: Environment Canada, 2014[79]

Key finding 7	**Theme** Biomes

Ice across biomes

National key finding
Declining extent and thickness of sea ice, warming and thawing of permafrost, accelerating loss of glacier mass, and shortening of lake-ice seasons are detected across Canada's biomes. Impacts, apparent now in some areas and likely to spread, include effects on species and food webs.

Boreal Shield Ecozone+

Lake ice

Most Canadian lakes had a tendency or significant trend towards earlier ice break-up (Figure 35). The rate of change in lake-ice thaw was much more rapid from 1950 to 2006 than the rate during the first half of the 20th century.[191] For example, Brochet Bay on Reindeer Lake, MB, broke up 0.5 days earlier per year between 1951 and 1980 for a total of 14.5 days.[192]

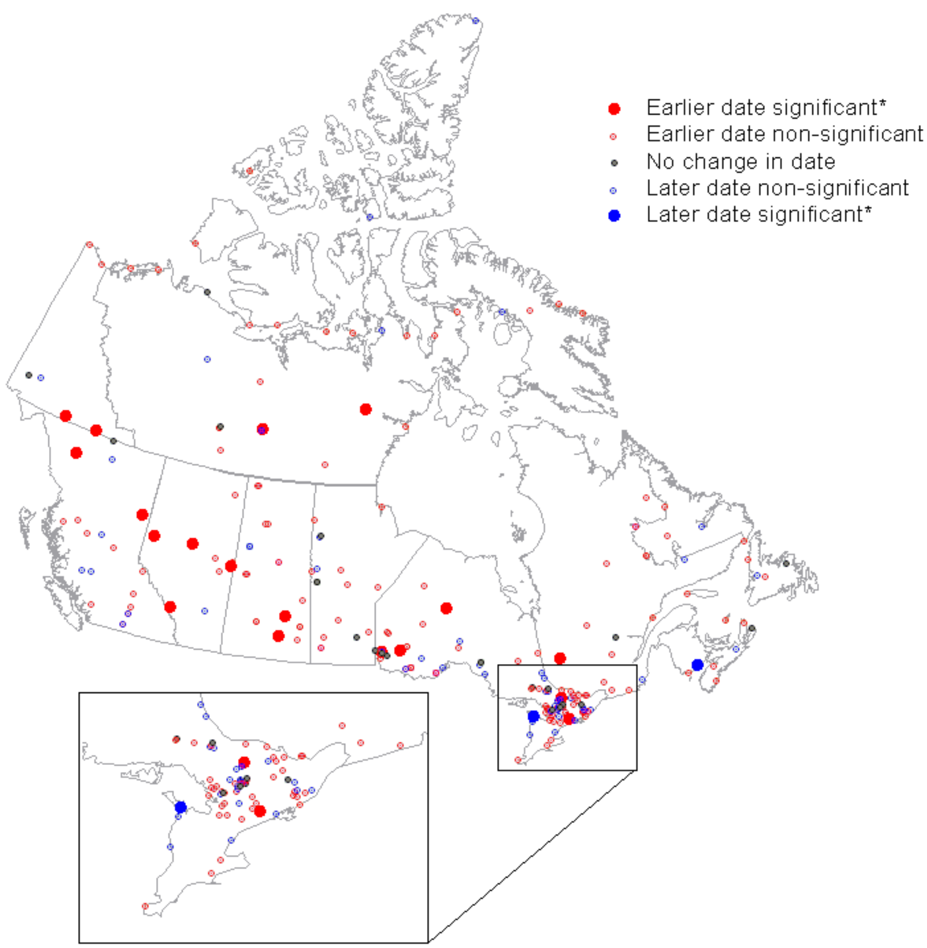


Figure 35. Changes in the date of ice thaw on lakes across Canada, 1950–2005. These nation-wide data exceed the Boreal Shield Ecozone+ boundaries. Source: Environment Canada, 2008[191]

Ice in lakes and rivers of the Boreal Shield Ecozone+ tended to break up earlier over the past 35 to 200 years,[14, 193-195] although there was one exception where ice break-up was later from 1950 to 1998.[194] Figure 36 shows trends in ice break-ups using in situ records and remote sensing observations of 12 large lakes (over 100 km^2) in Canada.[196] Ice break-up shifted 12 days earlier over the period of 1970 to 2004 (Figure 36a).[196] Earlier ice break-up corresponded to an earlier arrival of the spring 0°C-isotherm date.[197] Warmer temperatures in spring (Figure 67a) and winter (Figure 67d) in the Boreal Shield Ecozone+ may partly account for the earlier ice break-up.

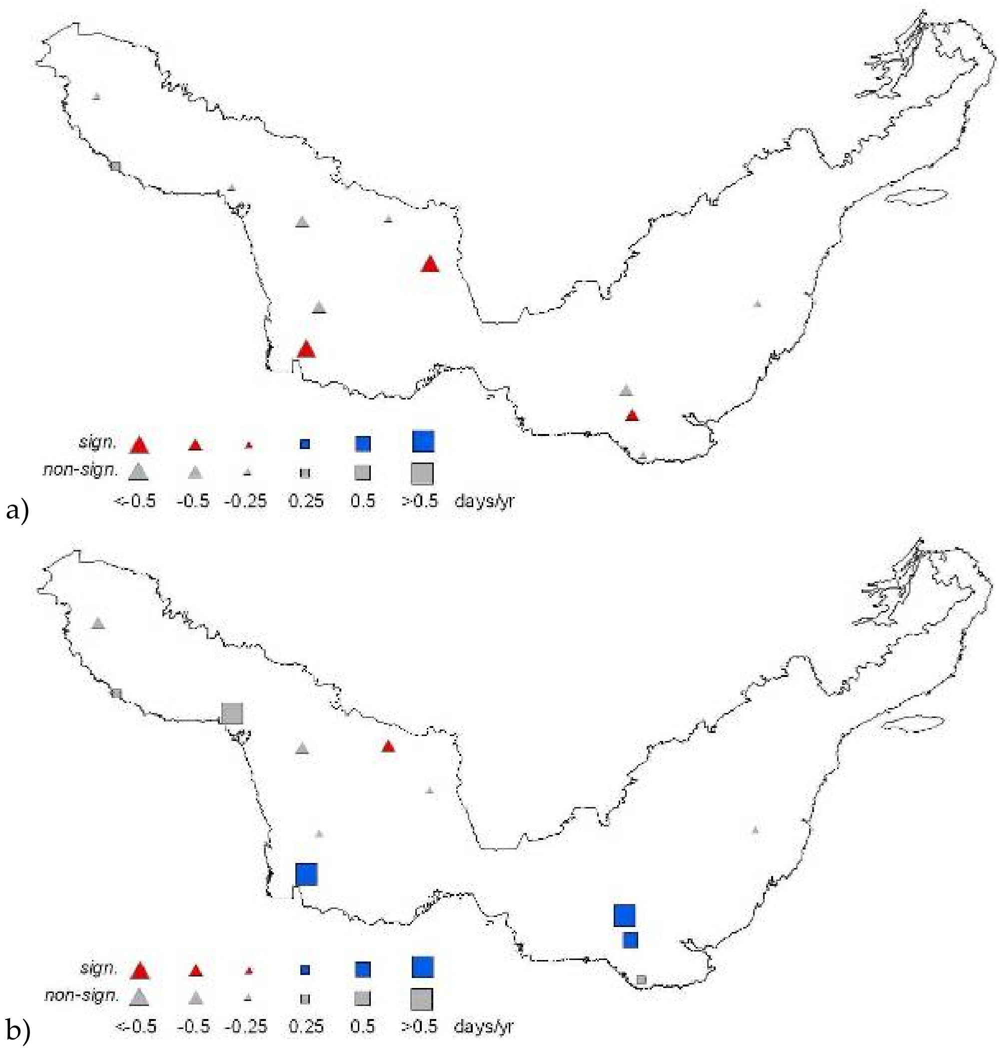


Figure 36. Lake a) break-up trends and b) freeze-up trends for 12 lakes in the Boreal Shield Ecozone+, 1970–2004.

Analyses for break-up are based on in-situ and remote sensing data. Trends for freeze-up for the six most northerly stations are based only on remote sensing data from 1984–2004. Triangles indicate earlier break-up/freeze-up; squares indicate later break-up/freeze-up. Symbols are coloured when trends are significant (p<0.1).

Source: adapted from Latifovic and Pouliot, 2007[196]

There is more variability in lake and river freeze-up than in ice break-up,[14] at this ecozone+ level and nationally over 35 to 200 years.[194, 195, 197, 198] The air temperature from one to three months before the event appears to be a potential factor causing changes in ice break-up and freeze-up dates.[199, 200] From 1970 to 2004, freeze-up occurred 15 days later for three lakes across the southern half of the ecozone+. Freeze-up occurred 10 days earlier for one more northern lake (Figure 36b).[196]

Permafrost

Permafrost in the Boreal Shield Ecozone+ is largely confined to organic terrain and has a sporadic distribution over its northeastern and western regions (Figure 37).[201]

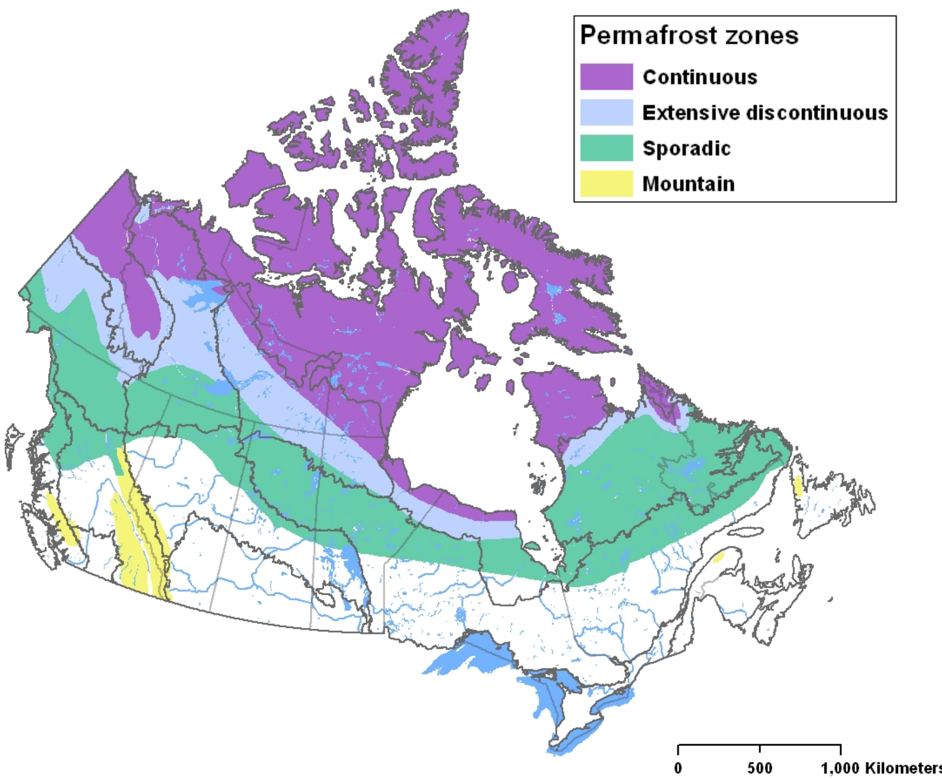


Figure 37. Permafrost map for Canada.
Source: Heginbottom et al., 1995[201]

Thawing and peatland collapse has occurred over the last 50 to 100 years[202-204] in northern Saskatchewan and Manitoba. The thaw rate of permafrost increased from 4.3 cm/yr between 1948 and 1991 to 10.5 cm/yr between 1995 and 2002 at Gillam, from 9.0 cm/yr in 1941–1988 to 28.0 cm/yr in 1995–2002 at Thompson, from 10.2 cm/yr in 1951–1992 to 22.3 cm/yr in 1995–2002 at Wabowden, and 10.9 cm/yr in 1968–1991 to 31.1 cm/yr in 1995–2002 at Snow Lake[204] (Figure 38). Near Saskatchewan's Lake Athabasca and Black Lake, Aboriginal communities noticed disappearing permafrost in muskeg, which they attributed to warming temperatures.[4] Although frozen peatlands go through natural cycles of permafrost formation and thawing, this permafrost degradation is likely due to climate change.[16]

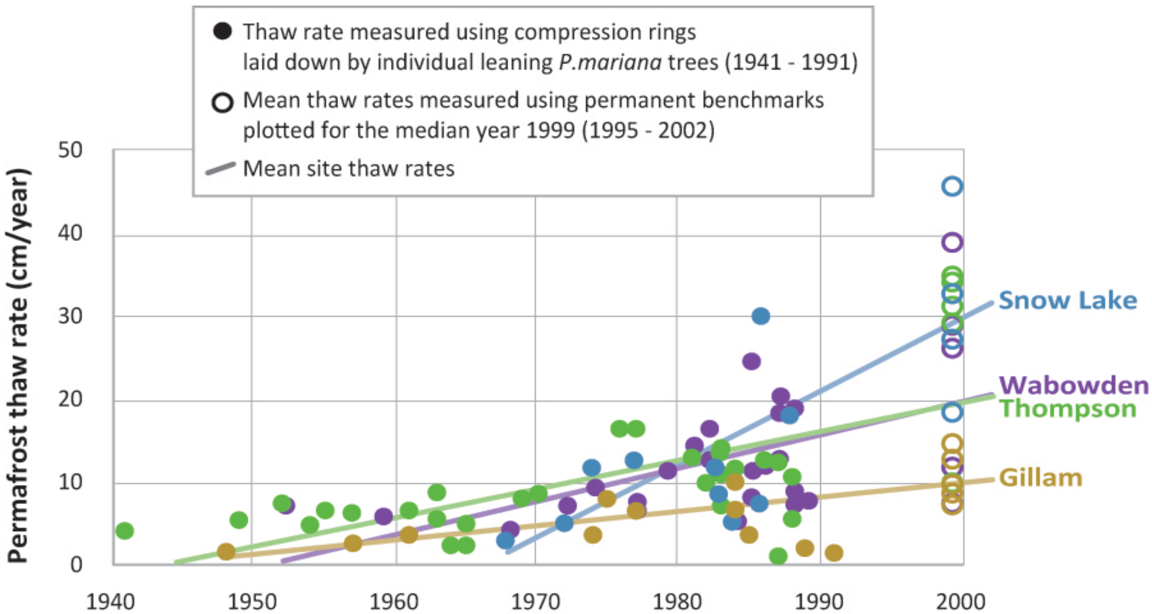


Figure 38. Permafrost thaw rate (cm/yr) in the Boreal Shield Ecozone+, 1940- 2000.
Purple circles represent thaw rate measured for the 1941–1991 period using compression rings laid down by individual leaning P. mariana *trees. Green circles represent mean thaw rates measured using permanent benchmarks for the 1995–2002 period (plotted for the median year, 1999). Mean site thaw rates for the 1941–1991 and 1995–2002 periods are also shown.*
Source: adapted from Camill, 2005[204]

Permafrost degradation in the Boreal Shield Ecozone+ can affect biodiversity through its influence on ground stability, drainage patterns, soil-moisture conditions, and surface and subsurface hydrology.[16] Although the Boreal Shield Ecozone+ does not have continuous permafrost, the discontinuous ice-rich soil has similar physical conditions to more northern ecosystems.[205] In peatland areas, as ice-rich peat thaws and collapses, ponds may replace frozen peat plateaus, creating the conditions for fen ecosystems to develop.[206, 207] Although most of these effects were observed in Arctic sites, permafrost in the Boreal Shield Ecozone+ is primarily on organic terrain, suggesting a possible loss of peatland in the landscape.[16] Understanding of permafrost hydrology for the ecozone+ is limited by a lack of data. For example, it is uncertain why streamflows in Grass River have decreased annually (Figure 20). Permafrost melt may have altered underground hydrology, which generated drier conditions on the surface, and reduced contributions to the river.

Newfoundland Boreal Ecozone+

Lake ice

There were few data for ice trends for the Newfoundland Boreal Ecozone+ except for one location, Deadman's Pond, in the north-central part of the ecozone+. From 1961 to 1990, freeze-up at Deadman's Pond shifted 0.5 days/yr earlier, which differed from the national trends for later lake ice freeze-up.[197]

THEME: HUMAN/ECOSYSTEM INTERACTIONS

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

Protected areas

National key finding
Both the extent and representativeness of the protected areas network have increased in recent years. In many places, the area protected is well above the United Nations 10% target. It is below the target in highly developed areas and marine areas.

Boreal Shield Ecozone+

The rate at which protected areas in the Boreal Shield Ecozone+ have been created has increased since the 1970s (Figure 39). Before 1992 (the signing of the Convention on Biological Diversity), 3% of the Boreal Shield was protected.[1] As of May 2009, 8.1% (143,491 km²) were protected.[10] Of this, 7.9% of the ecozone+ was in 1,336 sites classified as IUCN protected area categories I–IV. These categories include nature reserves, wilderness areas, and other parks and reserves managed to conserve ecosystems and natural and cultural features, as well as those managed mainly for habitat and wildlife conservation.[208] A further 0.06% (482 protected areas) were in IUCN categories V–VI, which focus on sustainable resource use.[208] The remaining <0.01% (10 protected areas established since 2004) have not been categorized under the IUCN criteria.

For example, although not presently included in IUCN categories I-V, Kitchenuhmaykoosib Inninuwug (KI) First Nation declared 13,025 km² of the Big Trout Watershed protected by their community through their Water Declaration.[209] The Province of Ontario also withdrew 23,181 km² "in the vicinity of KI" from prospecting and mine claim staking, further supporting protection goals by KIFN.

[1] Note that there is 7,440 km² of protected land in the Boreal Shield Ecozone+ with no information on the year established. If all of this land was protected prior to 1992, then 3.4% of the ecozone+ was protected prior to 1992.

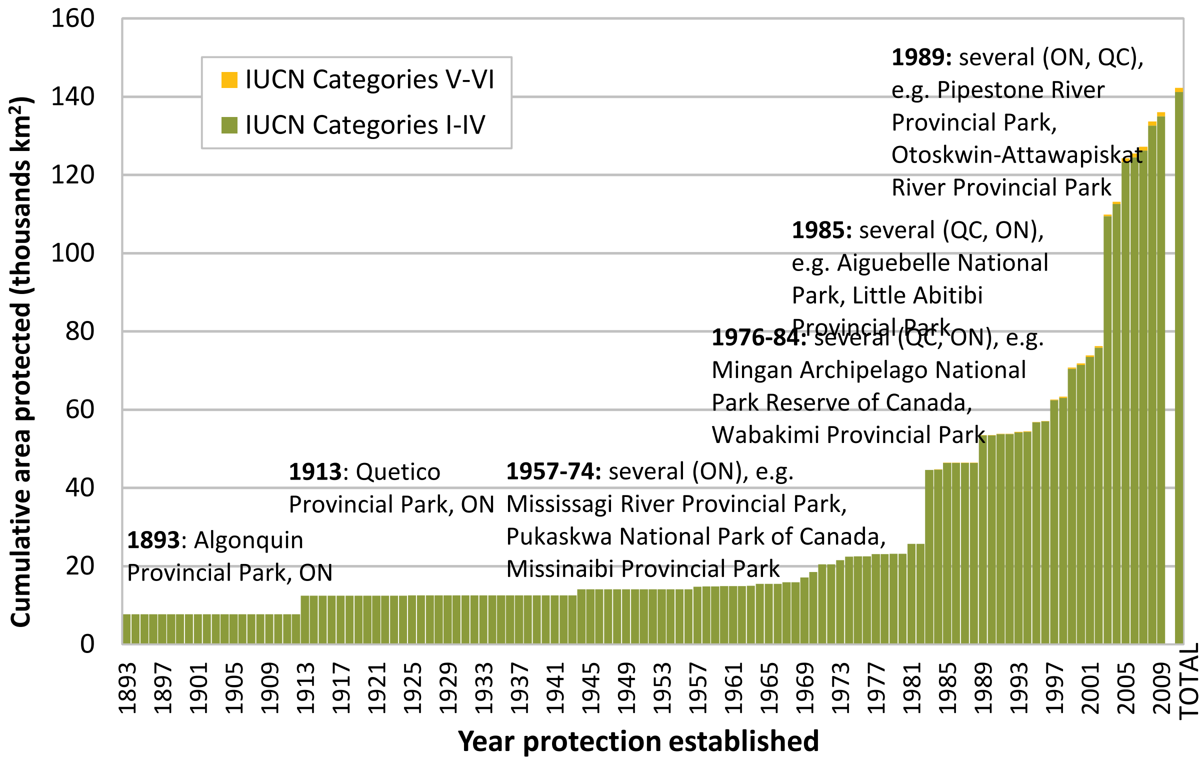


Figure 39. Cumulative area protected in the Boreal Shield Ecozone+, 1893–2009.
Data provided by federal, provincial and territorial jurisdictions, updated to May 2009. Only legally protected areas are included. International Union for Conservation of Nature (IUCN) categories of protected areas are based on primary management objectives (see text for more information).
The last bar marked 'TOTAL' includes protected areas for which the year established was not provided.
Source: Environment Canada, 2009[210] using Conservation Areas Reporting and Tracking System (CARTS) (v.2009.05), 2009;[10] data provided by federal, provincial, and territorial jurisdictions.

Protected areas are fairly well distributed across the ecozone+, although they are less numerous in the northwest (Figure 40).

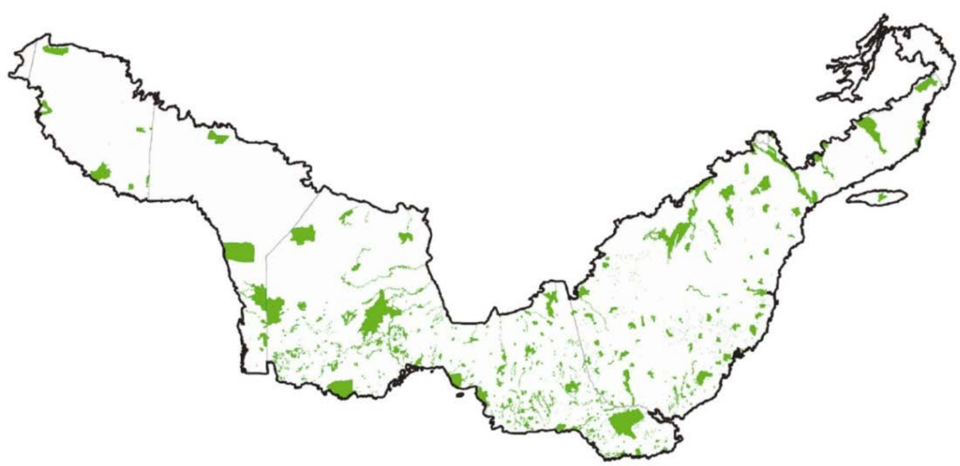


Figure 40. Distribution of protected areas in the Boreal Shield Ecozone+, May 2009.
Source: Environment Canada, 2009[210] using Conservation Areas Reporting and Tracking System (CARTS) (v.2009.05), 2009;[10] data provided by federal, provincial, and territorial jurisdictions.

In 2009, the Ontario and Quebec governments announced plans to protect northern boreal sites. [211, 212] Ontario's Far North Act became law in 2010 which mandated protection for about 50% of the area north of currently managed forest land for Ontario. Pikangikum was the first community to complete a community based land use plan in 2006. In 2011, Cat Lake and Slate Falls celebrated the completion of their plan with a signing ceremony, as did Pauingassi and Little Grand Rapids, two Manitoba communities with planning areas in Ontario.[213]

Newfoundland Boreal Ecozone+

As of May 2009, 6.3% (7,098 km²) of the ecozone+ had been protected through 45 protected areas in IUCN categories I–III (Figure 41 and Figure 42).[10] In addition, 1.2% of the ecozone+ was protected through five category VI protected areas, a category that focuses on sustainable use by established cultural tradition within the protected area.[208]

Two wilderness reserves (>1000 km²) and fifteen ecological reserves (<1000 km²) have been created in the Newfoundland Boreal Ecozone+ since the provincial *Wilderness and Ecological Reserves Act* was passed in 1980.[214] There are also two national parks, Gros Morne and Terra Nova, and 32 provincial parks and provincial park reserves.[214]

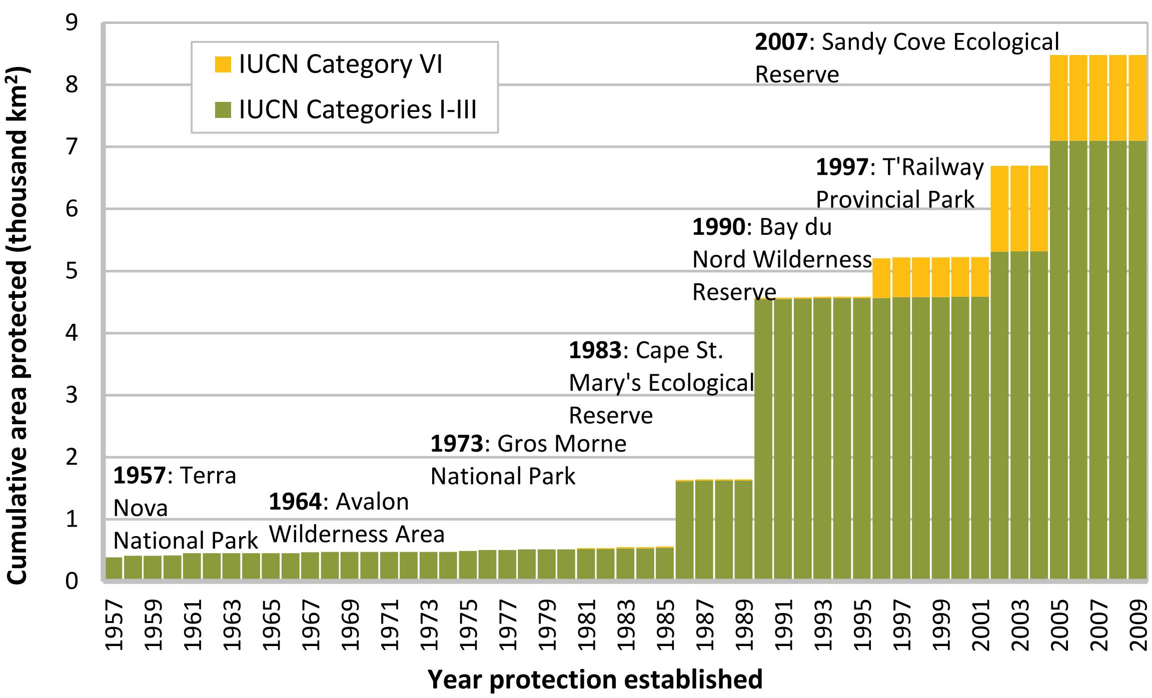


Figure 41. Cumulative area protected in the Newfoundland Boreal Ecozone+, 1957–2009.
Data provided by federal and provincial jurisdictions, updated to May 2009. Only legally protected areas are included. IUCN (International Union for Conservation of Nature) categories of protected areas are based on primary management objectives. Several small biodiversity reserves and other protected areas have been established since 2003. Labels are protected areas in IUCN Categories I–IV. The grey 'unclassified' category represents protected areas for which the IUCN category was not provided.
Source: Environment Canada, 2009[210] using data from the Conservation Areas Reporting and Tracking System (CARTS) (v.2009.05), 2009;[10] data provided by federal, provincial, and territorial jurisdictions.

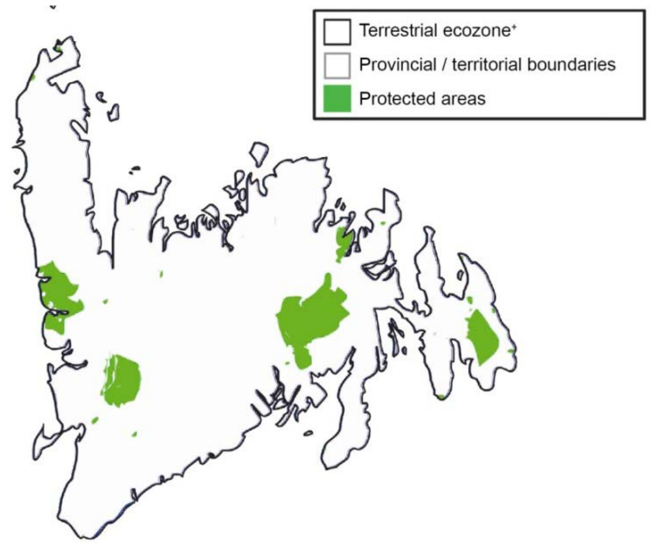


Figure 42. Map of protected areas in the Newfoundland Boreal Ecozone+, 2009.
Source: Environment Canada, 2009[210] using Conservation Areas Reporting and Tracking System (CARTS) (v.2009.05), 2009;[10] data provided by federal, provincial, and territorial jurisdictions.

Between 1995 and 1997, the provincial government privatized a number of Provincial Parks and Natural and Scenic Attractions to reduce expenses in the Parks and Recreation system. Some of these privatized properties are no longer operating and are no longer protected such as Pipers Hole River Provincial Park, abandoned in 2008.[215]

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.

Boreal Shield Ecozone+

Much of the Boreal Shield Ecozone+ is unpopulated and in a natural state, so community-driven stewardship activities are relatively rare in this ecozone+. However, stewardship activities are coordinated among larger conservation, First Nations, and industry networks.

Pimachiowin Aki is a cultural landscape and large protected area of intact boreal forest that has been nominated as a UNESCO natural and cultural World Heritage Site. The Ontario and Manitoba governments manage the area in partnership with the Anishnaabe First Nation. The area has a rich diversity of boreal flora and fauna, as well as ancestral lands of great value to Aboriginal communities.[216] Pimachiowin Aki has yet to be finalized.

Forest companies and environmental organizations in Canada came together in 2010 to create the Canadian Boreal Forest Agreement (CBFA). It is the world's largest conservation initiative. It includes the Forest Products Association of Canada, its 19 member organizations, and seven non-government environmental organizations such as the David Suzuki Foundation, Canadian Parks and Wilderness Society, and the Nature Conservancy. It entails a commitment by the environmental groups to stop boycotting the forest companies involved. In return, the companies have suspended logging operations on almost 290,000 km^2 of boreal forest. The suspension of forestry activities gives the signatories an opportunity to work together on action plans for the recovery of caribou and producing ecosystem-based management guidelines that participating companies can use to improve their forestry practices.[217] The Boreal Leadership Council, first convened in December 2003, is comprised of conservation groups, First Nations, resource companies, and financial institutions. Members of the Council are signatories to the Boreal Forest Conservation Framework, which aims to protect at least 50% of the boreal in a network of large, interconnected protected areas and support sustainable communities, ecosystem-based resource management, and stewardship practices across the remaining landscape.[218]

In the Athabasca region of Alberta, the oil industry engages in stewardship activities. The Oil Sands Leadership Initiative (OSLI), a collaborative network comprised of ConocoPhillips Canada, Shell Canada, Statoil Canada, Suncor Energy Inc., Nexen Inc., and Total E&P Canada, has four working groups including one that focuses on land stewardship.[219] The Land Stewardship Working Group (LSWG) is participating in a voluntary restoration in the Algar region, roughly 100 km from most of Alberta's in situ oil sands operations and within the East Side Athabasca River (ESAR) caribou range. The linear footprint from 20–30 year old seismic lines have left it fragmented, reducing the habitat quality for the caribou herd in the area. These areas are extremely slow to re-vegetate naturally due to cold wet soils. Field treatments applied by LSWG included mechanical site preparation for tree planting, collection and dispersal of coarse woody material along the treated seismic lines, identification and protection of existing natural vegetation for retention, and winter wetland planting of 45,000 black spruce trees (a technique successfully pioneered by the OSLI collaborative network with the Government of Alberta).[219]

Some other notable stewardship activities in the ecozone$^+$ include the following initiatives:

- The Government of Manitoba convened a State of Knowledge Workshop on November 29, 2010 with 34 experts to develop a boreal peatlands stewardship strategy.[220]
- Ontario's "Safe Harbour Agreement" is a stewardship agreement between the Ontario Ministry of Natural Resources and either an individual property owner or a group of landowners. Under the agreement, landowners voluntarily create, restore and maintain valuable rare habitat such as grasslands or wetlands.[221]
- Ducks Unlimited Canada (DUC) has programs in each of the provinces of the Boreal Shield Ecozone$^+$. DUC's goal is to protect more than 650,000 km^2 in the boreal through a combination of permanent protected areas and environmentally sustainable land use practices.

- In response to a Greenpeace and Natural Resources Defense Council campaign from 2004 to 2009, Kimberly-Clark Corporation, maker of Kleenex, Scott and Cottonelle brands, announced that it would stop buying wood fibre from the Canadian boreal forest that is not certified by the Forest Stewardship Council by 2012.[222]

Newfoundland Boreal Ecozone⁺

Much of the wetlands stewardship activity in the Newfoundland Boreal Ecozone⁺ is part of the Eastern Habitat Joint Venture under the North American Waterfowl Management Plan.[147] An increasing number of municipalities throughout Newfoundland and Labrador have also committed to protect and enhance wetlands through agreements with the provincial Department of Environment and Conservation.[223] Through this partnership, municipalities develop a conservation plan for the wetlands, assist in the restoration of degraded wetlands, provide educational opportunities, and promote the participation of the local residents in the use and protection of their resource. The municipalities incorporate the stewardship agreement into municipal planning documents and associated regulations. These long-term agreements have secured 142 km^2 (Figure 43) of wetland, wetland associated upland, and coastal habitat from development thereby contributing to wildlife and habitat conservation and mitigating the effects of climate change.[223]

Stewardship agreements are also an important part of protection and recovery for species at risk. Four species at risk stewardship agreements have been signed between the Provincial Government and local entities within the "limestone barrens" regions that are habitat for rare plants. As of 2013, 33 municipalities have signed municipal stewardship agreements.[224]

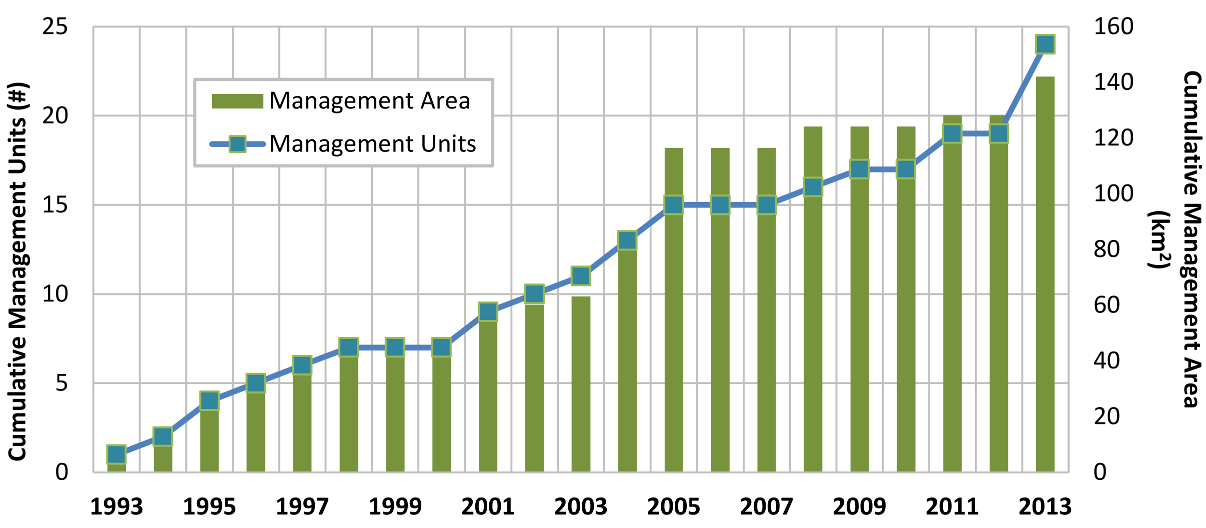


Figure 43. Cumulative number of management units and total area managed under municipal stewardship agreements in the Newfoundland Boreal Ecozone⁺, 1993–2013.
Source: Newfoundland Department of Environment and Conservation, unpublished data.[225]

Finally, Ocean Net, a grassroots non-governmental organization, has orchestrated the cleanup of over 1,600 beaches and shorelines in Newfoundland with more than 32,000 community volunteers over the past 10 years.[226]

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.

Boreal Shield Ecozone+

Invasive species affect ecosystem composition and structure by displacing native species and altering ecological processes.[227] The relatively extreme climate, low biodiversity, and poor resource availability of the Boreal Shield Ecozone+ have thus far resisted invasions of non-native species relative to other ecozones+.[228] Most invasive species occur in the southern part of the Boreal Shield Ecozone+, in the Great Lakes-St. Lawrence Forest (82–90 species) and Boreal transition areas (64–72 species) in Ontario and Quebec (Figure 44).[229] Southeastern Quebec and parts of the aspen parkland in Saskatchewan had the second highest numbers of invasive species. The third highest was Labrador, northern and northwestern Ontario, and Manitoba close to Lake Winnipeg (28-36 species). Most of the rest of the Boreal Shield Ecozone+ had from 19 to 27 invasive species (Figure 44).

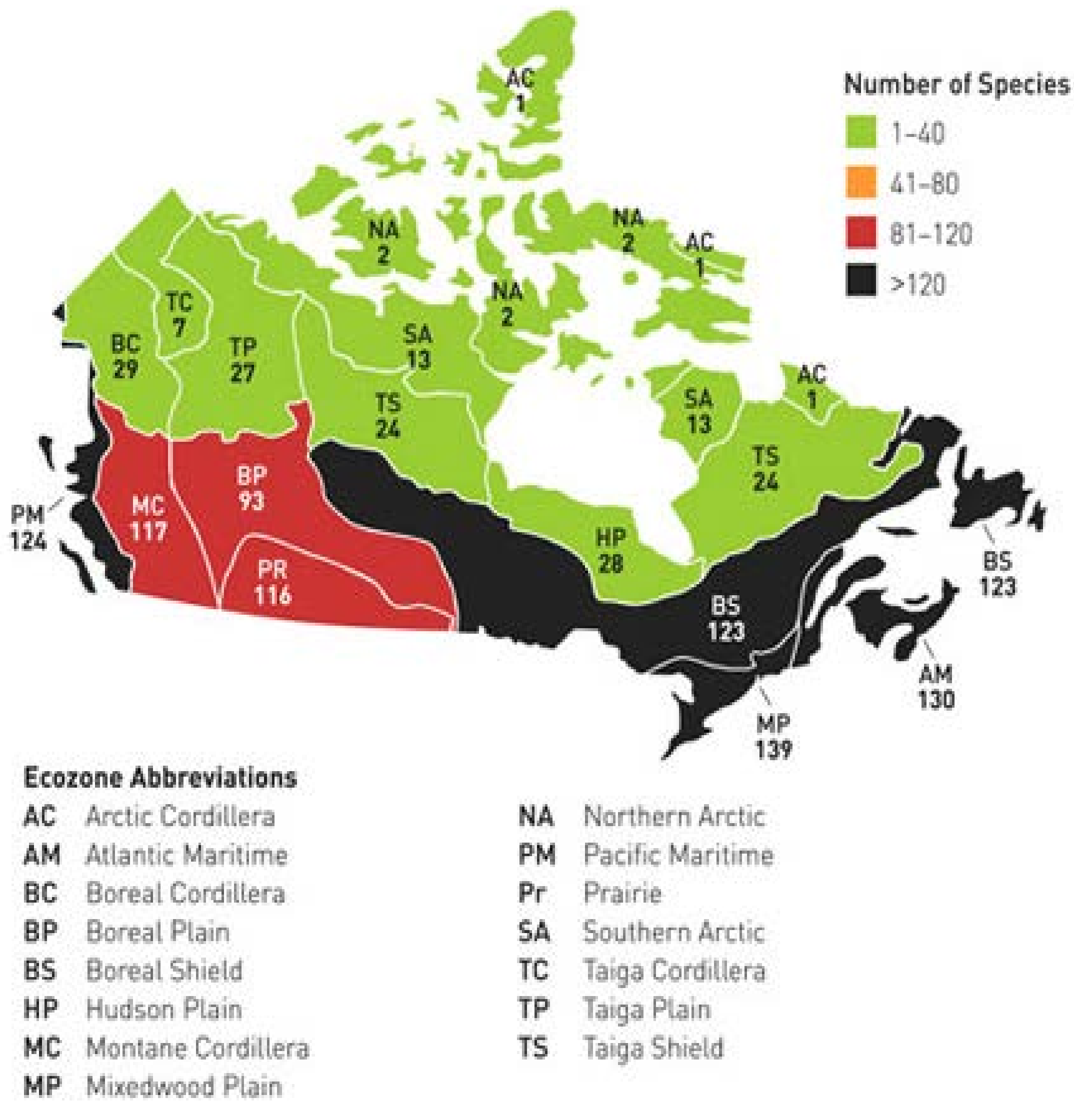


Figure 44. Number of invasive non-native plant species in Canada by ecozone+.
Based on the 162 species for which distribution maps were available.
Source: Canadian Food Inspection Agency, 2008.[230]

Invasive species are largely unstudied in the boreal. A search on Web of Science for 'invas*' AND 'boreal' spanning from 1864 to 2011 resulted in only 288 papers.[231] The first was published in 1964 and most of these papers did not address invasive species in the boreal forest directly. Invasive species have been invading the boreal forest from southern Quebec and Ontario. Climate change and resource exploitation are expected to intensify the arrival and establishment of non-native species in this ecozone+.

Invasive non-native invertebrates

Terrestrial Invasive non-native invertebrates

Terrestrial invasive non-native invertebrates in the boreal include forest insects, earthworms, and slugs. Invasive non-native insects capable of causing tree mortality or defoliation are economically harmful to the forest product industry in the Boreal Shield Ecozone+.[232] Four of the five species of non-native defoliating European sawfly that attack birch and alder (*Alnus* spp.) are found in the Boreal Shield Ecozone+.[233] Within the ecozone+, late birch leaf edgeminers (*Heterarthrus nemoratus*) are in central Saskatchewan and southern Ontario and Quebec, birch leafminers (*Fenusa pusilla*) and ambermarked birch leafminers (*Profenusa thomsoni*) are concentrated in Quebec, early birch leaf edgeminers (*Fenusella nana*) are in Ontario and Quebec, and the fifth species, *Scolioneura vicina*, was just south of the ecozone+ in 2009.[233]

Emerald ash borers (*Agrilus planipennis*) are invasive beetles from China and eastern Asia that have invaded Ontario and Quebec. In 2008, they were found in Ottawa, Sault Ste. Marie, and at one location in Quebec.[234] Green ash (*Fraxinus pennsylvanicus*), white ash (*F. americanus*), black ash (*F. niger*), and possibly blue ash (*F. quadralangus*) are all affected by emerald ash borers.[235] Black ash is distributed from western Newfoundland to Manitoba and the invasion of emerald ash borer may substantially reduce the abundance of black ash in the Boreal Shield Ecozone+.[236]

Probably introduced during the 1700s by European settlers, earthworm species (principally *Lumbricus terrestris*, *L. rubellus*, *Aporrectodea tuberculata*, and *A. turgida*) are "ecosystem engineers", detritivores that decrease soil organic content in boreal forests and mix organic and mineral soil materials.[237, 238] Not only does this reduce the abundance of many native plant species (including seedling trees), but it also causes a shift in ground cover composition from one dominated by forbs to one dominated by sedges. Moreover, disruption of soil processes can also affect nutrient cycling (reduced availability, soil carbon fluctuations, and increased leaching of nitrogen and phosphorous,[239, 240] and other organisms inhabiting the forest floor (e.g., microarthropods and small vertebrates).[237, 239]

Non-native species of slugs found in areas of the North American boreal forest include *Arion hortensis*, *Carinarion fasciatus*, *Deroceras reticulatum*, and *A. subfuscus*.[241, 242] Slugs were found in spruce-associated lichens and mosses as well as in burned areas of eastern Quebec in the Boreal Shield Ecozone+ indicating high phenotypic plasticity for habitat requirements.[241] As with earthworms, slugs may alter ecosystems because their consumption of detritus promotes carbon, nitrogen and phosphorus cycling within ecosystems. However, studies of slug abundance and habitat distribution across the North American boreal forest have not been conducted and their ecological impacts remain, for the most part, unknown.

Aquatic Invasive non-native invertebrates

The Great Lakes are barriers to the spread of terrestrial invasive species, but they are also a conduit for aquatic invasives. Several invasive aquatic invertebrate species are associated with Great Lakes waterways and some of the most aggressive invaders, both in rate of spread and impact on native biota, include rusty crayfish (*Orconectes rusticus*), zebra mussels (*Dreissena polymorpha*), and spiny water fleas (*Bythotrephes longimanus*).

Native to the U.S. Midwest, rusty crayfish are invasive herbivores now common in several northern and northeastern states and Canada (Figure 45). They occur in southern and northwestern Ontario (e.g., Lake of the Woods, Quetico Provincial Park, Lake Superior, and its tributaries near Thunder Bay) as well as in Falcon Lake, part of Whiteshell Provincial Park in southeastern Manitoba. This species displaces native crayfish (*O. virilis* and *O. propinquus*) and reduces the diversity and abundance of other invertebrates.[243] They may also impact fish indirectly by altering food resources (e.g., abundance of macrophytes) and directly through egg predation.[244] Human activities (e.g., anglers dumping bait buckets or intentional releases by commercial crayfish harvesters) coupled with connectivity among watercourses have been linked to the spread of rusty crayfish, which advance at an average rate of 0.68 km/yr.[245]

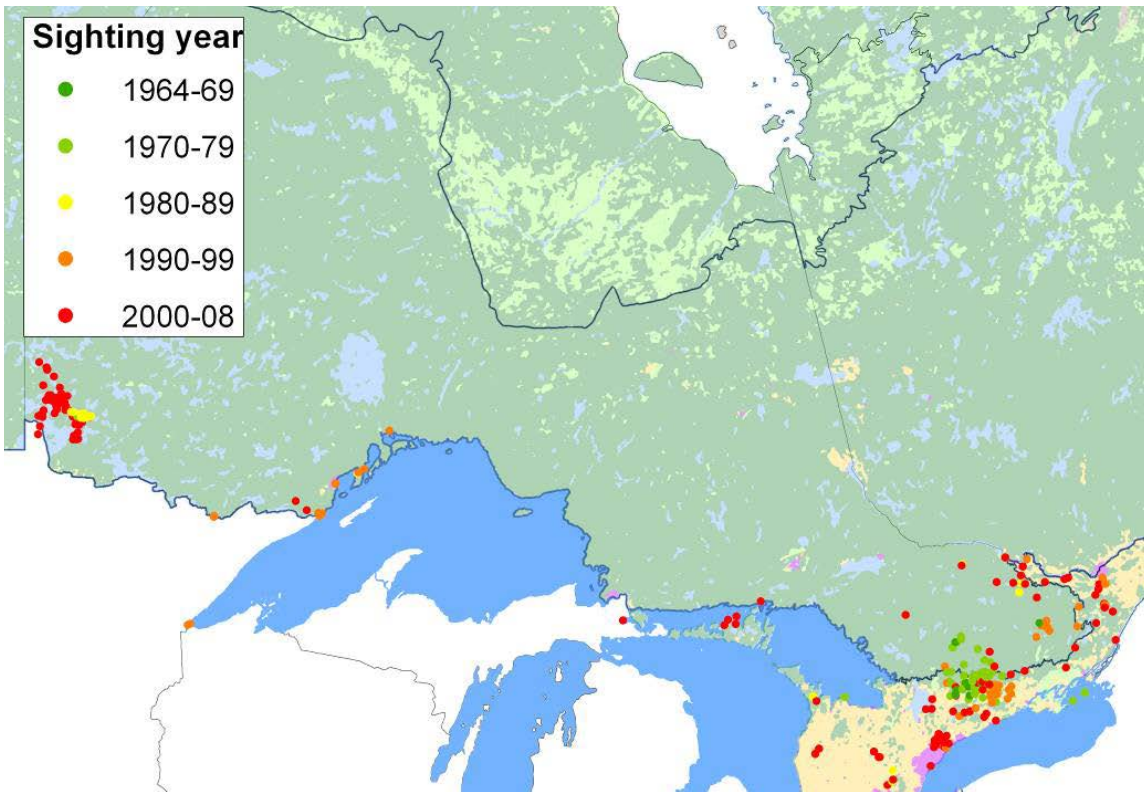


Figure 45. Growth in distribution of sightings of rusty crayfish in Ontario over time, 1964–2008. Source: Ontario Federation of Anglers and Hunters, 2008[246]

Zebra mussels spread from Lake St. Clair near Detroit in 1988 (Figure 46) and have altered Great Lakes ecosystems by reducing the abundance of zooplankton (especially *Diporeia*) that are important for the growth of young fish. Decreases in numbers and declining condition of lake whitefish (*Coregonus clupeaformis*), smelt (family *Osmeridae*), and lake trout (*Salvelinus namaycush*) in the Great Lakes may be linked to declines in *Diporeia*.

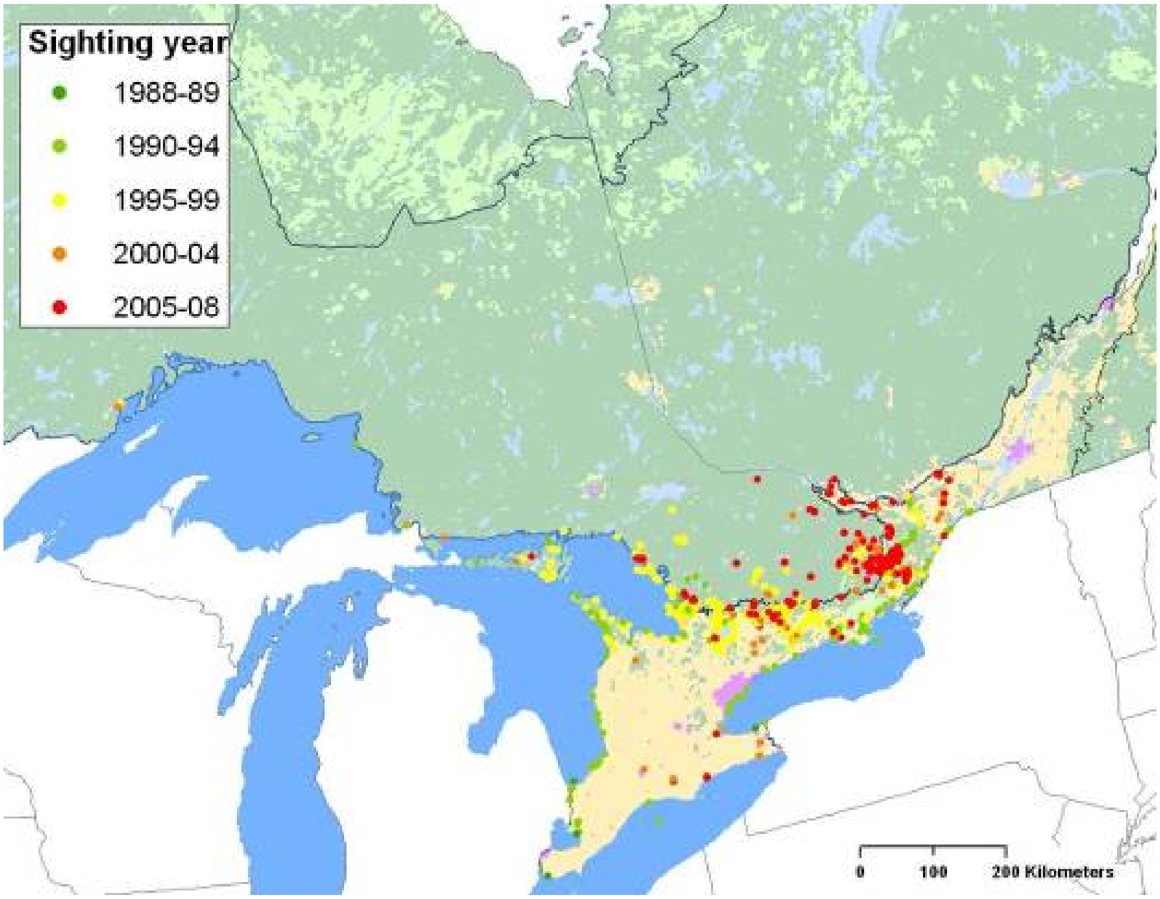


Figure 46. Growth in distribution of sightings of zebra mussels in Ontario over time, 1988–2008. Source: Adapted from Ontario Federation of Anglers and Hunters, 2012[246]

Spiny water fleas are a predatory invasive zooplankton species that reduce the biodiversity of zooplankton in freshwater lakes of the southern Boreal Shield Ecozone+ (Figure 47).[247, 248] Invading the Great Lakes from Eurasia in the mid-1980s, this species subsequently spread to inland lakes in Canada and the United States in the 1990s and has now expanded its range into more than 70 lakes in Ontario (Figure 48).[249] A 21-year study found that species richness of crustacean zooplankton declined and pH decreased (7 years post-invasion) in Harp Lake after the invasion of spiny water fleas.[250] These effects on lake biodiversity add stress to a region already impacted by the detrimental effects of acidification[251] and recovering following reductions in sulphur dioxide emissions (see the Acid deposition key finding on page 100).

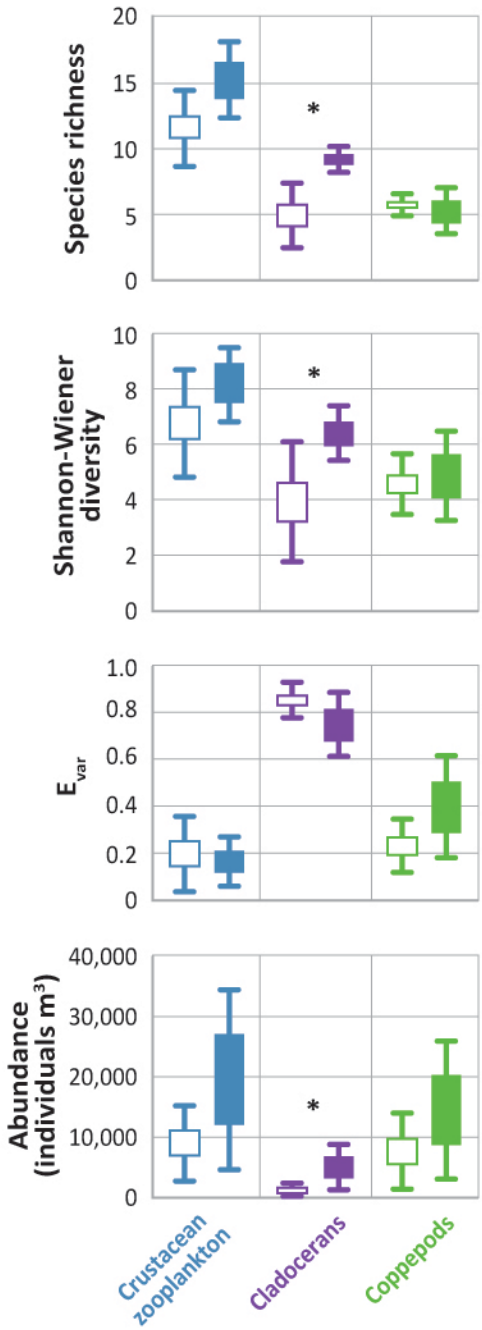


Figure 47. Changes in a) species richness, b) Shannon Wiener diversity, c) E_{var}, and d) total abundance (individuals per m^3), for crustacean zooplankton, cladocerans, and copepods in lakes invaded by spiny water fleas and reference lakes in the southern Boreal Shield Ecozone[+].
Invaded lakes are open boxes (n=10 lakes) and reference lakes are shaded boxes (n=4 lakes). Boxes are ±1 standard error with the average at centre, bars are standard deviations, and asterisks (*) indicate significant differences ($p < 0.05$).
Source: adapted from Strecker et al., 2006[247]

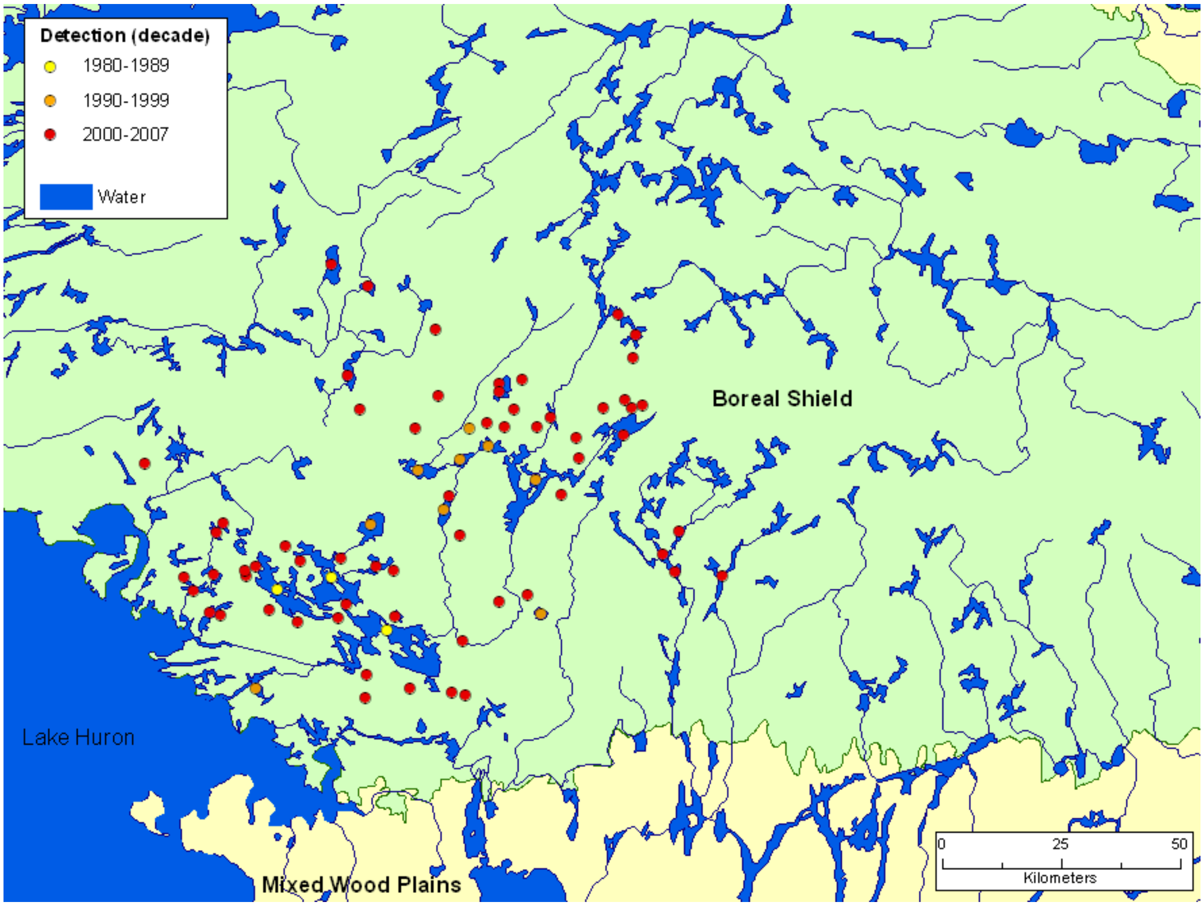


Figure 48. Growth in distribution of detections of spiny water fleas in Ontario lakes, 1980–2007. Detection year does not necessarily correspond to the year invaded as many lakes were only sampled in 2000–2007.
Source: Strecker et al., 2006[248] using data from Arnott, 2009[252] and Cairns et al., 2007[253]

Invasive pathogens

Non-native tree diseases threatening the North American boreal forest include Scleroderris canker, caused by the introduced European strain of the fungal pathogen *Gremmeniella abietina var. abietina*,[254] and white pine blister rust, caused by the rust fungus *Cronartium ribicola*. Boreal red pine (*Pinus resinosa*) are at risk of disease if *Gremmeniella abietina var. abietina* is introduced because temperature and moisture conditions required for infection could be favourable for the pathogen in Ontario's boreal forest.[255]

White pine blister rust was accidentally introduced into eastern North America from Europe over 100 years ago.[256] The disease has spread throughout the range of eastern white pine (*Pinus strobus*), causing high levels of mortality in plantations and natural stands.[257] Based on climatic conditions suitable for infection, most of the boreal range of eastern white pine is rated in the moderate and high/severe hazard levels for infection.[258] In 2011, a new virulent strain of white pine blister rust was detected in previously immune black currant (*Ribes nigrum*). This new strain is the result of a new mutation or the genetic recombination of a North American strain of the fungus and not a new introduction of the disease.[259]

Invasive plants

As of 2008, a total of 123 invasive species were known from the Boreal Shield Ecozone+[227] ; the Boreal Shield Ecozone+ is relatively uninvaded and occurrences of many species are infrequent or not widely distributed. Fast-growing plant species are not typically adapted to the low light, low levels of nutrients and low pH found in the podzolic soils of the boreal forest.[260] Other factors adding to the relative resistance of the boreal forest to non-native plant invasions are distance from seed source populations, absence of agriculture, and relatively low levels of anthropogenic disturbance.[261]

Most non-native species in boreal areas are opportunistic weedy species. Species that could interfere with forest regeneration include Siberian peashrub (*Caragana arborescens*), narrowleaf hawksbeard (*Crepis tectorum*), bird vetch (*Vicia cracca*), Canada thistle (*Cirsium arvense*), and spotted knapweed (*Centaurea maculosa*). Only two non-native species were present close to roads or resorts in Saskatchewan's boreal forest: Canada bluegrass (*Poa compressa*) and common dandelion (*Taraxacum officinale*). These species were likely introduced when seeding roadsides to reduce soil erosion.[262]

Purple loosestrife was introduced to North America from Eurasia in the early 1800s and has invaded riparian habitats in the southern portion of the Boreal Shield.[118, 263] This species affects nutrient cycling, dries up wetlands, and can form monocultures over large areas.[264, 265] In the 1990s, purple loosestrife was the most frequently reported invasive species in national wildlife areas and migratory bird sanctuaries, mostly in eastern Quebec overlapping both the Boreal Shield and Mixedwood Plains ecozones+.[266] From 1992 to 2009, purple loosestrife expanded northwest in Ontario (Figure 49).

Figure 49. Range expansion of purple loosestrife in North America, 1880, 1940 and 1992.
Area with darker shading represents region with population of dense stands; solid circles represent individual or local occurrences.
Source: adapted from White et al., 1993,[118] after Hight and Drea, 1991[267] and Thompson et al., 1987[268]

Other invasive plants are at the southern boundaries of the Boreal Shield Ecozone+ including Eurasian watermilfoil (*Myriophyllum spicatum*) (Figure 50) and garlic mustard (*Alliaria petiolata*) (Figure 51).

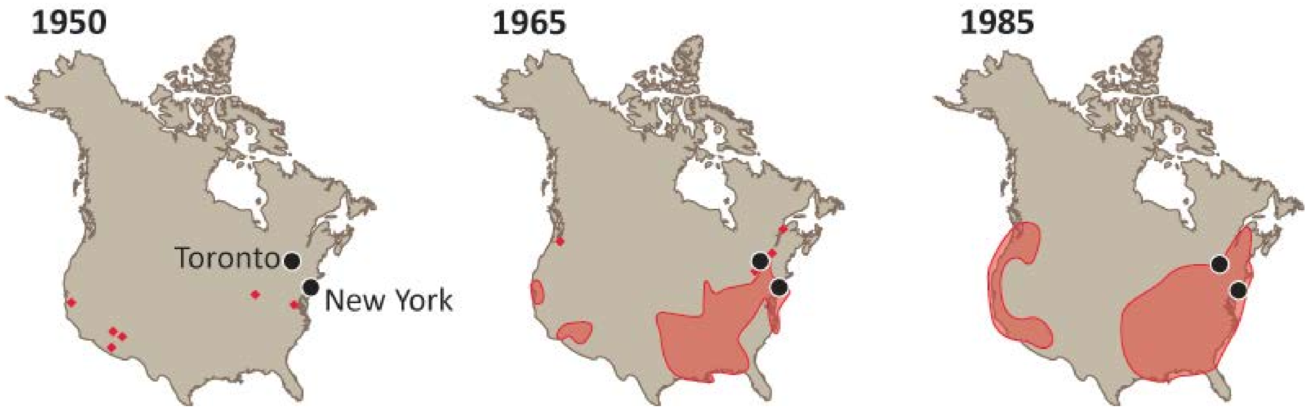


Figure 50. Range expansion of Eurasian watermilfoil in North America, 1950, 1965 and 1985.
Solid circles represent individual or local occurrences.
Source: adapted from White et al., 1993,[118] after Aiken et al., 1979[269] and Couch and Nelson, 1985[270].

Figure 51. Generalized distribution of garlic mustard in North America based on herbarium specimens and floras.
Solid circles represent individual or local occurrences. Garlic mustard has not been recorded at the Gaspé site since 1891.
Source: adapted from White et al., 1993[118]

Newfoundland Boreal Ecozone+

The native flora and fauna of the Newfoundland Boreal Ecozone+ are less diverse than many mainland communities, and species not native to this island ecozone+ comprise a comparatively large portion of the total species present (Figure 52).[271, 272] Accidental and intentional introductions have occurred since the early 16th century.[273-276]

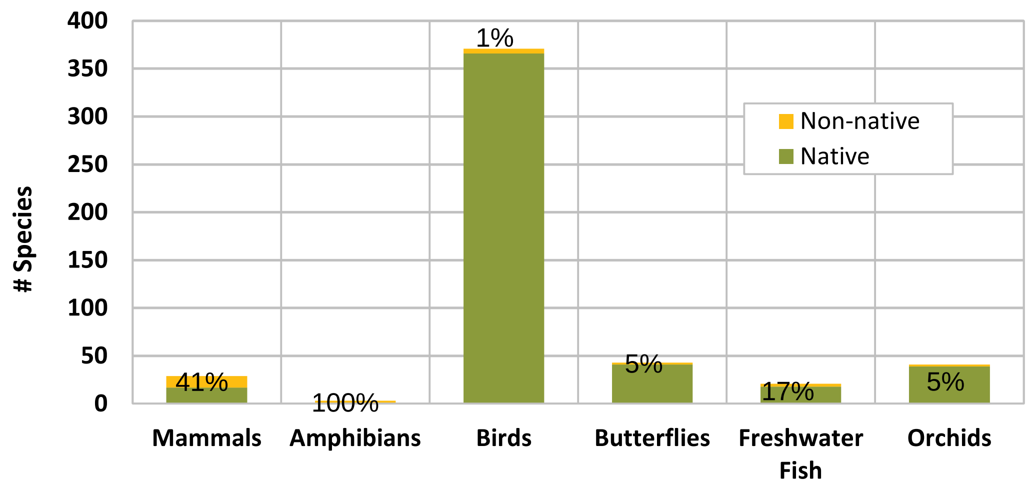


Figure 52. Non-native species in the Newfoundland Boreal Ecozone+, 2000.
Source: Canadian Endangered Species Conservation Council, 2000[272]

Invasive mammals

In addition to 17 native mammals, there are 12 non-native mammal species established in the ecozone+.[272] These include moose, snowshoe hare (*Lepus americanus*), masked shrew (*Sorex cinereus*), red squirrel (*Tamiasciurus hudsonicus*), mink (*Mustela vison*), and eastern coyote (*Canis latrans*), a recent colonizer, which is now widespread throughout the ecozone+.[272] Coyotes are discussed in the Food webs key finding on page 148.

Moose were successfully introduced to Newfoundland in 1904 and rapidly colonized the island. The abundance of available forage, negligible competition from native herbivores,[97] and paucity of predation after the extirpation of their primary predator, wolves (*Canis lupus*), in the 1930s[277] provided ideal conditions for moose population increase. Moose occupy all ecoregions on the island. In habitats that are primarily forested, densities often exceed 4 moose/km² (>1,000 kg/km²).[97] The island population, at 125,000 moose, represents >10% of the total continental number of moose (1.05 million), while the total island area, including areas unsuited to moose, is < 2% of the estimated continental moose range.[97] Population increases have been further amplified within Gros Morne National Park and Terra Nova National Park where moose hunting was prohibited when the parks were established in 1973 and 1957, respectively. In Gros Morne National Park, moose populations increased from 0.14 moose/km² in 1971 to 5 moose/km² in 2007.[100, 278] To protect the ecological integrity of these national parks, annual harvest of moose began in 2011/12.

Red squirrels were introduced in 1963 and forage heavily on the seeds of cone-bearing trees[279] which are the preferred food source for many native bird species including an endangered subspecies of red crossbill (*Loxia curvirostra*). Red squirrels also predate heavily on the nests of native birds.[280] They have also had a significant negative impact on white pine reforestation efforts in the Newfoundland Boreal Ecozone+[281] and have decreased regeneration of balsam fir and black spruce through pre-dispersal cone predation.[279, 282]

Non-native mammals are generally increasing throughout the ecozone+[283] In 2001, 91% of small mammals captured in the forests of Gros Morne National Park were non-native species.[100] Non-native mammals may be affecting forest regeneration. Snowshoe hares forage heavily on woody deciduous species[281] and small mammals such as voles are voracious consumers of tree seeds and newly emerged tree seedlings.[104, 284, 285]

Invasive plants

Over 35% of plant species in the ecozone+ are non-native.[286] Non-native plants are concentrated in anthropogenic areas such as settlements, roadsides, and abandoned fields.[287, 288]

Two of the most invasive plants in forests of the Newfoundland Boreal are Canada thistle (*Cirsium arvense*) and coltsfoot (*Tussilago farfara*). Both form dense patches which displace native species.[104, 289, 290] In Gros Morne National Park, sites with higher numbers of non-native invasive plants had lower abundances of non-vascular plants compared to uninvaded sites.[102] Disturbance has facilitated the prevalence of Canada thistle. Although the thistle reduces seedling emergence of balsam fir, the balsam fir seedlings are also protected by the thistles against grazing by moose, another introduced species.[291] Invasion of coltsfoot throughout forest disturbances in Gros Morne National Park began in 1973, when the park opened to the public and occurs nowhere else in Newfoundland in such densities except between the park and Channel-Port aux Basques, where the ferry arrives from mainland Canada.[289] Its invasion of natural areas in the national park has been greatly facilitated by management activities. Importing bedrock aggregate into the park to neutralize or bury unfavourable acidic soils also brought in rhizome fragments derived from coltsfoot plants established in aggregate stockpiles.[289]

Invasive amphibians

The Newfoundland Boreal Ecozone+ has no native amphibians, but four non-native species are currently established: green frog (*Rana clamitans*), American toad (*Bufo americanus*), wood frog (*R. sylvatica*), and mink frog (*R. septentrionalis*).[292] Green frogs are distributed throughout the ecozone+. [293] American toads and green frogs are highly mobile and can travel across land for long distances.[294] American toads are established on the west coast and have been transplanted to the Avalon Peninsula and in Central Newfoundland. Dispersal of wood frogs may be gradual since most individuals show high fidelity to their breeding pond.[292] Wood frogs are well established in the Corner Brook area.[292, 294] Northward expansion of these species appears to have stalled in the southern part of Gros Morne National Park as of 2001 (Figure 53).[292] The potential impacts of these non-native species expansions on native biodiversity are unknown.

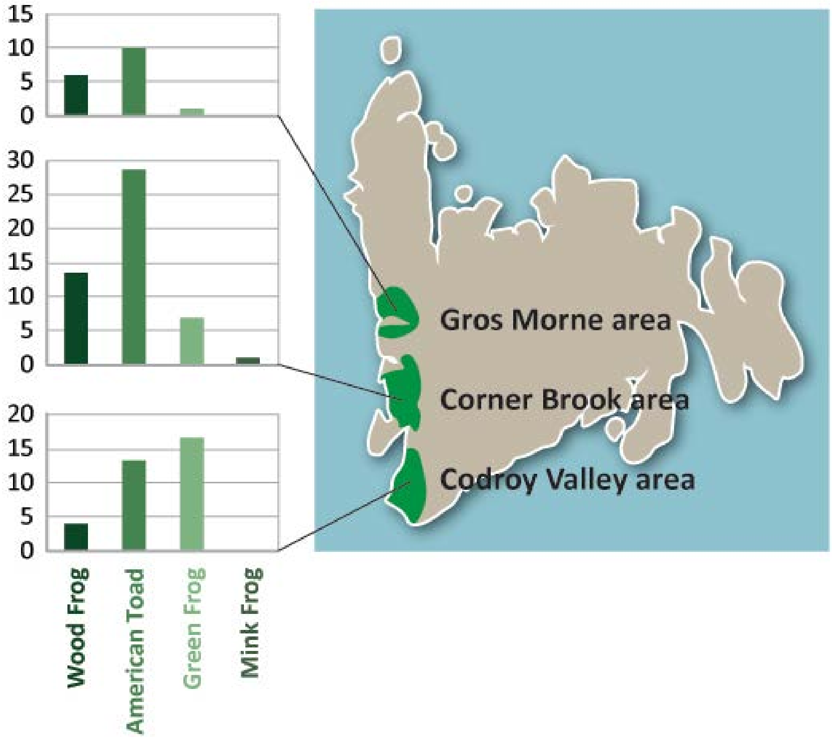


Figure 53. The number of sites (max = 3) in each of three areas surveyed for frog and toad species in western Newfoundland, 2001/02.
Source: adapted from Campbell et al., 2004[292]

Invasive terrestrial invertebrates

The Newfoundland Boreal Ecozone+ contains a large suite of invasive terrestrial invertebrates. Newfoundland and Labrador contain 456 species of non-native arthropods,[295] with St. John's being an important entry point for non-native arthropod introductions within the Ecozone+ as well as within the country.[295] The Newfoundland Boreal Ecozone+ contains at least 10 species of established slugs (*Arion* spp., *Limax* spp., and *Deroceras* spp.) and all but one species (*Deroceras laeve*) is non-native.[296] Slugs are voracious consumers of newly emerged tree seedlings[285, 297] and threaten early establishment stages of balsam fir and other native trees.[284, 285] Newfoundland and Labrador have no native earthworms and 12 non-native earthworm species.[298] The impact of earthworms within the Newfoundland Boreal Ecozone+ is speculative, but since earthworms can greatly modify litter properties and change soil structure, chemistry, and microorganisms,[299] it is likely that these species have had a significant impact on forest floor dynamics and nutrient cycling. The introduced golden nematode (*Globodera rostochiensis*) and pale cyst nematode (*G. pallid*) infest soils and are considered quarantine pests because, if left unmanaged, they can reduce yields of potatoes and other host crops by up to 80%.[300] In Canada, the golden nematode is present only in Newfoundland, on Vancouver Island, in Quebec, and in Alberta. Pale cyst nematode is only present in the Newfoundland Boreal Ecozone+.[300] These pests are very difficult to eradicate because they can survive dormant in the soil for several decades. Strict quarantine measures are in place to prevent the potential spread of these potato cyst nematodes.[300]

Other introduced insects have had major impacts on forests within the Newfoundland Boreal Ecozone+. The balsam wooly adelgid (*Adelges piceae*) was introduced to Newfoundland in the 1930s; it has killed stands of balsam fir trees, causing considerable financial losses to silviculture operations.[281] The European pine shoot moth (*Rhyacionia buoliana*) is a newly introduced insect pest within Newfoundland and within the past few years, infestations of this insect have spread throughout red pine plantations in central Newfoundland, causing widespread deformity in trees less than 25 years of age.[281]

Invasive diseases

The European strain of the scleroderris canker (*Gremmeniella abietina* var. *abietina*) was first recorded in the Newfoundland Boreal Ecozone+ in 1979 and the first major infection occurred in 1981 when this disease destroyed a red pine plantation near Torbay, 10 km north of St. John's. Periodically since this time there have been several flare-ups of this disease causing considerable mortality of primarily red pine and scots pine (*Pinus sylvestris*) trees. Throughout the mid-1990s there were incidences of this disease throughout the Avalon Peninsula.[301] A major infection destroyed a red pine plantation on the Tilton barrens in 1996. A quarantine zone for limiting the spread of the disease was established for the Avalon Peninsula in 1980 restricting the movement of any hard pine stock off the Avalon. Yet, in 2007, a scleroderris outbreak occurred in a red pine plantation in central Newfoundland. Efforts to quarantine the outbreak and control further spread of the disease are ongoing.

White pine blister rust (*Cronartium ribicola*) is a serious introduced tree disease affecting eastern white pine throughout its range.[302] It was introduced to North America from Europe around 1900 and rapidly spread throughout northeastern North America by infected nursery stock. It affects eastern white pine through needle infection and results in the formation of perennial cankers that girdle the branches and stem, leading to tree mortality.[303] Since the introduction of white pine blister rust to the Newfoundland Boreal Ecozone+, it has infected white pine trees throughout the entire range of the tree[302] and damage has been devastating.[303] In the Newfoundland Boreal Ecozone+, white pine populations have decreased from a dominant part of the forest canopy to a minor component with restricted stands.[303]

Invasive aquatic invertebrates

In 2005, the Newfoundland and Labrador Department of Fisheries and Aquaculture (DFA), in collaboration with Fisheries and Oceans Canada (DFO) and Memorial University of Newfoundland, initiated an Aquatic Species Monitoring Program in the Newfoundland Boreal Ecozone+. This involves ongoing invasive species monitoring within high-risk harbours, navigational buoy surveys, aquaculture site monitoring, and province-wide bi-annual surveys of yacht clubs, shorelines, and high-risk ports. By 2007, this program had identified and confirmed four new aquatic invasive species:

Lacy bryozoan (*Membranipora membranacea*), also known as coffin box, is an epiphyte that encrusts the blades of various low intertidal to subtidal macrophytic kelp species and causes kelp fragmentation and defoliation under heavy wave action.[304, 305] The species was first recorded in the Gulf of Maine in 1987 where it became the dominant epiphyte on *Laminaria* kelps within two years. In Nova Scotia, *Membranipora* was first recorded in the 1990s.[306] The ectoproct was recorded in Bonne Bay, NL, in 2002; it was later discovered near Merasheen Island, Placentia Bay, in 2005 during the Aquatic Species Monitoring Program.[307] Since 2005, this species has been recorded widely throughout coastal areas of the Newfoundland Boreal Ecozone+[307] and has devastated native kelp beds, which are critical habitats for juvenile fish, on the west and southwest coasts of the island of Newfoundland.[307, 308]

Golden star tunicate (*Botryllus schlosseri*) was found in the Argentia, Placentia Bay, in 2006 and has subsequently been found throughout Placentia Bay and Hermitage.[307] In the Maritime provinces, this colonial tunicate is one of four species of tunicate that has had minimal impact on the mussel aquaculture industry, yet it is considered to be a high risk.[307] Its potential impact in Newfoundland and Labrador is unknown and thus controls have been placed on mussel transfers to prevent movement of tunicates.

Violet tunicate (*Botryloides violaceus*) was first discovered in Belleoram, Fortune Bay in 2007.[307] This colonial tunicate has had both an ecological and economic impact on the mussel aquaculture industry in the Maritime provinces and has been determined to be 'high risk' by a national risk assessment.[307] This species is considered a more significant fouling organism than the golden star tunicate, but yet has a very limited distribution within Fortune Bay.[307] DFA is working in collaboration with DFO and the Newfoundland and Labrador Aquaculture Industry Association to assess the potential impact in Newfoundland and Labrador and to provide strategies to mitigate these two species of tunicates.

European green crab (*Carcinus maenas*) was first discovered in the Newfoundland Boreal Ecozone+ in North Harbour, Placentia Bay, in 2007.[307] This is a high-profile aquatic invader in Canada and in much of the world, and is listed as one of the top 100 worst invasive non-native species in the world.[309] It has been a pest in the Maritimes from as early as the 1950s.[310] The species outcompetes lobsters and other crabs and may also prey upon juvenile lobsters.[308] Elsewhere, the species is known to cause significant ecological harm and destroy prime habitats for shellfish stocks and nurseries for juvenile fish by its burrowing.[310] It preys heavily on wild and cultured bivalve shellfish such as soft shell clams, bar clams, surf clams, oysters and mussels.[308]

The degree of its potential impact in the Newfoundland Boreal Ecozone+ is yet unclear. A green crab mitigation pilot project in North Harbour has been initiated by the Fish, Food and Allied Workers Union (FFAW) and funded by the provincial government.[311] This has involved both a directed fishery on green crab as well as public education, and its purpose is to gather information to assist the federal and provincial governments as well as the industry to prevent the spread of green crab to other areas.[311]

In addition to the above species, the Aquatic Species Monitoring Program closely monitors shorelines for high-risk invaders currently undetected within the Newfoundland Boreal Ecozone+ so that potential future invasions might be prevented. These undetected high-risk species include the vase tunicate (*Ciona intestinalis*), oyster thief (*Codium fragile*), clubbed tunicate (*Styela clava*), and *Didemnum* sp., among others.[307]

Within the Newfoundland Boreal Ecozone+, Placentia Bay is a particularly high-risk area for aquatic non-native species introductions because it contains the largest oil handling port in Canada (Come by Chance, NL), and is a main hub for commercial fishing and transportation. A total of 564 commercial fishing enterprises, 870 vessels, and 12 processing plants are based in it harbours. Marine construction is occurring in several of its multiple harbours and the bay also provides a transportation and shipping link to mainland Canada (i.e., North Sydney, NS) and coastal communities.[307]

Non-native Invasive fish

Freshwater ecosystems of the Newfoundland Boreal Ecozone+ have experienced relatively few fish introductions compared with many other regions.[312] The native freshwater fish fauna of insular Newfoundland is comprised of 15 species. Three species of salmonids were successfully introduced to the ecozone+ during the 1880s in an attempt to increase stocking for the purposes of freshwater fisheries: brown trout (*Salmo trutta*), rainbow trout (*Oncorhynchus mykiss*), and lake whitefish.[313] The latter species has only two established populations near St. John's and is not invasive within Newfoundland.[313] Aquaculture escapees are also abundant in the marine environment and may pose a new threat to native fish species, but the status of these populations is not known.[313, 314]

In the Newfoundland Boreal Ecozone+, the brown trout has extended its range from original planting sites, developed anadromous runs, and established populations throughout the Avalon Peninsula[313] and in Trinity Bay.[307] It has also colonized new watersheds from the Burin Peninsula to Cape Freels.[307] Brown trout populations outcompete native brook trout and Atlantic salmon (*Salmo salar*) populations for habitat.[315, 316] Hybridization of brown trout with Atlantic salmon or, infrequently, with native brook trout, further threatens native species.[313]

Rainbow trout distribution has also expanded from the original plantings. The species has developed anadromous runs and is common in some Avalon Peninsula systems and in discrete river systems throughout the Newfoundland Boreal Ecozone+.[313, 314] In some areas it has displaced the native brook trout.[313] In addition, juvenile rainbow trout overlap in preferred habitats and feeding with juvenile salmon resulting in negative interactions between the two species.[313, 317]

In addition to competitive and genetic impacts, predation by both brown trout and rainbow trout has impacted native fish populations and caused irreversible effects on salmonid populations where they have been introduced across North America.[313, 318]

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.

Boreal Shield Ecozone+

Mercury contamination

Mercury is a focal contaminant for the Boreal Shield Ecozone+ because of its potential to have neurotoxicological effects on organisms[319] and because anthropogenic activity during the 20th century has tripled the amount of mercury (Hg) in the atmosphere and surface ocean compared to the global background level.[320] Methylmercury (MeHg), an organic form, is retained in biota more efficiently than inorganic Hg. With a bioaccumulation factor of 10 million, MeHg bioaccumulates in species at upper trophic levels[321] and so the concentration of Hg in fish is much higher than surrounding water concentrations. Humans and wildlife with high dietary fish intake show elevated Hg levels and adverse health effects.[319, 322, 323]

Mercury concentrations in the air within or near the Boreal Shield Ecozone+ declined (-5.1—10.4%) from the mid to late 1990s to 2005.[324] However, due to large inter-annual variability, no change in atmospheric Hg deposition was detected at the Experimental Lakes Area (ELA) in northwestern Ontario, a long term monitoring station for Hg since 1992 (Figure 71).[325] Similarly, no change was detected in Hg concentrations in precipitation at a monitoring station in northeastern Quebec from 2000 to 2005.[326] While discernable trends in Hg loading to lakes may be difficult to detect at the 5 to 10-year scale, several studies have identified elevated Hg concentrations in lake sediments between pre and post-North American industrialization time frames across the Boreal Shield Ecozone+ in Ontario and Quebec (Figure 55).[327-329]

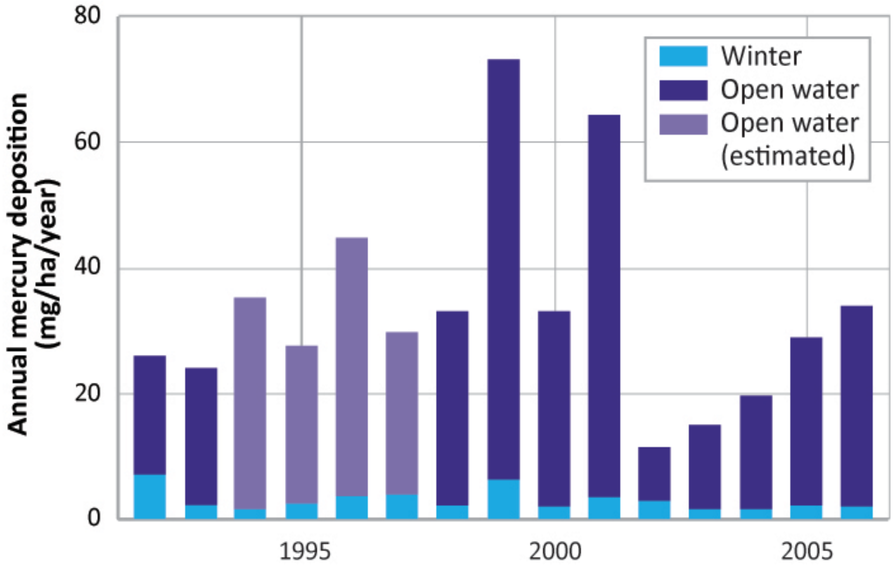


Figure 54. Annual winter and open-water season (i.e., late spring to fall) deposition of total Hg in open area precipitation at the Experimental Lakes Area (ELA) in northwestern Ontario, 1992-2006.
For years when rain was not collected, open water was estimated for the calculation of total Hg. Total Hg loadings for these years were estimated using the long-term average concentrations in rain at the ELA.
Source: adapted from Graydon et al., 2008[325]

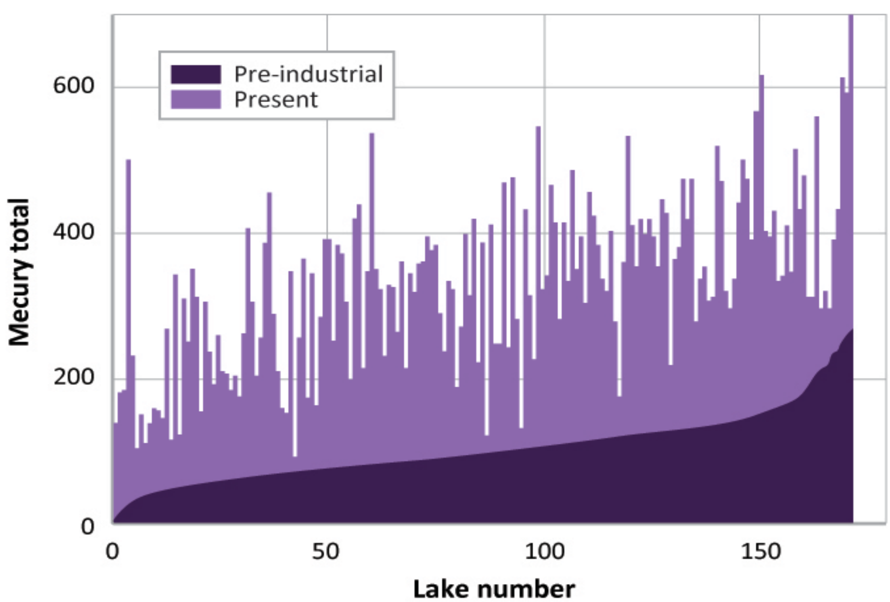


Figure 55. Mercury concentrations in pre-industrial and present-day sediments collected from the profundal zone of 171 lakes in southern and central Ontario.
The profundal zone is a deep zone of an inland body of freestanding water. It is below the range of effective light penetration and is typically below the thermocline, the vertical zone in the water through which temperature drops rapidly.
Source: Mills et al., 2009[329]

Forestry and dam construction in the Boreal Shield Ecozone+ has altered ecosystems resulting in post-disturbance increases in water and fish Hg concentrations, then decreases in subsequent years and decades following the perturbation (Figure 56).[330-332] In a study of hydroelectric reservoirs in Quebec, dam construction exported Hg downstream into successive reservoirs, mostly by suspended particulates and by zooplankton, which increases Hg levels in fish downstream.[331] The increase in MeHg was temporary because only part of the flooded soils and vegetation readily decomposed; mainly grasses, mosses, lichens, leaves, and surface soil litter. These components decomposed within five to eight years after flooding whereas most of the flooded woody biomass, such as branches, trunks, and roots of trees, resist decomposition for up to 60 years.[332]

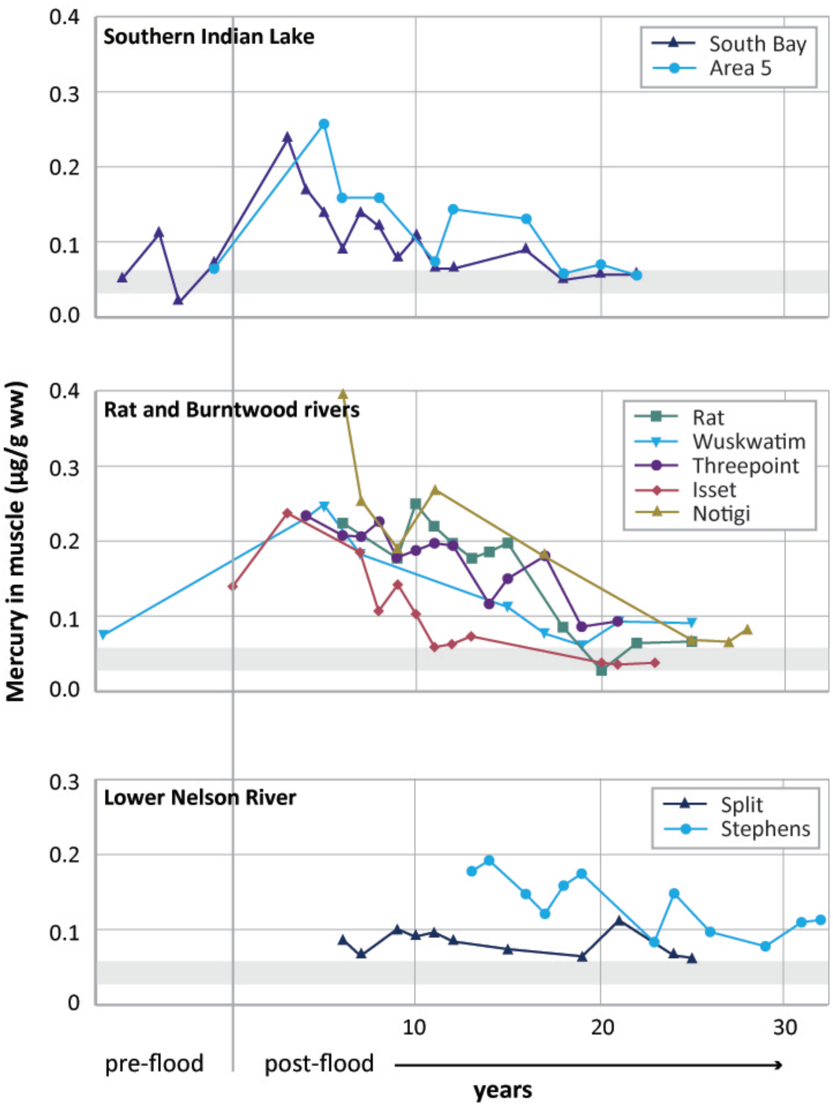


Figure 56. Average concentrations (±95% CI) of total Hg (µg/g wet weight) in the muscle of lake whitefish from hydroelectric reservoirs of northern Manitoba.
Upper panel: Basins in South Indian Lake (South Bay, Area 5). Middle panel: Basins on the Rat and Burntwood rivers (Issett, Rat, Notigi, Threepoint, and Wuskwatim lakes). Lower panel: Basins on the lower Nelson River (Split and Stephens lakes).
Source: Bodaly, 2007[330]

Boreal Shield Ecozone+ biota that are most affected by elevated Hg are piscivorous fish and mammals and birds with high fish intake such as mink, otters, and loons.[333-335] Mercury levels in river otters (*Lontra canadensis*) (fish comprise 90% of their diet) in central Ontario can vary by greater than 10-fold due to differences in the fish Hg levels within their range (Figure 57).[335] High Hg levels (0.25–2.48 μg/g) are associated with adverse impacts on loons, including reduced reproductive success, abnormal breeding behaviour, asymmetric feather growth, immune suppression, altered hormone levels, and changes in brain neurochemistry.[322, 333, 333, 336-341]

Mercury concentrations in predatory fish have either remained stable or declined during the last 20 years in the Boreal Shield Ecozone+ of Ontario and Manitoba.[342] Mercury concentrations have also declined in fish from regions that were subject to historic point source contamination (pre-1970s) over the last 25 years (Figure 58).[343] Though the Hg levels have declined in the ecozone+, several species in several lakes are still above concentrations considered safe for frequent consumption.[343] Some typically non-piscivorous species of fish (e.g., lake whitefish) downstream from hydroelectric projects had Hg near the values expected for naturally piscivorous species (e.g., northern pike). These non-piscivorous fish consumed fish stunned after their passage through turbines.[344]

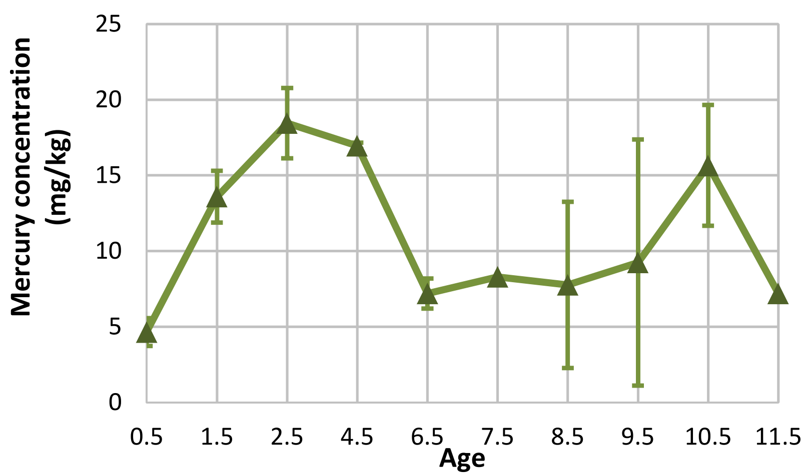


Figure 57. Mercury levels (dry weight) in hair of otters aged 0.5 to 11.5 years old from townships in Ontario.
Error bars are ±1 standard deviation.
Source: adapted from Mierle et al., 2000[335]

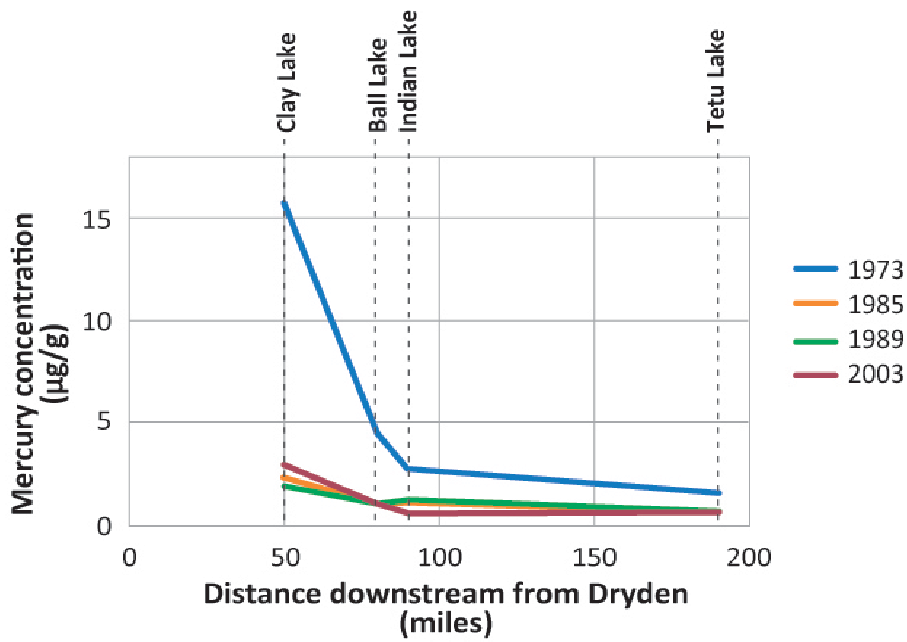


Figure 58. Mercury concentrations in walleye from four lakes, presented by harvest year and distance of harvest lake from point source of contamination, 1973, 1985, 1989, and 2003.
Source: Kinghorn et al., 2007[343]

Some reservoirs in the Quebec region of the Boreal Shield Ecozone+ experienced a "biological boom" due to the release of nutrients associated with flooding. This increase of biomass up the food chain, from plankton to fish and their predators, improves the densities, conditions, and growth rates some species after impoundment.[332, 345] In all modified environments, water quality remained adequate for aquatic life, recovery to pre-impoundment Hg concentrations occurred within 5–15 years, and increased nutrients had positive effects on the aquatic food chain.[346] The temporary increase in fish Hg levels was also below thresholds of effects for humans, particularly given that the rate of fish consumption in this region is low.[347]

Newfoundland Boreal Ecozone+

Petroleum pollution

Petroleum and its products represent an increasing contamination hazard to the shorelines of the Newfoundland Boreal Ecozone+ given the increased rate of development of the offshore petroleum industry (e.g., development of the Hibernia, Terra Nova, and White Rose oilfields). Threats include accidental spillage from tankers, offshore wells, or pipelines.[160] In addition to offshore events, accidental discharge of petroleum and gasoline at the shoreline during refinery and tanker operations,[348, 349] removal and disposal of waste from vessels in port,[350] and leakages from strictly terrestrial sources pose further threats.[160]

Placentia Bay and the Avalon Peninsula may be the most likely locations in Canada to suffer a petroleum contamination event within the next 10 years.[351] Placentia Bay currently hosts the highest volume of ship traffic along the Atlantic Canadian coastline, and is exposed to accidental and deliberate discharges of petroleum products by Trans-Atlantic ship traffic. In particular, Arnold's Cove and Come by Chance are considered the most vulnerable beaches to oil contamination.[351] Tanker traffic through Placentia Bay to the Whiffen Head trans-shipment terminal and the Come-by-Chance oil refinery, located in Arnold's Cove, has increased substantially since 1990.[351] Similarly, the Avalon Peninsula lies directly adjacent to a major trans-Atlantic shipping route connecting eastern North America with northwestern Europe, and to offshore petroleum development and areas of ongoing exploration.[352] Incidents and legal proceedings associated with discharge of petroleum-laden bilge by offshore vessels, and the onshore consequences, have been noted along shorelines from Cape Race to Placentia Bay.[352-354]

Domestic sewage

Sewage constitutes a serious form of pollution in many coastal environments of the Newfoundland Boreal Ecozone+. This is particularly true in harbours where circulation with the open ocean is limited, such as shorelines with very deep harbours and connected to the open ocean by narrow, curved channels.[160] Harbours with sewage problems include Corner Brook, Marystown, Burin Bay Arm, St. Alban's, Terrenceville, and St. John's. St. John's Harbour experiences insufficient rates of flushing with the open ocean.[160, 355, 356] At depths below 20 m, the harbour waters are virtually stagnant and the discharge of the Waterford River is insufficient to flush the embayment.[160]

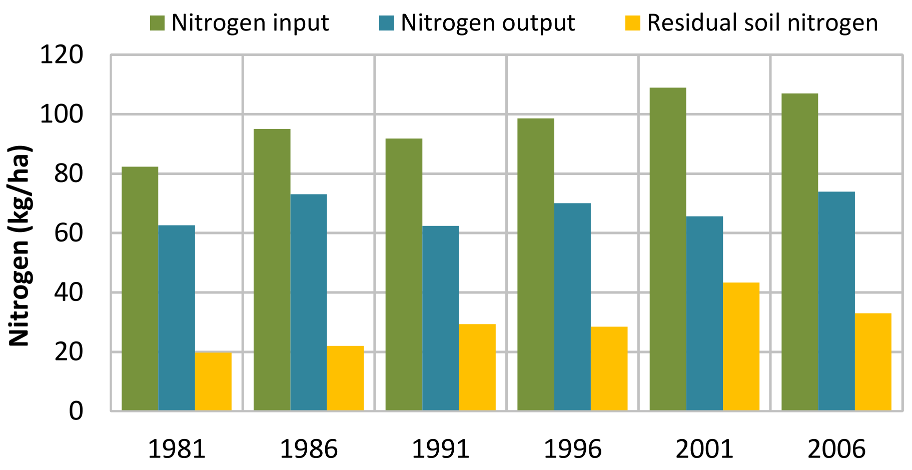
Key finding 12 **Theme** Human/ecosystem interactions

Nutrient loading and algal blooms

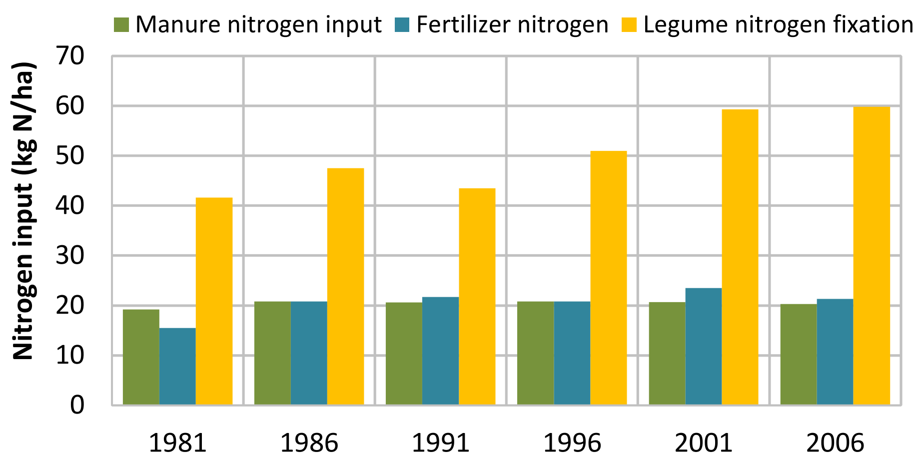
National key finding
Inputs of nutrients to both freshwater and marine systems, particularly in urban and agriculture-dominated landscapes, have led to algal blooms that may be a nuisance and/or may be harmful. Nutrient inputs have been increasing in some places and decreasing in others.

Boreal Shield Ecozone+

Residual soil nitrogen (RSN) is a variable indicating the amount of inorganic nitrogen remaining in the soil, per hectare, after crops are harvested.[357] The Boreal Shield Ecozone+ contains a relatively small amount of agricultural land given its size (9,200 km^2, representing only 1.5% of Canada's agricultural land in 2006); nevertheless, between 1981 and 2001, nitrogen (N) inputs increased from 82.4 to 109 kg N/ha and then decreased to 107 kg N/ha from 2001 and 2006. Most N inputs in 2006 were from legume crops (59.8 kg N/ha), followed by fertilizer (21.3 kg N/ha), and manure (20.3 kg N/ha).[358] The increase in N fixation was due to an increase in the area of legume crops over the 25-year period. From 1981 to 2006, N outputs increased from 62.6 to 74.0 kg N/ha. The RSN more than doubled from 1981 to 2001, from a low of 19.8 kg N/ha to a maximum of 43.4 kg N/ha, followed by a decrease to 33.0 kg N/ha by 2006 (Figure 59).[358]



a)

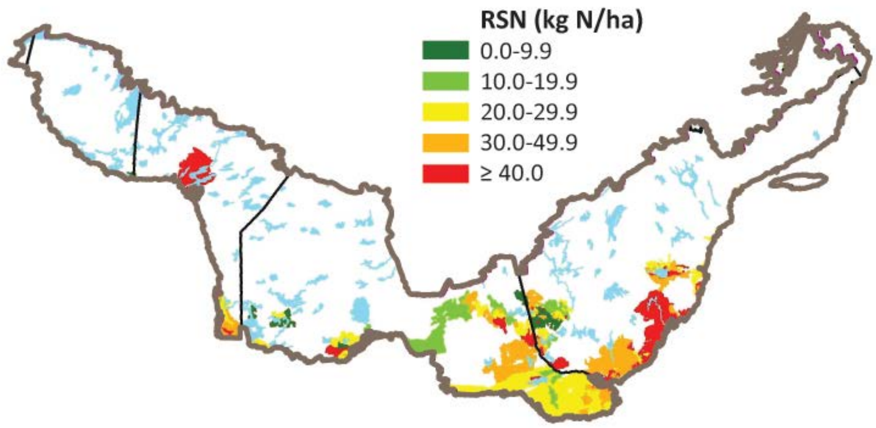


b)

Figure 59. a) Nitrogen input, output, and residual soil nitrogen (RSN) and b) Amount of nitrogen (N) from manure, fertilizer, and fixation by leguminous crops in the Boreal Shield Ecozone[+], 1981–2006. Manure N input represents the net amount of mineral N applied to the soil or released from the mineralization of organic N over three years.
Source: Drury et al., 2011[358]

Low RSN risk areas remained stable from 1981 to 2006. High legume-crop inputs and fertilizer use in southeastern Quebec and Ontario north of the St. Lawrence lowlands[358] resulted in an increase in risk class in 2006 for areas that were already medium to high risk in 1981 (Figure 60).

a)



b)

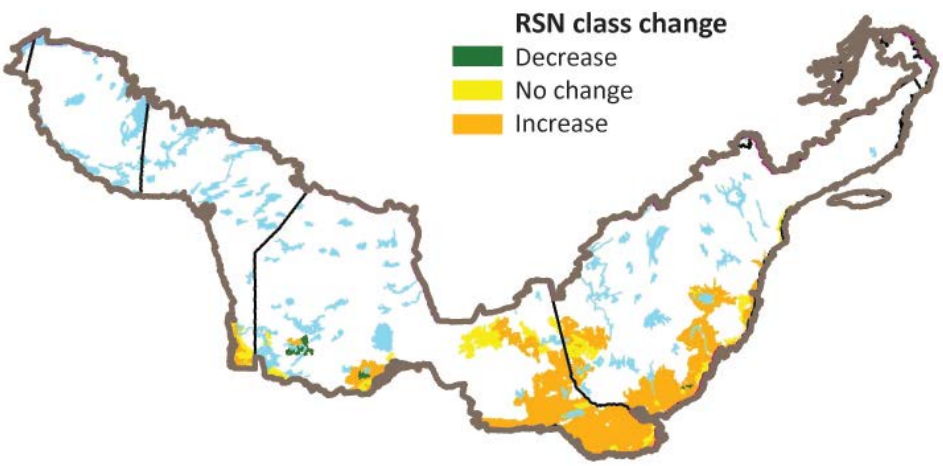


Figure 60. Map of a) residual soil nitrogen (RSN) risk classes in 2006 and b) changes in RSN risk class from 1981 to 2006 for farmland in the Boreal Shield Ecozone+.
<10 kg N/ha = very low risk (dark green), 10 to 19.9 kg N/ha = low risk (light green), 20 to 29.9 kg N/ha = medium risk (yellow), 30 to 39.9 kg N/ha = high risk (orange), and >40 kg N/ha = very high risk (red).
Source: Drury et al., 2011[358]

Nutrient loading results in the eutrophication of aquatic systems. Algae thrive on the increased nutrients and consume more oxygen. This results in hypoxia, the depletion of oxygen in the water, which changes community composition. For example, the number of lakes and rivers affected by blue-green algae in the Quebec portion of the Boreal Shield Ecozone+ increased from less than 10 in 2004 (unpublished data) to no fewer than 70 each year since 2007 (Figure 61).[359] The geographic area for this trend overlaps with the Mixedwood Plains Ecozone+, which may bias the trend reported for the Boreal Shield Ecozone+.

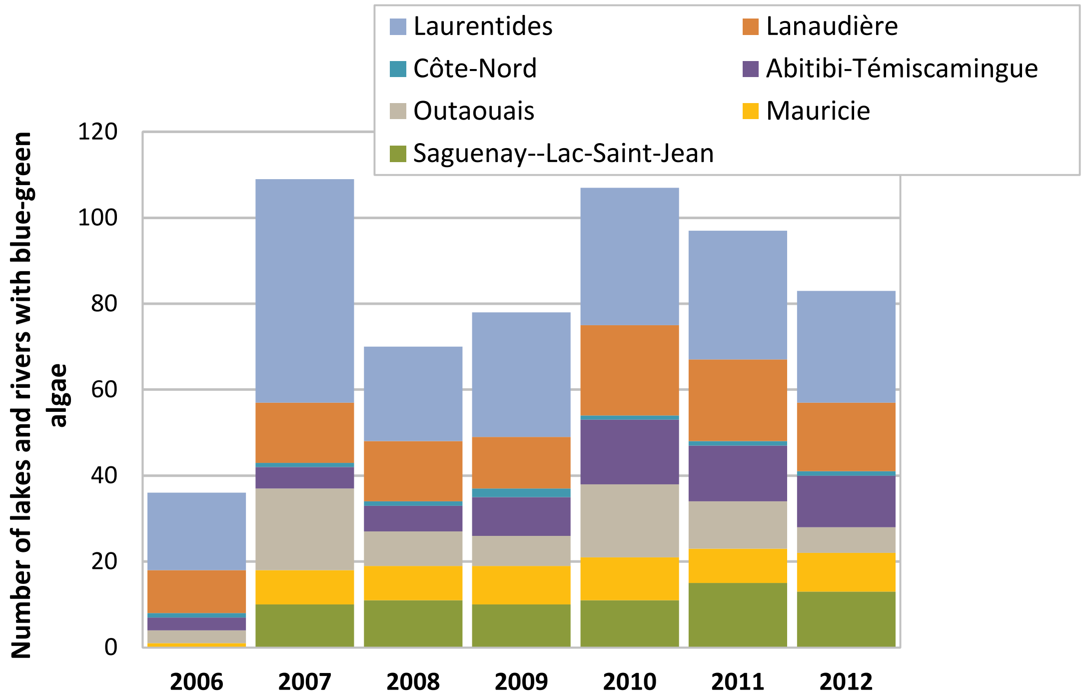
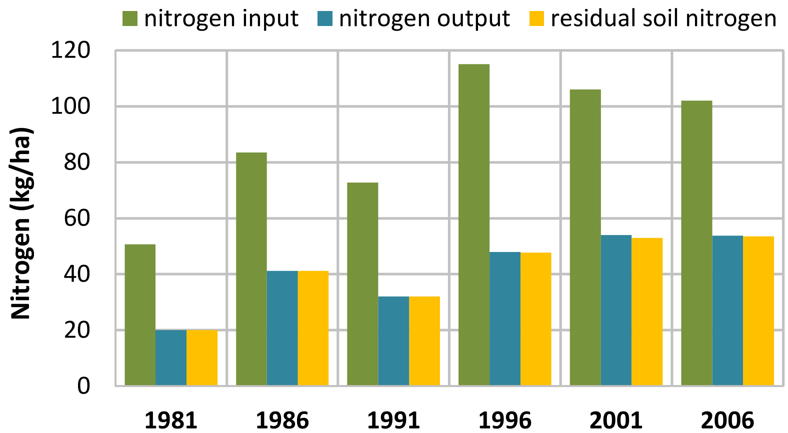


Figure 61. Number of lakes and rivers (stacked) where blue-green algae was detected for Quebec administrative units that occur within the Boreal Shield Ecozone⁺, 2006-2012.
Note: These results overlap with the Mixedwood Plains Ecozone⁺.
Source: Ministère du Développement durable, de l'Environnement et des Parcs, 2009[359]

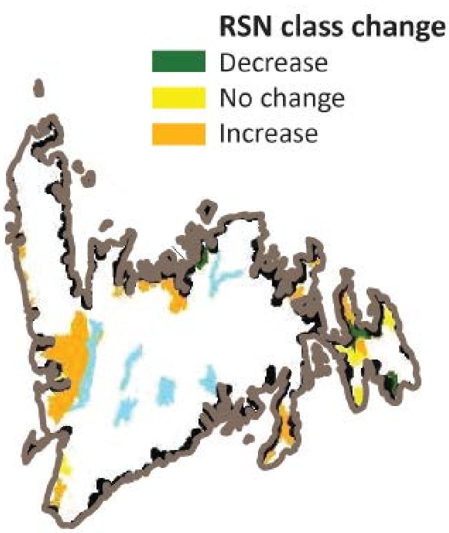
Newfoundland Boreal Ecozone⁺

The Newfoundland Boreal Ecozone⁺ contained the second smallest area of agricultural land (210 km^2) of the agricultural ecozones⁺ in 2006.[358] Agricultural land in the mid-west and northern parts of the ecozone⁺ was in the very high risk class, whereas the southeastern areas ranged from very low to high risk (Figure 62).[358]

a)



b)



c)

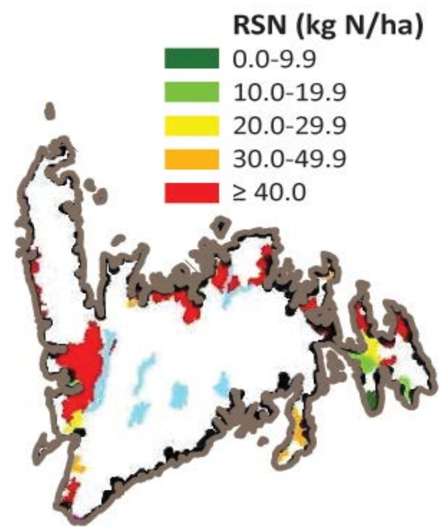


Figure 62. a) Nitrogen input, output, and residual soil nitrogen (RSN), 1981-2006, b) map of overall changes in RSN risk class from 1981 to 2006, and c) map of RSN risk classes in 2006 for agricultural land in the Newfoundland Boreal Ecozone[+].
Source: Drury et al., 2011[358]

Nitrogen inputs doubled over 15 years (from 50.7 kg N/ha in 1981 to 115 kg N/ha in 1996) and then decreased to 102 kg N/ha in 2006 (Figure 62).[358] Manure was the greatest source of nitrogen in 1981 at 23.8 kg N/ha compared to 11.3 kg N/ha for fertilizer and 13.6 kg N/ha for legume nitrogen fixation. However, by 2006, legume fixation (37.7 kg N/ha) and manure addition (34.5 kg N/ha) contributed similar amounts of N to agricultural lands with fertilizer the lowest of these three nitrogen sources at 28.1 kg N/ha.[358] Nitrogen output increased from 30.6 kg N/ha in 1981 to 48.4 kg N/ha in 2006 (Figure 62).[358] The RSN levels generally increased over time from a low of 20.0 kg N/ha in 1981 to 53.8 kg N/ha in 2006 (Figure 62).[358]

Risk classes based on the RSN level present in the soil at the end of the growing season were assigned to farmland and the area of land in each risk class was mapped for the agricultural areas in the Newfoundland Boreal Ecozone+. The agricultural land in the midwest and northern regions of the Newfoundland Boreal Ecozone+ was in the very high risk class whereas the south eastern areas ranged from very low to the high risk class (Figure 62).[358] Agricultural land in the midwest and eastern parts of the Newfoundland Boreal Ecozone+ increased by at least one risk class between 1981 and 2006 (Figure 62).[358]

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.

Boreal Shield Ecozone+

Acid deposition is primarily the result of emissions of sulphur dioxide (SO_2) and N oxides (NO_x) that can be transformed into dry or moist secondary pollutants such as sulphuric acid (H_2SO_4), ammonium nitrate (NH_4NO_3) and nitric acid (HNO_3) as they are transported in the atmosphere over distances of hundreds to thousands of kilometres.[360] Acid deposition is traditionally associated with smelting, other industrial processes, and thermal electric power generation. More recently, new sources of acid leading to acid deposition include oil and gas production and transportation. Acid deposition can affect lakes, rivers, soils, forests, buildings, and human health.[361] Sensitive terrain is typically underlain by insoluble granitic bedrock and overlain by thin-to-absent glacially derived soils, conditions that occur throughout the Boreal Shield Ecozone+.

From 1990 to 2005, acid deposition was highest in the southern portion of the Boreal Shield Ecozone+ in Ontario and Quebec because emission sources are concentrated in southeastern Canada and the eastern United States. This part of the ecozone+ received greater than 20 kg of wet sulphate/ha/yr in 1990, but this declined to 10 to 15 kg/ha/yr by 2005.[362] The western and eastern parts of the ecozone+, which are less affected by SO_2 emissions, have experienced little change in their wet sulphate deposition (5 kg/ha/yr or less). Wet nitrate deposition also declined from 1990 to 2005 in the southern Ontario–Quebec part of the Boreal Shield Ecozone+. Compared to sulphate, the degree of change was modest (from >18 kg nitrate/ha/yr to 12 to 15 kg/ha/yr).[362]

The work conducted and knowledge gained during the early years of acid deposition science in North America (i.e., the 1980s) prompted political action to reduce SO_2 (and later NO_x) emissions. This culminated in the 1991 Canada–United States Air Quality Agreement.[363] Combined Canada–United States SO_2 emissions declined by about 45% (from 28 to 15.4 Mt) between 1980 and 2006.[364] Over half of the eastern Canadian SO_2 reductions have occurred at the base-metal smelters in Sudbury, ON, and Rouyn-Noranda, QC, both of which are located within the Boreal Shield Ecozone+. Similarly, from 1980 to 2006, total Canada–United States NO_x

emissions declined by about 19% (from 22.7 to 24 Mt), although most of this was due to reductions from United States sources.[364] Further reductions may occur as Ontario implements progressive green energy policies such as phasing out thermal electric power generation by 2014.[365]

Critical loads and exceedances

The critical load is the maximum level of both sulphur and N deposition that can occur and still maintain the integrity of aquatic and forest ecosystems.[366] Acid deposition and an ecosystem's critical loads can be compared to calculate the "exceedance". The exceedance can be positive (meaning that the lakes or forest soils are receiving too much acid deposition) or negative (meaning that the lakes or soils could absorb more acid deposition without harmful effects). Positive exceedance can occur when extremely sensitive (low critical load) terrain receives low levels of deposition as well as when less sensitive terrain receives high levels of deposition. The steady-state exceedance is the maximum value that would occur in the future (at the "current" deposition level) should the aquatic or terrestrial ecosystem become N-saturated.[62] Figure 63 illustrates the spatial variation in steady-state exceedances that occurs across the Boreal Shield Ecozone+. Acid-sensitive terrain is reflected in the local geology and, overall, 38.9% (730,000 km^2) of the Boreal Shield Ecozone+ is within the four lowest, most sensitive critical load classes.

Highest steady-state exceedance occurred in the regions of maximum acid deposition, southcentral Ontario and southwestern Quebec, as well as near local sources, such as the base metal smelters at Flin Flon and Thompson, MB (Figure 67). Except for the northeastern part of the ecozone+, positive steady-state exceedance (the four "hot-coloured" classes) occurred in 25% (470,000 km^2) of the Boreal Shield Ecozone+ (Figure 67).

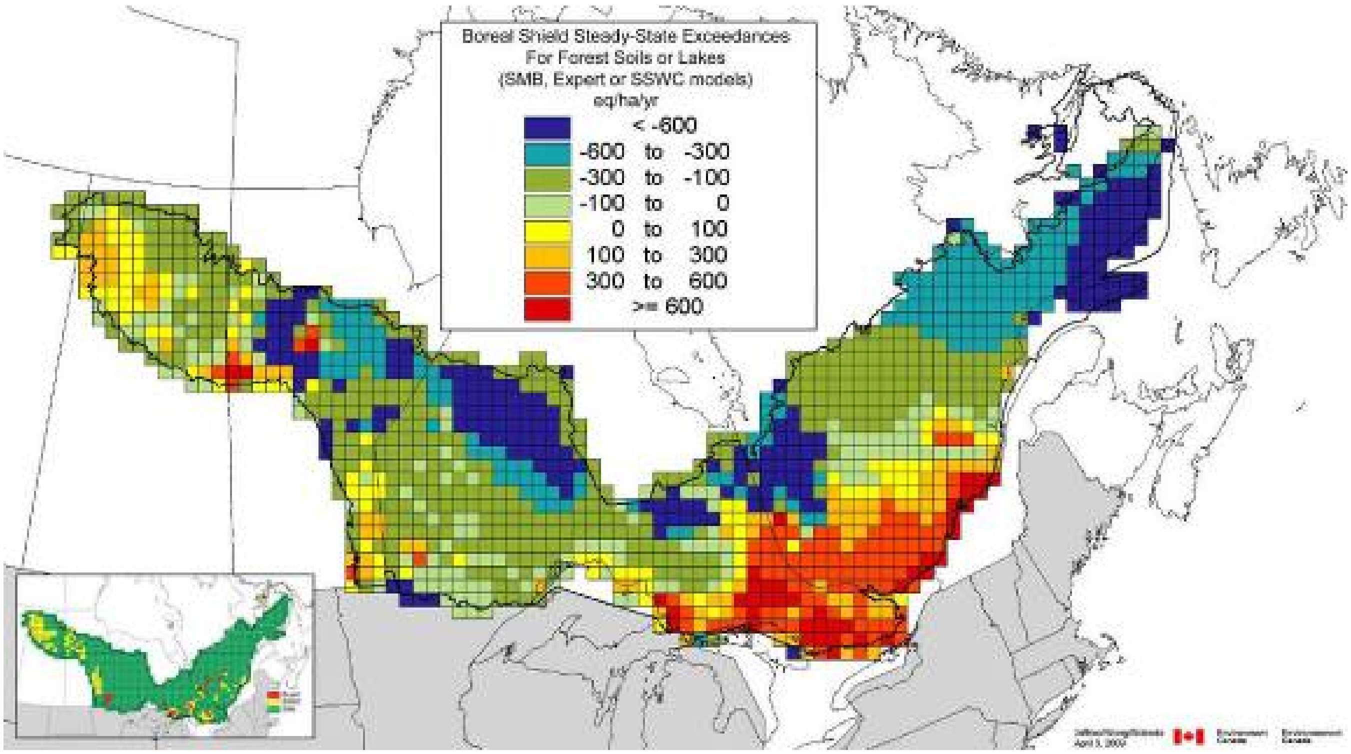


Figure 63. Steady-state critical load exceedances calculated using the estimated "current" total sulphur and N deposition, best available data as of 2009.
Source: Jeffries et al., 2010[367]

Trends in aquatic ecosystems

Many lakes located within the Boreal Shield Ecozone+ are sensitive to acid deposition, and those in Quebec and Ontario have already been chemically altered and have not recovered despite reductions in emissions.[368] Reflecting the SO_2 emission history from local smelters in Ontario and Quebec, the rates of changes in sulphur were often steeper in the 1970s and 1990s than in the 1980s. Although lakes in Manitoba and Saskatchewan are also sensitive, they have yet to show the effects of acid deposition.[368] This may change as acidifying pollutants emitted from smelters in Manitoba and from oil sands operations in Alberta continue or grow.[369, 370] Due to their buffering capacity, lakes in the Manitoba portion of the Boreal Shield Ecozone+ are the least likely to be affected by acid deposition.

Within the Boreal Shield Ecozone+, trends in acid deposition from 1990 to 2004 were reported for 28 lakes in southwestern Quebec, 72 lakes in the Sudbury region of Ontario, and 80 lakes in the remainder of Ontario.[362] Sulphate, which ranged from -1.6 µeq/L/yr (Ontario) to -4.1 µeq/L/yr (Sudbury), declined ($p<0.05$) for all three groups.[362] There were no trends for nitrate for any group. Base cations (mostly dissolved calcium (Ca)), which ranged from -1.4 µeq/L/yr (Quebec) to -3.6 µeq/L/yr (Sudbury), compensated for the declining sulphate. Trends in the alkalinity concentrations of lakes were positive, but much smaller in absolute magnitude, ranging from +0.2 µeq/L/yr (Ontario, $p>0.05$) to +0.9 µeq/L/yr (Sudbury, $p<0.05$). Overall, lakes in areas of the Boreal Shield Ecozone+ with the most acid deposition responded to declines in deposition, but recovery of their alkalinity (pH) was delayed. Part of the delay is due to the chemical compensation provided by declining base cation concentrations, a predictable but temporary geochemical effect. On the other hand, the declining Ca concentrations in Ontario lakes are approaching levels that threaten the sustainability of keystone zooplankton species[371] and lake recovery may be slow and possibly never re-established.[372]

Estimates of trends in precipitation chemistry for Saskatchewan were not possible due to insufficient sampling. To address this limitation, the Saskatchewan Ministry of Environment initiated a precipitation collection program. From 2007 to 2011, the Ministry assessed acid sensitivity for 259 headwater lakes in northwest Saskatchewan, all within 300 km of Alberta's Athabasca oil sands region.[373] As a result of the geological and meteorological conditions of the area, 68% of the surveyed lakes were classified as sensitive or very sensitive to acid deposition due to their low buffering capacity.[374]

Effects of acidification on aquatic ecosystems

Algae, invertebrates, fish, and waterbirds are affected by acidification through direct acidity effects, metal toxicity, loss of prey, and reduced nutritional value of remaining prey.[375] Although certain acid-tolerant species (e.g., some dragonflies) tend to be more abundant at higher acidity (e.g., below pH 5.5), the abundance of other invertebrates, particularly mayflies and molluscs, is reduced under acidic conditions (Figure 64). Large invertebrates are important food for breeding waterbirds and are essential nutrition and energy sources for nesting females and their young. Common loon breeding success is particularly affected by changes in lake acidity and associated food web impacts. Many fish species are sensitive to acidification and may suffer lower recruitment and growth rates, increased accumulation of toxic metals, and impaired anti-predator responses in acid-stressed lakes. Fish species richness declined in lakes in southeastern Canada at pH ranges of 5.0 to 5.9.[376, 377]

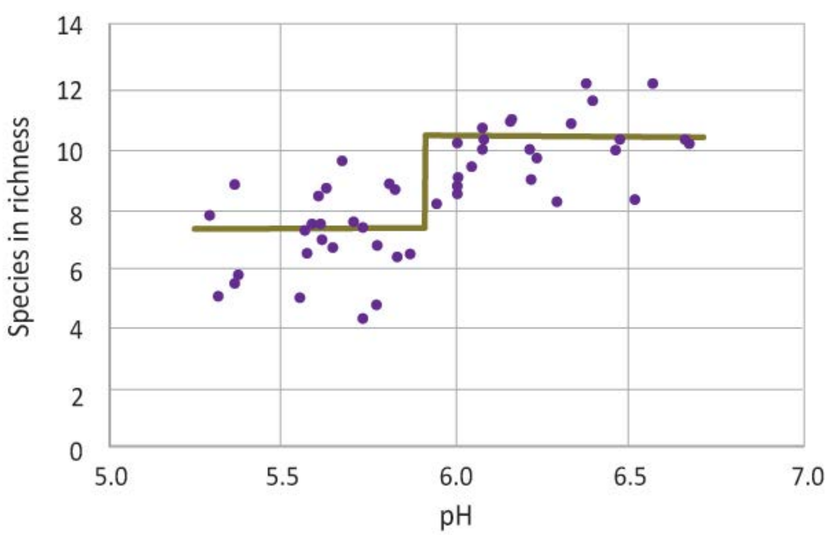


Figure 64. Step function plot modelling the relationship between pH and zooplankton species richness. Source: Holt et al., 2003[378]

The acidification of aquatic systems often leads to increases in MeHg. For more information on the distribution and levels of Hg contamination in the Boreal Shield Ecozone+, see the Contaminants key finding on page 90.

Many of lakes with biological improvements were located in the Sudbury and Muskoka regions of Ontario.[379, 380] Acid-sensitive mayflies increased as acidity in two Sudbury lakes was reduced (Figure 65).[381] Zooplankton in several Sudbury area lakes became more similar to non-acidic reference lakes.[379] Species richness increased in three Ontario lakes but declined in a fourth. Changing phosphorus levels, declining acidity, and rising dissolved organic carbon resulted in shifts in zooplankton community composition.[382]

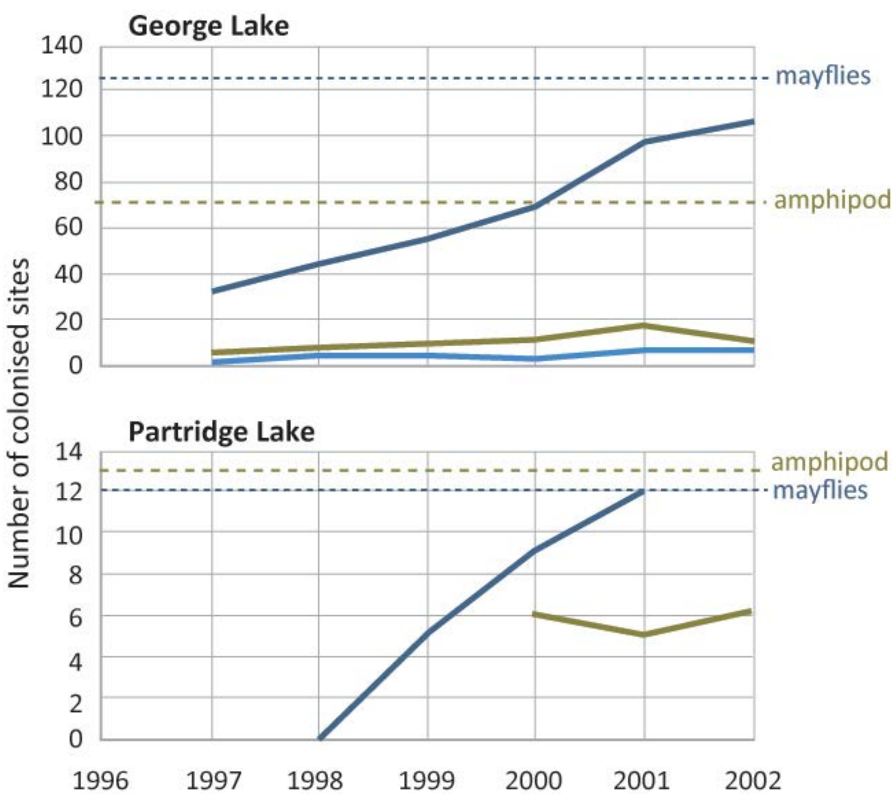


*Figure 65. Number of sites colonised by the mayflies (*Stenacron interpunctatum*) (dark blue) and* S. femoratum *(light blue) and the amphipod (*Hyatella azteca*) (green) in a) George Lake and b) Partridge Lake near Killarney, ON, sampled between 1997 and 2002.*
Note: The annual surveys of Partridge Lake began in 1998 for mayflies and in 2000 for amphipods. The total number of surveyed sites available for colonization by each group is indicated by the dashed lines.
Source: Environment Canada, 2005[361], adapted from Snucins, 2003[381]

Sport fish affected by acidification include lake trout and smallmouth bass (*Micropterus dolomieu*). Lake trout introduced to acid-stressed lakes near Sudbury and Killarney, ON, did poorly in species rich lakes and had slower growth, lower survival, and delayed recruitment.[383] The biomass of natural lake trout recruits remained well below reference levels five to 15 years after water quality recovery and spawning by adults occurred.[383] In contrast, smallmouth bass reintroductions can succeed in lakes with species-rich fish communities. For example, improved water quality recovery and spawning by stocked fish resulted in the biomass of natural smallmouth bass recruits increasing to reference lake levels within five years.[383] New populations of smallmouth bass, rock bass (*Ambloplites rupestris*), pumpkinseed (*Lepomis gibbosus*), and walleye (*Sander vitreus*) have been found in recovering lakes, some of which had not contained those species prior to acidification.[384]

The liming of lakes is used to reverse acidification and maintain habitat for aurora trout (*Salvelinus fontinalis timagamiensis*), a type of brook trout native to just two lakes in the world. Both lakes are located in the Boreal Shield Ecozone+, 110 km north of Sudbury. Aurora trout were extirpated when these lakes were acidified during the 1960s. Captive-bred trout were successfully reintroduced after liming in 1989.[385]

Breeding numbers of two piscivorous waterbirds, common loons and common mergansers (*Mergus merganser*), increased in the Ontario portion of the Boreal Shield Ecozone+ from the late 1980s to 2002 (see the Effects of acidification on aquatic ecosystems section on page 103). These birds are increasingly using low-pH (pH<5.5) lakes, possibly a result of generally improving conditions in the region.[379] However, breeding productivity of common loons declined in Ontario (1981–1999) and La Mauricie National Park, QC (1987–2002) (Figure 66).[379] Common loon chicks did not fledge on lakes with pH less than 4.4 due to a shortage of food.[386] Lakes with pH values of 4.4–6.0 are suboptimal, but can support chicks to fledging if the lakes are sufficiently large in size. As sulphur dioxide emissions from the Sudbury smelters and sulphur deposition from other long-range sources decreased, some breeding success returned.[386]

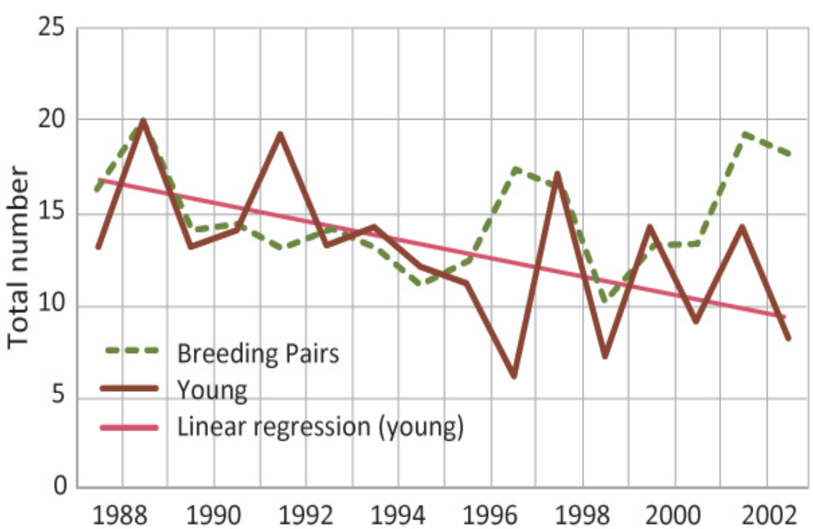


Figure 66. The total number of common loon breeding pairs (dashed line) and young (solid line) observed during surveys of 76 lakes in La Mauricie National Park, QC, 1987-2002.
The regression line represents a significant (p=0.02) trend for the total number of young observed in the park.
Source: Environment Canada, 2005[361]

Newfoundland Boreal Ecozone+

An acid rain monitoring program (the Newfoundland Environment Precipitation Monitoring Network (NEPMoN) was in operation between 1983 and 2004. NEPMoN consisted of a series of wet-only precipitation collectors set up at specially selected sites across Newfoundland and Labrador. The number of sites peaked at seven in 1995 but was cut back to two in 1996 due to decreased funding. In 1998, the program was revived to five sites with support from provincial industries. One of the previous sites was re-opened in addition to the opening of two new sites. The weekly wet-only precipitation data from these stations were used to complement the daily data collected by Environment Canada's Canadian Air and Precipitation Monitoring Network (CAPMoN) Stations in the Province (Bay d'Espoir and Goose Bay).[387]

There was pronounced spatial variation in the deposition of sulphates and nitrates across the island.[388] The largest depositions occurred on the southwest corner of the island with the quantities of sulphates and nitrates diminishing to the north and east. The rate of deposition of sulphate may have diminished since 1990, but the rate of deposition of nitrate increased. These declining trends may be related to emission abatement measures, but could also result from changes in weather patterns.[388]

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.

Boreal Shield Ecozone+

From 1950 to 2007, temperatures increased in the Boreal Shield Ecozone+ in spring by 1.7°C, in summer by 1.3°C, and in winter by 1.8°C, resulting in an earlier growing season by eight days (Table 17, Figure 67).[154] There were no overall significant trends in precipitation in spring, summer, and winter, however, precipitation in the fall increased by 17% (Figure 68). Major changes in snowfall patterns, likely associated with increased temperatures, included shallower snow cover (-13.7 cm) and earlier snow melt (10.3 days) from February to July (Figure 69). Additionally, changes in snowfall were regionally variable with less winter precipitation along the eastern and western ecozone+ boundaries and more winter precipitation in the central part of the ecozone+. These regional variations also correspond to changes in moisture observed throughout the 20th century, as described in the Boreal Shield Ecozone+ key finding on page 140.

Table 17. Summary of changes in climate variables in the Boreal Shield Ecozone+ from 1950 to 2007

Driver	Trends from 1950–2007
Temperature	Overall ↑ of 1.7 °C in spring temperature Overall ↑ of 1.3 °C in summer temperature No significant fall trend Overall ↑ of 1.8 °C in winter temperature
Growing season	Weak tendency toward an earlier start by 8 days to the growing season in spring
Precipitation	17% ↑ in fall precipitation No significant spring, summer, or winter trends No significant trend in the amount of precipitation falling as rain vs. snow
Snow	13.7 cm ↓ in maximum annual snow depth No significant trend in # of days with snow cover from August to January Weak tendency toward an earlier end of the snow season from February to July by 10.3 days

Source: Zhang et al., 2011[154] and supplementary data provided by the authors

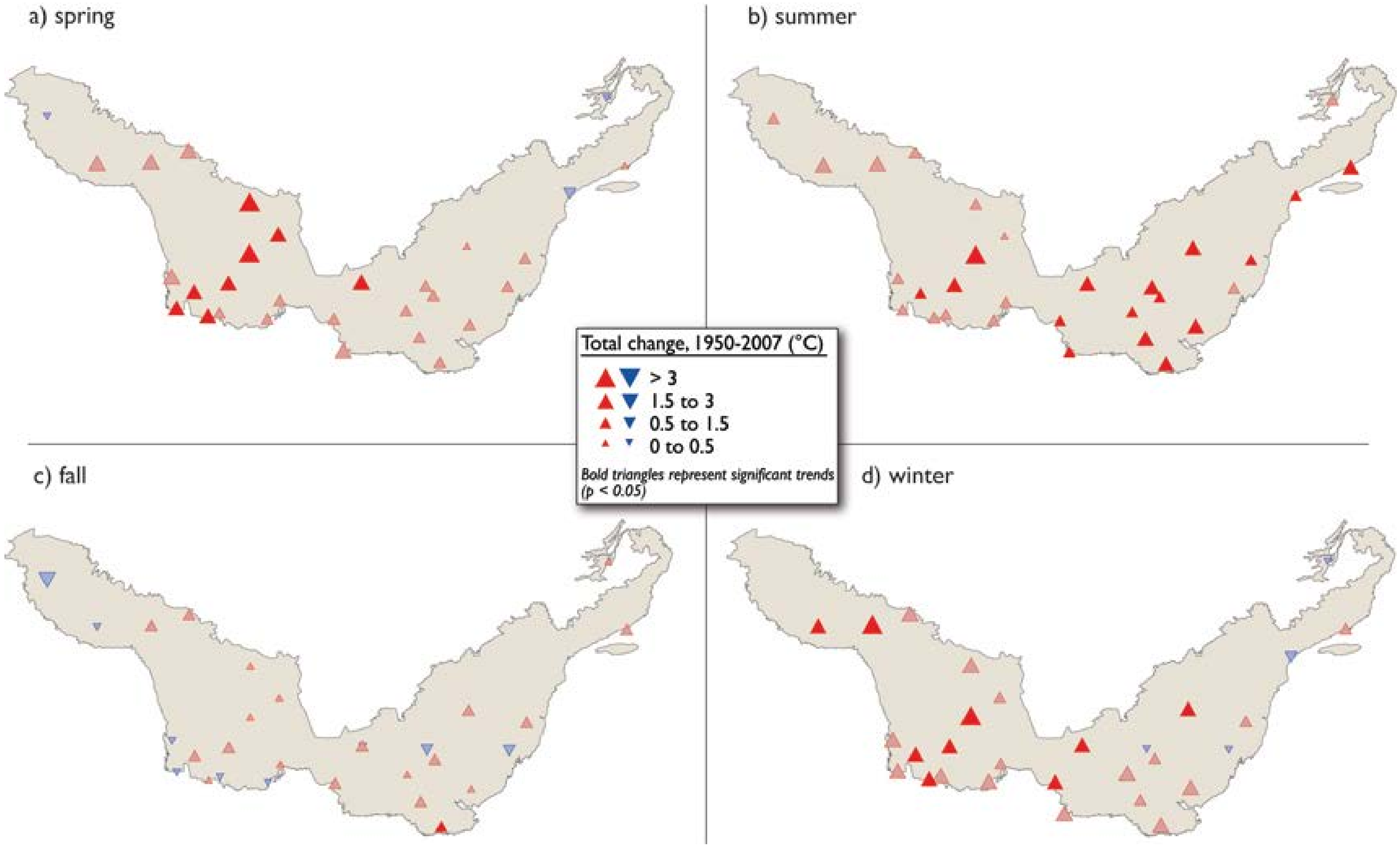


Figure 67. Change in mean temperatures in the Boreal Shield Ecozone+ from 1950–2007 for: a) spring (March–May), b) summer (June–August), c) fall (September–November), and d) winter (December–February).
Source: Zhang et al., 2011[154] and supplementary data provided by the authors

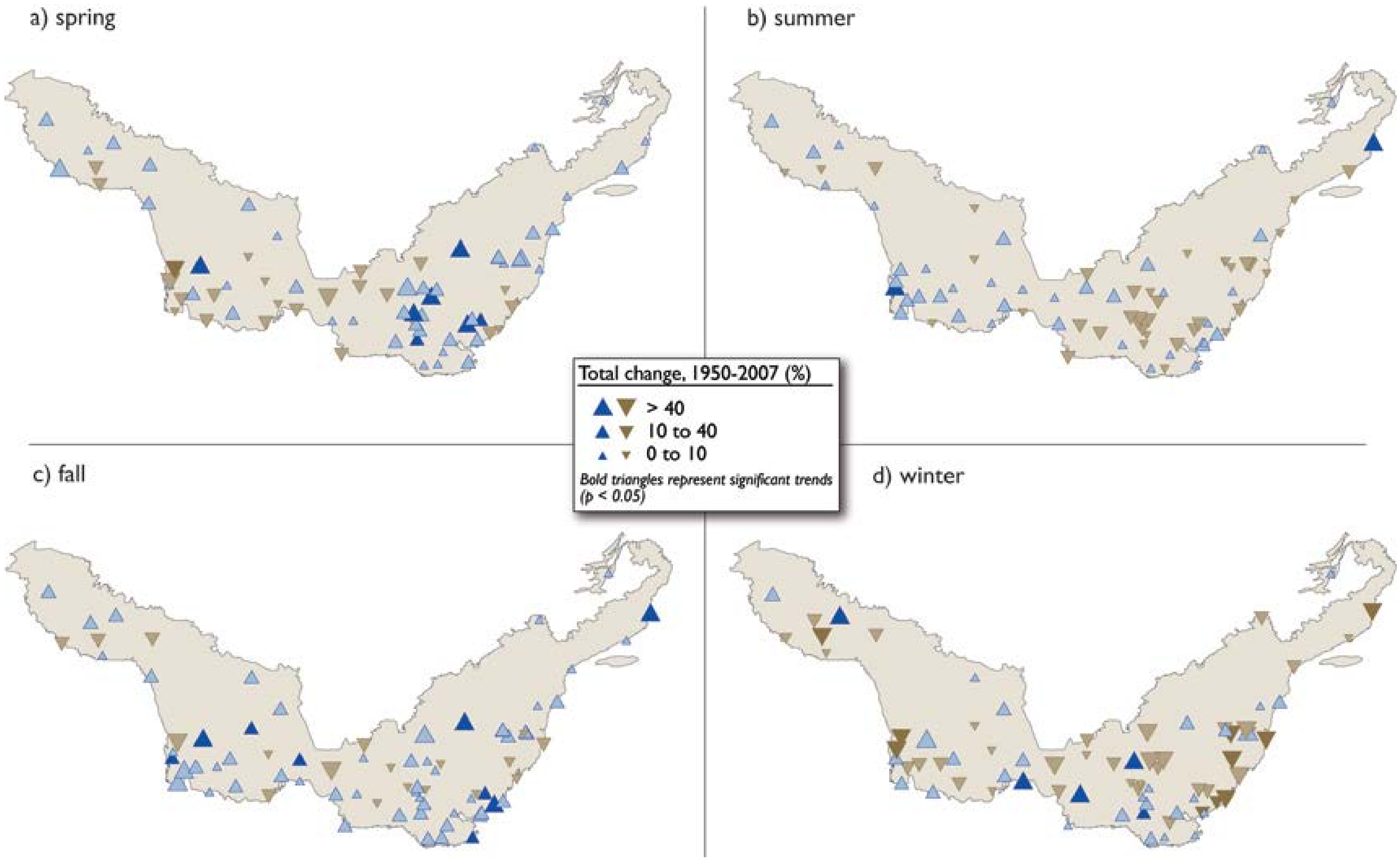


Figure 68. Change in the amounts of precipitation in the Boreal Shield Ecozone+ from 1950 to 2007 for a) spring (March–May), b) summer (June–August), c) fall (September–November), and d) winter (December–February).
Source: Zhang et al., 2011[154] and supplementary data provided by the authors

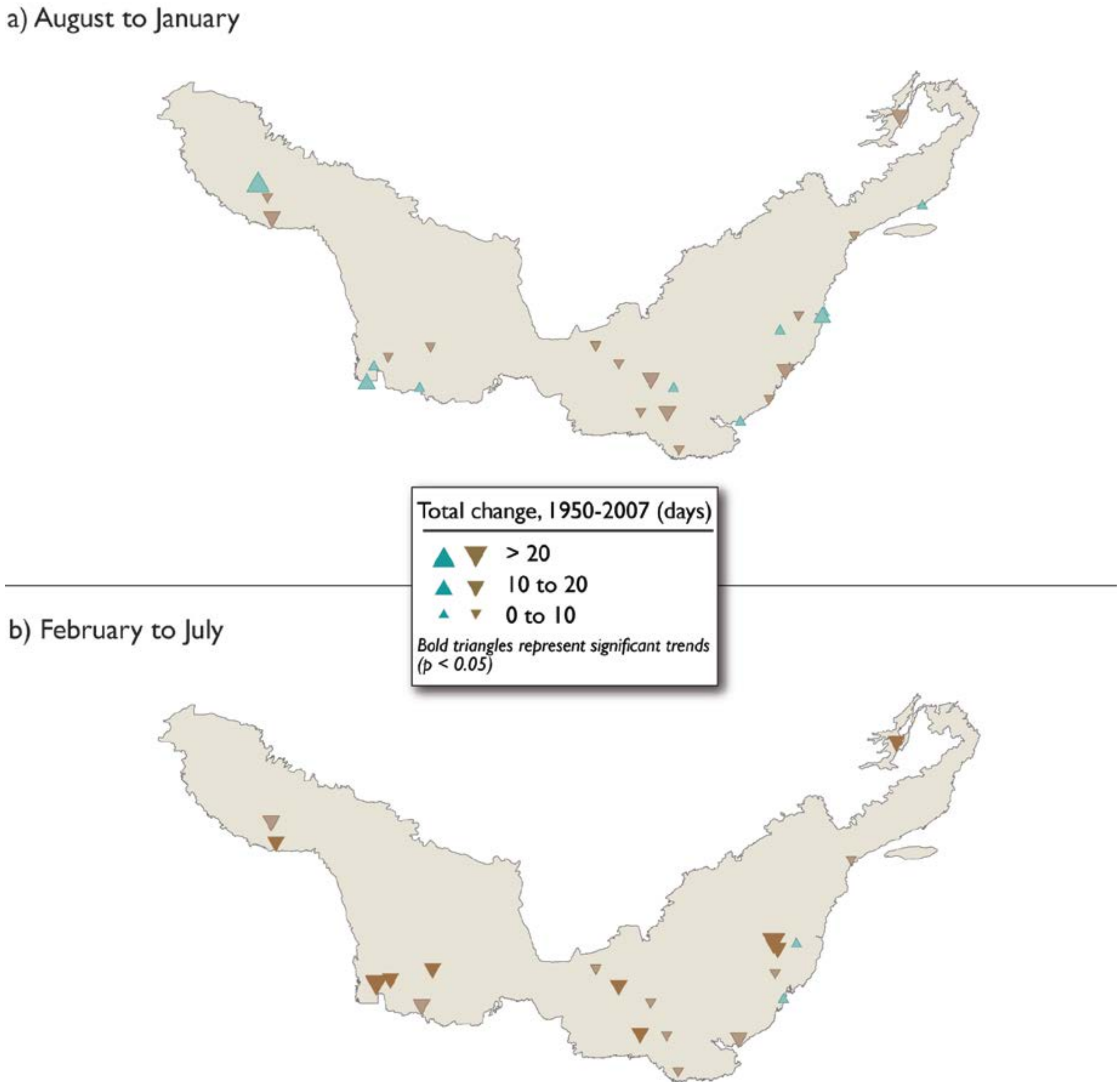


Figure 69. Change in snow durations (the number of days with ≥2 cm of snow on the ground) in the Boreal Shield Ecozone[+] from 1950–2007 in: a) the first half of the snow season (August–January), which indicates change in the start date of snow cover, and b) the second half of the snow season (February–July), which indicates changes in the end date of snow cover.
Source: Zhang et al., 2011[154] and supplementary data provided by authors

These climatic changes have had direct and indirect impacts on biodiversity through changes to hydrological processes, natural disturbances, primary productivity, and invasions of non-native species. Increases in spring and winter temperatures as well as a shallower snow cover and earlier snowmelt, contributed to decreases in annual flows, earlier spring peak flows, and earlier ice melt (see the Lakes and rivers key finding on page 47).[14, 153, 154] Climate change also accelerated erosion (see the Coastal key finding on page 58) through higher water levels that intensified wave action, decreased ice that would otherwise stabilize shores and regulate sediment loads, and caused more frequent freeze-thaw events, particularly affecting clayey cliffs. Forecasted increases in storm events may also facilitate coastal erosion.[169]

Precipitation and temperature changes are contributing to more abundant, earlier, yet less intense fires in central Quebec (see the Boreal Shield Ecozone+ key finding on page 140). These altered natural disturbance patterns resulted in significant replacement of closed-crown boreal forests by less productive lichen woodlands in the latter half of the 20th century.[69] Here the boreal forest is receding northward, which corresponds to predicted changes in ecosystem composition and structure in a changing climate.[389] In Quebec and southern Labrador, climate change from 1985–2006 was associated with positive trends in net primary productivity (see the Primary productivity key finding on page 138).[390]

Range expansions of native and invasive species are consistent with trends towards warmer spring, summer, and winter temperatures, an earlier start of the growing season, and reduced snow depth and duration of snow. The 2007 to 2009 expansion of hemlock looper (*Lambdina fiscellaria fiscellaria*) outbreaks led to unprecedented pesticide treatment plans in southern Labrador. Great blue herons (*Ardea herodias*), American white pelicans (*Pelecanus erythrorhynchos*), and a few forest-dwelling landbird species, were reported more frequently in the northern range of their distributions. Some of these birds are decreasing in their southern range, suggesting a northward shift. Water temperature increases may benefit warm water fish species such as smallmouth bass whereas cold water fish species, such as lake trout, may decline. Non-native invasive species, parasites, and pathogens are spreading northwards (see the Invasive non-native species key finding on page 75). Other species, notably the mountain pine beetle (*Dentroctonus ponderosae*), have expanded their ranges into neighbouring ecozones+ and are expected to reach the Boreal Shield Ecozone+ in coming years.

Newfoundland Boreal Ecozone+

Significant changes have occurred in average summer and fall temperatures in the Newfoundland Boreal Ecozone+ (Table 18 and Figure 70).[154] The amounts of spring, fall, and winter precipitation have all increased by 0.2%, while no significant changes were found for summer precipitation (Figure 71). Changes in precipitation have led to changes in streamflow.[153] For example, discharge in the Bay du Nord River has increased in the spring and decreased in the summer since 1970.[153] No change was found in the proportion of precipitation falling as rain versus snow, or the duration of snow cover. However, the maximum annual snow depth has increased by 32.5 cm since 1950.[154]

Table 18. Summary of changes in climate variables in the Newfoundland Boreal Ecozone+ from 1950–2007.

Climate variable	Trends from 1950–2007
Temperature	Overall ↑ of 1.7 °C in summer temperature Overall ↑ of 1.0 °C in fall temperature No significant spring or winter trends
Growing season	No significant trend in the start, end or length of the growing season
Precipitation	0.2% ↑ in spring precipitation 0.2% ↑ fall precipitation 0.2% ↑ winter precipitation No significant summer precipitation trends No significant trend in the amount of precipitation falling as rain vs. snow
Snow	32.5 cm ↑ in maximum annual snow depth No significant trend in # of days with snow cover
Drought index	No significant trend

Source: Zhang et al. 2011[154] and supplementary data provided by the authors

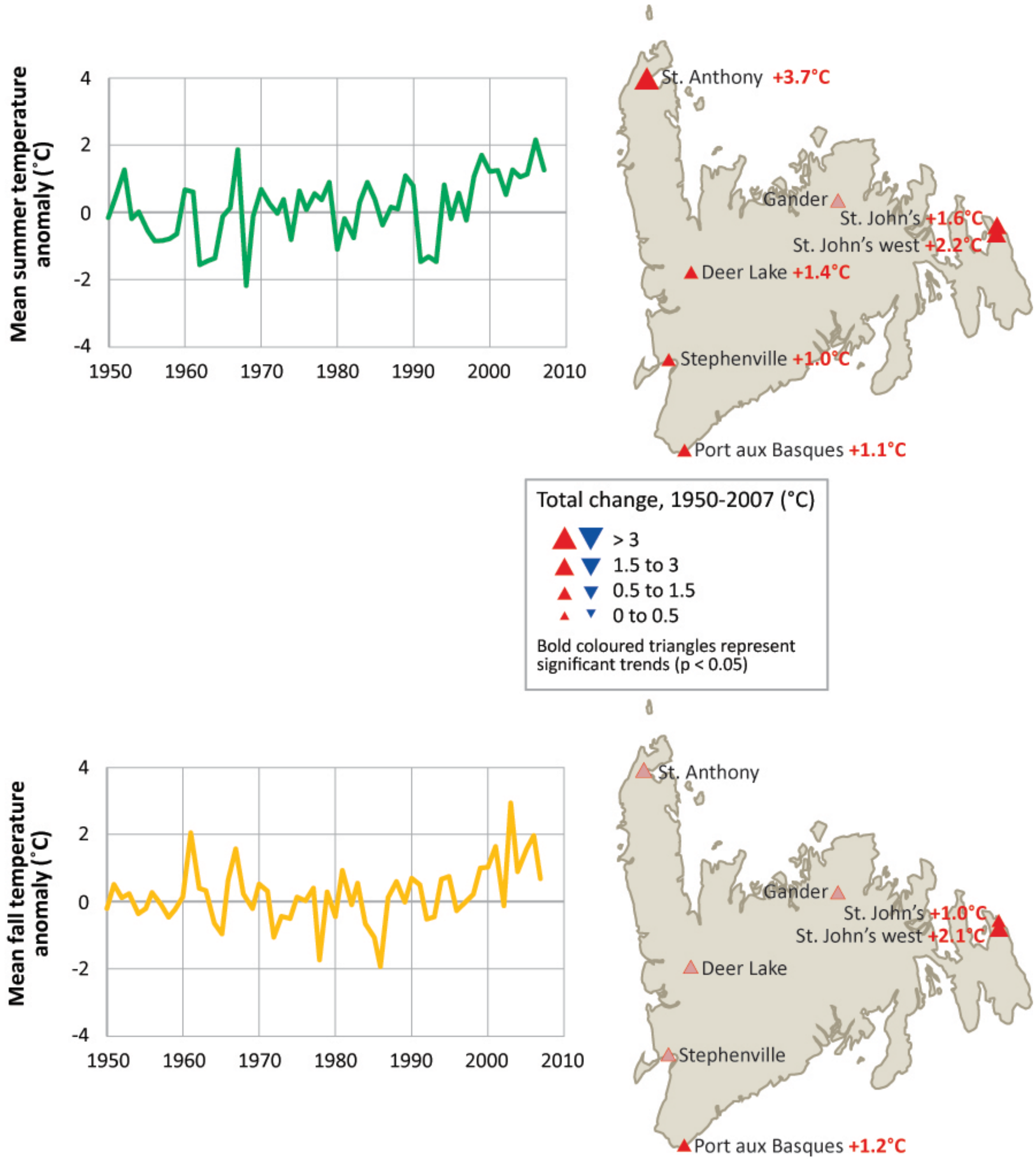


Figure 70. a) Summer (June–August) and b) fall (September–November) average temperature anomalies for 1950 to 2007 relative to the base period (1961–1990) average in the Newfoundland Boreal Ecozone⁺. The graphs show the overall trends for the ecozone⁺ and the maps show trends ($p < 0.05$) for individual stations.
Source: Zhang et al., 2011[154] and supplementary data provided by the authors

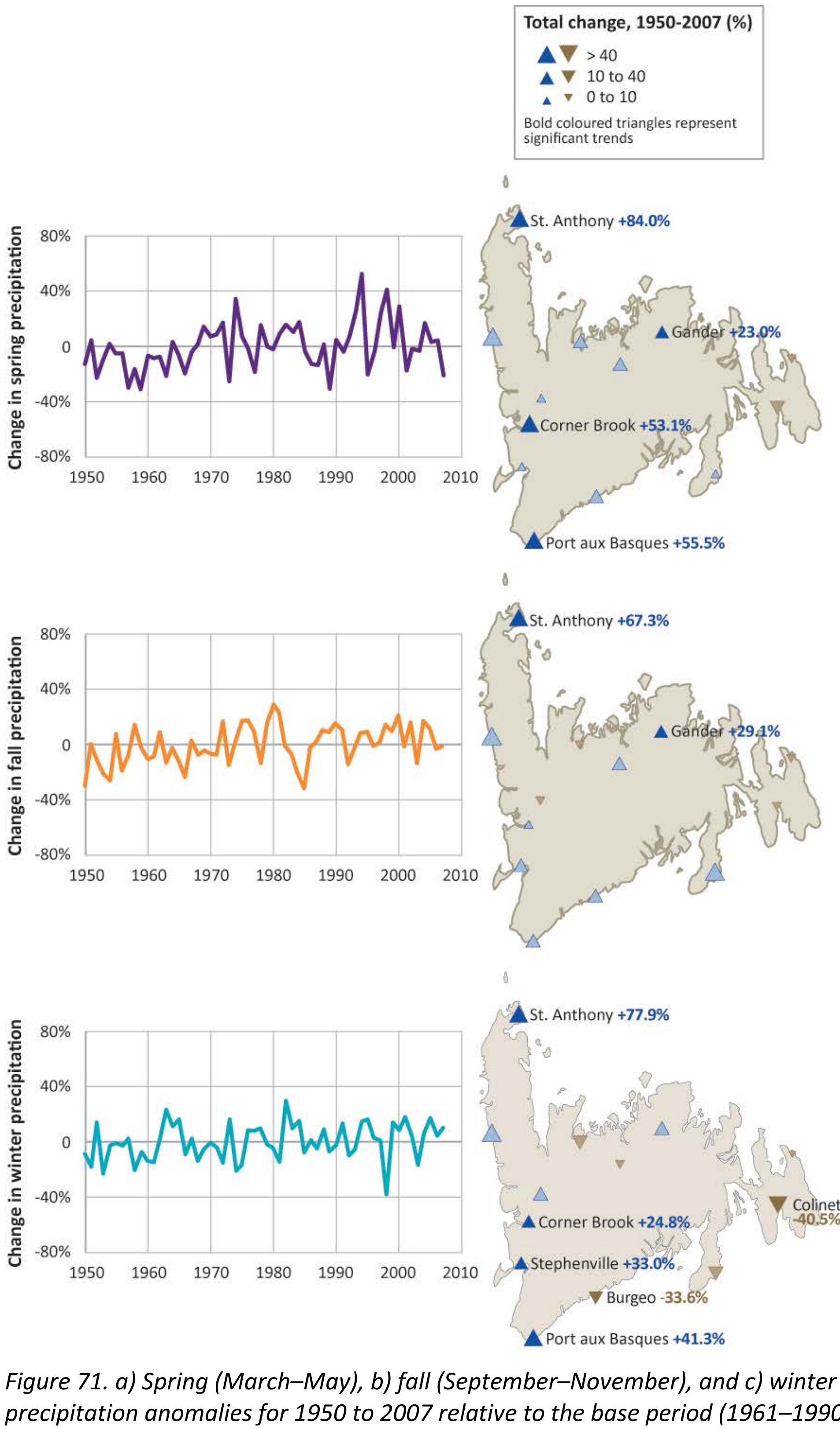


Figure 71. a) Spring (March–May), b) fall (September–November), and c) winter (December–February) precipitation anomalies for 1950 to 2007 relative to the base period (1961–1990) average in the Newfoundland Boreal Ecozone^{+}.
The graphs show the overall trends for the ecozone^{+}; maps show trends (p< 0.05) for individual stations. Source: Zhang et al., 2011[154] and supplementary data provided by the authors

Like the rest of Atlantic Canada, Newfoundland is expected to experience rising sea levels, more storm events, increasing storm intensity, and increased coastal erosion and flooding with climate change.[144, 391]

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.

Boreal Shield Ecozone+

Ecosystem services are the direct goods and indirect services from a healthy, natural environment that ensure human well-being. These include provisioning, regulating, supporting, and cultural services. Following the UN's Millennium Ecosystem Assessment Report in 2005,[392] the Pembina Institute identified, inventoried, and measured the full economic value of the many ecological goods and services provided by Canada's boreal region. They developed the Boreal Ecosystem Wealth Accounting System (BEWAS), a tool for measuring and reporting on the physical conditions and the full economic value of the boreal region's natural capital and ecosystem services.[393] The estimated net market value in the year 2002 was $37.5 billion across all products extracted from boreal forest annually. If accounted for, this would equate to 4.2% of Canada's GDP in 2002.[393] The net market value calculation is based on the contribution to Canada's GDP from boreal timber harvesting, mineral and oil and gas extraction, and hydroelectric generation ($62 billion) minus the estimated $11 billion in environmental costs (e.g., air pollution costs) and societal costs (e.g., government subsidies) associated with these industrial activities. Non-marketable ecosystem goods and services were valued at $703.2 billion (Table 19).[393]

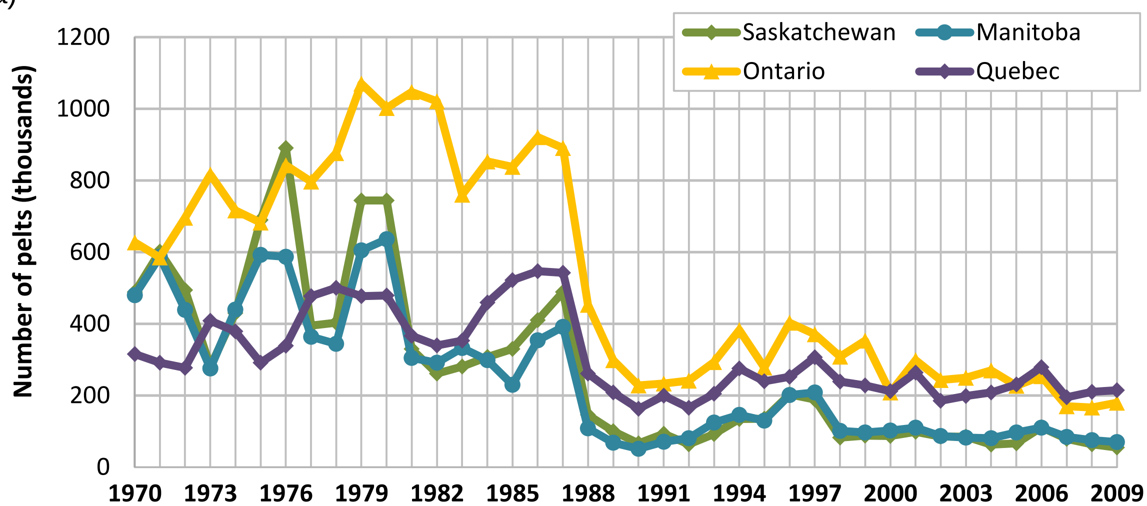
Table 19. Summary of natural capital economic values for Canada's boreal region.

	Forests	Wetlands and peatlands	Minerals and subsoil assets	Water resources	Waste production	TOTAL
Market Values	$18.8 billion		$23.6 billion	$19.5 billion		$62 billion
Costs[a]	$150 million		$1 billion		$9.9 billion	$11 billion
Non-market values	$180.1 billion	$512.6 billion				$703.2 billion
Examples	Pest control by birds Nature-related activities Carbon sequestration	Flood control Carbon sequestration Water filtering Biodiversity value	Federal government expenditures for subsidies to the oil and gas and mining sectors	Hydroelectric generation from dams and reservoirs	Air pollution costs to human health[b]	

Market values are denoted in blue; environmental/societal costs in red, and non-market values in green. The GDP chained, implicit price index was used throughout the study to standardize to 2002 dollars.
[a]These are either environmental or societal costs associated with market-based activities (e.g., forest industry operations).
[b]based on European Union air pollution cost estimates for SO_2, NO_x, $PM_{2.5}$, and VOC for 2002.
Source: Anielski and Wilson, 2005[394]

Further information was available for certain provisioning and cultural services at a provincial or local scale. Harvest data from hunting and trapping were used to extract trends for the Species of special economic, cultural, or ecological interest key finding on page 126. Some trapping information was presented for the cumulative number of wildlife pelts produced in Quebec, Ontario, Manitoba, and Saskatchewan from 1970 to 2009.[395] From 1987 to 1988, trapping fur yields dropped more than 50%, driven in large part by a reduction in the number of muskrat (*Ondatra zibethicus*) furs. This decline in trapping was likely attributable to new trapping methods introduced in Canada in the late 1980s. Thus it does not likely reflect actual population trends. The Agreement on International Humane Trapping Standards (AIHTS) was eventually ratified by Canada in 1999 and implementation of standards was completed in 2007.[396]

a)



b)

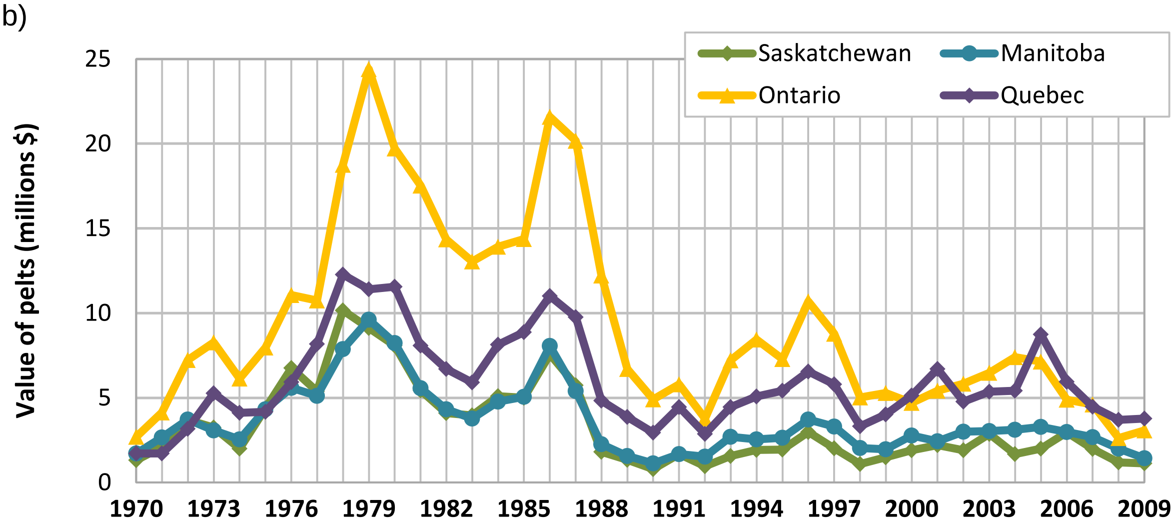


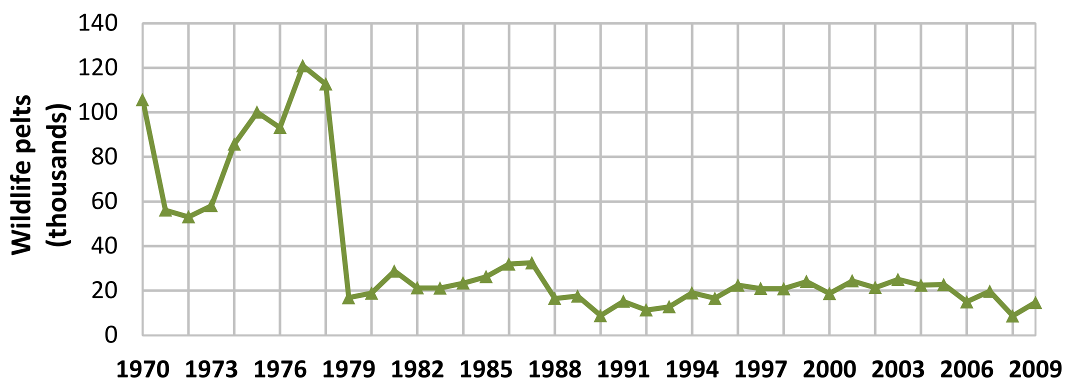
Figure 72. a) Total number of wildlife pelts (representing all trapped species in the ecozone+) and b) value of wildlife pelts from trapping by province, 1970-2006.
These province-wide data exceed the Boreal Shield Ecozone+ boundaries.
Source: Statistics Canada, 2009[395]

Aboriginal People have observed changes in blueberry (*Vaccinium myrtilloides*), wild rice (*Zizania aquatica*), and fish in the Boreal Shield Ecozone+. Blueberry growth may be reduced by increased temperatures, drought, and fire suppression.[4, 397] Wild rice distribution and harvest were altered due to hydroelectric development in the early 1900s.[398] Hydrological changes related to hydro-developments were also reported to cause changes in fish ecology, including spawning behaviour,[399] presence of certain species,[400] and an overall reduction in freshwater biodiversity.[401]

Newfoundland Boreal Ecozone+

No valuations of ecosystem goods and services were found for the Newfoundland Boreal Ecozone+. Moose are a wildlife resource valued by Newfoundland people for their subsistence, aesthetic, and economic value, and the annual hunt is an important cultural practice within the Newfoundland Boreal Ecozone+. Annual license sales have exceeded 25,000 for the past five years with up to 10% of sales going to non-resident hunters.[96] Hunting revenues and other tourist activities related to moose contribute more than $100 million annually to the Newfoundland economy.[96]

a)



b)

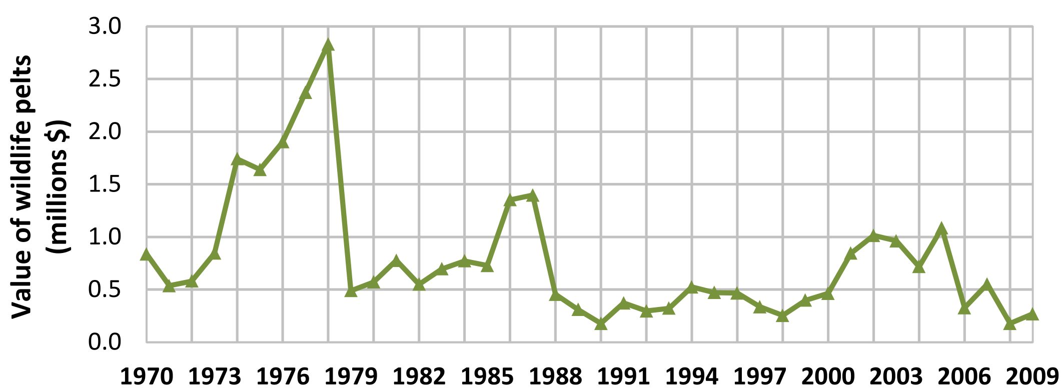


Figure 73. a) Total number of wildlife pelts (representing all trapped species in the ecozone+) and b) value of wildlife pelts from trapping in Newfoundland and Labrador, 1970-2009.
These are provincial data and exceed the Newfoundland Boreal Ecozone+ boundaries.
Source: Statistics Canada, 2010[395]

THEME: HABITAT, WILDLIFE, AND ECOSYSTEM PROCESSES

Theme Habitat, wildlife, and ecosystem processes

Intact landscapes and waterscapes

Intact landscapes and waterscapes was initially identified as a nationally recurring key finding and information was subsequently compiled and assessed for the Boreal Shield Ecozone+. In the final version of the national report,[6] information related to intact landscapes and waterscapes was incorporated into other key findings. This information is maintained as a separate key finding for the Boreal Shield Ecozone+.

Boreal Shield Ecozone+

As of 2006, 64% of the total area of the Boreal Shield Ecozone+ was composed of intact terrestrial landscape fragments larger than 10 km^2 (Figure 74). A terrestrial 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. Most of these fragments were north of the limit of managed forest.[11] Fragmented landscapes are a result of forest harvesting, roads, mining, dams and reservoirs, power lines, and industrial development.

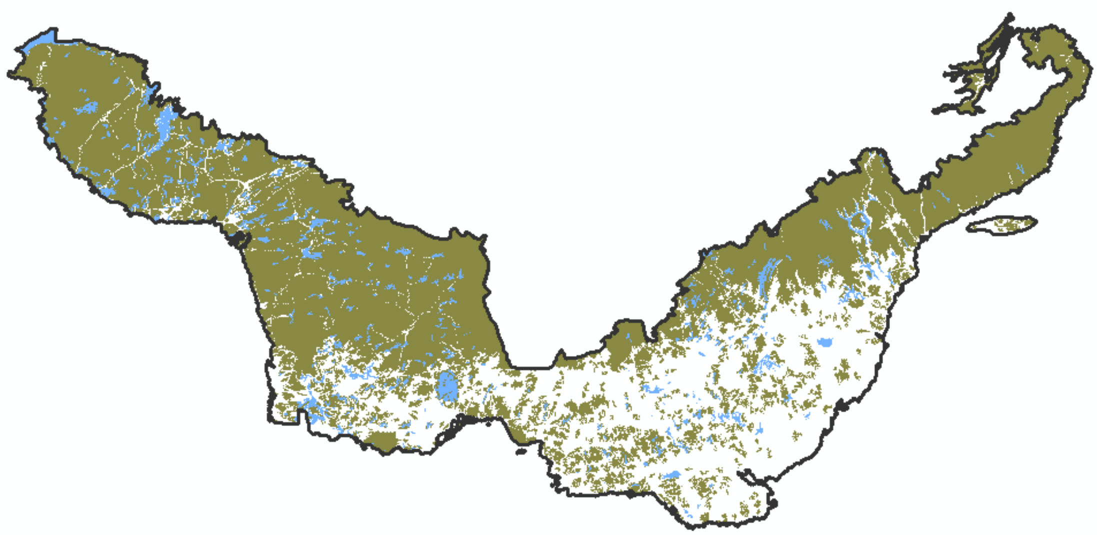


Figure 74. Intact terrestrial landscape fragments larger than 10 km^2 (shown in green) in the Boreal Shield Ecozone+, 2006.
Source: Lee et al., 2006[11]

Nearly 10% of the Boreal Shield Ecozone+ was under active mining claims in 2006,[402] although much of this is unlikely to become an active mine. Mines fragment the landscape due to the infrastructure and road development required to service them. Mining is the principal industry in northern Saskatchewan and there are six uranium mines and two gold developments within the Saskatchewan portion of the Boreal Shield Ecozone+. The uranium facilities in the eastern portion of the Athabasca Basin produce 17% of the world's uranium supply.[403] As of September 2012, 55,000 km^2 were under disposition for mineral exploration in Saskatchewan.[403] There are eight operating mines within the Manitoba portion of the Boreal Shield Ecozone+, two for gold and six for base metals.[404] Northern Ontario has an active mining history, particularly in Greater Sudbury.[23] The number of staked claims increased by 500% from 1998 to 2008, especially in the region called the "Far North" in Ontario which includes the Boreal Shield and Hudson Plains ecozones+ (Figure 75).[405] Gold and copper are mined in the northwest part of the Boreal Shield Ecozone+ in Quebec. Minerals and other metals are mined in the east (iron in Fermont and niobium near Chicoutimi and Sept-Îles) and the three largest open pit mines are in Abitibi.[406]

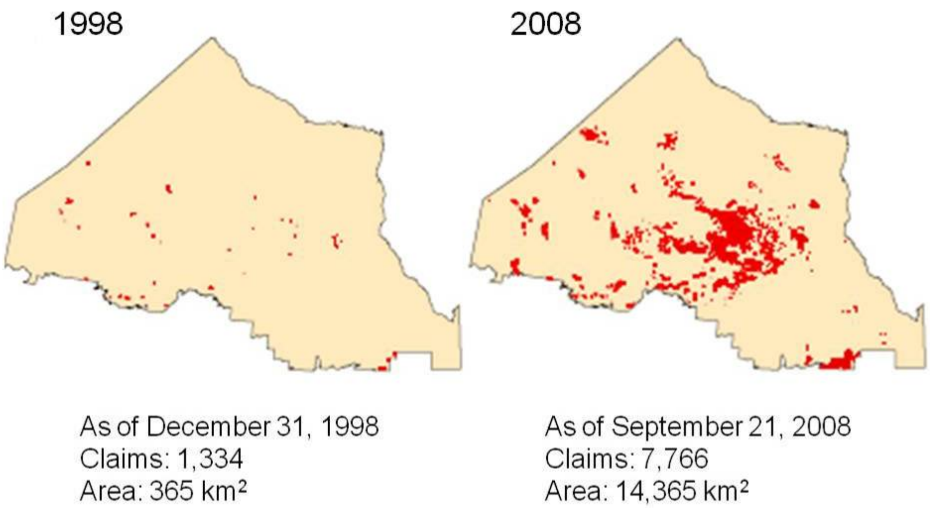


Figure 75. Area of claims staked in the 'Far North' region of Ontario, 1998 and 2008.
Note: The Boreal Shield and Hudson Plains ecozones+ split the staked area in red almost evenly.
Source: Ontario Ministry of Northern Development and Mines, 2009[405]

Dams and reservoirs alter the physical landscape, interrupt hydrological regimes, and the process of impoundment introduces contaminants that can accumulate along the food chain. More specifically, dams interrupt fish migration, increase sedimentation, affect habitat for many species, and change water levels and water chemistry.[155] The degree of impact depends on the size of the dams, their operation, and the ecosystems' biophysical characteristics.[156, 157] However, dams can be operated to emulate natural hydrological regimes and mitigate adverse effects.[158]

Dams are more common in the southeastern portion of the ecozone+ (Figure 23).[159] Most dams (79%) were constructed between 1920 and 1969 (Figure 24) and many are approaching the end of their productive lives.[12, 159]

Newfoundland Boreal Ecozone+

As of 2006, 57% of the Newfoundland Boreal Ecozone+ was composed of intact "terrestrial landscape fragments" (contiguous blocks of forest, bog, water, tundra and rock outcrops of more than 10 km^2) (Figure 76).[11]

Figure 76. Intact terrestrial landscape fragments larger than 10 km^2 (shown in green) in the Newfoundland Boreal Ecozone+, 2006.
Source: Lee et al., 2006[11]

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.

Boreal Shield Ecozone+

Agricultural land in the Boreal Shield Ecozone+ is limited to a few areas of suitable soil quality and microclimate. From 1986 to 2006, approximately 1,930 km^2 were removed from the agricultural land base, leaving just over 130,000 km^2 of farmland (1% of the ecozone+) (Figure 77).[18] Where farmland occurs, it is well dispersed among forested areas. Thus, the impact of agricultural land on wildlife at the ecozone+ scale is low.

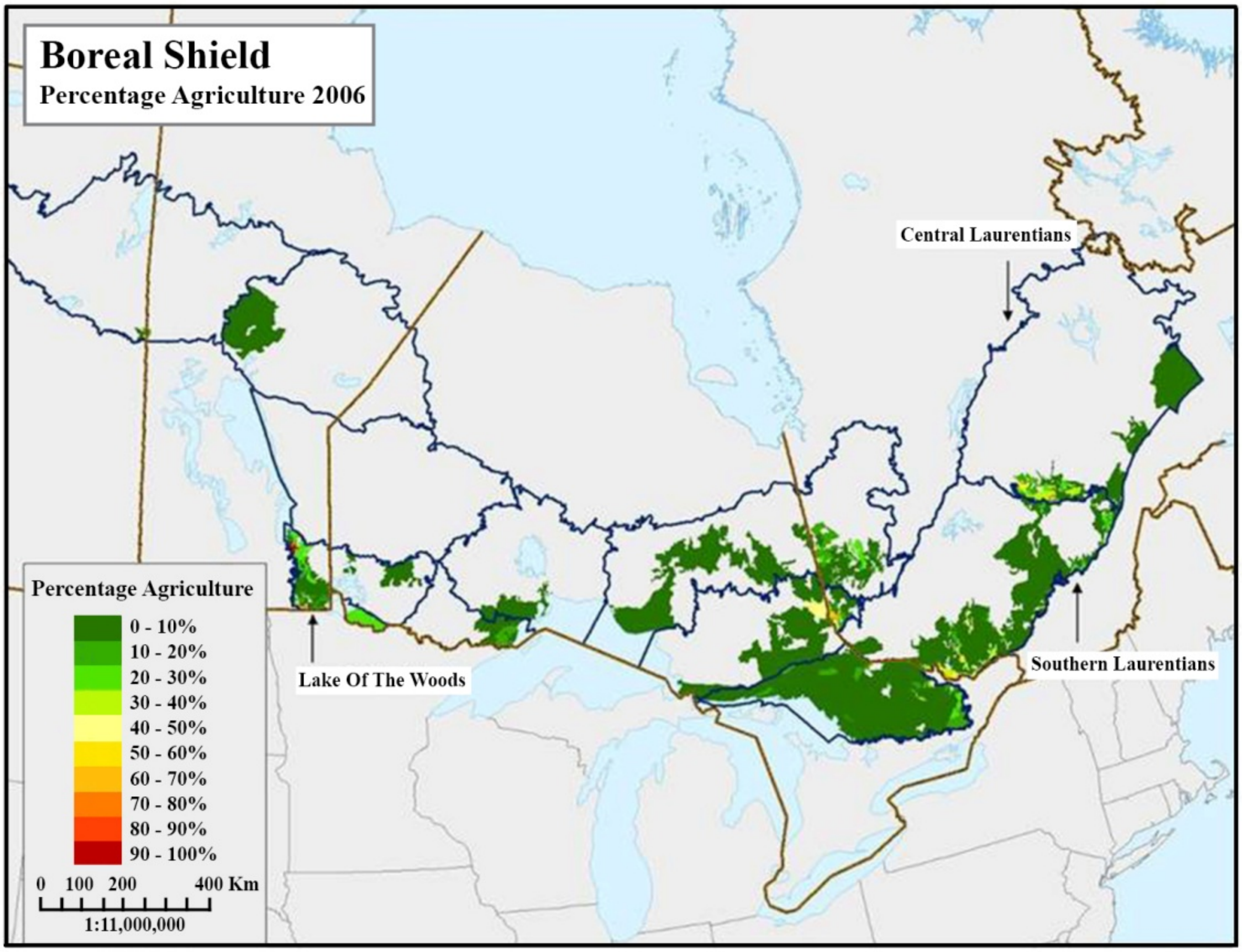
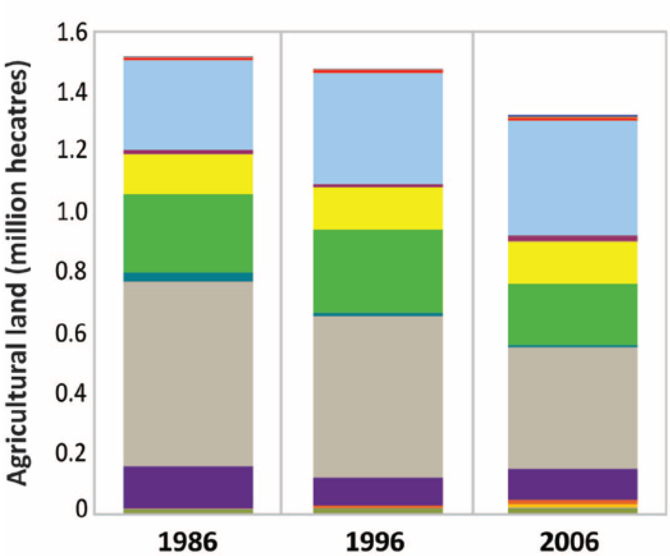


Figure 77. Percentage of land defined as agricultural in the Boreal Shield Ecozone+, 2006. Soil Landscapes of Canada polygons were the base unit used for this analysis. Source: Javorek and Grant, 2011[18]

Wildlife habitat capacity

The Wildlife Habitat Capacity on Agricultural Indicator, an agri-environmental indicator developed and tracked by Agriculture and Agri-Food Canada, provides a multi-species assessment of broad-scale trends in the potential of the Canadian agricultural landscape to provide habitat for terrestrial vertebrates.[18] The index rates the value of each cover type for 588 species of birds, mammals, reptiles, and amphibians.[18] A total of 349 species (249 birds, 60 mammals, 21 reptiles, and 19 amphibians) used agricultural land in the Boreal Shield Ecozone+. The 15 land-cover types were based on the Canadian Census of Agriculture (Figure 78).[407] Overall, cropland is a minor land cover in the Boreal Shield amounting to only 0.3% of the land area. This 0.3% excludes "All Other Land", "Tame Hay", "Unimproved Pasture", and "Improved Pasture" to leave only the cropland categories in Figure 78. "All Other Land" was the most important land cover category for wildlife in Canada that use farmland. This category included wetlands (with margins, without margins and open water), riparian (woody, herbaceous and crop), shelterbelts (including natural hedgerows), woodland (with interior, without interior, plantation), and idle land/old field, and anthropogenic land (farm buildings, green houses, lanes). In the Boreal Shield Ecozone+, "All Other Land" provided both breeding and feeding habitat for 85% (298) of the species that use farmland (Figure 78). However, cover in this important wildlife habitat category declined from 40 to 30% from 1986 to 2006 (Figure 78). "Unimproved Pasture" provided both breeding and feeding habitat for 17% (59) of the species and at least a single habitat requirement for 32% (112 species) (Figure 78). Only 13% (46 species) could fulfill both breeding and feeding habitat needs entirely on cropland and 26% (89 species) could use these cover types for a single habitat requirement (Figure 78). Therefore, maintaining heterogeneous agricultural landscapes benefits wildlife because wildlife may breed in one land cover type but feed in another.[18]



Cover type	Percentage of agricultural land 1986	1996	2006
Winter Cereals	0.1	0.1	0.4
Vegetables	0.1	0.1	0.1
Fruit Trees	0.0	0.0	0.0
Other Crops	0.5	0.8	0.8
Tame Hay	19.6	24.8	28.7
Corn	0.9	0.8	1.5
Cereals	8.8	9.5	10.6
Unimproved Pasture	17.1	18.6	15.4
Summerfallow	2.0	0.9	0.5
All Other Land	40.3	36.1	30.4
Improved Pasture	9.2	6.3	7.8
Berries	0.1	0.6	1.0
Soybeans	0.0	0.1	1.0
Pulses	0.1	0.1	0.1
Oilseeds	1.0	1.2	1.6

Figure 78. Total agricultural area, the amount of land per cover type (chart), and the relative percentage of each cover type (table) for the Boreal Shield Ecozone+ in 1986, 1996, and 2006.
Source: Javorek and Grant, 2011[18]

Wildlife habitat capacity on farmland in the Boreal Shield Ecozone+ declined significantly (ANOVA: F=88.6, Tukey HSD p=0.0001) from "high" (79.7 ± 13.4) in 1986 to "moderate" (63.8 ± 14.4) in 2006 (Figure 78). From 1986 to 2006, habitat capacity decreased on 71% of farmland, increased on 6% and was constant on 23% (ANOVA, Tukey HSD $p<0.05$, Figure 79).

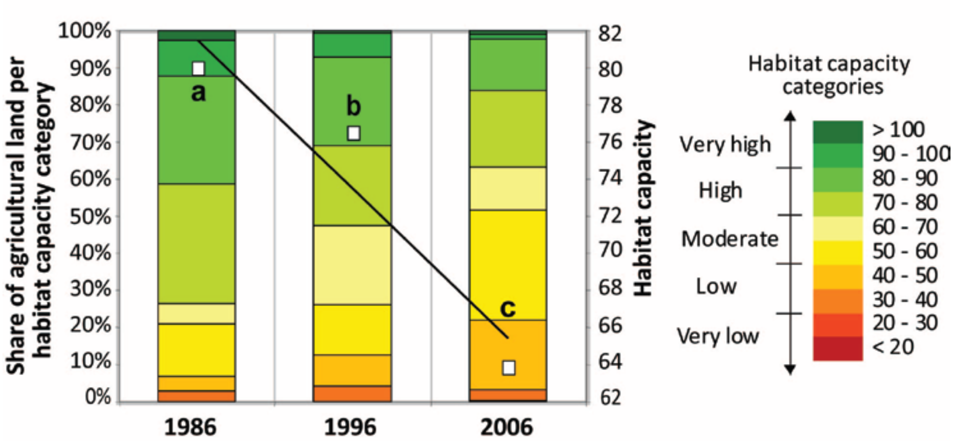


Figure 79. The share of agricultural land in each habitat capacity category (left axis, stacked bars) and the average habitat capacity (right axis, points and line) for the Boreal Shield Ecozone+ in 1986, 1996, and 2006.
Years with different letters indicate a statistically significant difference (p<0.05).
Source: Javorek and Grant, 2011[18]

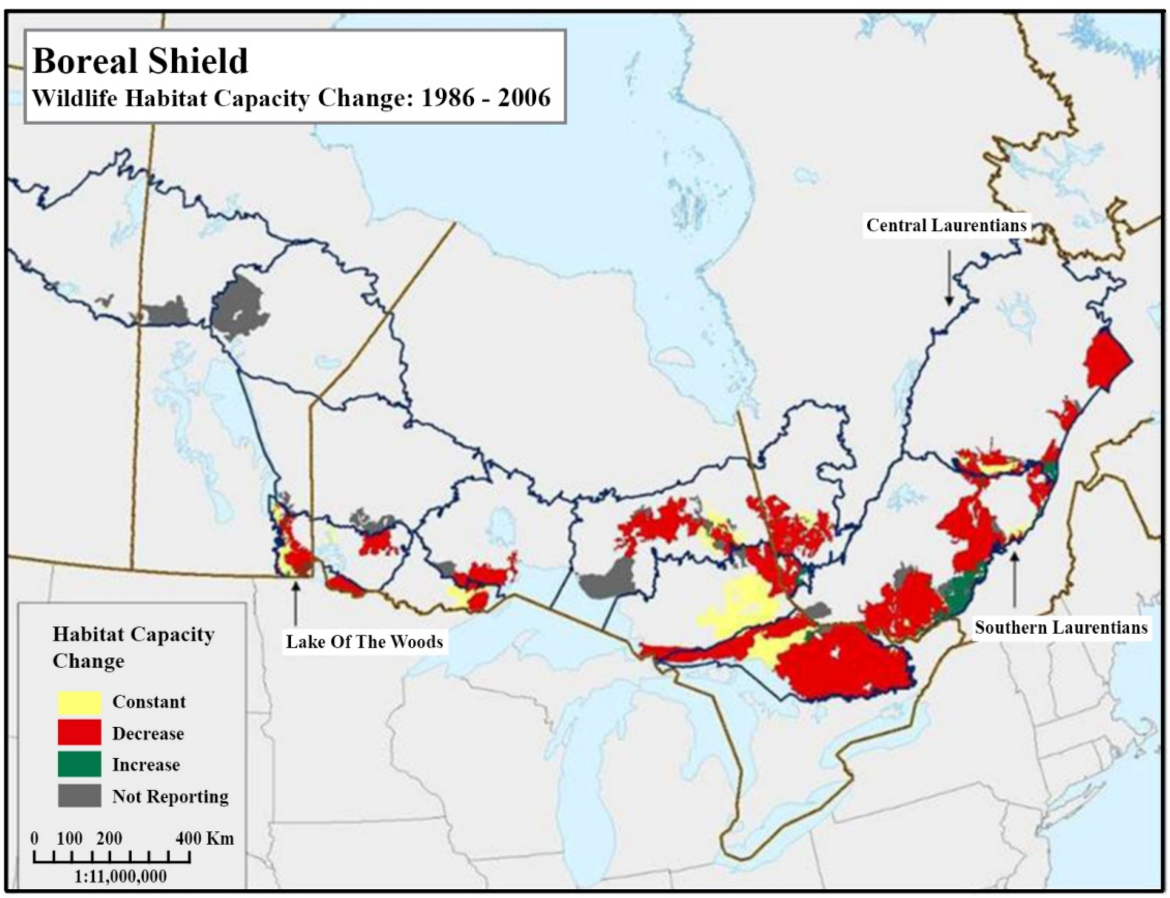


Figure 80. Changes in wildlife habitat capacity on agricultural land in the Boreal Shield Ecozone+ from 1986 to 2006.
Source: Javorek and Grant, 2011[18]

Trends for three ecoregions with higher agriculture production in the Boreal Shield Ecozone+ are as follows: the Central Laurentians had the largest decline in habitat capacity (78 to 59%); the Southern Laurentians had the second largest decline (83 to 74%); and finally Lake of the Woods declined from 58 to 51% (Figure 80). Lake of the Woods consistently recorded the lowest habitat capacity primarily due to its small and declining share of "All Other Land" (23 to 17%). In comparison, "All Other Land" in the Central Laurentians declined from 37 to 26% and from 46 to 39% in the Southern Laurentians. As the agricultural footprint shrank in the Boreal Shield Ecozone+, the cover of cropland expanded from 32 to 43% (Figure 78). This was primarily due to a 9% increase in "Tame Hay" from 1986 to 2006 (Figure 78). These factors combined to reduce wildlife habitat capacity on farmland from high to moderate over the 20-year period (Figure 79). This loss of wildlife habitat capacity was correlated with declines in the landbirds that use these habitats (see the Birds section on page 126).

Birds of open habitat

Birds of open habitat are a minor part of the avifauna, located mainly in the southern part of the ecozone+. With the exception of Eastern bluebird (*Sialia sialis*), most open habitat bird species are declining (Table 20). Declines in swallows and common nighthawks (*Chordeiles minor*) are consistent with a general decline in aerial insectivores throughout Canada.[76]

Table 20. Trends in abundance (% change/year) and reliability of the trend in birds of open habitats in the Ontario and Quebec portions of the Boreal Shield Ecozone+ from 1970 to 2012.

Species	BCR 8 Annual Trend	BCR 8 Reliability	BCR 12 Annual Trend	BCR 12 Reliability
American kestrel (*Falco sparverius*)	-0.93	Low	-1.33	High
Bank swallow (*Riparia riparia*)	-7.23	Low	-12.6	Medium
Barn swallow (*Hirundo rustica*)	-4.32	Low	-6.17	Medium
Brown-headed cowbird (*Molothrus ater*)	-7.54	Medium	-7.86	High
Cliff swallow (*Petrochelidon pyrrhonota*)	-6.96	Low	-8.62	High
Common nighthawk (*Chordeiles minor*)	-1.76	Low	-5.76	Medium
Eastern bluebird (*Sialia sialis*)			1.64	Medium
Eastern kingbird (*Tyrannus tyrannus*)	-1.28	Low	-3.75	Medium
Tree swallow (*Tachycineta bicolor*)	-3.39	Low	-4.98	High

These data only include the Ontario and Quebec portions of Bird Conservation Region 8 and 12. Only the northern half of BCR 12 falls within the ecozone+, so these data exceed the boundaries of the ecozone+.[86]
Source: Environment Canada, 2014 [79]

Newfoundland Boreal Ecozone+

The Agricultural Landscapes as Habitat key finding was not relevant for the Newfoundland Boreal Ecozone+ due to the small amount of agricultural land in the ecozone+.

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.

Boreal Shield Ecozone$^+$

The highest species richness is found in the southernmost region of this ecozone$^+$, east of Georgian Bay, with over 200 bird species and 60 tree species.[408] Species richness declines progressively northwards, with a notable reduction at the limit of managed forests, especially for mammals, reptiles, and amphibians.[11, 408]

There are few population surveys of species of special interest in the Boreal Shield Ecozone$^+$. Trends can be derived from commercial or recreational harvests of furbearing species (Figure 72), but these carry biases due to fluctuations in markets and hunter effort. There are major gaps for fish, reptiles, and amphibians.

Birds

Estimates of bird assemblages were based on an ecozone$^+$-scale analysis (1968 to 2006) of the North American Breeding Bird Survey (BBS).[76]

Landbirds

Much of the data collected by the BBS in the Boreal Shield Ecozone$^+$ is from the southern shield portion of Ontario and Quebec. The BBS covers agricultural areas in the region relatively well because they tend to be accessible by roads.[76] Declines were significant for shrub/successional birds and urban birds (0.7% decline/yr), birds of other open habitat (4% decline/yr), and grassland birds (2.5% decline/yr) (Figure 81). Trends for wetland landbirds were not calculated because few landbirds fit cleanly into this assemblage and the BBS does not cover wetland habitat well. The forest birds assemblage shows close to stable populations, although trends of individual species within this group range from large declines to large increases.[76] Declines in birds, especially songbirds, have also been noted by Aboriginal elders from the western Boreal Shield Ecozone$^+$.[4]

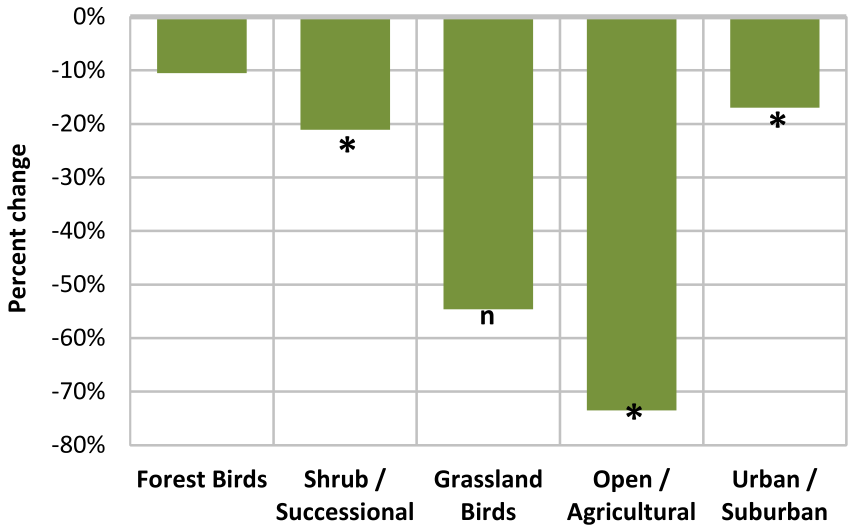


Figure 81. Percent change in the average relative abundance of bird assemblages in the Boreal Shield Ecozone+ between the 1970s and 2000–2006.
*p is the statistical significance: * indicates p <0.05; n indicates 0.05<p<0.1; no value indicates not significant.*
Source: Downes et al., 2011[76] using data from the Breeding Bird Survey[409]

Forest birds

Forest bird populations as an assemblage were relatively stable (Figure 82), though individual species show a mix of increasing, declining, and stable populations (Table 6). See the Forest birds section on page 30.

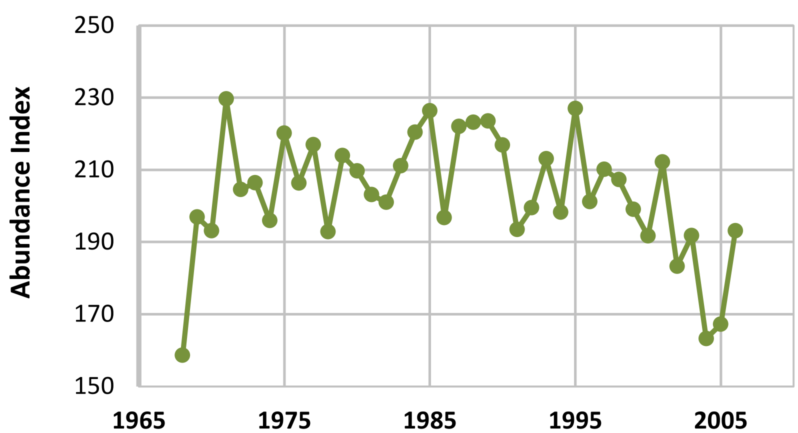


Figure 82. Change in annual abundance index for forest birds in the Boreal Shield Ecozone+, 1968-2006.
Source: Downes et al, 2011[76] based on data from the Breeding Bird Survey[409]

Birds of shrub/early successional habitats

The assemblage of birds in early successional habitat, such as old fields and regenerating forests, are declining (Figure 83). White-throated sparrows (*Zonotrichia albicollis*) are declining at a greater rate in the south of the ecozone+ (-0.49 in BCR 12, which includes the Mixedwood Plains Ecozone+) relative to the north (-0.25 in BCR 8) according to the BBS. Likewise, the CBC shows a decline in the south of its winter range and an increase in the north, suggesting a northward shift in their wintering distribution.[410]

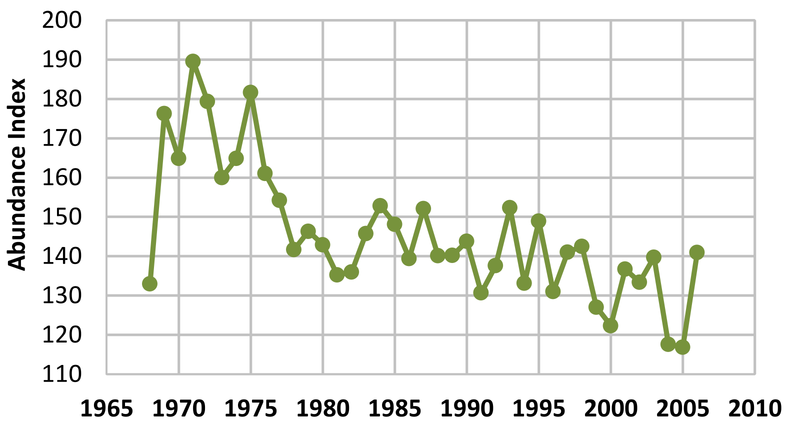


Figure 83. Change in annual abundance index for birds of shrub/successional habitats in the Boreal Shield Ecozone+, 1968-2006.
Source: Downes et al., 2011[76] based on data from the Breeding Bird Survey[409]

Birds of other open habitats

Birds in the other open habitat assemblage show the largest overall decline of all assemblages in the Boreal Shield Ecozone+, with declines mainly apparent since the late 1980s (Figure 84). Many of these species historically occurred in the ecozone+ only in small numbers. Land clearing for agriculture created more habitat and populations increased. Declines since the mid-1980s may be a reflection of the loss of this habitat through reforestation of abandoned farmland in some parts of this ecozone+.[411] Increased agriculture also resulted in a loss of wildlife habitat capacity between 1986 and 2006 (see the Wildlife habitat capacity indicator on page 122).

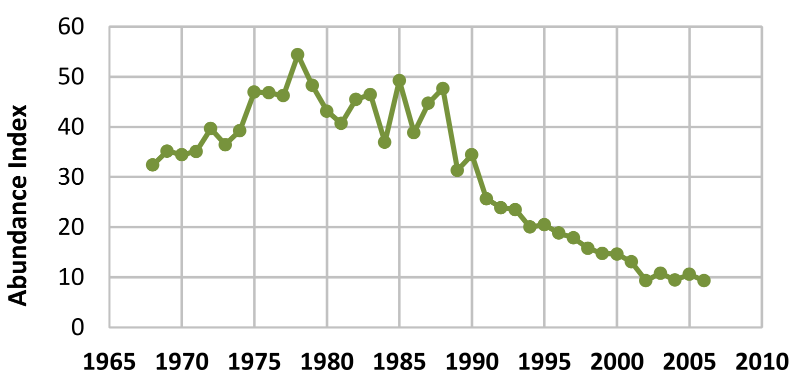


Figure 84. Change in annual abundance index for birds of other open habitats in the Boreal Shield Ecozone+, 1968-2006.
Source: Downes et al., 2011[76] based on data from the Breeding Bird Survey[409]

Woodland caribou (boreal population)

Woodland caribou, boreal population (i.e., boreal caribou) was listed as Threatened under the *Species at Risk Act* (SARA) in 2003.[412] 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*[413] and the *2012 Recovery Strategy for the Woodland Caribou* (Rangifer tarandus caribou)*, boreal population in Canada*.[414] The information in this report has been updated since the release of the ESTR national thematic report, *Woodland caribou, boreal population, trends in Canada.*[415]

Boreal caribou are forest-dwelling, sedentary caribou that occur only in Canada and are distributed broadly across the boreal forest.[416,417] The distribution of boreal caribou in the Boreal Shield Ecozone+ stretches from the Richardson range in the northeast corner of Alberta, east to the Mealy Mountain local population in Labrador, and extends as far south as the Coastal local population at Lake Superior in Ontario[413, 413, 418] (Figure 85). Across Canada, the southern limit of boreal caribou distribution has receded northward since the early 1900s, a trend that continues today.[413, 416, 417, 419] Aboriginal Traditional Knowledge indicates that boreal caribou have moved northward as a result of habitat loss in the south.[414]

Across the Boreal Shield Ecozone +, logging and other industrial disturbances affect boreal caribou through a combination of habitat loss, habitat degradations, and the development of linear features such as roads and seismic lines.[420] These habitat alterations resulted in increased early seral-stage forest and promoted higher densities of moose and white-tailed deer. These "alternate prey" support higher predator densities, especially wolves[413, 420-427] and the primary proximate limiting factor for boreal caribou is predation.[428]

Boreal caribou may therefore be indicators of the health of boreal forest ecosystems. Boreal caribou depend on large patches of mature coniferous forests to reduce the risk of predation. These patches allow boreal caribou to maintain low population densities and avoid areas of high predation risk.[413, 418-420, 429-432] Late-successional coniferous forests and peatlands function as refugia for caribou, away from high densities of predators and their alternate prey.[413, 424, 433-436]

The Boreal Shield Ecozone+ includes 29 boreal caribou local populations (or portions thereof) (see Figure 2 in Callaghan et al. 2011).[415] Based on caribou surveys and expert opinion, 1 local population is increasing, 5 are declining, 13 are stable, and the status of 10 are not available (Figure 85). The boreal caribou's contiguous range has retracted northwards and its southern boundary generally corresponds to the northern limit of forest harvesting.[413, 419, 437] The Coastal local population is located south of this boundary.[413, 415] In 2012, fewer than 10 caribou were thought to remain in Pukaskwa National Park, ON.[438] The feasibility of translocations to augment caribou populations is being explored for Ontario.[439, 440] The southern populations are also most at risk of meningeal brainworm (*Parelaphostrongylus tenuis*) because white-tailed deer are advancing north and into the southern range of caribou. Deer are vectors of this brainworm, which is fatal for caribou but not deer.[413, 429] Actions in *Ontario's Woodland Caribou Conservation*

Plan include expanding deer hunting seasons in northern Ontario to help slow deer range expansion.[439]

Although the trend of most caribou populations in the Boreal Shield Ecozone + are stable or not available,[413, 415] many of these are thought to be not self-sustaining or as likely as not self-sustaining, according to the *Recovery Strategy* risk assessment. [414] The Richardson, Kississing, Naosap, Sydney, Kesagami, Charlevoix, Pipmuacan and Val d'Or local populations are not self-sustaining and the Manitoba North, Owl-Flinstone, Berens, Manouane and Lac Joseph local populations are as likely as not self-sustaining due to habitat loss from industrial activities, natural disturbances such as wildfire, human recreational activities, and illegal hunting.[414, 441, 442] The decline of the Val d'Or sub-population, estimated at 30 individuals in 2012, was also attributed to habitat loss and degradation from mining and forestry.[414, 418] Hunting, facilitated by roads and off-road vehicles, may be the most significant threat to boreal caribou in Labrador (e.g., Red Wine Mountain).[413, 443]

Stable or increasing local populations occur in areas with little industrial activity or where predators are controlled. For example, the Charlevoix local population in Quebec was estimated at 10,000 animals before the 19th century, but declined rapidly due to hunting and lichen harvest. Following a report of a caribou harvested in 1914, the herd was soon extinct. The first release occurred in 1969 as part of reintroduction program initiated in 1967. The herd's population was considered stable at 75 individuals in 2012.[413-415, 444]

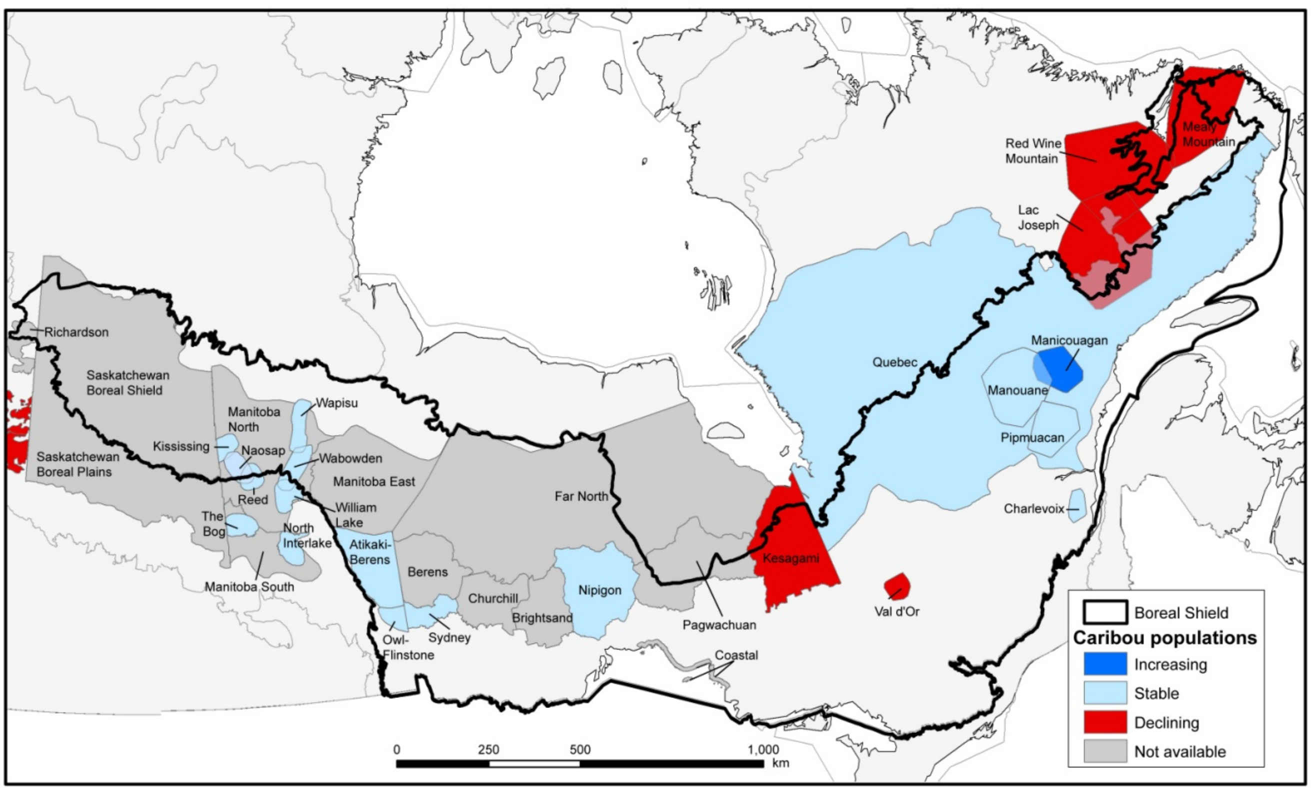


Figure 85. Status of boreal caribou local populations in the Boreal Shield Ecozone+.
Source: updated from Callaghan et al., 2011[415] based on Environment Canada, 2012[414]

Fish

The number of freshwater and diadromous fish taxa classified as imperiled in the Boreal Shield Ecozone+ doubled from 1979 to 2008 (Table 21). However, the status of two taxa also improved over this period.[445] Also, earlier lists did not include geographic sub-populations such as striped bass (*Morone saxatilis*). The main threats to the 14 imperiled fish taxa in the Boreal Shield Ecozone+ include habitat degradation and loss, over-exploitation, invasive species, and competition.[445] Most of the extinct species inhabited the Boreal Shield Ecozone+ as well as the Mixedwood Plains Ecozone+, where there is a long history of invasive species and pollution.[446]

Table 21. Identification of imperiled freshwater and diadromous fish taxa in the Boreal Shield Ecozone+.

Common name	1979	1989	2008
Atlantic sturgeon (*Acipenser oxyrinchus*)	V	V	V
Aurora trout (*Salvelinus fontinalis*)		E	E
Blackfin cisco (*Coregonus nigripinnis*)	E	X	X
Bridle shiner (*Notropis bifrenatus*)			V
Copper redhorse (*Moxostoma hubbsi*)	T	T	E
Deepwater cisco (*Coregonus johannae*)	E	X	X
Greater redhorse (*Moxostoma valenciennesi*)			V
Lake sturgeon (*Acipenser fluvescens*)	T	T	V
Nipigon blackfin cisco (*Coregonus nigripinnis regalis*)			T
Redside dace (*Clinostomus elongates*)			V
Shortjaw cisco (*Coregonus zenithicus*)	E	E	T
Shortnose cisco (*Coregonus reighardi*)	E	E	X
Spring cisco (*Coregonus* sp.)			V
Striped bass (St. Lawrence Estuary population) (*Morone saxtilis*)			X

X are 'Extinct', E are 'Endangered', T are 'Threatened', and V are 'Vulnerable'; as defined in Jelks et al.[445].
Shading illustrates a change in status: downlisting (green) or uplisting (red).
Source: adapted from Jelks et al., 2008[445]

Carnivorous mammals and furbearers

Population estimates for carnivorous mammals and furbearers were limited, localized, or inconsistent at the ecozone+ scale. Many of these species are important socioeconomically for meat, fur, or wildlife viewing (also see the Ecosystem services key findings on page 115), and so some provinces have long-term data from hunters and trapper harvests (Figure 86) that may be used to infer population trends. However, these data cannot necessarily be a reliable estimate of populations because hunter and trapper effort is biased and dependent on socio-economic factors.[447] The economic value of pelts is well correlated with trapping effort.[448] Also, trappers/hunters do not "sample" animals randomly; weather and ease of trapping/hunting also influence trapper effort. Furthermore, given that hunting, trapping, and fishing are activities that result in the direct mortality of the focal species, using these data to estimate population trends is problematic. Finally, yields of trapped furs declined by over 50% in the 1980s, especially muskrat furs (Figure 86), as a result of changes to trapping methods. The Agreement on International Humane Trapping Standards (AIHTS) was ratified by Canada in 1999 and implementation of standards was completed in 2007.[396] Therefore, population estimates should not be deduced from trap/harvest data and these data are presented for interest only. Possible noteworthy trends include the return of wolverines to their historic range and a national decline in wild mink populations.

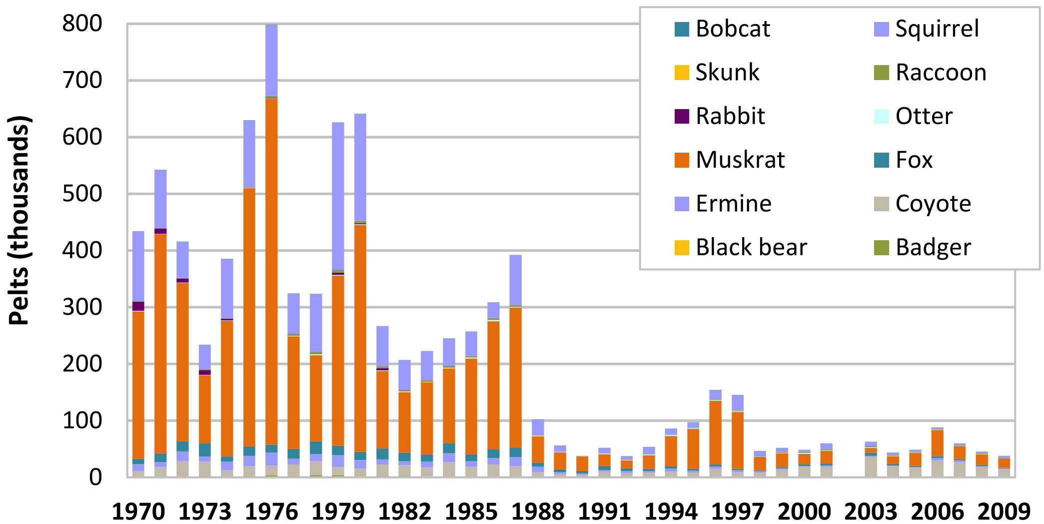


Figure 86. Total number of pelts from Quebec, Ontario, Manitoba, and Saskatchewan by type of wildlife from 1970 to 2009.
These province-wide data exceed the Boreal Shield Ecozone+ boundaries.
Source: Statistics Canada, 2009[395]

Wolverines have large home ranges and low lifetime reproductive rates, similar to larger carnivores.[449, 450] Based on the number of harvested wolverine pelts, significant ($p<0.05$) population declines occurred in Saskatchewan, Manitoba, and Quebec (Figure 87). The last wolverine pelt was harvested in Quebec in 1979 (Figure 87).

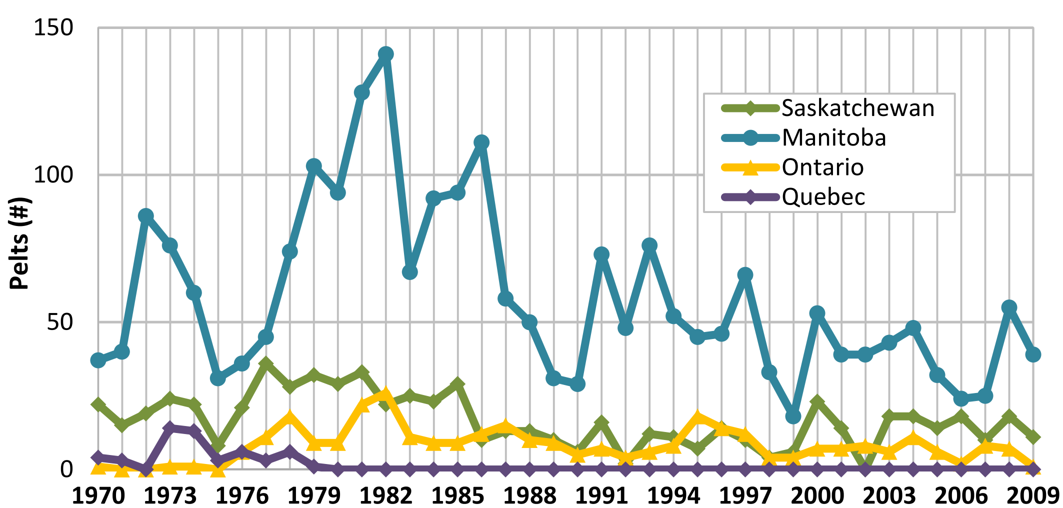


Figure 87. Number of wolverines harvested by trappers per year in Saskatchewan, Manitoba, Ontario, and Quebec from 1970 to 2009.
These province-wide data exceed the Boreal Shield Ecozone+ boundaries.
Source: Statistics Canada, 2009[395]

Although there were no detectable trends for wolverine in Ontario, their distribution retracted by more than 5% since the mid-1800s. The species was extirpated from the Great Lakes region of Ontario and Minnesota by 1900.[451] Human activities including land clearing, development, timber harvesting, and mining were primarily responsible for these range retractions.[452] Based on observations in 2008, wolverines re-colonized some of their former range in the Hudson Bay area and the central portion of Ontario's far north (Figure 88).

Figure 88. Historic and "current" (2003) range of wolverine in North America.
Source: Adapted from COSEWIC, 2003[452]

The decline of trapped wild mink (Figure 89) could reflect a true population decline. Matings between wild and feral mink escaped from fur farms has resulted in less fit offspring (out-breeding depression) and perhaps an increased incidence of disease.[453] Mercury poisoning may also contribute to declining mink populations (see the Contaminants key finding on page 90).[454]

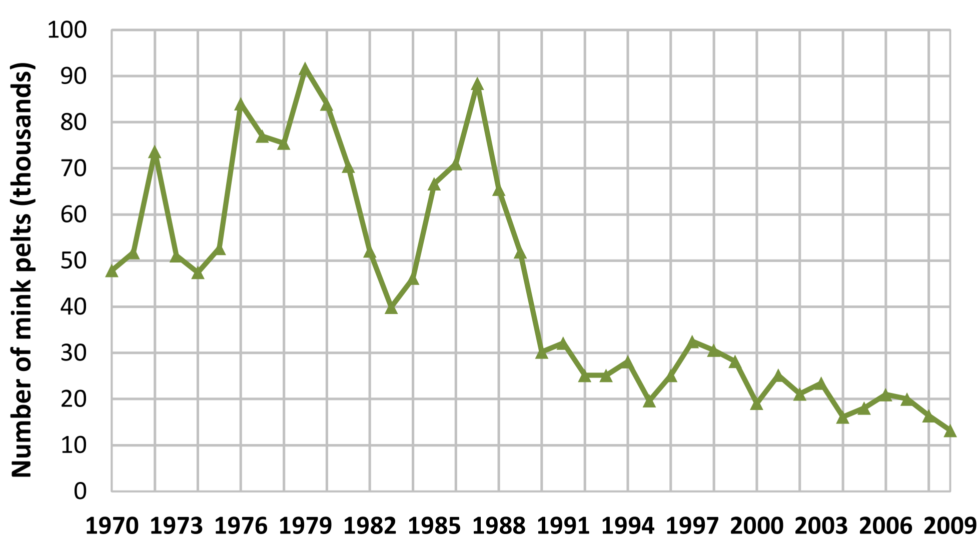


Figure 89. Numbers of wild mink trapped in Quebec, Ontario, Manitoba, and Saskatchewan, 1970-2009. These province-wide data exceed the Boreal Shield Ecozone+ boundaries.
Source: Statistics Canada, 2009[395]

Newfoundland Boreal Ecozone+

Woodland caribou (Newfoundland population)

The insular Newfoundland caribou population is one of the six geographically distinct populations of the forest-dwelling woodland caribou.[414] Caribou populations in the Newfoundland Boreal Ecozone+ have been declining since the mid to late 1990s (Figure 90), but are not designated as "at-risk" by COSEWIC.[414] Population numbers are higher than in the 1950s.[455] Between the early 1900s and the 1930s, caribou declined from an estimated 40,000 animals to just a few thousand animals, where the population size remained until the mid-1970s. A phase of rapid population growth began in the mid-1960s and continued until the late 1990s when the population peaked at 80,000 to 100,000.[456] From an estimated peak of over 95,000 caribou in 1997, the population declined to about 32,000 in 2008, representing a decrease of approximately 66%.

Studies on caribou mortality by the Newfoundland and Labrador Wildlife Division[455] show high percentages of calves being lost to coyotes, black bears (*Ursus americanus*), and to a lesser extent, lynx (*Lynx canadensis*). Adult caribou are also susceptible to coyote predation in winter.

Another stressor on caribou is cerebrospinal elaphostrongylosis (CSE), a disease caused by the introduced parasitic nematode *Elaphostrongylus rangiferi.*[457] The parasite spread to native caribou after introduction from infected reindeer in 1908, with at least two outbreaks since then.[457] *Elaphostrongylus rangiferi* has been implicated in the decrease in the Avalon caribou sub-population on the east coast of Newfoundland, a decline from 7,000 to 2,500 animals between 1998 and 2000.[458]

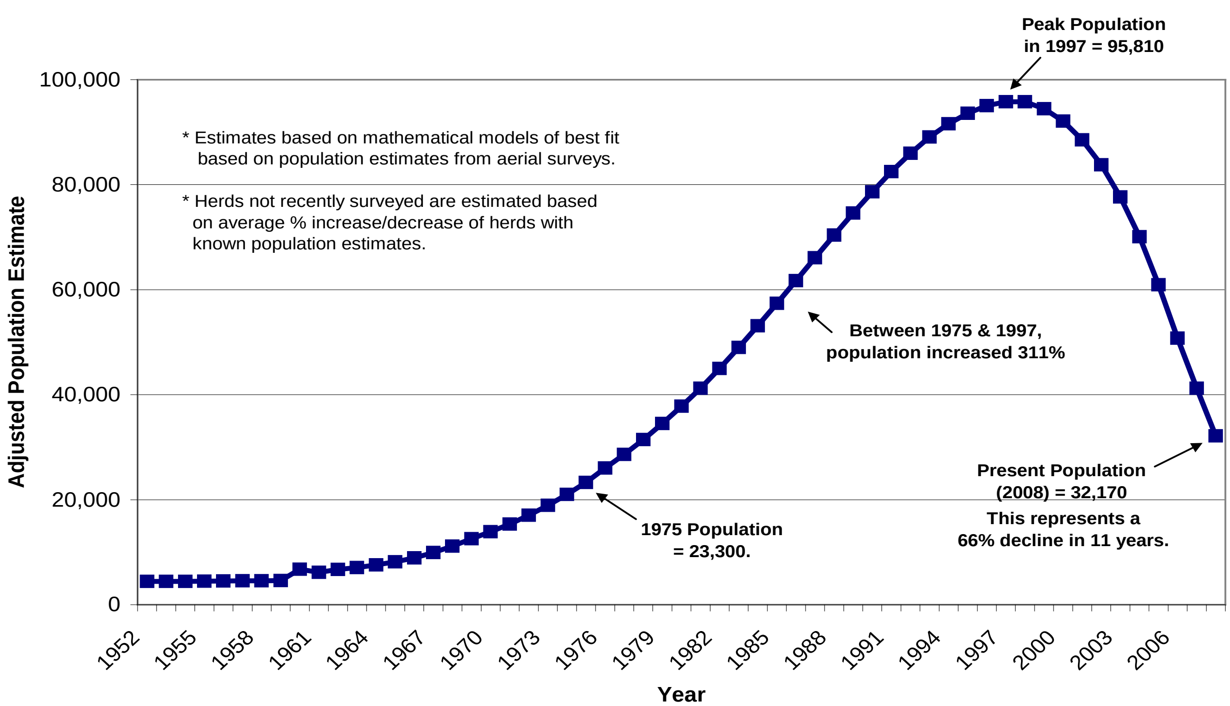


Figure 90. Population estimates for insular Newfoundland caribou, 1952–2008.
Source: Newfoundland and Labrador Wildlife Division, 2009[455]

Newfoundland marten

The Newfoundland marten (*Martes americana atrata*), restricted to the island of Newfoundland, is a genetically and geographically distinct population of the American marten (*Martes americana*), and 1 of only 14 native mammals found on the island.[459] The Newfoundland marten is part of the natural biological diversity of the boreal forest and functions as both a predator and prey species. Harvested by European settlers, marten were scarce by the early 1900s and their commercial harvest ended in 1934. Despite this harvest restriction, numbers continued to decline and, by 1960, the distribution of marten across west-central Newfoundland was no longer contiguous.[460]

Loss of habitat and accidental snaring and trapping are the primary threats to marten in Newfoundland. Newfoundland marten are a forest-dependent species. Thus loss of forest cover from resource extraction activities (timber harvesting, mining), human development (road construction, agriculture, townsite expansion) or natural disturbance events (e.g., forest fire) have a direct influence on the capacity of an area to support marten.[461]

Accidental snaring and trapping is currently viewed as a significant threat impeding recovery. Hearn[462] monitored 95 marten in an area open to snaring and trapping in south-central Newfoundland and reported that accidental captures accounted for 92% of juvenile mortality and a minimum of 58% of adult mortality. Incidental captures returned to the Newfoundland and Labrador Wildlife Division indicate that this problem is pervasive and occurs across the entire range of marten on the island. Other threats to individual survival include natural predation and disease.

Originally designated as Threatened by COSEWIC in 1985, Newfoundland marten were re-evaluated in 1995 and 2000 and subsequently listed as Endangered.[463] The distribution of breeding animals was limited to Little Grand Lake/Red Indian Lake, the Main River watershed, and Terra Nova National Park. In 2007, the effective (breeding) population was estimated to be between 286 and 556 individuals. There was also qualitative information to suggest that the population was expanding; consequently, marten were down-listed to Threatened in 2007.[463]

Freshwater and diadromous fish

Two fish species that are found in the Newfoundland Boreal Ecozone+ have been assessed for listing under the federal *Species at Risk Act* (SARA). Banded killifish (*Fundulus diaphanus*) was designated as a Species of Special Concern in 2003 and was subsequently listed under SARA.[464] Atlantic sturgeon (*Acipenser oxyrinchus*) was designated as Threatened by COSEWIC in 2011[445] but has not yet been listed under SARA.

Plants

There are about 20,000 km^2 of heath in the Newfoundland Boreal Ecozone+, comprising the largest tract of this type of vegetation in North America.[465] Data on the condition and extent of these communities are limited. The six heath types include: alpine, empetrum, moss, kalmia, limestone, and serpentine (Table 22).

Table 22. Descriptions of heath types in the Newfoundland Boreal Ecozone+

Heath Type	Description	Location
Alpine	Discontinuous vegetation consisting of bare soil alternating with cushions of *Empetrum eamesii*. The vegetation is characterized by the occurrence of arctic-alpine species.	Highest mountain ridges or extremely exposed headlands of the south coast.
Empetrum	Dominated by vegetation carpets of rockberry and crowberry (*Empetrum* spp.). Woody species are compressed into vegetation cushions. Grasses and herbs, when present, project 10–20 cm above ground.[465]	Coastal headlands and inland ridges.
Moss	Similar to Empetrum heath except that *Racomitrium lanuginsum* is the dominant vegetation.	Extreme southeast coast of the ecozone+ as well as locally on the Isthmus of Avalon.[92]
Kalmia	These heaths are dominated by dwarf ericaceous dwarf shrubs, primarily sheep laurel (*Kalmia angustifolia*), which form dense closed thickets approximately 30–50 cm high. Mosses and lichens dominate the ground surface.[92] Small areas of Kalmia heath occur naturally in tree-line ecotones.[465] Most large areas of Kalmia heath originated following repeated low intensity fires and local cutting around coastal communities has contributed to expansion of smaller Kalmia heaths.	Sheltered inland areas throughout the ecozone+.
Limestone	The limestone barrens are composed of a series of terraces which extend, from just behind the beach berm, inland 300–400 m to a maximum elevation of 40 m.[92] Soils are basic or ultrabasic.[92] These unique heaths consist of numerous calcicolous species which form a sparse vegetation cover over calcareous boulder pavement.[465] Of the 271 vascular plant species considered rare on the island, 114 occur on the limestone barrens. Twenty-nine of these grow only on the barrens.[466] Long's braya (*Braya longii*) and Fernald's braya (*Braya fernaldii*) are listed as Endangered and Threatened, respectively, under *SARA*.[467, 468]	Restricted to a narrow coastal strip along the west side of the northern peninsula, with the most extensive heaths occurring along the Strait of Belle Isle.[92]
Serpentine	Vegetation cover on the boulder talus is sparse and is composed of a few specialized species adapted only to serpentine substrates as well as species which favour basic substrates.[92] The effects of frost action can be seen in the large sorted boulder polygons, common throughout the level terraces, and in the solifluction terraces on the slopes.[92]	Serpentine mountains in the western part of the island.

Braya

Long's braya (*Braya longii*) and Fernald's braya (*Braya fernaldii*) were listed as Endangered and Threatened, respectively, under *SARA* and the *Newfoundland and Labrador Endangered Species Act* in 2002. Both species are small (1–10 cm and 1–7 cm, respectively), herbaceous perennials in the family *Brassicaceae* endemic to exposed limestone barrens along the northwest coast of Great Northern Peninsula on the Island of Newfoundland.[469]

Long's braya is distributed into six populations in a range of 25 km and Fernald's braya is distributed into 16 populations in a range of 150 km.[469, 470] The 1998–2000 censuses of these species revealed that 75% of the global Long's braya population (7235 individuals) and 57% of the global Fernald's braya population (3,434 individuals) were growing on anthropogenically disturbed substrate. A 2008 census confirmed that both braya species declined as a result of anthropogenic disturbance and pest and pathogen pressure. There were 5,549 Long's braya and 3,282 Fernald's braya, 90% of which were found on anthropogenically disturbed substrate.[470] Biotic threats, such as insect herbivory and pathogens, also threaten plant reproductive output and survival.[471]

Erioderma

Boreal felt lichen (*Erioderma pedicellatum*) occurs in Newfoundland and Nova Scotia, and has recently been discovered in Alaska. In 2002, the boreal (Newfoundland) population was listed as Special Concern under the federal *SARA* and as Vulnerable under the *Newfoundland and Labrador Endangered Species Act*. All other known populations from Sweden, Norway, and New Brunswick are believed to be extirpated.[472]

In the Newfoundland Boreal Ecozone+, two major population concentrations of the boreal felt lichen have been documented from the central Avalon Peninsula and the Bay D'Espoir area. Smaller populations have also been found on the western Avalon Peninsula, the Avalon Isthmus, the area north of the Burin Peninsula, several areas along the south coast as far west as Burgeo, and on the western side of the Great Northern Peninsula.[473] Due to the scattered distribution of this lichen and the large areas of unsurveyed potential, it is very difficult to determine how many relatively isolated populations there are in Newfoundland. In 2002, approximately 6900 thalli were reported in the COSEWIC status report for this species.[472] With the recent discovery of two locations with approximately 1,000 thalli each, and several other finds of hundreds of thalli, it is believed that the number of thalli in Newfoundland exceeds 10,000 with most of these located in the Bay D'Espoir area.

Data on population trends are not yet conclusive. During population revisits at several sites on the Avalon Peninsula population declines of 60–80% over a five-year period have been documented.[474] In the Bay D'Espoir area, both population increases and declines have been observed.[475] Two Boreal felt lichen populations on the Avalon Peninsula have been intensively monitored for three years and the study was duplicated a year later in the Bay D'Espoir area. However, overall mortality rates have not yet been calculated.

A five-year management plan for boreal felt lichen was released by the Government of Newfoundland and Labrador in 2006. The management goal is to maintain and enhance, where necessary, self-sustaining populations of the species within its current geographic distribution in Newfoundland. Several anthropogenic factors threaten or potentially threaten this lichen, singly or through complex interactions with each other and with natural forest processes that would not by themselves be considered threats. Threats and stress factors include stand senescence, blowdown, insect outbreaks, slug/mite herbivory, wood harvesting, land development, moose browsing of balsam fir, air pollution, forest fire, pesticides and climate change.[473] The relative impact of these is difficult to assess, but it appears that more of these threatening factors are present in the Avalon Peninsula.

The amount of available habitat is expected to decline over time due to balsam fir forests being replaced by planted spruce and larch stands after cutting or by being converted to essentially treeless "moose meadows", where moose have killed all balsam fir seedlings in areas affected by blowdown. The impact of browsing by moose on balsam fir regeneration in Newfoundland has been amply documented,[476, 477] however, a detailed analysis of the magnitude of the problem relating to boreal felt lichen habitat has not been conducted.

On the Avalon Peninsula, pre-harvest surveys are performed on forest stands slated for commercial harvesting and following the recommendations by Robertson,[478] 20 m buffers have been employed around thalli found in these surveys. Due to a resource shortage, this is not done for domestic cutting blocks on the Avalon Peninsula, nor on commercial or domestic cutting blocks on crown land in the Bay D'Espoir area. The Miawpukek First Nation in Conne River is performing surveys and employing mitigations in their forest management area.

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.

Boreal Shield Ecozone⁺

Net primary productivity, as inferred from the Normalised-Difference Vegetation Index (NDVI), significantly increased for 21% of the Ecozone⁺ area in 2006 compared to 1985 levels. Decreases were only significant for 0.9% of the area, mainly observed on the western ecozone⁺[23] (Figure 91).

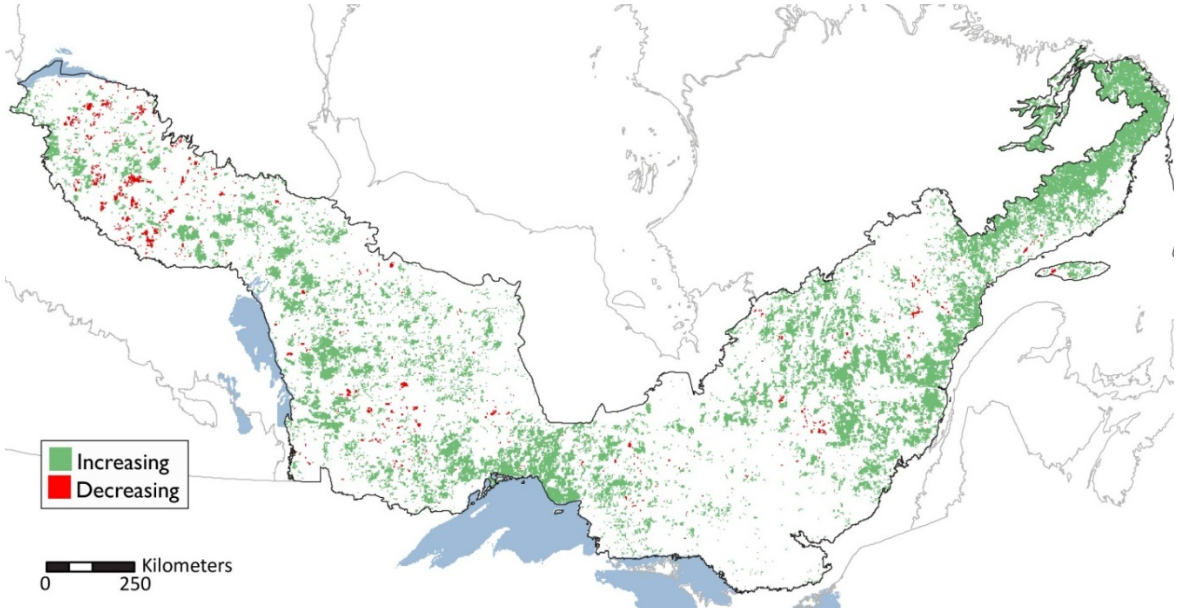


Figure 91. Map of change in the Normalized Difference Vegetation Index (NDVI) for the Boreal Shield Ecozone+, 1985–2006.
Trends are in annual peak NDVI, measured as the average of the three highest values from 10-day composite images taken during July and August of each year. Spatial resolution is 1 km, averaged to 3 km for analysis. Only points with statistically significant changes (p<0.05) are shown.
Source: adapted from Pouliot et al., 2009[390] by Ahern et al., 2011[23]

Increases to the east and south likely reflect forest composition changes following harvesting. Since broadleaf tree species register higher NDVI values than conifers, changes in forests from conifer-dominated stands to a higher proportion of mixed and deciduous stands would increase primary productivity.[23] Trends in the northwestern part of the ecozone+, where fire cycles are more frequent, may be attributed to post-fire responses rather than directly to increases in ecosystem productivity.[390] Trends in natural disturbance may also cause primary productivity to vary, although variations may simply reflect natural cycles. It is unclear how much of the overall increase in primary productivity can be attributed to climate change.

Newfoundland Boreal Ecozone+

At nearly 41%, the Newfoundland Boreal Ecozone+ shows a greater portion of its area with a positive trend in NDVI from 1985 to 2006 than any other ecozone+ in Canada.[23]

Much of north-central Newfoundland shows an increase in NDVI over this period (Figure 92). This is an area of extensive shrub and poor forest cover. A warming climate may be enabling this vegetation to increase in density and vigour.[23]

This increase in NDVI could otherwise be the result of forest harvesting. When mature conifer-dominated boreal forests are harvested, early stages of succession have higher NDVI than the previous mature forests. Additionally, over-browsing by hyperabundant moose stalls forest regeneration in early successional stages,[97, 104, 290] which may be responsible for the observed NDVI trends.

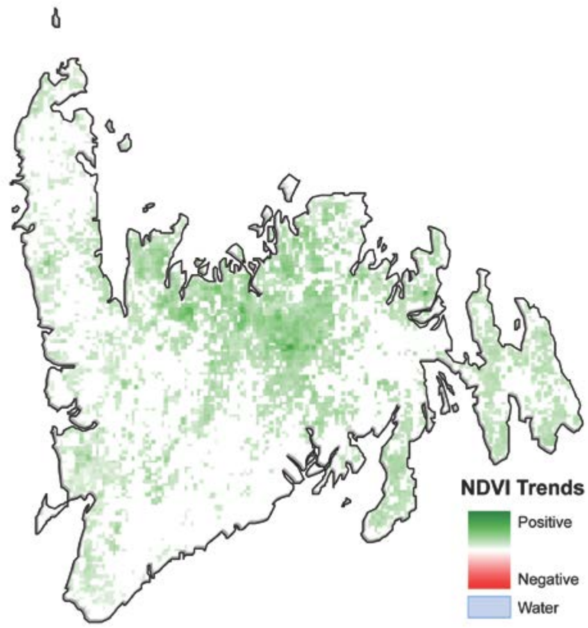


Figure 92. Map of change in the Normalized Difference Vegetation Index (NDVI) for the Newfoundland Boreal Ecozone+, 1985–2006.
Trends are in annual peak NDVI, measured as the average of the three highest values from 10-day composite images taken during July and August of each year. Spatial resolution is 1 km, averaged to 3 km for analysis. Only points with statistically significant changes ($p<0.05$) are shown.
Source: adapted from Pouliot et al., 2009[390] by Ahern et al., 2011[23]

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.

Boreal Shield Ecozone+

Natural disturbances in the Boreal Shield Ecozone+ appear to be changing. Early warnings include increasing wildfire risk in some regions, northward range expansion of hemlock looper (*Lambdina fiscellaria*), and the threat of mountain pine beetle invasion from the northwest. The beetle has already expanded its range from the within the Montane Cordillera Ecozone+ through to the Boreal Plains Ecozone+.[479-481] Fire and insects can interact to increase an ecosystem's vulnerability and decrease resilience. For example, higher wildfire risk, earlier fire occurrence, and severe insect defoliation events in the northeastern Boreal Shield Ecozone+ have caused closed-crown boreal forest stands to be replaced by lichen woodlands.[69, 70] In the western part of the ecozone+, increased wildfire risk and mountain pine beetle invasion could lead to decreased ecosystem productivity and significant releases of stored carbon, as observed for the Montane Cordillera Ecozone+.[482] Caribou may also decline as a result of the reduced connectivity in their mature and dense boreal forest habitats (see the Woodland caribou section on page 129).

Fire

Fire is the dominant natural disturbance in boreal forests of the ecozone+, especially north of managed areas. The area burned by large fires (>200 ha) over the entire ecozone+ increased until the 1980s then decreased into the 2000s.[483] The most important factors explaining these apparent trends are better monitoring and increased temperatures in the 1980s, as well as increased fire suppression effectiveness in the past 20 years. Hence, the effect of natural changes is masked by anthropogenic influences. There were no significant changes in fire seasonality from 1959 to 2007 (Figure 93).

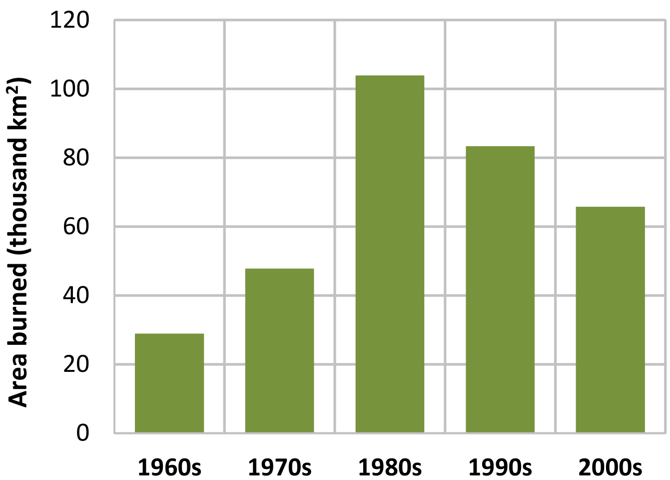


Figure 93. Total area burned by large fires (> 2km^2 in size) per decade in the Boreal Shield Ecozone+, 1960s–2000s.
Note: The 2000s decade value was pro-rate over 10 years, based on the 2000–2007 average.
Source: Krezek-Hanes et al., 2011[483] using data from 1959–1994 from the large fire database (Stocks et al., 2003)[37] and data from 1995–2007 from remote sensing.

Wildfire risk, as estimated from the Monthly Drought Code, was evaluated from 1901 to 2002.[479] These trends are likely to represent changes in environmental conditions rather than influences of fire suppression or advances in monitoring methods. The trends presented below (Figure 94) illustrate regional variability, which would not be apparent in ecozone+-wide data analyses. Over the 20th century, wildfire risk has increased in north-central Quebec and in the westernmost part of the ecozone+ due to drier conditions. Conversely, decreases in wildfire risk associated with wetter conditions have occurred from eastern Manitoba to western Quebec. Changes in temperature and precipitation from 1950 to 2007 support these trends (see the Climate change key finding on page 106).[154]

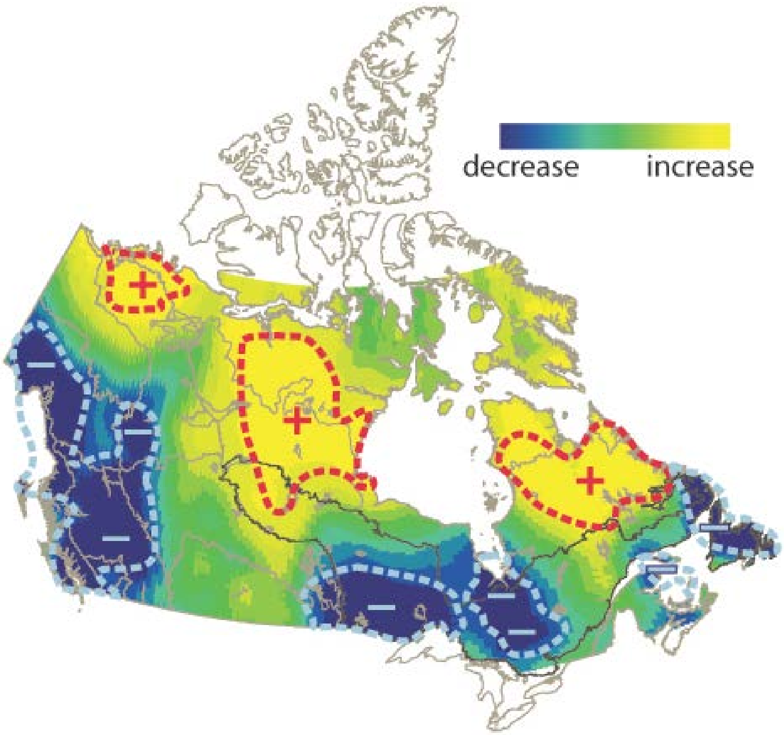


Figure 94. Spatio-temporal evolution of wildfire risk from 1901 to 2002 as modeled from the Monthly Drought Code of the Canadian Forest Fire Weather Index System.
Note: A "+" sign indicates increasing wildfire risk during that period; a "-" sign indicates decreasing wildfire risk; ecozone⁺ boundaries are in black.
Source: adapted from Girardin and Wotton, 2009[479]

Large scale native insect outbreaks

Large-scale native insect outbreaks have become more important than fire as drivers of ecosystem change in the southern portion of the Boreal Shield Ecozone⁺.

Spruce budworm

Spruce budworm (*Choristoneura fumiferana*) is the major defoliator of balsam fir and spruce trees in the boreal forest. The area covered by moderate to severe defoliation caused by spruce budworm outbreaks over the 20th century greatly increased for each of the three main events recorded (Figure 95). However, there is uncertainty regarding the severity of future spruce budworm outbreaks, mainly because stands of mature balsam fir, its favoured food, have been depleted during recent outbreaks. It is uncertain whether there were changes in outbreak duration and frequency for spruce budworm before the early 2000s, although both outbreak duration and frequency are expected to increase throughout the 21st century.[484]

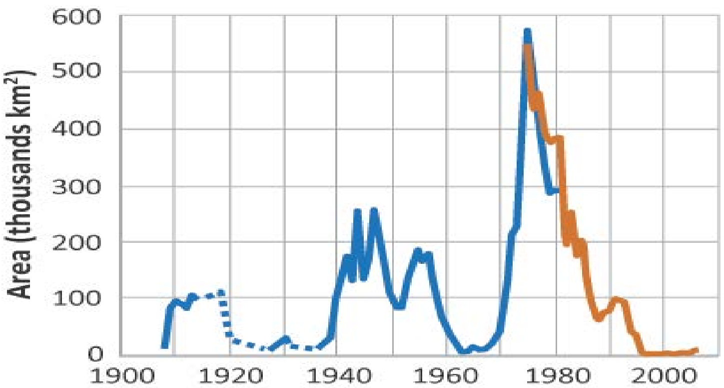


Figure 95. Total annual area of moderate-to-severe defoliation by spruce budworm in Ontario, Quebec, Newfoundland and Labrador, New Brunswick, Nova Scotia, Prince Edward Island, and Maine, USA, 1909–2007.
The blue dotted and plain line from 1909 to 1981 was reported by Kettela in 1983.[485] The brown dotted line was adapted from data provided by the National Forestry Database Program (2008) and by the Maine Forest Service (2008).[486, 487]
Note: Amalgamated data should be interpreted with caution due to different aerial survey methods for each jurisdiction and reporting methods that have been modified in time, explaining the differences between lines from 1975 to 1981.
Source: adapted from Kettela, 1983,[485] the National Forestry Database Program, 2008,[486] and Strubble, 2008[487]

Hemlock looper

Hemlock looper is another defoliator of balsam fir that primarily affects the eastern half of the ecozone+. Historically, the Newfoundland Boreal Ecozone+ has been more at risk from hemlock looper outbreaks that the Labrador portion of the Boreal Shield Ecozone+.[488] However, the range of outbreaks seems to be expanding north of its historical distribution and, for the first time in 2008, a biological insecticide treatment was applied over 15 to 17 km^2 in Labrador.[480]

Other insect defoliators

Other native insects that can cause large-scale forest damage in the Boreal Shield Ecozone+ are the jack pine budworm (*Choristoneura pinus*), the forest tent caterpillar (*Malacosoma disstri*), and large aspen tortrix (*Choristoneura conflictana*). No significant trends in outbreak duration, frequency, or extent have been reported for these species.[486] The absence of detectable trends may be due to the cyclical nature of these outbreaks and the lack of accurate long-term data.

Newfoundland Boreal Ecozone+

Fire

Fire is not a significant natural disturbance in the Newfoundland Boreal Ecozone+; the contribution to area burned in Canada was less than 1% from 1959 to 2007.[483] From 1959 to 2007, the average area burned by large fires (>2 km^2 in size) was 123 km^2/yr and the percent annual area burned was 0.13%.[483] In the 1960s, the ecozone+ contributed 4.7% of the area burned in Canada due to an extreme fire year in 1961 when 3,962 km^2 burned. The total annual area burned decreased dramatically since the 1960s (Figure 96). The decline was most likely due to successful government policies aimed at preventing and suppressing fires.[37] The doubling in area burned from the 1970s to the 1980s may be related to warmer temperatures[489, 490] that resulted in more fires escaping from suppression efforts. Area burned declined again significantly in the 1990s and has remained small into the 2000s. Similar to the Atlantic Maritime and Pacific Maritime ecozones+, these trends should be assessed with caution because they are based on a small number of fires, especially in more recent decades. Otherwise there was little variability in annual area burned and more commonly there were many years where there were no large fires in this ecozone+.

The active fire season is 35 days. Fire occurrence peaks in May but fires commonly occur between May and July. The dominant cause of fire is humans at 96%. Lightning ignitions have only been documented four times in the large fire database for the Newfoundland Boreal Ecozone+.

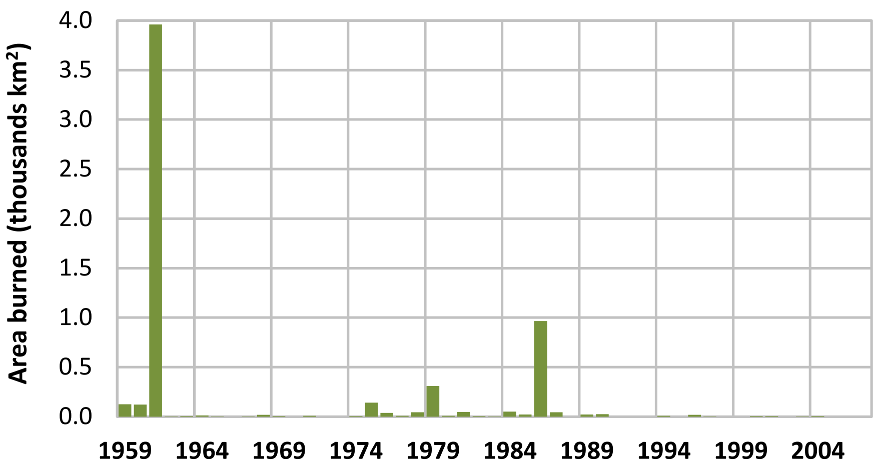


Figure 96. Total annual area burned by large fires (>2 km^2 in size) for the Newfoundland Boreal Ecozone+, 1959–2007.
Source: Krezek-Hanes et al., 2011[483] using data from 1959–1994 from the large fire database (Stocks et al., 2003)[37] and data from 1995–2007 from remote sensing.

Large scale native insect outbreaks

The three main native defoliating insects in the Newfoundland Boreal Ecozone+ are the eastern hemlock looper, eastern spruce budworm (*Choristoneura fumiferana*), and balsam fir sawfly (*Neodiprion abietis*). Dendrochronological analyses have documented light to moderate infestations of spruce budworm and hemlock looper during the 19th and 20th centuries.[491] Major outbreaks have been primarily restricted to the west and central regions of the ecozone+.

Balsam fir sawfly

Balsam fir sawfly has been the most detrimental defoliator. As seen in the western portion of the ecozone+ (Figure 97), the extent and severity of outbreaks increased with time (Figure 98). The first recorded large outbreaks lasted three to four years (1944–1947, 1954–1956, and

1960–1963) and were relatively localized. The next large outbreak lasted eight years (1967–1975), and covered a larger area than the first three large outbreaks. The most recent sawfly outbreak started in 1991 and is unprecedented in severity, extent and duration.[492]

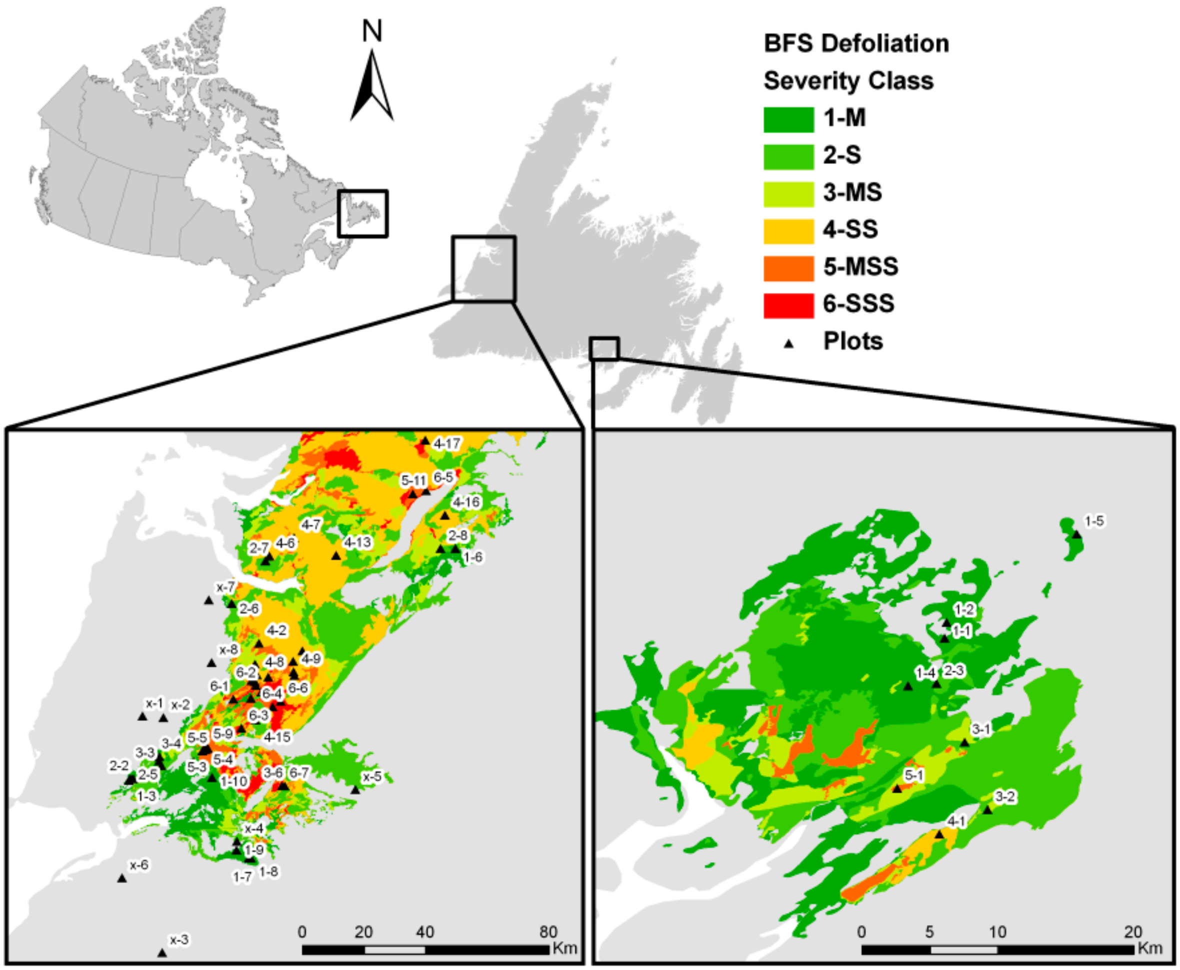


Figure 97. Map of plot locations and severity of balsam fir sawfly defoliation in Newfoundland from 1996 to 2008.
Six defoliation severity classes were based on levels of defoliation in up to 3 years, with 'M' denoting moderate (31–70%) and 'S' severe (71–100%) defoliation.
Source: Iqbal et al. 2011[493]

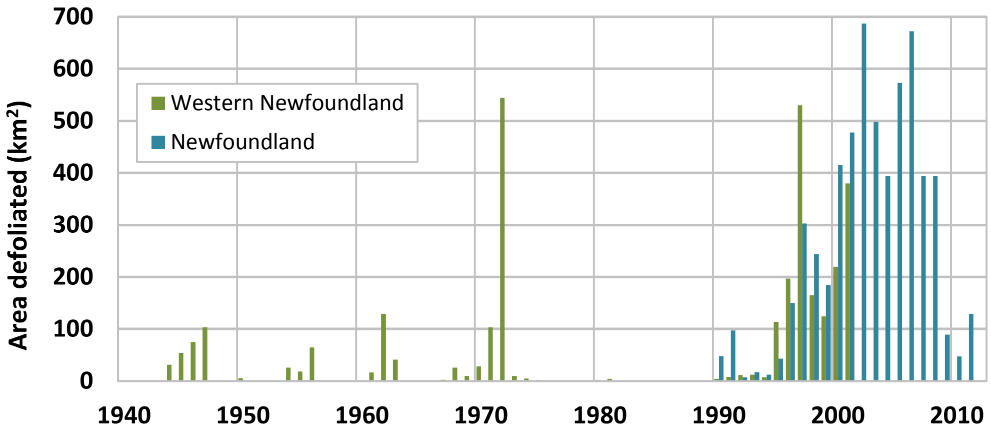


Figure 98. Annual estimates of the area severely defoliated by the balsam fir sawfly in western Newfoundland between 1940 and 2011.
Defoliation was less than 0.1 km^2 in many years.
Source: Moreau, 2006[492] with updated data from the author

The impacts of balsam fir sawfly can be severe, even with only one year of severe defoliation.[493] Because balsam fir sawfly feeds on multiple age-classes of foliage in one year, there is less time for managers to react than for other insect defoliators. For example, eastern spruce budworm typically feeds on current-year foliage. It can take up to four years for tree mortality to occur as a result of eastern spruce budworm. In contrast, one to three years of severe balsam fir sawfly defoliation can cause large long-term losses to stand growth and yield from both tree mortality in mature plots and slow growth recovery.[493]

Spruce budworm

There have been numerous outbreaks of the spruce budworm in Newfoundland and these have all occurred as a result of an eastward movement of outbreaks that originated in eastern Canada.[494, 495] Three minor outbreaks were recorded for the period 1940 to 1970; these were sporadic, localized, collapsed within three years, and resulted in little or no damage to forest stands.[32, 494] A widespread and severe outbreak began in 1971 in the western region of the ecozone+. All mature and immature productive forests in the Newfoundland Boreal Ecozone+ were infested by 1977; budworm densities increased until 1985.[32, 496] Mean reduction of radial growth in damaged stands was approximately 80%;[32] mean total volume lost was 112 m^3/ha, which equates to 45% of potential volume based on growth prior to defoliation.[496] Budworm densities remained relatively high in the Newfoundland Boreal Ecozone+ until 1992.[497] The total volume of forest stands with tree mortality due to spruce budworm infestation for the period 1971 to 1992 was greater than 50 million m^3 (Figure 99).[32, 494, 497]

Damage caused by the spruce budworm can be severe and irrevocable. Host trees in the ecozone+ include balsam fir and white and black spruce.[498] Of these, balsam fir is the most vulnerable; individual trees die four to five years after initial attack.[32] Regeneration of dead balsam fir stands in the Newfoundland Boreal Ecozone+ is suppressed and succession to shrubs and competing hardwood species can occur. In pure stands, black spruce trees may survive, but some stands in the central region of the ecozone+ have been killed and replaced by kalmia heath vegetation.[32]

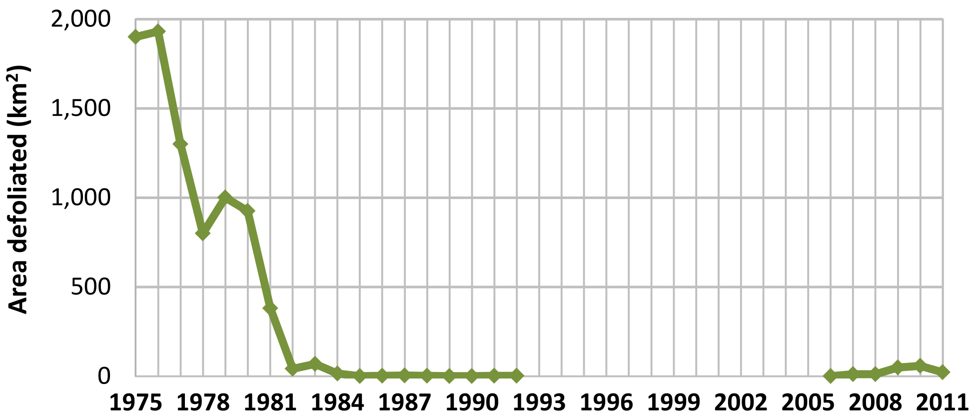


Figure 99. Area defoliated by eastern spruce budworm in Newfoundland and Labrador, 1975-2011. No data were available from 1993 to 2005. These province-wide data exceed the Newfoundland Boreal Ecozone+ boundaries.
Source: National Forestry Database, 2008[499]

Hemlock looper

Prior to the severe spruce budworm outbreak of 1972–1985, the eastern hemlock looper was the ecozone's major forest pest.[500] The recurrence of hemlock looper outbreaks in North America has been highest in the Newfoundland Boreal Ecozone+.[501, 502] Recorded outbreaks have been cyclic, lasted six to nine years, and reached their peaks in three to seven years; the period between outbreaks has ranged from 7–18 years.[301, 501, 503] Eight hemlock looper outbreaks have been recorded since 1910.[301, 501, 504] Prior to 1966, infestations were local but varied in duration. The most widespread outbreak occurred between 1966 and 1972; 15,000 km^2 and 8.6 million m^3 of wood was lost, which represents more than twice the sum of that for all preceding hemlock looper outbreaks.[301, 501] Forests in the ecozone+ have also been infested with hemlock looper in the periods 1983–1995 and 1999–2006; total volumes of productive forest lost during these periods were approximately 877 km^2 and 153 km^2, respectively.[301] The volume of trees lost to hemlock looper infestations from 1947 to 1991 was approximately 25 million m^3, which is equivalent to a seven-year supply for the three paper mills in the ecozone+.[505] Hemlock looper larvae feed on a range of conifers, but the primary host is balsam fir.[506] Larvae consume only a portion of an individual needle and then forage on adjacent needles; partially-eaten needles die.[32] Hemlock looper outbreaks generally occur where eastern spruce budworm densities have decreased.[501]

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.

Boreal Shield Ecozone+

Among the most commonly known boreal forest producer-consumer relationships are the cone production fluctuations influencing seed-consuming boreal birds,[507, 508] mink and muskrat,[509] the Canada lynx and snowshoe hare cycle,[510-512] and caribou/wolf dynamics. Due to the fluctuating nature of predator-prey interactions, trend analyses can be difficult.

The primary proximate limiting factor for boreal caribou populations is predation, driven by human-induced or natural landscape changes that favour early seral stages and higher densities of alternative prey.[414, 418, 420-424, 513-518] Habitat disturbance, including logging, likely increased early seral-stage forests that typically support high densities of alternate prey such as moose and white-tailed deer (*Odocoileus virginianus*). This in turn resulted in increased wolf and bear populations. When alternate prey populations decreased, the abundant predators turned to caribou as a food source.[428, 433]

In addition to predator-prey relationships, community dynamics are affected by diseases and parasites. Those having the most significant impacts on wildlife of this ecozone+ are the West Nile virus, which especially affects native wild birds, and the brain worm of white-tailed deer (*Parelaphostrongylus tenuis*).[519] Brain worm threatens woodland and barren ground caribou (*Rangifer tarandus groenlandicus*) populations as the white-tailed deer range expands northwards.

Newfoundland Boreal Ecozone+

There have been significant changes in the trophic dynamics of the Newfoundland Boreal Ecozone+. Wolves, the only native top predator, were extirpated in the 1920s. The introduction of moose, a dominant herbivore, has impacted the forest biome (see the Newfoundland Boreal Ecozone+ key finding on page 34). The first confirmed coyote in the ecozone+ was in 1987.[520] Coyotes compete for prey with lynx and red fox (*Vulpes vulpes*), and they may become a significant predator of caribou, arctic hare (*Lepus arcticus*) and American marten.

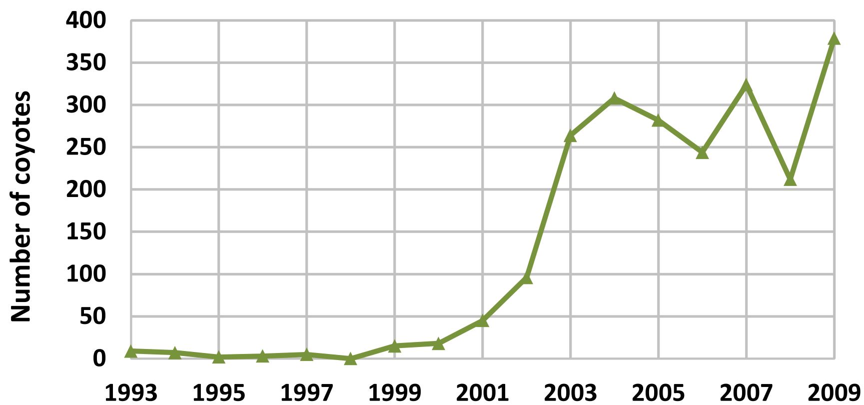


Figure 100. The number of coyotes harvested in the Newfoundland Boreal Ecozone⁺, 1993-2009. Source: Statistics Canada, 2010[395]

Changes in phenology have resulted in new predator-prey interactions. Historically, the residency of seals in rivers and estuaries did not coincide with salmon runs; however, seals have increased residence times by up to three months since the 1990s.[521] Research is underway to determine if the increased time seals spend in estuaries has increased the rate of predation on salmon.[521]

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 lack of monitoring, research, information management, and reporting on biodiversity is not unique to these ecozones⁺. Few data were available at the scale of the ecozone⁺ for the Boreal Shield Ecozone⁺. Monitoring programs varied widely among provinces, making it difficult to combine and interpret provincial data for an ecozone⁺-level trend.

When data were available, they were seldom available for sufficiently long periods to define trends. Specifically:

- Long-term, ecosystem and ecozone⁺-scale data for mining were unavailable;
- Long-term, ecosystem and ecozone⁺-scale data for hydroelectric developments were inconsistent across the ecozone⁺;

- Wetland ecosystems were not monitored and there was a lack of consensus among jurisdictions regarding protections afforded to wetlands, wetland size, and wetland type;
- Population surveys of indicator species or species assemblages were unavailable at the ecozone+-scale. Often, the only available trends were derived from commercial or recreational harvest data, which carried biases from market demand and harvester effort; and,
- Data for fish, reptiles, and amphibians populations were lacking relative to birds and mammals.

Quantitative data was difficult to acquire for key findings for the Newfoundland Boreal Ecozone+. Challenges include the difficulty in accessing part of Labrador and cuts or changes to monitoring programs and protected areas.

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 last half of the 20th century, many forests of the Boreal Shield Ecozone+ reached a tipping point where closed-crown conifer forests and conifer-dominated stands converted to mixed and deciduous-dominated stands. This was a reaction to changes in forest management practices, fire regimes, and insect outbreaks (see the Forests key finding on page 22). Some portions of the boreal forest in central Quebec became lichen woodland ecosystems in the latter half of the 20th century. In this case, the less productive lichen woodlands (a more northern forest type) have become well established further south. There is no sign that this trend could soon be reversed.[69] In this area, wildfire risk increased from 1901 to 2002.[479] These changes correspond to expected results in ecosystem composition and structure due to a rapidly changing climate.[389] Further, the cumulative pressures from the range expansion of viruses, parasites, and invasive species are largely unknown. West Nile virus and *P. tenuis* (the brain worm of white-tailed deer that is fatal to caribou) could have the most significant impacts on wildlife in this ecozone+.[519, 522, 523]

In contrast, invasive species have impacted the Newfoundland Boreal Ecozone+ for over 100 years. The shift in tree species composition and lack of forest regeneration decades following disturbance suggests that moose and insect defoliators have permanently altered forested ecosystems in Newfoundland.

CONCLUSION: HUMAN WELL-BEING AND BIODIVERSITY

Human communities in the Boreal Shield and Newfoundland Boreal ecozones+ depend heavily on natural resources whose economic value are subject to global markets. Aboriginal communities in particular depend on healthy ecosystems and the goods and services they provide. Forestry was a major employer in these ecozones+, and fisheries were important both recreationally and as a source of food for many communities.

A changing climate and ecological pressures from the spread of invasive non-native species are challenges for boreal ecosystems and the people who depend on them. Non-native species have recently invaded the Boreal Shield Ecozone+ and their impacts are largely unknown. Invasive species, particularly mammals, have altered food webs and the structure and composition of forested ecosystems in the Newfoundland Boreal Ecozone+.

The Boreal Shield Ecozone+ will undoubtedly play an important role in Canada's future in a changing climate. Its vast forests and wetlands store huge amounts of carbon. Properly managed, these carbon stores can help to mitigate the effects of climate change. Conversely, losses in this sequestration capacity would be a great threat to Canada's ability to adapt and thrive. Ecological goods and services provided by the Boreal Shield Ecozone+ are important Canada-wide.

The Newfoundland Boreal Ecozone+ has many of the same environmental and resource management issues as the Boreal Shield. Here there are some added socioeconomic and environmental challenges due to declining fisheries and the rapid rise of offshore oil development.

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