



Mixedwood Plains Ecozone⁺

Evidence for key findings summary

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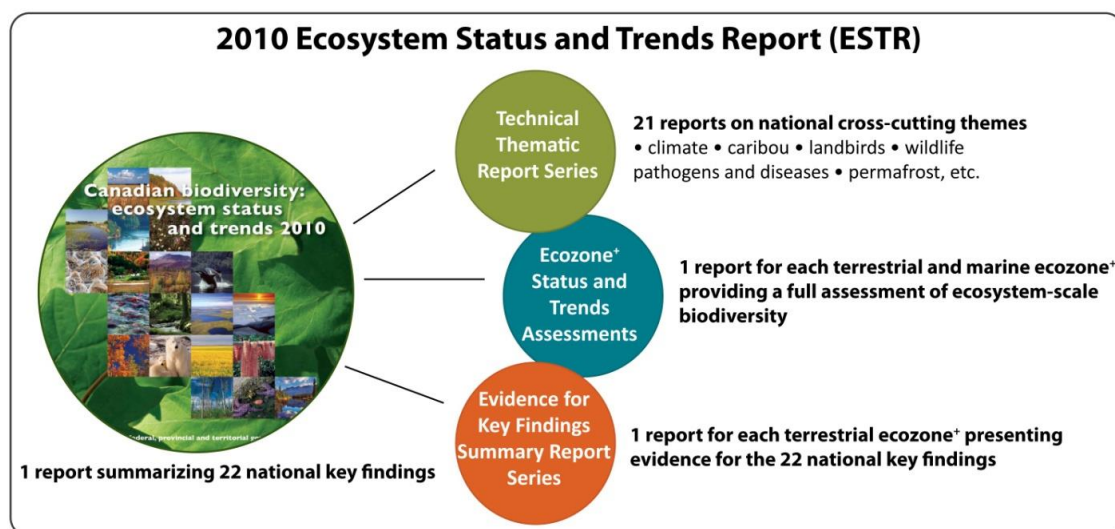
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PREFACE

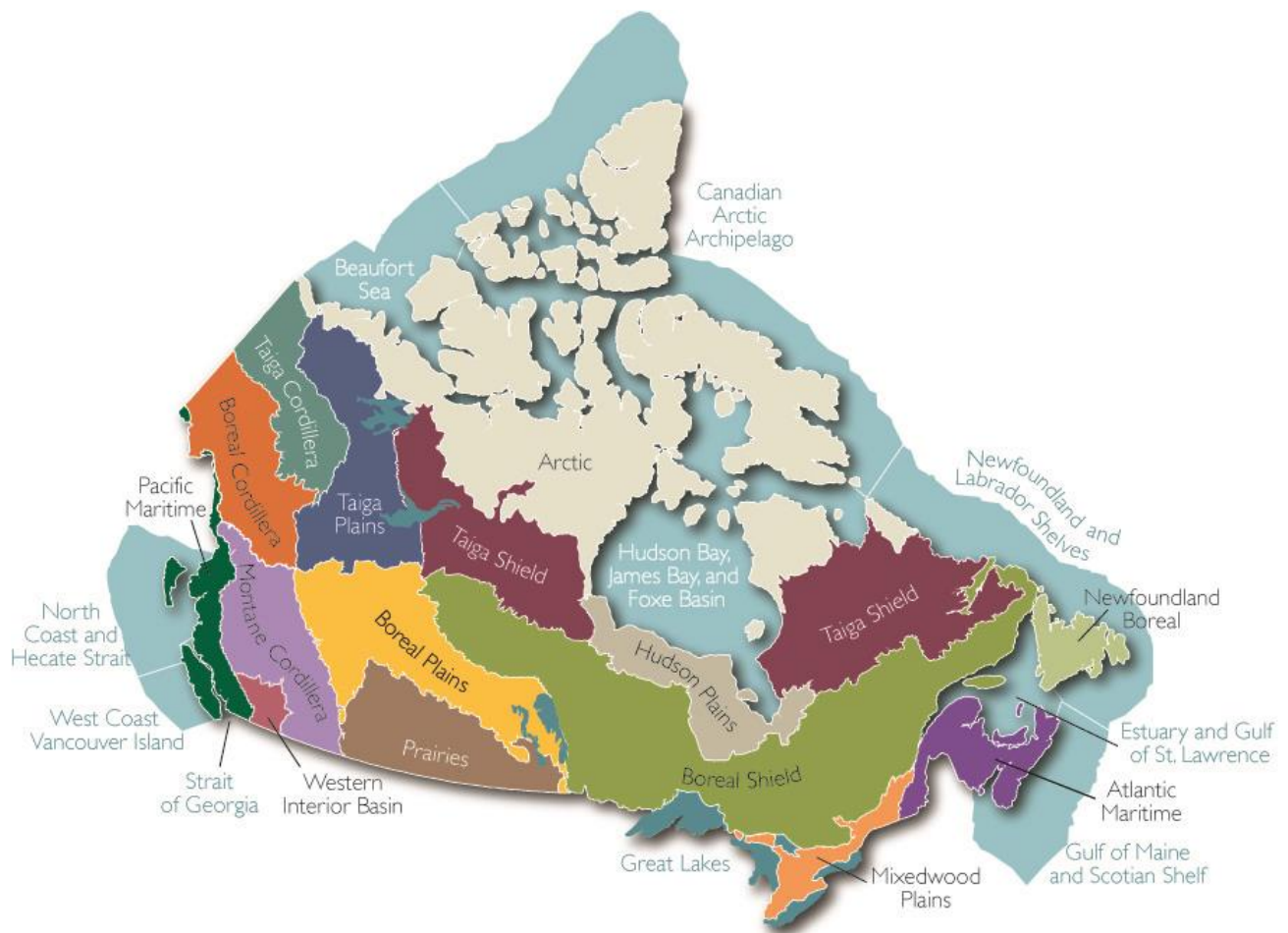
The Canadian Councils of Resource Ministers developed a Biodiversity Outcomes Framework¹ in 2006 to focus conservation and restoration actions under the *Canadian Biodiversity Strategy*.² *Canadian Biodiversity: Ecosystem Status and Trends 2010*³ was the first report under this framework. It presents 22 key findings that emerged from synthesis and analysis of background technical reports prepared on the status and trends for many cross-cutting national themes (the Technical Thematic Report Series) and for individual terrestrial and marine ecozones⁺ of Canada (the Ecozone⁺ Status and Trends 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, *Mixedwood Plains Ecozone⁺ Evidence for Key Findings Summary*, presents evidence from the Mixedwood Plains Ecozone⁺ related to the 22 national key findings and highlights important trends specific to this ecozone⁺. It is based on the *Mixedwood Plains Ecozone⁺ Status and Trends Assessment—with an emphasis on Ontario*,⁴ as well as further synthesis done to specifically address the national key findings. Additional information was provided by the Quebec Region of Environment Canada. The report 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. 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. Many experts from a broad range of disciplines, including university researchers, government scientists, and renewable resource and wildlife managers, contributed to the technical report as authors and reviewers (see Acknowledgements section). This key finding summary report was also reviewed by federal and territorial government scientists and managers and, in part or as a whole, by several university researchers.

Ecological classification system – ecozones⁺

A slightly modified version of the Terrestrial Ecozones of Canada, described in the *National Ecological Framework for Canada*,⁵ provided the ecosystem-based units for all reports related to this project. Modifications from the original framework include: adjustments to terrestrial boundaries to reflect improvements from ground-truthing exercises; the combination of three Arctic ecozones into one; the use of two ecoprovinces – Western Interior Basin and Newfoundland Boreal; the addition of nine marine ecosystem-based units; and, the addition of the Great Lakes as a unit. This modified classification system is referred to as “ecozones” throughout these reports to avoid confusion with the more familiar “ecozones” of the original framework.⁶ The boundary for the Mixedwood Plains is the same in both frameworks.



Acknowledgements

Content for this report for the Ontario portion of the ecozone⁺ is drawn heavily from *Mixedwood Plains Ecozone⁺ Status and Trends Assessment—with an emphasis on Ontario*.⁴ Specialists from the Ministère des Ressources naturelles et Faune du Québec as well as Environment Canada and Agricultural and Agri-Food Canada contributed to several key findings as both authors and reviewers extending the coverage beyond Ontario for those key findings. Reviews of versions of this summary report were provided by scientists and resource managers from relevant provincial and federal government agencies.

Mixedwood Plains Ecozone⁺ Evidence for Key Findings Summary acknowledgements

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Coastal: K. Taylor and W. Bakowsky
Ice across biomes: K. Taylor and J. Casselman
Protected areas: J. Thompson
Stewardship: A. Handyside
Ecosystem conversion: K. Taylor and B. Pond
Invasive non-native species: K. Taylor
Contaminants: S. Bhavsar
Nutrient loading and algal blooms: S. Bhavsar
Acid Deposition: K. Taylor
Climate change: K. Taylor
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Intact landscapes and waterscapes: K. Taylor
Agricultural landscapes as habitat: S. Javorek, M. Grant and K. Taylor
Species of special economic, cultural or ecological interest: K. Taylor
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Human well-being and biodiversity: K. Taylor

Authors of Thematic Technical Reports from which material is drawn

Canadian climate trends, 1950-2007: X. Zhang, R. Brown, L. Vincent, W. Skinner, Y. Feng, E. Mekis
Large-scale climate oscillations influencing Canada, 1900-2008: B. Bonsal and A. Shabbar
Monitoring biodiversity remotely: a selection of trends measured from satellite observations of Canada: F. Ahern, J. Frisk, R. Latifovic and D. Pouliot
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Key Finding Summary Reviewers:

H. Anderson, W. Bakowski, T. Bellhouse, Y. Boucher, J. Brimsmead, S. Brinker, J. Casselman, S. Columbo, A. Corlett, B. Dalton, A. Dextrase, C. Downes, J. Dungavell, K. Elliot, K. Ferguson, R. Gagnon, J. Gleeson, B. Graham, P. Grondin, A. Handyside, T. Haxton, C.-L. Hazard, T. Hayes, B. Jobin, J. Jutras, E. Kennedy, J. Lebreque, P. Lafleur, T. Leighton, D. LeMoire, P. Lilley, M. McMurtry, K. Milian, E. Miller, A. Norman, B. Naylor, G. Nielson, M. Oldham, D. Pare, R. Pineo, B. Pond, B. Potter, G. Pulham, D. Puric-Mladenovic, D. Rodrigue, B. Rose, P. Smith, L. Stanfield, S. Strobl, D. Sutherland, S. Thompson, M. Twiss, S. Voros, S. Watmough, W. Wistowsky, E. Wright

Mixedwood Plains Ecozone⁺ Status and Trends Assessment—with an emphasis on Ontario acknowledgements

Lead authors: D. Krahn and K. Taylor

Contributing authors: A. Todd – Ontario Ministry of Environment (OMOE), A. Crook – Ontario Ministry of Natural Resources (OMNR), A. Woodliffe (OMNR), A. MacIntosh (OMNR), A. Shabbar – Environment Canada, A. Handyside (OMNR), A. Dyk – Canadian Forest Service, A. Ecclestone (OMNR), A. Evers – University of Guelph, A. Tanentzap – Cambridge University, UK, A. Wallace – Toronto Region Conservation Authority, A. Norman (OMNR), B. Boysen (OMNR), B. Bonsal – Environment Canada, B. Brownson (OMNR), B. Dalton, (OMNR), B. Kowalyk (OMNR), B. Collins – Canadian Wildlife Service, B. Pond (OMNR), C. Nielsen – Environment Canada, C. Heydon (OMNR), C. Jones (OMOE), D. Tilon (OMNR), D. DuMoulin (OMNR), D. Puric-Mladenovic (OMNR), D. Bazely – York University, D. Burke (OMNR), D. Featherstone – Nottawasaga Valley Conservation Authority, D. Tammadge – Canadian Forest Service, D. Leckie – Canadian Forest Service, D. Krahn (OMNR), D. Campbell – Canadian Cooperative Wildlife Health Centre, E. Wright (OMNR), F.A. Leighton – Canadian Cooperative Wildlife Health Centre, F. McKay (OMNR), G. McLaren (OMNR), G. Nielsen (OMNR), G. Kaltenecker (OMOE), I. Ockenden – Nottawasaga Valley Conservation Authority, J. Hughes – Canadian Wildlife Service, J. McHattie (OMNR), J. Bowman (OMNR), J. Rzadki – Conservation Ontario, J. Lumsden – Canadian cooperative Wildlife Health Centre, J. Thompson (OMNR), J. Switzman (OMNR), K. Falk – Trent University, K. Milian (OMNR), K. Elliot (OMNR), K. Reese (OMNR), K. Taylor (OMNR), K. Ferguson – Nature Conservancy of Canada, L. Stanfield (OMNR), L. Duchesne (MRNF) M. Heaton (OMNR), M. Nicol – Saugeen Valley Conservation Authority, M. Furrer (OMNR), M. Garvin (OMNR), M. Bevan (OMNR), M. Gatt (OMNR), M. Irvine (OMNR), M. McMurtry (OMNR), N. Hooseinny (OMNR), O. Williams (OMNR), P. Gray (OMNR), P. Smith – Ontario Ministry of Agriculture, Food and Rural Affairs, P. Waring (OMNR), P. Kor (OMNR), Q. Chiotti – Pollution Probe, R. Gagnon – Ontario Invasive Plant Council, R. Dixon (OMNR), R. Zeran (OMNR), R. Wilson (OMNR), R. Spence (OMNR), R. Pineo – Ontario Federation of Anglers and Hunters, S. Bhavsar (OMOE), S. Jarvie – Toronto Region Conservation Authority, S. Poser (OMNR), S. Strobl (OMNR), S. Hounsell – Ontario Power Generation, S. Voros (OMNR), T. Dunkley (OMNR), T. Scarr (OMNR), T. McIntosh (OMNR), T. Schwan (OMNR), T. Hutchinson – Trent University, W. I. Dunlop (OMNR), W. Bakowsky (OMNR), W. Wistowsky (OMNR).

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Figure 1. Overview map of the Mixedwood Plains Ecozone[†].

ECOZONE⁺ BASICS

The Mixedwood Plains Ecozone⁺, shown in Figure 1 and summarized in Table 1, is the most southerly Canadian ecozone⁺ encompassing the provinces of Ontario and Quebec south of the Precambrian Shield.⁵ It contains only 1.2% of Canada’s land mass (one of the smallest ecozones⁺) but has 53% of the country’s population making it the most human-dominated ecozone⁺ in the country. The deep soils and moderate climate of the ecozone⁺ (by Canadian standards) have made it an attractive place for settlement. The population density, 140 people/km², is an order magnitude higher than that found in the next most populated ecozone⁺ (Pacific Maritime at 16 people/km²).¹⁰ The rapid population growth is projected to increase by 30% between 2006 and 2031.⁷ The Mixedwood Plains is the second most fragmented ecozone⁺ in Canada.⁸ The main stresses are habitat loss and fragmentation, the spread of invasive species, pollution, and climate change.

Table 1. Mixedwood Plains Ecozone⁺ overview.

Area	118,870 km ²
Topography and Geology	Extremely flat to gently rolling plains dominate most of the ecozone ⁺ . Broken up by several striking physical features, most notably the rugged terrain of the Niagara Escarpment which runs from Niagara Falls to the northern tip of the Bruce Peninsula and Manitoulin Island. Contains an extensive system of waterways draining into the St. Lawrence River and the Great Lakes. Formed by mix of Precambrian mountain building episodes and more recent glacial advances and retreats. Includes five distinct geologic units: <ul style="list-style-type: none"> • Frontenac Arch – ridge of Precambrian bedrock with shallow soils in the Kingston Area; southerly extension of the Canadian Shield. • Niagara Escarpment – long, linear feature composed of Silurian bedrock; includes bare bedrock uplands and steep bedrock cliffs. • East of Frontenac Arch and extending east to Québec City – deep soiled, flat marine clay plains deposited by the Champlain Sea. • Between the Escarpment and the Frontenac Arch – series of large ridges formed by the growth and melting of glaciers (Oak Ridges Moraine is the best-known of these features). • West of the Niagara Escarpment – deep soiled, broad, flat clay plains deposited by freshwater glacial lakes.
Climate	Warm summers (average temperature 17°C) and cool winters (average temperature –5°C) moderated by surrounding water bodies. Annual precipitation ranges from 720 mm to 1,000 mm. Prone to highly changeable weather due to location in one of the major storm tracks of North America.
River basins	Thames River into Lake St. Clair Grand River into Lake Erie Trent River into Lake Ontario St. Lawrence River and its tributaries flowing into the Atlantic Ocean: <ul style="list-style-type: none"> • Ottawa River; • Chateauguay River; • Richelieu River;

	<ul style="list-style-type: none"> • Sainte Francois River; • Saint-Maurice River; • Yamaska River; • Becancour River; and • Chaudière River.
Settlement	Most heavily populated ecozone ⁺ in Canada. Includes the major metropolitan areas of Toronto, Montréal, and Ottawa. Other major cities include Quebec City, Hamilton, and London.
Economy	Diverse economy of manufacturing, services, and agriculture.
Development	Extensive urban development in both the Golden Horseshoe of Ontario and around Montréal, Quebec. Extensive road networks. Agricultural intensification is occurring throughout the ecozone ⁺ particularly in the marine clay plains of St. Lawrence Lowlands of Quebec and the lacustrine clay plains of southern Ontario.
National/global significance	<p>Three national parks: Point Pelee; Bruce Peninsula; and Thousand Islands.</p> <p>Thirteen National Wildlife Areas: St. Clair; Big Creek; Long Point; Mohawk Island; Wye Marsh; Wellers Bay; Scotch Bonnet Island; Prince Edward Point; Mississippi Lake; Lac Saint-François; Îles de la Paix; Îles de Contrecoeur; and Cap Tourmente.</p> <p>Eight Ramsar sites: Point Pelee; St. Clair; Long Point; Minesing Swamp; Matchedash Bay; Mer Bleue Conservation Area; Lac Saint-François; and Lac Saint Pierre.</p> <p>Seventy-two Important Bird Areas.</p> <p>Five UNESCO biosphere reserves: Niagara Escarpment; Frontenac Arch; Long Point National Wildlife Area; Lac St. Pierre; and Mont Saint Hilaire.</p> <p>The Great Lakes and St. Lawrence River are a major entry point for invasive non-native species to both Canada and the United States.</p>

Jurisdictions: The Mixedwood Plains Ecozone⁺ in Canada includes the southernmost parts of the provinces of Ontario and Quebec. Approximately 73.2% of the ecozone⁺ is located in Ontario and 26.8% in Quebec. Major Aboriginal cultural groups represented in this ecozone⁺ include the Ojibway (Chippewa), Haudenosaunee (Iroquois), Delaware, and Potawatomi.

Population: Between 1971 and 2006, the human population of the Mixedwood Plains Ecozone⁺ increased from approximately 11 million people to over 16 million people (Figure 2).

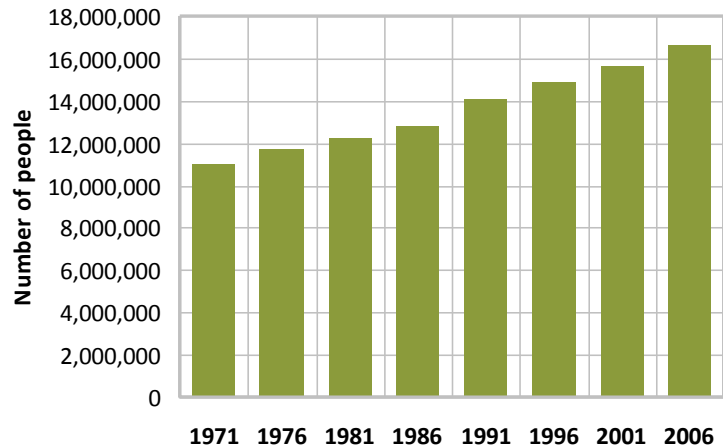


Figure 2. Human population of the Mixedwood Plains Ecozone⁺, 1971–2006.
Source: adapted from Statistics Canada, 2009⁹

Land cover: Based on 2005 remote sensing data, cultivated land was the predominant land cover type representing 68% of the total area, followed by forest at 25%. Urban lands comprised 4% of the ecozone⁺ (Figure 3Error! Reference source not found.).

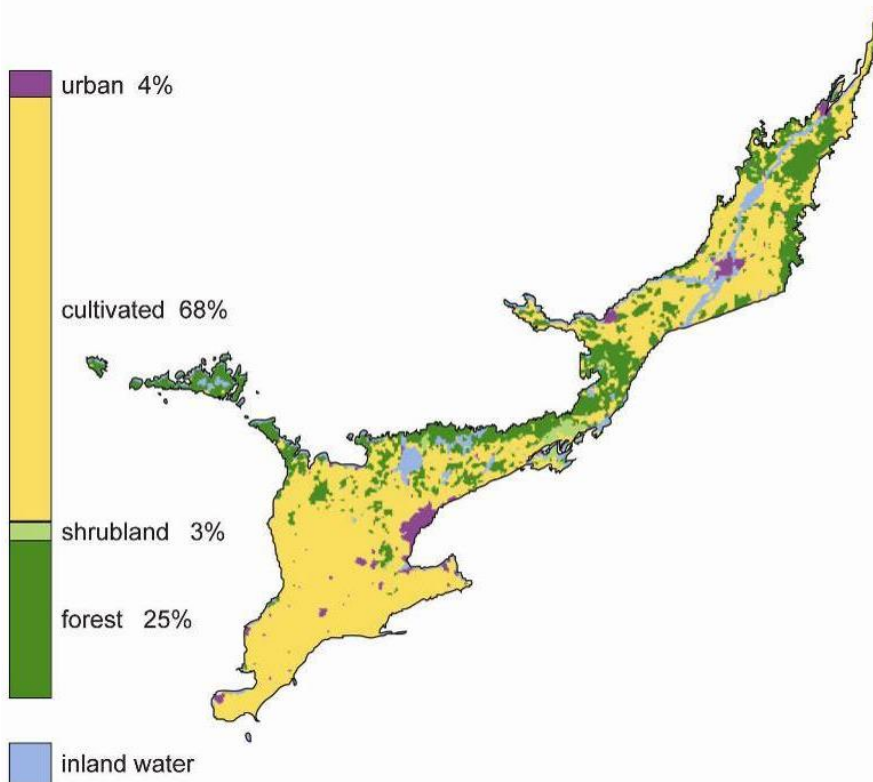


Figure 3. Distribution of major land cover types in the Mixedwood Plains Ecozone⁺ as delineated by remote sensing, 2005.

Source: Ahern et al., 2011⁸ using data from Latifovic and Pouliot, 2005¹⁰

Landscape vignettes



Downtown Toronto skyline

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Marsh, Lake St. Clair

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*Black oak savannah in Rondeau Provincial Park
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*Maple-oak forest, Skunk's Misery
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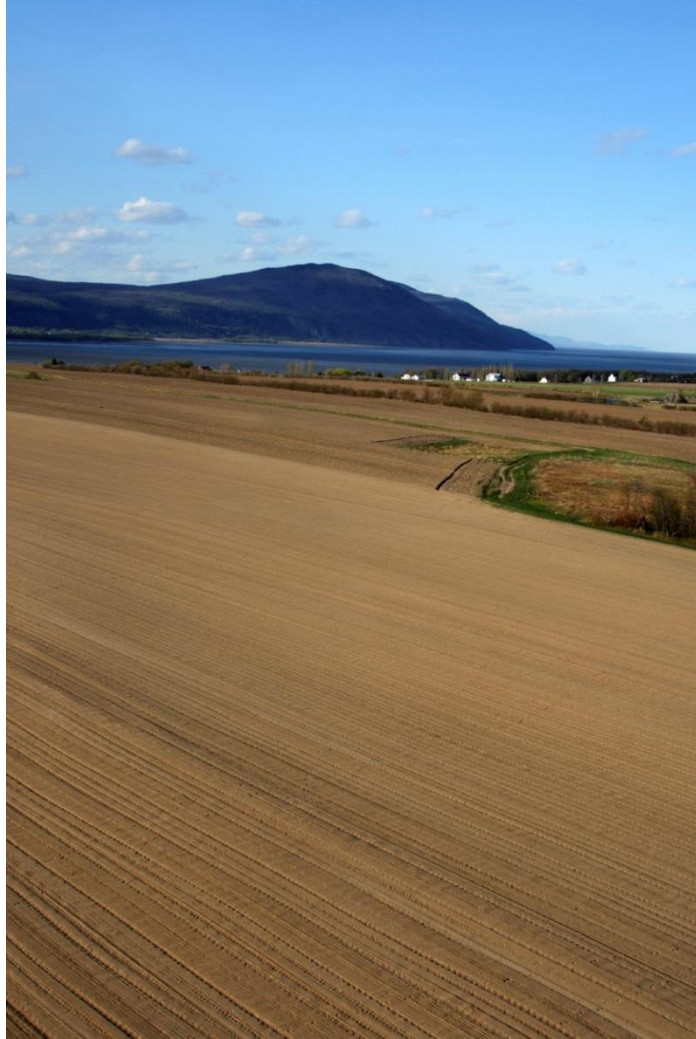
Uxbridge, Ontario area

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Carden Alvar

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*Newly ploughed agricultural field on Îles d'Orleans, Quebec
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KEY FINDINGS AT A GLANCE: NATIONAL AND ECOZONE⁺ LEVEL

Table 1 presents the national key findings from *Canadian Biodiversity: Ecosystem Status and Trends 2010*³ together with a summary of the corresponding trends in the Mixedwood Plains Ecozone⁺. Topic numbers refer to the national key findings in *Canadian Biodiversity: Ecosystem Status and Trends 2010*. Topics that are greyed out were identified as key findings at a national level but were either not relevant or not assessed for this ecozone⁺ and do not appear in the body of this document. Evidence for the statements that appear in this table is found in the subsequent text organized by key finding. For many topics, additional supporting information for the Ontario portion of the ecozone⁺ can be found in the *Mixedwood Plains Ecozone⁺ Status and Trends Assessment – with an emphasis on Ontario*.⁴ See Preface.

Table 2. Key findings overview.

Themes and topics	Key findings: NATIONAL	Key findings: MIXEDWOOD PLAINS ECOZONE ⁺
THEME: BIOMES		
1. Forests	At a national level, the extent of forests has changed little since 1990; at a regional level, loss of forest extent is significant in some places. The structure of some Canadian forests, including species composition, age classes, and size of intact patches of forest, has changed over longer time frames.	Forests cover approximately 25% of the Mixedwood Plains Ecozone ⁺ . Whether forest cover has increased or decreased depends on the location within the ecozone ⁺ . Between 1959 and 1995, forest cover increased by 3.3% per decade in the Frontenac Arch and by 2.9% per decade in the Quebec portion of the ecozone ⁺ between 1969 and 1995. However, forest continues to be lost near urban areas. When compared to the forest found in the ecozone ⁺ during the 19 th century, current forests have younger old growth, less conifers, and more early successional species.
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.	Less than 3% of the prairie and savannah originally found in the ecozone ⁺ remains. Though the extent of alvar in Manitoulin Island and the upper Bruce Peninsula has decreased, there may have been increases in alvar in the Carden Plain. Both prairies and alvars are home to numerous species at risk.
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.	Only 28% of the total wetland area originally found in the Ontario portion of the ecozone ⁺ remained in 2002 (72% loss). Between 1982 and 2002, wetland loss averaged 0.17% per year. Most of the Ontario portion of the ecozone ⁺ has

Themes and topics	Key findings: NATIONAL	Key findings: MIXEDWOOD PLAINS ECOZONE⁺
		<p>less than 50% of its remaining wetlands in patches over 200 ha in size. Swamp is the most common wetland type.</p> <p>The freshwater tidal marshes found along the St. Lawrence River are the largest and some of the least polluted in North America and a very rare habitat worldwide. The Great Lakes coastal wetlands provide continentally significant habitat for many migratory waterfowl.</p> <p>Restoration efforts and reduced water levels in the Montréal and Lac Saint-Pierre areas have resulted in a 2.7% net gain in marshes and swamps between 1990 and 2002.</p>
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.	Water temperatures have increased over the last 30 to 40 years. Water levels and flows have been greatly altered by the construction of canals and dams. The ecozone ⁺ has the highest freshwater fish biodiversity in Canada (78% of the species found Canada). Of the 131 species native to the ecozone ⁺ , 36 are of conservation concern, more species than any other vertebrate group in the ecozone ⁺ . The distributions of cold-water species have contracted the distributions of warm-water species have expanded.
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.	Tidal marshes are discussed under the wetlands key finding.
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.	Not relevant for the Mixedwood Plains Ecozone ⁺ .

Themes and topics	Key findings: NATIONAL	Key findings: MIXEDWOOD PLAINS ECOZONE⁺
7. Ice across biomes	Declining extent and thickness of sea ice, warming and thawing of permafrost, accelerating loss of glacier mass, and shortening of lake-ice seasons are detected across Canada’s biomes. Impacts, apparent now in some areas and likely to spread, include effects on species and food webs.	A trend towards earlier break-up and longer ice free season has been observed for the ecozone ⁺ (1853–2001). On average, in the years between 1975 and 2004, freeze-up of the Great lakes has been occurring 3.3 days later per decade with an average decrease in ice duration of 5.3 days per decade, compared with historical rates. Fish species such as lake whitefish and lake trout which require cold water temperatures for successful spawning have poorer larval survival with warmer water temperatures (associated with less ice cover). Warmer water temperatures also create thinner near-shore ice which is easily broken up by wind resulting in ice piling and loss of invertebrate habitat. Increases in “lake effect snow” are also associated with years with lower ice cover on the Great Lakes.
Dunes [*]	Dunes are a unique biome with a very limited distribution in Canada. As a result, information on dunes was not identified as a nationally recurring key finding nor was it included in one of the other key findings in the national report.	Because of their significance to biodiversity in the Mixedwood Plains Ecozone+, information on dunes is included as a separate ecozone+-specific key finding in this report. The fragile ecosystems of coastal dunes can be easily disturbed by both human and natural forces. Lower lake levels and reduced groundwater supplies, resulting from predicted climate change, may have negative impacts on dune ecosystems, and development pressure is expected to continue along the Great Lakes shorelines, where dunes are predominately located in this ecozone ⁺ .

^{*} This key finding is not numbered because it does not correspond to a key finding in the national report.³

Themes and topics	Key findings: NATIONAL	Key findings: MIXEDWOOD PLAINS 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.	The Mixedwood Plains Ecozone ⁺ is predominately private land with few government lands available for protection. Growth in traditionally designated protected areas has thus been very difficult. Prior to 1992, 0.7% of the ecozone ⁺ was protected in these types of regulated protected areas. By May 2009, this had increased to 1.6%, covering 1,887 km ² . The majority of natural heritage protection occurs on private lands through a number of designations and mechanisms with varying degrees of protection.
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.	With a high proportion of the Mixedwood Plains in private ownership, voluntary stewardship activities are a crucial component of biodiversity conservation. Stewardship includes protection activities such as easements and land securement, incentive programs, restoration activities such as planting trees, and education and awareness activities such as nature interpretation centres and programs for youth. Overall, stewardship in the Ontario portion of the ecozone ⁺ has two long term trends: increasing levels of public engagement; and increasing scale of stewardship activities. Despite this there is little coordination between the parties doing stewardship and no monitoring to determine if the actions are adequate to help ensure a healthy and functioning ecosystem.

Themes and topics	Key findings: NATIONAL	Key findings: MIXEDWOOD PLAINS ECOZONE⁺
Ecosystem conversion*	Conversion of one land use or land cover type to another is poorly documented in Canada. Estimates available show an increase in some land uses, for example urban area (~ 15,200 km ²) and hydro reservoirs (~27,000 km ²), and a decrease in agricultural land (~ 18,500 km ²) over the past 30 to 40 years. These changes translate into loss of natural habitat and agricultural ecosystems. (under review)	The Mixedwood Plains has undergone some of the most extensive changes in land cover of any ecozone ⁺ in Canada (second only to the Prairies). In 2011, it was comprised of 68% agricultural land and contained 53% of Canada's population. In the Ontario portion of the ecozone ⁺ between 1951 and 2006, the sparsely populated and rural lands declined to 58% of the 1951 level while the land area with urban population densities almost tripled. The steepest growth was in the semi-urban category. The increases in urban area came at the expense of farmland and, to a lesser extent, forest cover. Agricultural intensification has occurred as pasturelands and hayfields have been reduced and cropland area increased.
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.	The Mixedwood Plains has the greatest number of invasive non-native plant species (139 in 2008) of any ecozone ⁺ in Canada due to the long settlement history and role as a port of entry for goods from around the world. Despite the ongoing influx of invasives, a few control measures, such as those taken against purple loosestrife, have begun to show positive results.
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.	The concentrations of legacy contaminants such as DDT, lead, and mercury have been reduced but still persist in the environment. Emerging contaminants such as PBDEs, PCNs, and PFCs are starting to be monitored but data is limited. Concentrations of mercury continue to be a concern and are the cause of more than 85% of fish consumption restrictions in the Ontario portion of the ecozone ⁺ .

* This key finding is not numbered because status and trend information related to it was incorporated into other key findings in the final national report.³ However, as information was compiled and assessed separately for this finding for this ecozone⁺, it has been included in this report.

Themes and topics	Key findings: NATIONAL	Key findings: MIXEDWOOD PLAINS ECOZONE⁺
12. Nutrient loading and algal blooms	Inputs of nutrients to both freshwater and marine systems, particularly in urban and agriculture-dominated landscapes, have led to algal blooms that may be a nuisance and/or may be harmful. Nutrient inputs have been increasing in some places and decreasing in others.	In general phosphorus levels have declined since the 1980s, however many rivers and streams in the Ontario portion of the ecozone ⁺ continue to exceed the interim Provincial Water Quality Objective of 30 ug/L of phosphorus in areas where soils are relatively rich and the land has been developed for agricultural and urban use. Between 1994 and 2009 there was a significant increase in the number of reports of cyanobacteria (blue-green algae) blooms in the 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.	Due to the underlying geology of the Mixedwood Plains most lakes are well-buffered against the impacts of acidification. Concerns about acidification are focused on the Frontenac Arch, which has soils susceptible to acidification and relatively high forest cover.
14. Climate change	Rising temperatures across Canada, along with changes in other climatic variables over the past 50 years, have had both direct and indirect impacts on biodiversity in terrestrial, freshwater, and marine systems.	Summer temperatures and fall and spring precipitation have increased in the ecozone. There has been a decrease in the number of growing degree days, and decreases in snow depth. Broad scale ecological impacts are projected based on continued warming related to changes in northward expansions of species, changes in timing of bird migration, and increases in plant pests and diseases.
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.	A recent conservative estimate of the economic value of the ecosystem goods and services provided by the Ontario portion of the ecozone ⁺ is \$84 billion per year.

Themes and topics	Key findings: NATIONAL	Key findings: MIXEDWOOD PLAINS ECOZONE⁺
THEME: HABITAT, WILDLIFE, AND ECOSYSTEM PROCESSES		
Intact landscapes and waterscapes*	Large tracts of relatively intact natural landscapes and waterscapes, where ecosystem processes are either known or presumed to be functioning properly, are found in many areas, but particularly in the north and west. This includes globally and nationally significant terrestrial, freshwater and marine movement corridors. (under review)	The Ontario portion of the Mixedwood Plains is highly fragmented with a low of 18% natural vegetation in the Southwest and a high of 57% in the Frontenac Arch. Large patches (greater than 200 ha) make up 41% of the Niagara Escarpment and only 5% of the Southwest. In the Ontario portion of the ecozone ⁺ , the area with the most roads is the central physiographic zone in Ontario with 1.89 km of roads/km ² . The lowest density of roads in Ontario portion of the ecozone ⁺ is found in the Frontenac Arch with 1.14 km of roads/km ² . Dams, weirs, and other barriers to aquatic systems are frequent in the 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.	The wildlife habitat capacity index of agricultural lands in the ecozone ⁺ declined between 1985 and 2006. This is due to a 37.6% decrease in pasture and a 4.8% decrease in natural cover on farm properties and an increase in the area of cropland. The lowest wildlife capacity on farmland is found in the Lake Erie lowland in southwestern Ontario.

* This topic is not numbered because status and trend information related to it was incorporated into other key findings in the final national report.³ However, as information was compiled and assessed separately for this finding for this ecozone⁺, it has been included in this report.

Themes and topics	Key findings: NATIONAL	Key findings: MIXEDWOOD PLAINS ECOZONE⁺
17. Species of special economic, cultural, or ecological interest	Many species of amphibians, fish, birds, and large mammals are of special economic, cultural, or ecological interest to Canadians. Some of these are declining in number and distribution, some are stable, and others are healthy or recovering.	As of 2009, there were 865 species of conservation concern in the ecozone ⁺ . In 2005, between 65 and 70% of freshwater mussels and reptile species fell into categories of conservation concern. Serious declines have also been found in birds of open agricultural habitats, grassland birds, colonial waterbirds, shorebirds, and even some birds of urban areas. This ecozone ⁺ has 97% of the freshwater fish species found in Ontario and 86% of the total for Quebec and 78% of the species for Canada. Significant declines are being seen in bumblebee species. All of the 12 species of reptiles and amphibians found only in the Mixedwood Plains are at risk. Turtles appear to be in the greatest peril as seven of the eight native species (87.5%) are at risk. Snakes are similarly imperilled, with 11 of 17 (65%) of the species listed as at risk. ¹¹
18. Primary productivity	Primary productivity has increased on more than 20% of the vegetated land area of Canada over the past 20 years, as well as in some freshwater systems. The magnitude and timing of primary productivity are changing throughout the marine system.	The forested portions of the ecozone ⁺ have some of the highest net primary productivity (NPP) reported in Canada though the average NPP for the ecozone ⁺ as a whole is moderate. Primary productivity has been increasing across the ecozone ⁺ at 2 g C/m ² /yr, potentially due to increases in precipitation.

Themes and topics	Key findings: NATIONAL	Key findings: MIXEDWOOD PLAINS 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.	Historically, wind is thought to have been a larger disturbance than fire in this ecozone ⁺ . The ecozone ⁺ currently does not have a natural fire regime due to fire suppression activities. Historically, frequent surface fires which supported small-scale gap disturbances would have been the most common fire type in the ecozone ⁺ 's forests. Insects damaged 14.8% of forests in the Ontario portion of the ecozone ⁺ between 2001 and 2005 while 0.05% of forest cover was impacted in Quebec between 1969 and 1995. Forest tent caterpillar and spruce budworm are the two most common forest pests and are responsible for about half of the damage done to Ontario forests within the ecozone ⁺ . It is difficult to know whether native insect infestations are at levels higher than would have historically occurred. The area infested by invasive non-native forest insects such as gypsy moth, emerald ash borer, and sirenix wood wasps is in excess of natural disturbance levels as these species never occurred naturally within the ecozone ⁺ .
20. Food webs	Fundamental changes in relationships among species have been observed in marine, freshwater, and terrestrial environments. The loss or reduction of important components of food webs has greatly altered some ecosystems.	Human activities in the ecozone ⁺ have led to a number of changes in the relationships among species. Large carnivores, though still found in the ecozone ⁺ , are restricted to areas with higher levels of natural cover. Species tolerant of human activities (e.g., white-tailed deer, skunks, raccoons) have increased.

Themes and topics	Key findings: NATIONAL	Key findings: MIXEDWOOD PLAINS 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.	Most of the Ontario data available for this ecozone ⁺ was generated to answer specific research or management questions and was not part of a long-term monitoring program. Generally, long-term, broad-scale monitoring programs which would provide data to support initiatives such as ESTR have not been designed, resourced, or implemented for the Ontario portion of this ecozone ⁺ . At the community level the lack of up-to-date land cover data prevents the tracking of broad-scale landscape change. At the species level, much of the long-term trend data comes from citizen science and little monitoring is being done overall. With the many jurisdictions involved in environmental monitoring (more than 200), data standards and lack of coordination are two of many issues.
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.	Three diseases found in the ecozone ⁺ typify the problem of rapid change coupled with poor understanding. White-nose syndrome, which often causes mortality rates of more than 75% in hibernating, cave-roosting bats has spread into the ecozone ⁺ . Chytridiomycosis which is considered a significant disease affecting amphibian diversity worldwide has been found to be present in amphibians within the ecozone ⁺ . Viral hemorrhagic septicaemia was originally considered a disease of freshwater rainbow trout in Europe. It has now been found in 30 species of fish from the Great Lakes and is often associated with significant mortality.

THEME: BIOMES

Key Finding 1

Theme Biomes

Forests

National key finding

At a national level, the extent of forests has changed little since 1990; at a regional level, loss of forest extent is significant in some places. The structure of some Canadian forests, including species composition, age classes, and size of intact patches of forest, has changed over longer time frames.

Forest extent

Forest was once the most common land cover type found in the Mixedwood Plains Ecozone⁺. Estimates of the amount of land historically cleared by Aboriginal peoples within the ecozone⁺ are not available, but Jenness¹² estimated that cornfields were planted as far as 3.7 km on either side of villages of Iroquoian speaking peoples in Ontario. By the time European settlers arrived in the 18th and 19th centuries, much of the land already cleared had returned to forest cover after Aboriginal populations were devastated by epidemics and warfare.¹³ Most of the forest in the Quebec portion of the ecozone⁺ was harvested between 1800 and 1880 at a time associated with the first population peak in the area.^{14, 15} At that time, more than 70% of the area was being used for agricultural activities. As a result, many areas were subject to changes in the drainage system, peat extraction, and other soil modifications for agriculture.^{13, 16, 17} Forest cover was at its lowest in Ontario around 1920 when it is estimated that only 10.6% forest cover remained.¹⁸

Since these times of historic lows in forest cover, the amount of forest in the ecozone⁺ has increased in both provinces. Currently there is an estimated average 25% forest cover within the Mixedwood Plains; the Prairie Ecozone⁺ is the only Canadian ecozone⁺ with less forest cover (0.9%).⁸ The amount of forest cover varies greatly throughout the ecozone⁺ from a low of about 5% in Essex County in southwestern Ontario, to a high of 75% in some areas along the northern border of the ecozone⁺, including the upper Bruce Peninsula¹⁹ (Figure 4). In recent years, whether there has been an increase or decrease in forest cover depends on the area under discussion. In some areas such as the Frontenac Arch (near Westport Ontario and Frontenac Provincial Park), there has been a significant increase in forest cover. The proportion of forest land increased from 29 to 40% between 1934 and 1995.²⁰ The rate of increase between 1959 and 1995 was 3.3% per decade.²⁰ In the St. Lawrence lowlands area of Quebec, forest cover and fragmentation remained unchanged in areas under intensive agriculture for the time period between 1950 and 1997.^{21, 22} In areas less suitable for cultivation, forest cover increased (26.8% in 1950 to 34.2% in 1997²²) and forest fragmentation decreased due to conversion of old fields into forest because of land abandonment,^{21, 22} a situation similar to that found in the Frontenac Arch of Ontario.²⁰ When forest cover in the entire Quebec portion of the ecozone⁺ was compared between 1969 and 1995,²³ a slight increase of 2.9% was found between the first (1969 to 1975) and the third (1990 to 1995) inventory program (Figure 5).²³

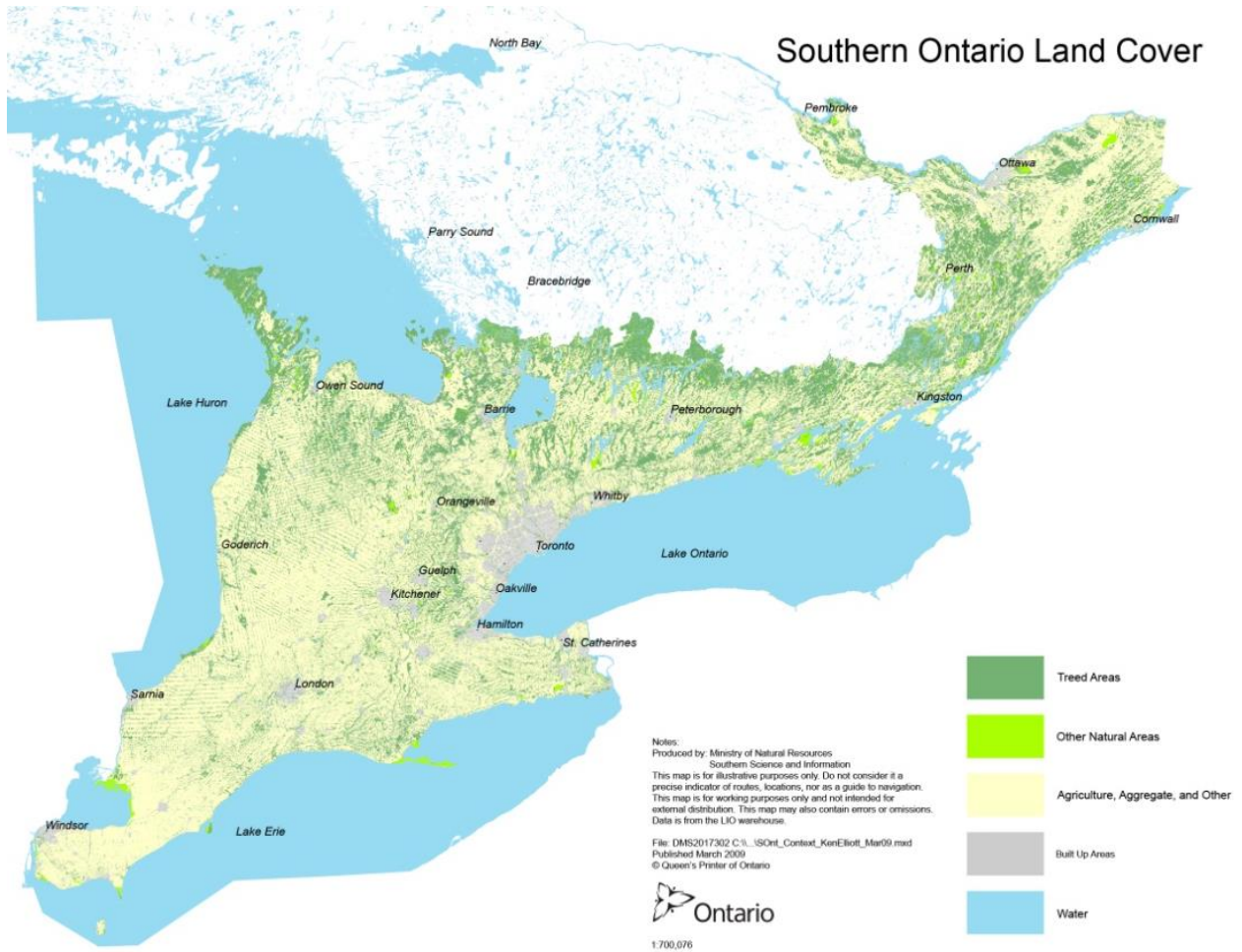


Figure 4. Land cover of the Ontario portion of the Mixedwood Plains Ecozone⁺ based on the Southern Ontario Land Resource Information System (SOLRIS) Phase 1 Wooded Areas Mapping (based on year 2000 imagery).

Source: Ontario Ministry of Natural Resources, 2006¹⁹

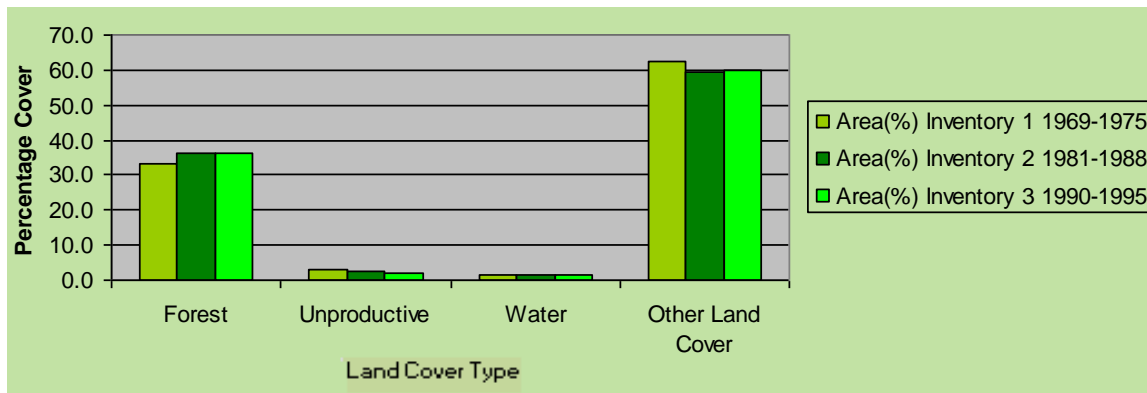


Figure 5. Changes in land cover in the Quebec portion of the Ecozone⁺, 1969–1995.

Source: Ministère des Ressources naturelles et Faune du Québec, 2010²³

Near urban areas such as the Golden Horseshoe around Toronto, forest cover has continued to be lost due to urbanization (though at a lesser rate than agricultural land is being lost).⁸ Human population density has the strongest correlation with the various indicators of forest fragmentation.²⁴ The major ice storm that hit the St. Lawrence Lowlands in 1998 may also have contributed to forest loss as numerous woodlots were removed due to ice damage.^{25, 26} In eastern Ontario, the ice storm is also believed to have increased forest patch isolation.²⁷

Forest structure

In the central portion of the ecozone⁺ (within Ontario) diameter limit cutting has led to generally young (<70 years old), almost even-aged stands.²⁸ Uneven-aged stands are limited to stands managed under the selection system or left uncut in parks or other areas (estimate of 10% or less of remaining forest cover²⁹). These stands contain few, if any, medium or large trees.^{18, 28} In eastern Ontario, the forest is primarily even-aged and even younger than in the central portion of the ecozone⁺ (average 63.5 years old³⁰). Old-growth forests used to dominate the landscape but they have been replaced with second-growth forests that, due to their young age and management history, lack the structural diversity and complexity of the pre-settlement landscape.¹⁸

In Quebec the situation is similar. The forest is dominantly immature (67% regenerating and young stands combined with mature and senescent stands making up 33% of the forested land base. The greatest amount of change in the Quebec portion of the ecozone⁺ over recent decades is seen in forest age as there has been an increase in mature and senescent forest of 15%, with a decrease in immature forest of 15% between the first and the third inventory program²³ (Figure 6).

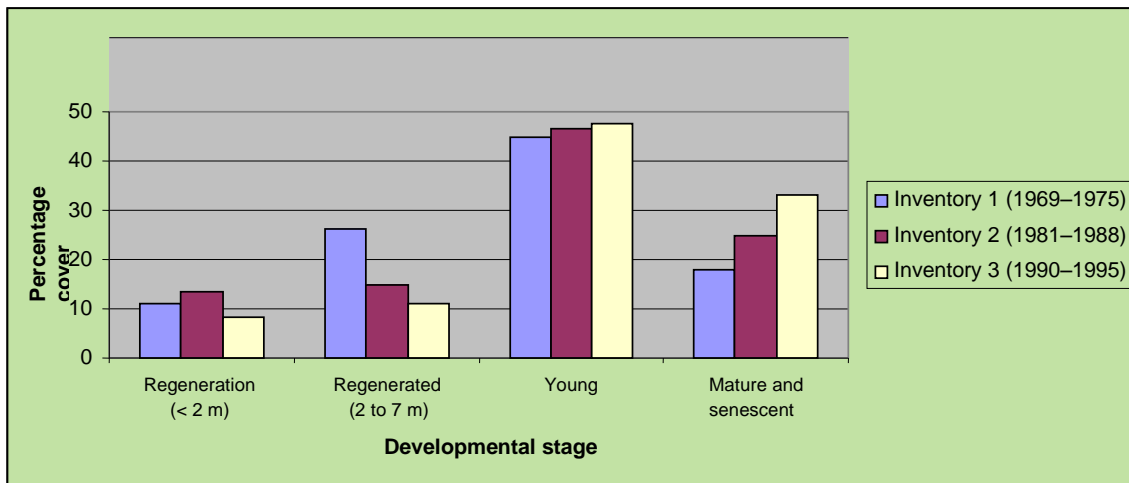


Figure 6. Changes in percentage forest cover by development stage within the Quebec portion of the ecozone⁺.

Source: Ministère des Ressources naturelles et Faune du Québec, 2010²³

Forest composition

The species composition of the ecozone's forest has changed greatly since pre-settlement times.^{13, 17, 31-33} How the species composition has changed depends on the area under study, the disturbance history, and the type of information used to reconstruct historical forest conditions.^{13, 34} However, generally, research has found that: 1) mature or old-growth forests generally achieved older ages in the past than in the present, as current forests are mostly the result of major human disturbances during settlement; 2) there was more conifer and less deciduous cover in the past than in the present; and 3) early successional species were less common and late-successional species more common than today.^{14, 17, 34-36}

When more recent changes in species composition were examined in Quebec,²³ it was found that the relative wood volume for conifers, white spruce (*Picea glauca*), black spruce (*Picea mariana*), white pine (*Pinus strobus*), and balsam fir (*Abies balsamea*) all decreased by between 1.1 and 2.3% between 1969 and 1995, while tamarack (*Larix laricina*), red spruce (*Picea rubens*), and hemlock (*Tsuga canadensis*) increased by 1.2, 2.3, and 2.8%, respectively. When deciduous species were examined, white birch (*Betula papyrifera*), yellow birch (*Betula alleghaniensis*), red oak (*Quercus rubra*), sugar maple (*Acer saccharum*), large tooth aspen (*Populus grandidentata*), and American basswood (*Tilia americana*) all decreased by between 1.4 and 4.9% between 1969 and 1995, while silver maple (*Acer saccharinum*) and red maple (*Acer rubrum*) increased by 1.2 and 15.4%, respectively. Many of these changes can be attributed to insect outbreaks. Decreases in conifer species composition are associated with insect outbreaks (mainly spruce budworm, *Choristoneura fumiferana*) and logging activities.³⁵⁻³⁷ The increase in red maple likely was a result of these disturbances³⁵ combined with its role as an early successional species in those areas where land is returning to forest cover.¹⁵ Red maple is a super-generalist species which has low resource requirements and the ability to rapidly capture the available growing space.^{38, 39}

The pattern with late successional deciduous species is more complex. Although sugar maple has shown important increases in many regions since European colonization,^{16, 17} its relative importance decreased by 5% over the 1969 to 1995 period. Though decreases in sugar maple are sometimes attributed to the 1998 ice storm which hit both Ontario and Quebec,²⁶ the ice storm occurred after the declines seen in the Quebec data set.²³ Since the late 1970s, sugar maple declines and dieback have been observed sporadically at different scales in the deciduous forest of northeastern North America,^{40, 41} and particularly in Quebec.^{35, 42, 43} Environmental factors such as extreme climate events, insect defoliation, and the negative impact of acid deposition on soil fertility may all be involved in the recent decline of the sugar maple population in some areas of northeastern North America.⁴⁴

Grasslands

National key finding

Native grasslands have been reduced to a fraction of their original extent. Although at a slower pace, declines continue in some areas. The health of many existing grasslands has also been compromised by a variety of stressors.

Prairies and savannahs

Prairies and savannahs occur only in the southern Ontario portion of the ecozone⁺ and it is estimated that approximately 82,000 ha (820 km²) were present at the beginning of European settlement.⁴⁵ The most extensive areas of prairie vegetation occurred in an almost continuous band along the Norfolk Sand Plain, from Turkey Point northward to Brantford and Cambridge, and from there eastward to Hamilton. Other large areas existed along the nearshore areas of Lake St. Clair (Walpole Island and Chatham area) and the Detroit River (Windsor and Amherstburg), as well as the Oak Ridges Moraine in the vicinity of Rice Lake.

Today, prairie and savannah vegetation has virtually disappeared from the Mixedwood Plains Ecozone⁺ (Figure 7). The largest remaining example, over 900 ha, is found in the Grand Bend–Port Franks area. A further 600 ha remain at Windsor and Walpole Island First Nation.

Together, these three large sites represent 1.8% of the estimated original extent in the ecozone⁺.⁴⁵ Aside from a few other remnants over several hectares in size, most remaining fragments are less than 0.5 ha, and often in the order of 0.1 ha. The total area of these small fragments is approximately 700 ha. Therefore, together, a total of 2,200 ha (22 km²) of prairie and savannah remain in the ecozone⁺, representing only 2.7% of the historic extent (and a loss of 97.3%).^{45, 46}

Tallgrass prairies, savannahs, and alvars in the Mixedwood Plains Ecozone⁺

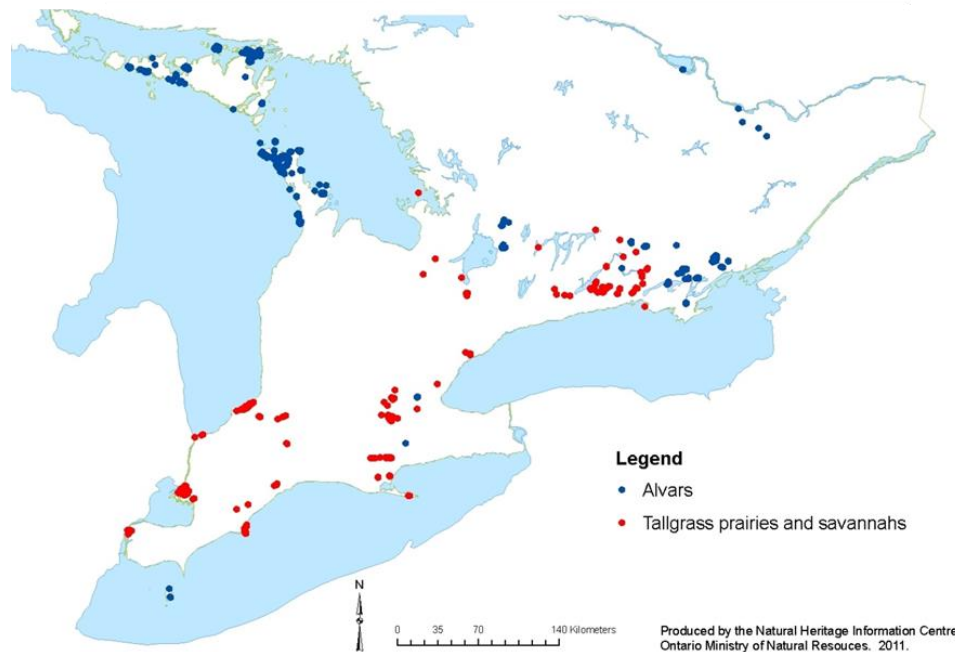


Figure 7. Tallgrass prairies, savannahs, and alvars in the Mixedwood Plains Ecozone⁺.
Source: Natural Heritage Information Centre, 2011⁴⁷

This pattern of decline in prairie and savannah vegetation in the ecozone⁺ is similar to that observed across North America broadly. Approximately 99.8% of both the tallgrass prairie⁴⁸ and tallgrass savannah of the mid-western U.S. and Canada⁴⁹ has been lost. No other vegetation type in North America has been so reduced in extent. For that reason, tallgrass prairie and savannah vegetation is one of the most threatened ecosystems in the ecozone⁺.⁵⁰

Prairies and savannahs support many plant and animal species considered to be rare in Ontario. As of 2009, there were 726 vascular plant taxa recognized as rare in the province.⁵¹ Of these, 160 (22%) occur in southern Ontario's prairies and savannahs. Many rare species of fauna are also present. A number of tallgrass prairie and savannah bird species, including lark sparrow (*Chondestes grammacus*), greater prairie-chicken (*Tympanuchus cupido*), and Bewick's wren (*Thryomanes bewickii*) no longer breed anywhere in Ontario.⁵² A number of rare insect species associated with tallgrass prairie, oak savannah, and sand barrens are only known (or were known) from single or a very few sites in Ontario, including barrens dagger moth (*Acrionicta albarufa*), aweme borer (*Papaipema aweme*), glorious flower moth (*Schinia gloriosa*), frosted elfin (*Callophrys irus*), the leafhoppers *Chlorotettix fallax*, *Graminella oquaka*, *Hecalus flavidus*, *Paraphlepsius turpiculus*, *Xerophloea peltata*, and the planthopper *Fitchiella robertsoni*.^{45, 53}

Alvars

Alvars are open grassland, savanna, and sparsely vegetated (rock barren) habitats that develop on very thin soils over flat limestone or dolostone bedrock.⁵⁴ Almost all of North America's alvars occur within the Great Lakes basin and the Mixedwood Plains Ecozone⁺.

Alvars in Ontario

In Ontario, alvars are located on the major limestone plains of the Mixedwood Plains including Manitoulin Island, the Bruce Peninsula, Carden, Napanee, and Smith's Falls (Figure 7). They also occur on smaller areas of near-to-surface limestone including the western Lake Erie islands, Flamborough Plain, local areas along the southern margin of the Precambrian Shield, and at a few sites along the Ottawa River.

The pre-European settlement extent of alvar vegetation is known for some areas within the Ontario portion of the Mixedwood Plains Ecozone⁺, including Manitoulin Island,⁵⁵ the northern Bruce Peninsula,⁵⁶ and the Carden⁵⁷ and Flamborough⁵⁸ limestone plains. Since European settlement, the areal extent of alvars has decreased on portions of Manitoulin Island. The south shore, from the middle of the island to the western tip, was originally described almost exclusively as open alvar. While numerous alvars are still present in this area, these systems are more isolated at present. Elsewhere on the island, some current alvars which were originally described as being forested, are apparently the product of forest fires.⁵⁵ Many of the extensive alvars that originally occurred along the northern shore of Manitoulin have been degraded by grazing activities.⁵⁹ Similarly, numerous areas of open alvar vegetation were noted by the original land survey in the upper Bruce Peninsula although fewer are present today.⁶⁰

In contrast to Manitoulin Island and upper Bruce Peninsula, the areal extent of alvar in other regions may be unchanged or have increased since European settlement.⁶⁰ Goodban⁵⁸ found that existing alvars on the Flamborough Plain originally occurred in a landscape dominated by deciduous forest, with only a very few areas referred to as "broken land". On the Carden Plain, numerous existing alvars were also noted by the original land surveyors, however, their extent and range has increased since European settlement. Logging and a subsequent conversion to ranch lands is responsible for the increase in areal extent of alvars in this area.^{57, 61} While the extent of original alvar vegetation in eastern Ontario has not been estimated, many currently open (i.e., alvar) areas were mapped by original land surveyors as extensive areas of conifer forest. It is assumed that logging, slash burning, and conversion to pasture were factors in the creation of many of these open sites.⁶⁰

There are at least 86 species of vascular plants known from alvars on the Ontario portion of the Mixedwood Plains, including seven endemic species. One of these, limestone hedge-hyssop (*Gratiola quartermaniae*), was only recently described⁶² as a scientific species from plant material collected in Ontario. Ten species are considered to be globally rare, and four others are nationally rare. Four provincially-rare moss species, and one lichen species, also occur on alvars.⁶⁰ Specialized alvar habitats are important for at least 62 plant species -- 50% or more of their occurrences in the Mixedwood Plains Ecozone⁺ in alvars. Of these, 21 are mainly confined to alvars (86 to 100% of occurrences) and another 13 largely confined (71 to 85%) to them.⁶³

Alvars also support a variety of rare and endangered animal species.⁴⁵ One of Ontario's most celebrated endangered species, the loggerhead shrike (*Lanius ludovicianus*), is found in alvars in the Mixedwood Plains. Alvar is important habitat for the blue racer (*Coluber constrictor foxii*), an endangered snake now known in Ontario only from Pelee Island. The endangered eastern foxsnake (*Pantherophis gloydi*) also inhabits alvar habitat on the island. On the Bruce Peninsula, the threatened eastern Massasauga (rattlesnake) (*Sistrurus catenatus*) is frequently found in alvars.⁶⁰ Brownell (2000)⁶⁰ also identified a number of terrestrial invertebrates, mainly butterflies, grasshoppers, tiger beetles, and, especially, mollusks associated with alvar habitat.

Alvars in Quebec

Small alvars, 21 in total, are known to exist in Quebec along the Ottawa River and in Montérégie and Lanaudière near Montréal, all located in the Mixedwood Plain Ecozone⁺. Covering a larger area historically, their total area is now 132 ha, with individual habitats varying in surface area from 1 to 27 ha.⁶⁴

Alvars are known to harbor 66 provincially-listed species at risk in Quebec;⁶⁴ for example, they are the only known habitats of the greater fringed gentian (*Gentianopsis crinita*). Of the alvars located in Quebec, those on Île-des-Cascades show the richest flora with 24 designated species.⁶⁵ Alvars, as any other habitats, are exposed to perturbations from alien invasive species; the European buckthorn (*Rhamnus cathartica*) represents a threat for those rare habitats.⁶⁴

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.

Evidence from Ontario

Wetland extent in Ontario

It is estimated that there were 2,026,591 ha of wetland in the Ontario portion of the ecozone⁺ prior to European settlement, constituting 25% of the landscape.⁶⁶ The highest concentrations of wetlands were found in southwestern and eastern Ontario. Essex County had the greatest wetland coverage in southwestern Ontario at 83%, followed by Kent and Lambton with wetland coverage of 56 and 50% respectively. In eastern Ontario, Prescott County had the greatest percentage of wetlands at 51% (Figure 8).⁶⁶

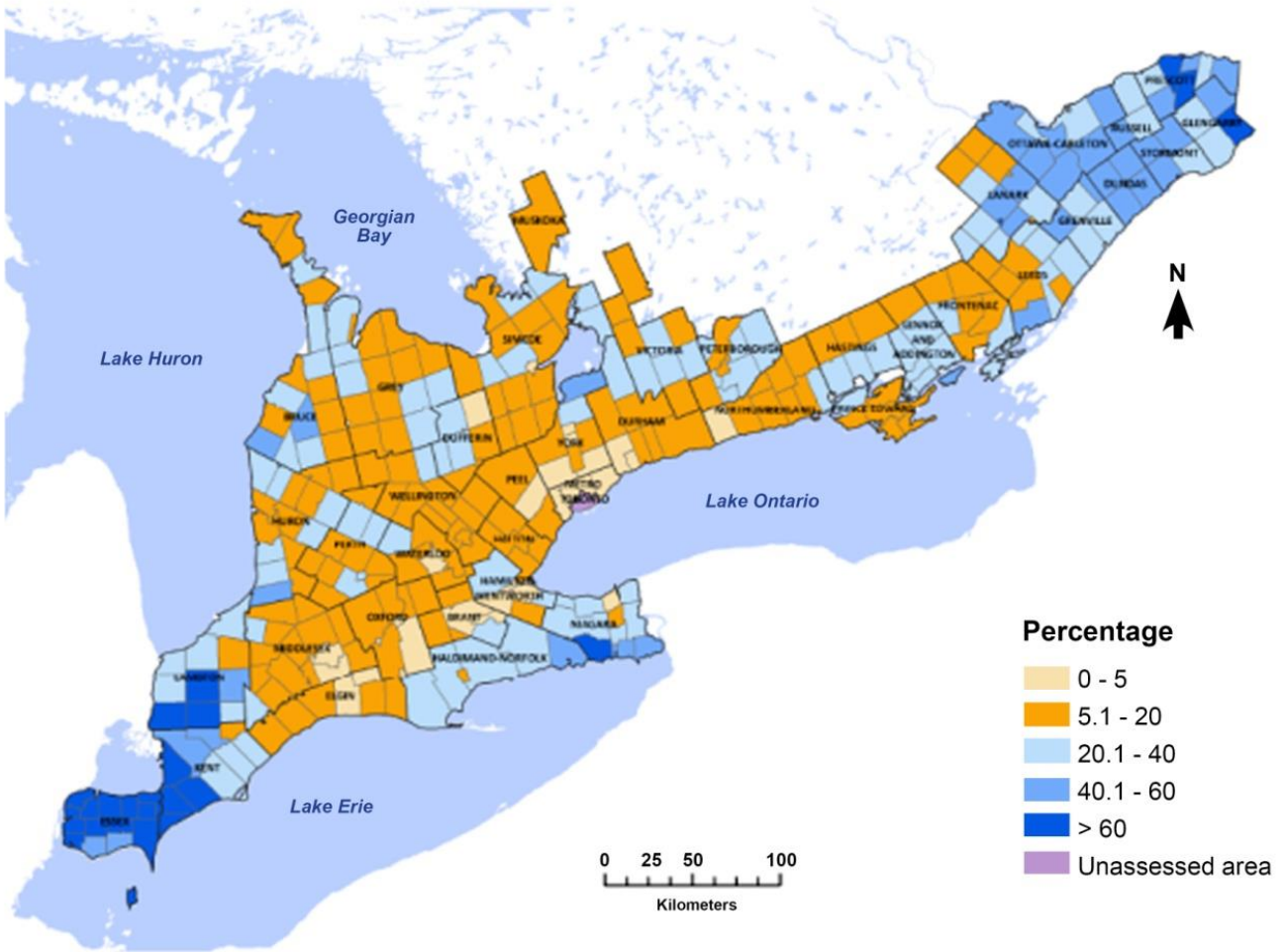


Figure 8. Percentage of wetland cover in the Ontario portion of the ecozone⁺ prior to European settlement.

Note: Wetlands under 10 ha not included in analysis.

Source: Ducks Unlimited, 2010⁶⁶

The extent of wetland in the Ontario portion of the ecozone⁺ has drastically declined with only 560,844 ha of pre-settlement wetland remaining by 2002 (Figure 9). This represents a loss of 72% of wetland area relative to pre-European settlement conditions and a reduction in total wetland coverage from 25 to 7%.⁶⁶

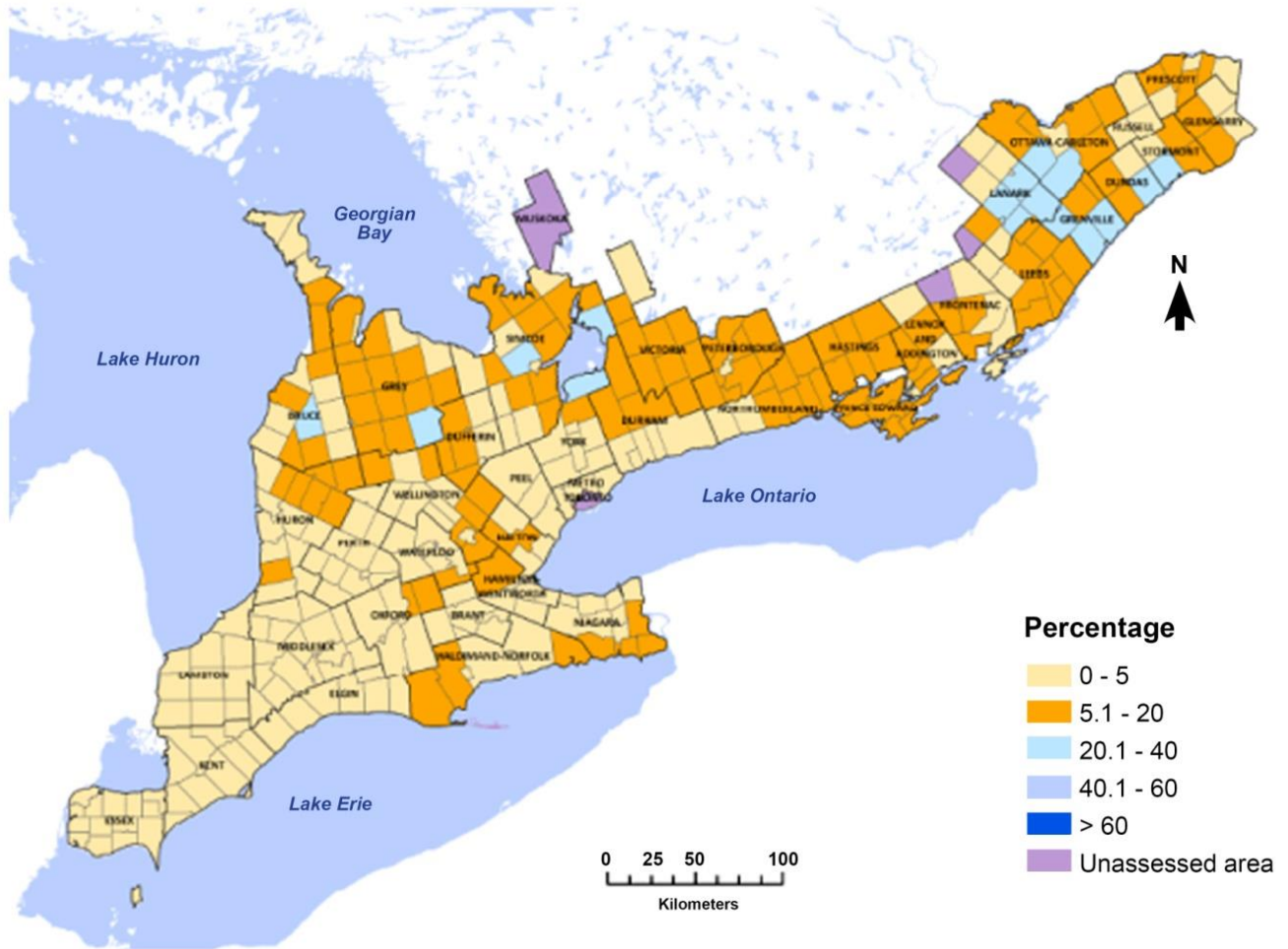


Figure 9. Percentage of wetland cover in Ontario portion of the ecozone⁺ in 2002.

Note: Wetlands smaller than 10 ha not included in analysis.

Source: Ducks Unlimited, 2010⁶⁶ based on mapping from the Southern Ontario Land Resource Information System (SOLRIS)..

Recent trend information on wetland losses suggest that some of the losses have been recent. From 1982 to 2002, there was an average loss of 3,543 ha per year, or 0.17% per year.⁶⁶ The greatest wetland losses have often occurred in areas which had the largest amounts of pre-settlement wetlands (Figure 10). By 2002, Essex County, which had the highest pre-settlement percentage of wetlands (83%), had some of the lowest rates of coverage (0 to 5%). A similar situation was found in Prescott County which also had a high percentage of wetland cover historically but only had between 5 and 20% in 2002. The wetland trends presented only apply to large wetlands (>10 ha) and are therefore a conservative estimate of wetland loss. If wetlands less than 10 ha in size had been included in these estimates, annual losses would be even higher.⁶⁶

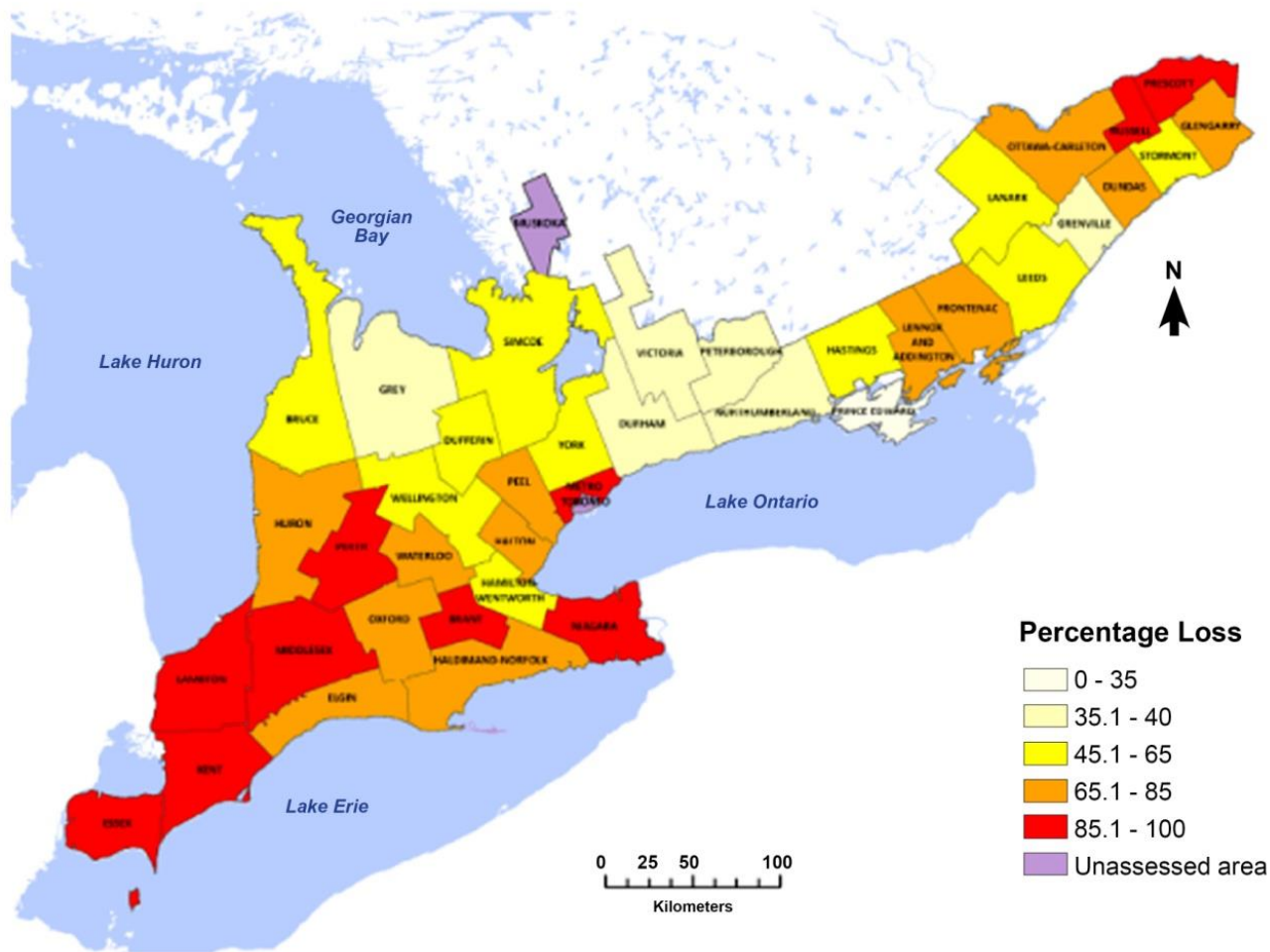



Figure 10. Percentage loss of wetlands in the Ontario portion of the ecozone⁺ between prior to European Settlement and 2002.
 Note: Wetlands smaller than 10 ha not included in analysis
 Source: Ducks Unlimited, 2010⁶⁶

Data showing the rates of wetland loss over time from pre-settlement to the present are not available for most of the ecozone⁺, but a study was done along the Canadian shoreline of Lake Ontario.⁶⁷ When mapping from as early as 1789 and up to 1962 was compared to mapping from 1977 and 1979, it was evident that wetland loss occurred along the Canadian shoreline throughout most of the 1800s, with the greatest loss occurring prior to 1950.⁶⁷ The rate of loss was often greater in the 1900s than in the 1800s, potentially due to improvements in drainage technology over time. The first reference to subsurface drains in Ontario is in 1844.⁶⁸ The rate of land drainage was at its maximum between 1967 and 1977 when new drainage technologies (plastic drainage tubing and machinery able to lay 30 m of drain per minute) were introduced.⁶⁸ Great Lakes coastal wetlands (see next section) were not included in the analysis presented above.

In 2009, percent cover of the different wetland types found in the Ontario portion of the ecozone⁺ varied greatly by physiographic zone. Swamp was the most abundant wetland type in all zones, ranging from 65.2% of the total wetland area in the Frontenac Arch to 89.4% of the wetlands in the Southwest physiographic zone (Table 3).⁴

Table 3. Composition of total wetland cover (based on area) across four wetland types in the Ontario portion of the ecozone⁺ by physiographic zone, 2009.

Physiographic area	Percent bog	Percent fen	Percent marsh	Percent swamp	Percent open wetland (bog, fen, marsh)
Central	0.2	0.3	12.3	87.2	13
Eastern	3.8	0.2	7.3	88.7	11
Escarpment	3.5	0.1	13.8	82.6	17
Frontenac Arch	0.2	0.2	34.4	65.2	35
Southwest	0.5	0.1	9.9	89.4	11



Zones shown in inset map

Source: Ontario Ministry of Natural Resources, 2009⁷⁰ and Taylor et al., 2012⁴

In 2009, most of the Ontario portion of the ecozone⁺ had less than 50% of its remaining wetlands in patches over 200 ha (Table 4). When looked at as a percentage of the physiographic areas as a whole, cover of wetlands over 200 ha was lowest (2%) in the Southwest and Escarpment, and highest (10%) in the Eastern Physiographic zone.⁴

Table 4. Percentage wetland patches in Ontario portion of ecozone⁺ by physiographic zone, 2009.

Physiographic area	Percentage of wetland patches larger than 200 ha	Percentage of wetland patches over 200 ha which are open wetland	Percentage of wetland patches over 200 ha which are swamp	Percentage of physiographic area which has wetlands 200 ha or larger	Average wetland patch size for patches 200 ha or greater
Central	43	16	84	7	648
Eastern	54	16	84	10	832
Escarpment	25	15	85	2	503
Frontenac Arch	22	45	55	3	729
Southwest	22	23	77	2	569

Note: Wetland includes bog, fen, marsh, and swamp while open wetland does not include swamp.

Source: Ontario Ministry of Natural Resources, 2009⁷⁰ and Taylor et al., 2012⁴

Great Lakes coastal wetlands

Located mainly along the shores of the southern Great Lakes (Ontario, Huron, and Erie) and their connecting channels (the St. Clair, Niagara, Detroit and St. Lawrence rivers, and Lake St. Clair), the Great Lakes coastal wetlands currently encompass over 70,000 ha.⁷¹ These wetlands provide continentally significant habitat for many migratory waterfowl,^{72, 73} breeding and non-breeding habitat for many species, including globally rare species and species at risk,^{74, 75} important spawning habitat for many fish, and a diversity of plants. They are considered vital to the health of the Great Lakes.⁷⁶

Despite their ecological value, the loss of Great Lakes coastal wetlands has been severe. McCullough⁶⁹ estimated that, by 1984, about 35% of the coastal wetlands along the Canadian shorelines of lakes St. Clair, Erie, and Ontario had been lost. Whillans⁶⁷ provides evidence that 43% (1,920 ha) of historical coastal wetlands along the Canadian shore of Lake Ontario west of the Bay of Quinte were drained or destroyed between 1789 and 1979, with the greatest loss occurring between Toronto and the Niagara River where 73 to 100% of original coastal wetlands have been lost.⁶⁷ Most of these losses occurred between the late 19th and early 20th centuries, when large wetlands were filled or dredged for shipping, industrial, and urban development purposes.⁷⁷ Today, many of the remaining coastal wetlands continue to be degraded by factors such as water level regulation, sedimentation, contaminant and nutrient inputs, climate change, invasion of non-native species, and intensive industrial, agricultural, and residential development.⁷⁷ Water level regulation in Lake Ontario, for example, is a major stressor to coastal wetlands and their inhabitants,⁷⁸ while along Lake Erie, sedimentation, nutrient loading, and contaminants are major wetland stressors.⁷⁷

Evidence from Quebec

Wetland extent in Quebec

In 2009, the total area of wetlands in the Mixedwood Plains Ecozone⁺ in Quebec was approximately 2,820 km², or 9% of the Quebec portion of the ecozone⁺ (31,925 km²).⁸⁰

Grenier and Allard (2012)⁸⁰ assessed the status of wetlands in the Quebec portion of the ecozone⁺ based on a compilation of existing wetland mapping for the region. Data consisted of seven different datasets from various projects derived either from satellite imagery (e.g., Landsat, Radarsat) or orthophotos from the early 1990s to 2009. Wetlands were divided into five categories: bog; fen; swamp; marsh; and shallow water (aquatic grass bed). Table 5 and Figure 11 present the breakdown and distribution by different categories of wetland.

Table 5. Area per category of wetland in the Quebec portion of the Mixedwood Plains Ecozone⁺, 2009.

Wetland Category	Area of the territory that is wetland (km ²)	Breakdown by wetland category (%)	Proportion of the territory that is wetland (%)
Bog	839	30	2.6
Fen	64	2	0.2
Marsh	411	15	1.3
Flooded forest	549	19	1.7
Shallow water	334	12	1.0
Unclassified	623	22	2.0
Total	2,820	100	8.8

Source: Grenier and Allard, 2012⁸⁰

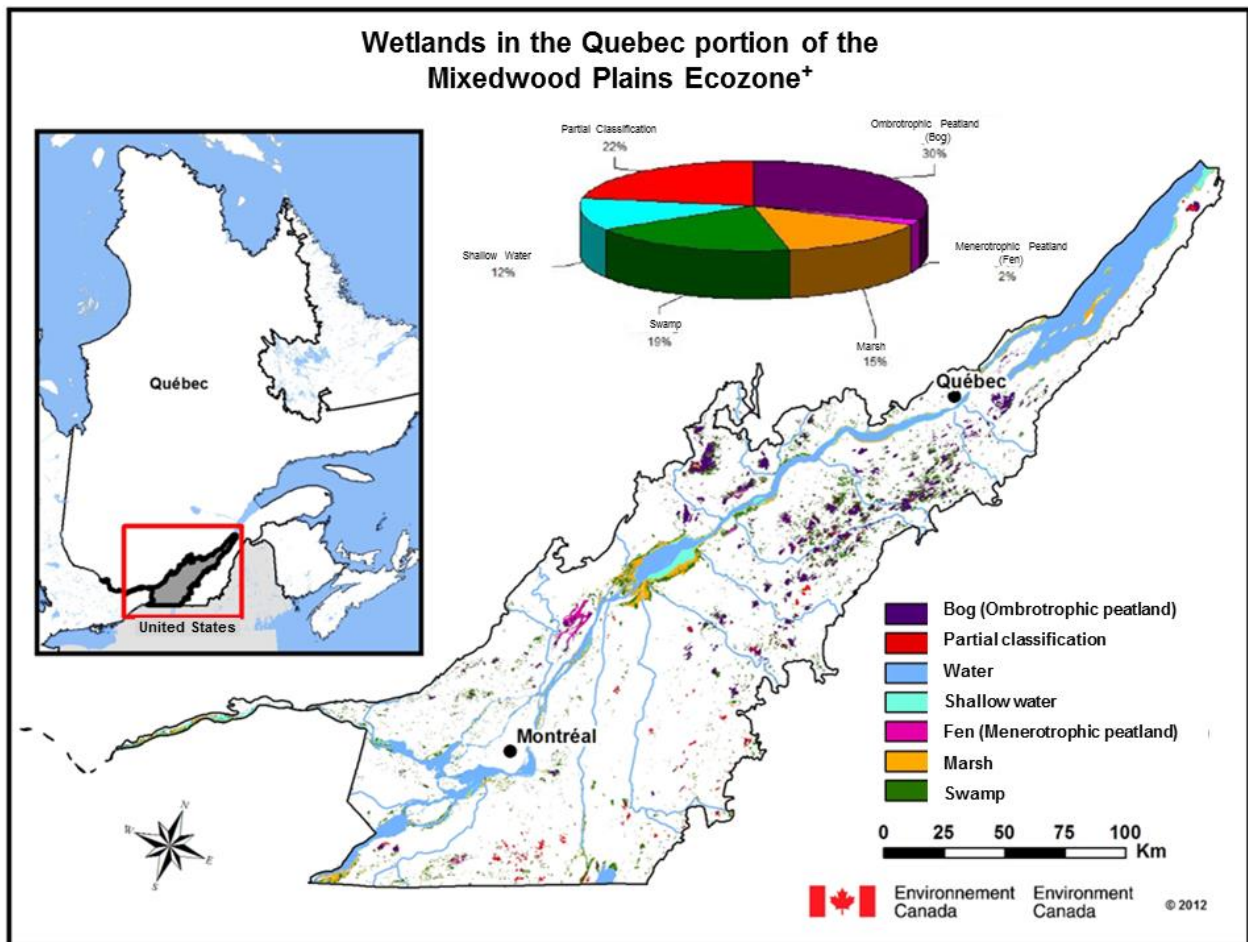


Figure 11. Distribution and classification of wetlands in the Quebec portion of the Mixedwood Plains Ecozone⁺, ca. early 1990s to 2009.

Source: Grenier and Allard, 2012⁸⁰

Bogs are spread out but occupy large areas, for a total of 839 km².⁸⁰ The Lac-à-la-Tortue bog (6,800 ha) south of Shawinigan, of which 8% is a designated "ecological reserve," and the Grande Plée Bleue bog (1,500 ha), south of Lévis, are examples of natural bogs that have remained relatively untouched by human activity. In terms of biodiversity, a few large fen complexes also exist near Villeroy and Lyster, southwest of Lévis. In Centre-du-Québec, where 80% of Quebec's cranberry farms are located, cranberry farming is responsible for the loss of large areas of bog.⁸¹

Fens are mostly found south of Montreal in the region of Napierville, Saint-Clotilde, and around Missisquoi Bay.⁸² These fens are highly exploited and have lost their original structure. "Ecological reserve" status ensures the strict conservation of part of the Lanoraie marshlands, which extend over 5,500 ha and are surrounded by farmland. Fens are the category of wetland that is least present in the territory, with an area of 64 km².⁸⁰ Marshes cover an area of 411 km², or 1.3% of the Quebec portion of the ecozone⁺.⁸⁰ The largest marsh areas are found near Lake Saint-Pierre; however, they also can be found along the St. Lawrence River, around different islands, at the mouths of rivers, and in the bays of the main watercourses.⁸³

The area covered by swamps is 549 km², or 1.7%, of the Quebec portion of the ecozone⁺.⁸⁰ Most of the swamps are found in the floodplain of Lake Saint-Pierre, but the Richelieu and Ottawa rivers are home to large areas of swampland as well. The periods of flooding for this type of wetland on the edge of terrestrial habitats can vary greatly from one year to the next. For example, along the St. Lawrence River, swamp areas where silver maple trees (*Acer saccharinum*) grow were flooded an average of 31 days per year between 1972 and 1976, but only 12 days per year between 1980 and 1984.

Shallow water (aquatic grass bed) covers 334 km², or 1% of the Quebec portion of the ecozone⁺.⁸⁰ Most of the shallow waters in the ecozone⁺ are located at Lake Saint-Pierre, where the water has gone down over many years, thus favouring the development of submerged and floating aquatic plants at the edges of the marshes. The mud flats in the region of Île d'Orléans are also included in this category along with many transition areas between the deep water and the marshes along rivers.

Urban development, agriculture, navigation, resorts, and poor land-use planning are all pressures that have had significant cumulative, and often permanent, impacts on wetlands in the Quebec portion of the ecozone⁺.⁸¹ While it is well-known that the losses recorded since European settlement are enormous, they are very difficult to assess because of the type of data that is available. Based on an analysis comparing the current wetlands area in the St. Lawrence Lowlands to a map of historical wetlands made based on types of soil, 80% of bogs have been lost due to human activity.⁸⁰ Similar losses (69 to 83%) were recorded for the territories surrounding the metropolitan areas of Montréal and Ottawa–Gatineau during the period from 1800 to 1981. Wetland drainage for agricultural purposes has been and remains the main threat to wetlands and is responsible for 85% of total losses; urban and industrial expansion accounts for 9% of all losses. Although it was not possible to precisely determine changes from two maps with different scales and created using very distinct methods of identifying wetlands, a visual comparison of the maps suggests that bog areas have been reduced by 50% since colonization.

The regions most affected are urban areas and the Montérégie region. Strong pressures observed between 1993 and 2001 in the farmscape towards intensifying annual crop production at the expense of forage crops and pastures and the loss of woodlands to housing developments and agriculture suggest that the wetlands present in this territory have been greatly affected.

Between Montréal and Lake Saint-Pierre, and specifically in the Lake Saint-Louis/Boucherville area, swamps have practically disappeared since this is the driest type of habitat and thus is the first to succumb to the pressures of urban expansion. Some islands in the St. Lawrence River have been spared, such as the Dowker Island, Iles-aux-Hérons, and Iles-des-Soeurs, as well as the islands in the Sorel-Tracy archipelago. Swamps in the latter area have been subject to stress, principally because of agricultural activities. Dowker Island is one of the most beautiful examples of swampland in the entire territory. More specific analyses of changes were performed for the metropolitan communities of Montréal and Quebec City, as well as for the Montérégie region. Since the 1990s, metropolitan Montréal and Quebec City have lost 6 and 7% of their wetlands respectively.⁸⁰ Between 1964 and 2006, the Montérégie region lost 2,800 ha, or 22%, of wetland of the area they occupied in 1964 (Table 6).⁸⁰ It should be noted that agricultural development and forest regrowth are responsible for 70 and 11% of wetland loss, respectively. The latter display a gradient of fragmentation similar to that of forests, a number that becomes greater as you move from west to east and reflects the amount of land used for agricultural purposes and urban expansion. In the Montérégie region, the average wetland area is 4 ha, with 86% of these wetlands under 5 ha. In the rest of the ecozone+, average wetland area is 8 ha, with 84% of wetlands under 5 ha.⁸⁰

Table 6. Distribution of wetland losses based on how the land was allocated in the Montérégie administrative region, 1964-2006.

<i>Allocation</i>	<i>Area (ha)</i>	<i>Proportion lost (%)</i>
Residential	92	3
Industrial	108	4
Agricultural	1,967	70
Forests	317	11
Transportation	18	1
Other	300	11

Source: Grenier and Allard, 2012⁸⁰

While an evaluation of wetland losses is not available for the rest of the ecozone+ due to a lack of reliable data, it is reasonable to believe that the rates of wetland disappearance for the whole ecozone+ are likely equivalent, or slightly below, the rates observed in Montérégie.

Tidal marshes

Both freshwater and saltwater tidal marshes are found in the Quebec portion of the ecozone+. The freshwater tidal marshes, which are almost continuous for 200 km (mostly along the south shore of St. Lawrence River) upstream and downstream of Quebec City, are the largest and some of the least polluted in North America and a very rare habitat worldwide.¹³⁶

Over 60 km² of riparian habitat along the St. Lawrence River was modified from 1945 to 1984.⁸⁴ Most changes occurred prior to the mid-1970s and were a result of draining and filling of open waters and wetlands for housing, roads, and agriculture. Some 360 ha were backfilled in favour of industrial development in the upstream section of the estuary, while harbour development and highway construction brought about the loss of 270 ha around Quebec City. At the downstream end of the estuary, more than 500 ha were lost to maritime facilities and agricultural activities.¹³⁸ Losses near major urban centres were the greatest;^{84, 85} for example, 83% of Montréal's wetlands were lost by 1976.⁸⁶ Construction of water control structures, including dams and the St. Lawrence Seaway (1954 to 1958), was also responsible for change in the late 1950s,⁸⁵ while urbanization was more important after that time.⁸⁶

Since the 1970s, the overall extent of wetlands has increased, although there is variability depending upon the type and location of the wetland (Figure 12).⁸⁴ While wetland loss continues due to urbanization (Montréal area) and agriculture (Lake Saint-Pierre), restoration efforts and reduced water levels have resulted in a 2.7% (603 ha) net gain of marshes and swamps between 1990 and 2002.⁸⁴ Gains were mainly in the fluvial and upper estuaries and occurred mainly at the expense of open water. Declining water levels in the 1990s may have accelerated the drying trend in some areas,^{84, 87} transforming low marshes to high marshes and swamps.

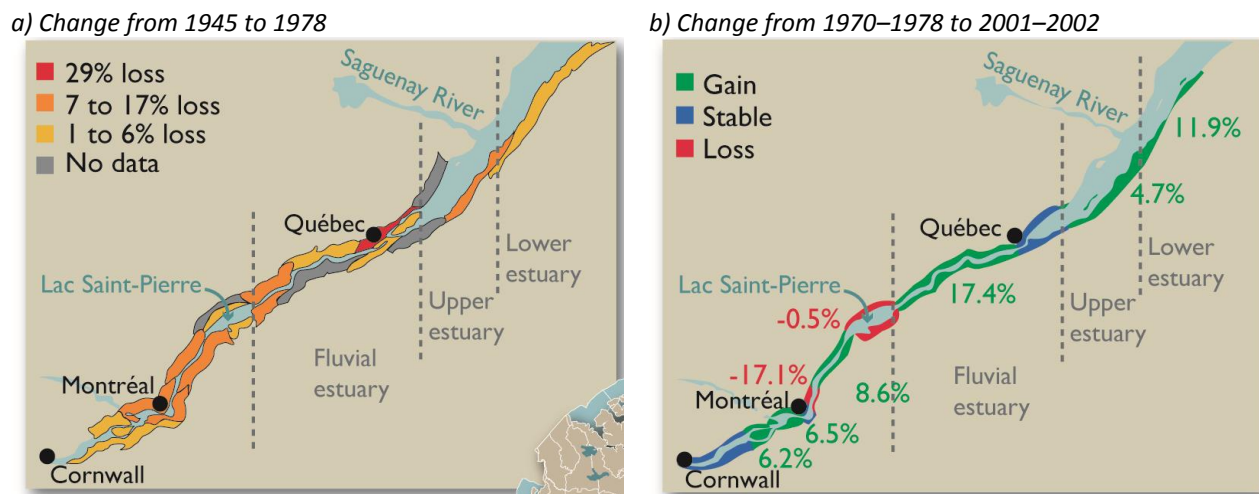


Figure 12. Percent change of wetland area by physiographic unit along the St. Lawrence River. Source: (a) adapted from Lehoux and Chamard, 2002;⁸⁵ (b) adapted from Jean and Létourneau, 2007⁹⁰

Considering the highly dynamic and harsh environmental conditions (e.g., strong tides, currents and waves, ice scouring) in the estuary, large variations in wetland surface area are to be expected from year to year, hence the importance to focus on permanent losses due to human activities. Some 27 ha of low marshes dominated by smooth (saltmarsh) cordgrass (*Spartina alterniflora*) have been lost to shore erosion and agriculture in the Kamouraska region.

Harsh tidal conditions (twice-daily tides as high as 6 m) have resulted in many specialized species, some of which are endemic species at risk such as the Victorin's gentian (*Gentianopsis virgata* ssp. *victorinii*) and the Victorin's water-hemlock (*Cicuta maculata* var. *victorinii*), while

others such as the rare Parker's pipewort (*Eriocaulon parkeri*) and eastern wild rice (*Zizania aquatica* var. *brevis*) are found in other estuaries of the east coast

The marshes become progressively more brackish downstream of the eastern point of Île d'Orléans (Orleans Island) until they eventually become true salt marshes, just east of Kamouraska at the extreme eastern tip of the ecozone⁺. These salt marshes are very rich and also are characterized by a unique assemblage of temperate, boreal, and even arctic species. American cordgrass species (*Spartina alterniflora*, *S. patens*, and *S. pectinata*) cohabit with circumpolar arctic species like Hoppner's sedge (*Carex subspathacea*), and boreal ampho-Atlantic (found on both sides of the Atlantic Ocean) species like chaffy sedge (*C. paleacea*), estuary sedge (*C. recta*), saltmarsh sedge (*C. salina*), and estuarine sedge (*C. vacillans*).¹³⁶

In 2000/01, exotic invasive plants comprised 14% of vascular plants in St. Lawrence River wetlands.⁸⁸ Their expansion can be attributed to shoreline alteration, excavation of the navigation channel, and water level regulation, which have reduced the magnitude of water level variation, decreased hydrodynamics in shallow littoral areas, and reduced the efficiency of the river to flush nutrients from sediments and to uproot emergent vegetation.⁸⁹

Although the number of exotic species is fairly stable along the St. Lawrence, their coverage varies, from 44 % in the Montréal sector to 6 to 10% in the fluvial and upper estuaries.⁸⁸ Flowering rush (*Butomus umbellatus*) is by far the most common invasive species in the marshes along with purple loosestrife (*Lythrum salicaria*), but the impact may not be as large as other invaders, such as common reed (*Phragmites australis*). For example, common reed can be considered rare but its cover is greater than 50% in 71% of the sites where it is found. In contrast, purple loosestrife may reach such coverage in only 9% of the numerous sites where it is found in the St. Lawrence marshlands.⁸⁸

Key Finding 4

Theme Biomes

Lakes and rivers

National key finding

Trends over the past 40 years influencing biodiversity in lakes and rivers include seasonal changes in magnitude of stream flows, increases in river and lake temperatures, decreases in lake levels, and habitat loss and fragmentation.

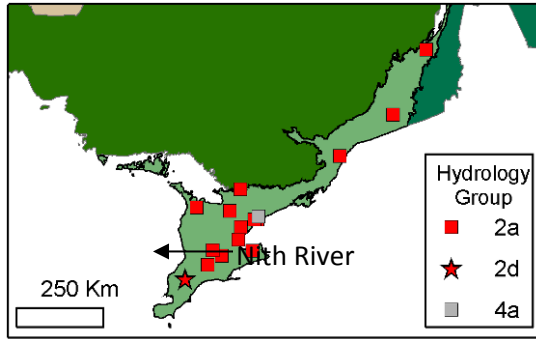
The Mixedwood Plains Ecozone⁺ includes portions of the St. Lawrence and Ottawa rivers plus several other large rivers and their watersheds, but excludes the waters of the Laurentian Great Lakes. Hundreds of lakes and thousands of kilometres of rivers make up approximately 3% of the total surface area of the Mixedwood Plains Ecozone⁺.⁹¹ The Mixedwood Plains is a human-dominated, heavily fragmented landscape. While agriculture dominates much of the land use in the ecozone⁺, the area is strongly affected by urban growth with several large cities and extensive urban land cover.^{92, 93} The combination of sedimentation and organic pollution from intensive agricultural operations,^{94, 95} fragmentation from dams,^{96, 97} introductions of aquatic

invasive species,^{98,99} and increasingly high proportions of impervious surfaces in urban areas¹⁰⁰ have contributed to highly stressed freshwater ecosystems.

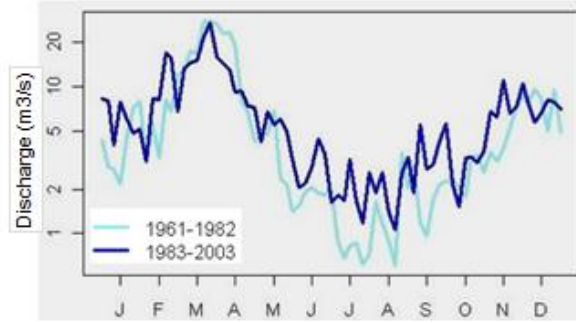
Streamflow

An analysis of changes in streamflow in rivers with minimal flow control or impact upstream was carried out for ESTR,¹⁰¹ updating results published in 2000 comparing 1976 to 1985 with 1986 to 1995.¹⁰² To facilitate the analysis of trends nationally, sites were organized into six groups with similar intra-seasonal patterns of flow (hydrology groups).

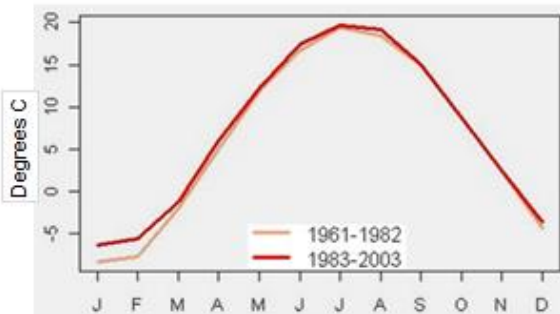
Between the periods 1961 to 1982 and 1983 to 2003, most streams in the Mixedwood Plains demonstrated a unique pattern for Canada showing an increased discharge throughout all seasons, except spring. During months with increased flows, there was an average 50% increase in discharge relative to the median for most stations. The majority of streamflows in the ecozone⁺ are driven by mixed rain and snow processes, with highest runoff occurring in the spring followed by low summer flows and then higher flows again in the fall. Snowmelt early in the year causes the spring peak while the higher fall flows are rain-induced.¹⁰¹ Climate variables associated with this group of streams exhibited warmer temperatures throughout most of the year, with wetter summers and falls. Figure 13 shows the location of the hydrometric stations used in the analysis and presents the change in streamflow between the time periods for the Nith River which exhibits change typical for this group of streams. It also shows the change in temperature and precipitation. Because this analysis was based on reference sites in streams and watersheds with little human alteration, observed changes through time are likely related to trends in temperature and precipitation.



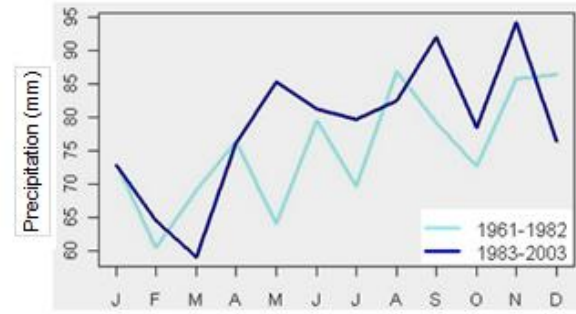
a) Stations in Mixedwood Plains



b) Streamflow change at Nith River



c) Temperature change at Nith River



d) Precipitation change at Nith River

Figure 13. Changes in streamflow, temperature, and precipitation between 1961–1982 and 1983–2003 for the Nith River in the Mixedwood Plains Ecozone⁺.

Hydrology groups represent clusters of rivers showing similar hydrologic responses to variations in climate. For information on the specific hydrology groups mentioned above, see Cannon et al. 2011.¹⁰¹ a) shows locations and hydrology groups of stations in the Mixedwood Plains, including the Nith River; b) shows streamflow change in Nith River, representative of Hydrology Group 2a; c) shows changes in temperature for the Nith River; and d) shows changes in precipitation for the Nith River.

Source: Cannon et al., 2011¹⁰¹

Although there has been no comprehensive analysis on trends in hydrology of human-impacted streams across the ecozone⁺, the hydrology of most major river systems in the Mixedwood Plains has been altered by common stresses such as riparian zone destruction, barriers (dams), drainage, and channelization, all the result of agricultural development and urbanization of watersheds.¹⁰³⁻¹⁰⁵ Evidence from the Ontario portion of the ecozone⁺ has shown that reforestation since the 1950s has resulted in improved base flows, reduced peak flows, and stability of channel form for some river systems (e.g., Buttle 1994¹⁰⁶ and 1995¹⁰⁷).

Water temperatures

Morris and Corkum (1996)¹⁰⁸ have shown that loss of riparian cover on streams in agricultural areas of the Ontario portion of the Mixedwood Plains resulted in increased mean monthly water temperatures, increased daily temperature fluctuations, and increased nutrient inputs.

Increased water temperatures, due to on-line ponds and deforestation, are also a major stress on the cold-water streams draining into Lake Ontario¹⁰⁵ and in many other watersheds

(e.g., GRFMPIC, 2005¹⁰³; OMNR and TRCA, 2005¹⁰⁴). Despite recent improvements in riparian condition in some watersheds, undisturbed reaches with more pristine habitat conditions tend to be restricted to headwater areas. Historically, many of these cold-water habitats extended substantially further down the watershed.¹⁰⁵ In contrast, some river systems have had reservoirs with hypolimnetic releases, artificially cooling downstream reaches and altering the fish and benthic community (e.g., Bellwood Reservoir, Grand River).^{109, 110}

Over the past 30 to 40 years, increased water temperatures have been observed for lakes of the Mixedwood Plains (e.g., Robillard and Fox, 2006¹¹¹). This warming trend has also been demonstrated with longer ice-free seasons and earlier spring breakup dates for lakes during a similar period.¹¹²

Water levels

Historic canal construction (e.g., Rideau Canal, Trent–Severn Waterway) has altered water levels and trophic status in many large rivers and lakes of the Mixedwood Plains.^{113, 114} For example, water level in Upper Rideau Lake was raised 1.5 m during canal construction.¹¹³ Both cold- and warm-water streams have undergone fragmentation, habitat alteration, declines in water quality, and altered water levels due to water control structures, small relic milldams, and recreational on-stream ponds.^{103, 104} Such barriers are extensive throughout the ecozone⁺. The natural flow regimes of the Ottawa and St. Lawrence rivers have also been greatly altered through the construction of dams for water level regulation and power generation over the past 130 years.^{96, 115} In a global study, Nilsson *et al.*¹¹⁶ found that large river systems across the Mixedwood Plains (and elsewhere) are strongly affected by dam-caused river fragmentation and flow regulation.

Aquatic biodiversity

The Mixedwood Plains Ecozone⁺ supports the highest freshwater fish biodiversity in Canada,¹¹⁷ representing 97% of the total number of taxa for Ontario, 86% of the total for Quebec, and 78% of the total for Canada. The ecozone⁺ also has the most diverse freshwater mussel fauna in Canada (41 species of out of total of 55 species in Canada).¹¹⁸

Fish and other aquatic communities are changing in response to changes in aquatic habitats throughout the ecozone⁺. Major stressors include eutrophication of cold-water lakes, changes in the productivity of warm-water lake habitats (see Nutrient loading and algal blooms), altered flows, habitat fragmentation, siltation and nutrient enrichment, contaminants, and impoundments in rivers and streams.^{103, 115, 119, 120}

A typical pattern of fish community change in flowing systems of the Mixedwood Plains has been a contraction of cold-water species ranges toward the headwaters while warm-water species have expanded their ranges upstream in the systems (e.g., Mahon *et al.*¹²¹). Brook trout (*Salvelinus fontinalis*) was historically the top predator in many shallow headwater lake/cold-water stream systems and are now largely restricted to headwater areas.^{104, 122-126} In addition to having more suitable cold-water habitats, these headwater areas are largely isolated from introduced migratory salmonines (e.g., Atlantic salmon *Salmo salar*, brown trout *Salmo trutta*).

Patterns of fish species dominance in lakes in the ecozone⁺ have also changed from historical distributions in response to stressors such as unauthorized and unintentional introductions (e.g., rock bass *Ambloplites rupestris*, zebra mussels *Dreissena polymorpha*, round gobies *Neogobius melanostomus*) and movements between once isolated watersheds.¹⁰⁵ For example, native fish communities of the Crowe River watershed differed from those of the Kawartha Lakes prior to the building of the Trent–Severn Waterway, but a change in water levels allowed movement of fish between these two systems and homogenized the fish communities over the last 150 years. Lakes in close proximity to these, but not connected to the Waterway (e.g., Dalrymple and Head lakes) still maintain fish community differences.¹⁰⁵

Freshwater biodiversity is at greatest risk throughout the more human-dominated watersheds of the ecozone⁺, reflecting degraded habitat and water quality. Loss of riparian areas, disconnection of rivers from their floodplains, habitat fragmentation, and increased urban and agricultural development within watersheds have contributed significantly to loss of freshwater biodiversity.¹²⁷⁻¹³⁰

Of the 131 fish taxa native to the ecozone⁺, 36 are of conservation concern, which is more than any other vertebrate group within the ecozone⁺.¹³¹ Several recovery strategies are being implemented that aim to rehabilitate the aquatic habitats upon which these species depend.

Metcalfe-Smith *et al.* (1998)¹³² documented a reduction in freshwater mussel diversity and a shift in community dominance over the last 140 years. A number of studies have documented population declines and a reduction in the ranges of species.^{120, 133, 134} Of the 41 species of freshwater mussels found in the Mixedwood Plains, 10 species have been assessed as Endangered and one species as Special Concern by the Committee on the Status of Endangered Wildlife in Canada (COSEWIC).

A number of efforts are underway to assist in the recovery of freshwater mussels in the Mixedwood Plains. Ecosystem-based recovery strategies have been developed for a number of systems. Metcalfe-Smith *et al.* (2000)¹³⁵ found that mussel populations in the Grand River had recovered from historic lows in the 1970s. The number of species throughout the system increased from 17 to 25 between the early 1970s and the late 1990s, while in the lower reaches of the mainstem, the number of species increased from 6 to 21. The increased number of species in the system was attributed to improved water quality over the past two to three decades.

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.

Tidal marshes are presented under the Wetlands key finding.

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.

Evidence from Ontario – lake and river ice

The formation and break-up of ice are important seasonal events in mid- to high-altitude lakes and rivers.¹³⁹ Changes in the timing of these events can have important impacts on aquatic communities. Ice cover limits the amount of the sun's energy that enters the water, decreases the amount of evaporation, and decreases the amount of time in which lakes and rivers are a source of greenhouse gases.¹⁴⁰ Ice cover affects both the flora and fauna within aquatic ecosystems.¹⁴¹ The effects of ice also reach beyond the water's edge as ice scouring of shorelines impacts the species living in riparian areas, while the flooding caused by ice jams as well as normal spring flooding as ice and snow are melting have a great impact on soils and thus the species living in flood plains and riparian areas.¹⁴² Generally, smaller lakes freeze earlier than large ones and deeper lakes freeze later than shallow lakes (due to the specific heat of water). Lakes that are able to warm more in the ice free season (clear lakes) will freeze later than lakes with cooler temperatures. Lakes further down a watershed often break up earlier than headwater lakes, perhaps due to increased flow from snowmelt higher in the catchment.¹¹²

The earliest data on ice break-up within the Mixedwood Plains Ecozone⁺ comes from Toronto Harbour, where data collection began in 1822¹⁴³, and Lake Simcoe, where data collection began in 1853.¹¹² When the data from Lake Simcoe was divided into time periods, it was found that the time period associated with the end of the Little Ice Age (1853–1899) showed a statistically

significant trend indicative of warming temperature in both ice break-up and length of the ice free season. The period from 1950 to 1995 also showed evidence of warming temperatures, while the time period between 1900 and 1949 showed a cooling trend.¹¹² When the entire time period was examined together (1853 to 2001) for the 46 lakes studied in southern Ontario, a significant trend towards earlier break-up dates and longer ice-free seasons was observed.¹¹² When the average rates of change in freezing and break-up were compared between the more recent period of rapid climate warming (1975 to 2004) and historical rates observed within the northern hemisphere, it was found that in the Great Lakes region of both Canada and the United States, freeze-up was occurring 3.3 days later per decade and break-up 2.1 days earlier per decade, while the average ice duration decreased by 5.3 days per decade.¹³⁹

The annual cycle of ice formation and loss on the Great Lakes affects physical processes within the lakes and in the adjacent atmospheric boundary layer, which in turn affect both the economy and the ecology of the Great Lakes region¹⁴¹ within the Mixedwood Plains. When the severity of ice cycles on the Great Lakes was examined for 1973 to 2002, it was found that about half of the mild ice cycles (late first ice, early last ice, and shorter ice duration) occurred in the last five years of the 30-year study period (1998 to 2002) while over half of the severe ice cycles occurred in the first 10 years of the study period (1977 to 1982).¹⁴¹

Percentage cover of ice on the Great Lakes decreased between 1973 and 2008 (Figure 14).¹⁴² Since 1970, there has been a decline of about 40% in ice cover on lakes Michigan and Ontario, while ice cover on Lake Superior decreased by about 35%, on Lake Erie by 19%, and on Lake Huron by 18% (Table 7). Seasonal average ice cover is usually greater on Lake Superior (due to its cooler more northerly location), Erie, and Huron (due to shallower depths) than on lakes Michigan and Ontario (which though more southerly than Superior are relatively deep).

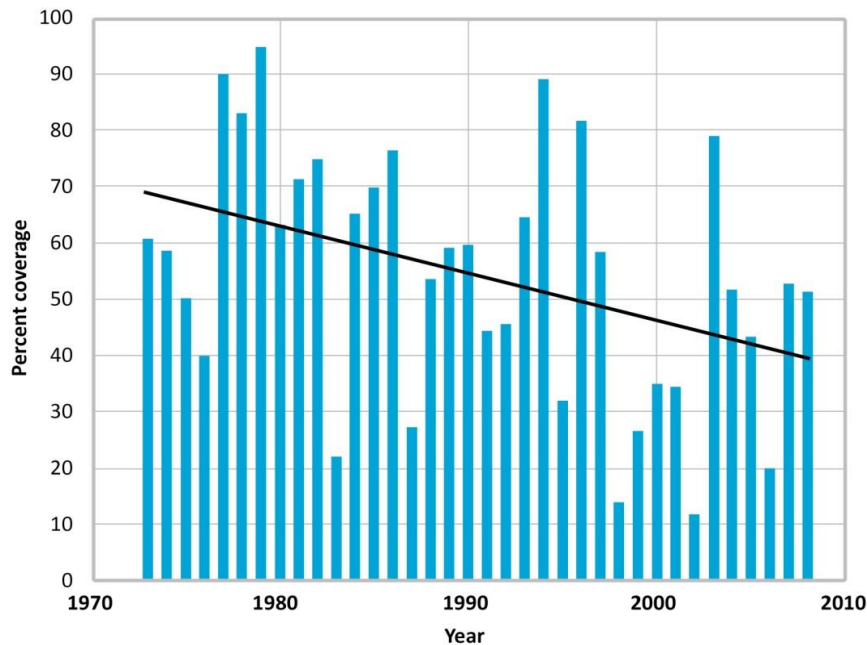


Figure 14. Changes in seasonal percentage maximum ice cover on the Great Lakes, 1973–2008.

Source: Karl et al., 2009;¹⁴⁴ updated from Assel et al., 2003¹⁴⁵ using data from the National Oceanic and Atmospheric Administration

Table 7. Mean maximum ice coverage (in %) on the Great Lakes by decade, 1970s to 2000s.

Lake	1970–1979	1980–1989	1990–1999	2000–2008	% change (1970–2008)
Erie	94.5	90.8	77.3	76.4	-19.2
Huron	71.3	71.7	61.3	58.7	-17.7
Michigan	50.2	45.6	32.4	28.4	-43.4
Ontario	39.8	29.7	28.1	23.9	-39.9
Superior	74.5	73.9	62.0	48.0	-35.6

Source: Ontario Biodiversity Council, 2010¹⁴⁶ – updated from SOLEC, 2009¹⁴⁷, using data from the Canadian Ice Service Seasonal Summaries for the Great Lakes (2000–2008)¹⁴⁸

The changes in ice cover since the 1970s may be connected to changes in the large-scale atmospheric and oceanic oscillations that influence the climate of the Mixedwood Plains. Links have been made between changes in the ENSO (El Niño/southern Oscillation) and changes in winter temperatures.¹⁴⁹ When Great Lakes ice records were examined between 1963 and 1990,¹⁵⁰ a relatively strong tendency for below average ice cover (46% of the lowest annual maximum ice) was found associated with warm El Niño winters. Since the mid-1970s, there has been a shift toward more prolonged and intense El Niño episodes.¹⁴⁹

The breeding success of many cold-water fish species is directly linked to the thermal conditions of the water body they live in. When studied in semi-controlled and laboratory conditions, breeding success of lake whitefish (*Coregonus clupeaformis*), a cold-water fish, was found to be inversely related to thermal conditions.¹⁵¹ Also, water temperatures directly determine when and how much ice forms. In a field study, the late falls and winters of 2003/04 and 2004/05 were cold with extensive ice cover in eastern Lake Ontario.¹⁵² Those spawning seasons were followed by abundant lake whitefish larvae in Chaumont Bay in 2004/05. In contrast, the winters of 2005/06 and 2006/07 were mild and with relatively little ice cover and the subsequent lake whitefish larval populations were low.¹⁵² The breeding success of lake trout (*Salvelinus namaycush*) is similarly impacted. When lake trout hatchling survival was examined in association with water temperature and time of hatch, warmer temperatures were associated with pre-mature hatch, early yolk absorption, and death while colder water temperatures were associated with slow development, later hatch, and high survivorship (Figure 15).¹⁵³ Loss of ice cover appears to be indicative of negative effects on these and other cold-water species.

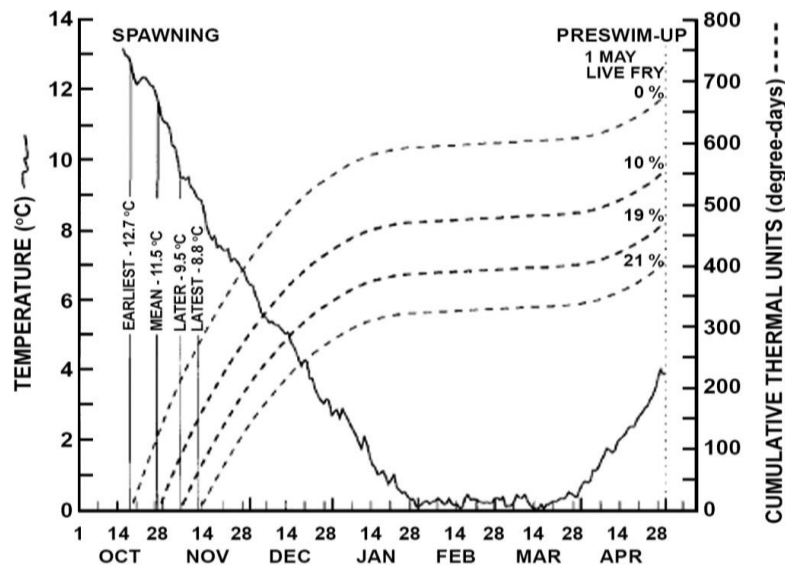


Figure 15. Mean daily water temperatures associated with lake trout spawning at Yorkshire Bar, eastern Lake Ontario, 1989–1993.

The mean daily water temperatures were taken at the surface of the boulder-cobble substrate (4.5 m) where the incubators were located on Yorkshire Bar from the beginning of the spawning period to the end of April the following spring. The months are delineated by long, dark ticks; shorter, lighter ticks mark 7-day intervals. Includes the beginning and end of the in situ incubation period. Mean daily water temperatures associated with the lake trout spawning period in eastern Lake Ontario are delineated by vertical solid lines falling on the appropriate dates: earliest, highest temperature; mean; later, lower temperature – 9.5°C; latest, lowest temperature. The dates when these temperatures are reached mark potentially important times when incubation would begin for naturally deposited and fertilized lake trout eggs in eastern Lake Ontario. Curves (dashes) illustrate the cumulative thermal units commencing on the respective dates (19 October, 29 October, 7 November, and 13 November). Percent survival to the pre-swim-up stage, extrapolated from these dates to 1 May (vertical dotted line), is also shown.

Source: Casselman, 1995¹⁵³

Warmer temperatures create thin nearshore ice cover which is easily broken up and pushed by offshore winds resulting in ice piling and loss of habitat for invertebrate species.¹⁵⁴ Such an occurrence is reported for Lake Ontario where in March of 1986, ice on Lake Ontario at Kingston weakened in rapidly warming air temperatures (17°C) and offshore winds combined to create ice piling along the shoreline to a height of 2.5 m. Stones from the shoreline weighing up to 206 kg were moved to the top of the ice pile.¹⁵⁵ A study of invertebrate habitat use in Lake Huron coastal wetlands showed that nearshore invertebrate community structure differed between areas experiencing wave exposure and those in protected locations.¹⁵⁶

The amount of ice free area on the Great Lakes has a large impact on the amount of “lake effect” snow experienced in the snow belts around the Great Lakes. In a study of snowfall data from 1925 to 2007 for the Great Lakes area, an upward trend in snowfall was found in both the Superior and Michigan snowbelt areas.¹⁵⁷ There were also upward trends in air temperature for Lakes Superior and Michigan which suggest that warmer surface waters and decreased ice cover are contributing to the upward snowfall trends by enhancing lake heat and moisture fluxes during cold air outbreaks.¹⁵⁷

One of a few positive changes that may occur due to decreased ice cover on lakes is a decrease in winterkill (death of fish due to oxygen depletion under ice). When the impacts of decreased ice cover on eutrophic lakes less than 40 m deep were modeled for the northern United States (adjacent to the Mixedwood Plains), based on a 2 X CO₂ scenario, winterkill was projected to disappear from all these lakes as under-ice dissolved oxygen levels will no longer reach anoxic conditions.¹⁵⁸

Ecozone⁺-specific key finding

Theme Biomes

Dunes

Coastal dunes on the Great Lakes

Freshwater coastal dunes are open sand ecosystems located predominantly along the shorelines of the Great Lakes (Figure 16). They are considered to be among some of the most fragile ecosystems found in North America.¹⁵⁹ They include both areas of exposed sand as well as areas stabilized by grasses, herbs, and shrubs. Trees may occur as scattered individuals or as small patches. As coastal dunes are narrow, linear features restricted to major lake and river shorelines, their total area in the Mixedwood Plains is quite small. Major dune systems are found on the Canadian Great Lakes at Sauble Beach, Carter Bay, Pinery Provincial Park, Great Duck Island, and Wasaga Beach on Lake Huron, Point Pelee National Park, Long Point, and Point Abino on Lake Erie, and at Sandbanks and Presqu'île Provincial Parks on Lake Ontario. Dunes are also found along the Ottawa River¹⁶⁰ at Westmeath (Constance Bay no longer has areas of open dunes, although there were dunes in this area historically).

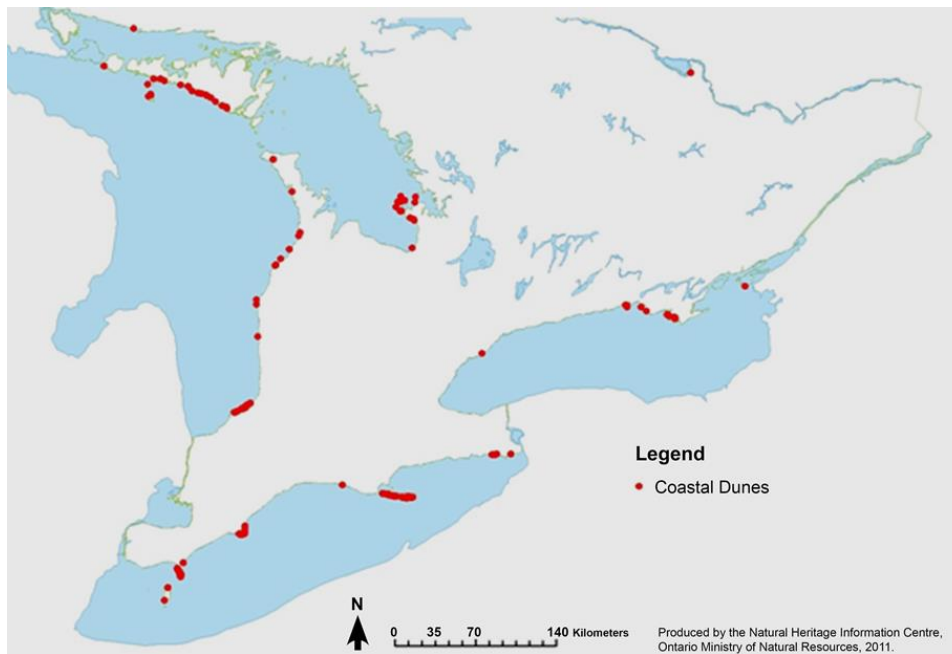


Figure 16. Coastal dunes of the Ontario portion of the Mixedwood Plains Ecozone⁺. Source: Natural Heritage Information Centre, 2011⁴⁷

Open dune ecosystems are provincially rare¹⁶¹ and home to many rare plant species, such as little bluestem (*Schizachyrium scoparium*), big bluestem (*Andropogon gerardii*), puccoon (*Lithospermum caroliniense*), fringed puccoon (*Lithospermum incisum*), indian grass (*Sorghastrum nutans*), and Canada wild rye (*Elymus canadensis*). Pitcher's thistle (*Cirsium pitcheri*) and long-leaved reed grass (*Calamovilfa longifolia* var. *magna*) are also found in these ecosystems and both are endemic to the Great Lakes. At least 24 other provincially rare plant species are known to occur in the coastal dunes of the ecozone⁺.¹⁶²

The endangered piping plover (*Charadrius melodus*) historically nested in the coastal dune areas of Great Lakes but was entirely missing from the Ontario portion of the ecozone⁺ by 1976.⁴⁵ The plover started to return in 1993. In a study examining breeding success between 1993 and 2008,¹⁶³ it was found that predation by merlins (*Falco columbarius*), another species once depleted in number and making a comeback, was responsible for most of the nest abandonment. Abandonment amounted to 5.7% of the marked plover population.

There are also many rare insects found in coastal dunes, including species of tiger beetles, grasshoppers, butterflies, and moths. Some, such as the Lake Huron locust (*Trimerotropis huroniana*), are globally rare.⁴⁵

Coastal dunes are very fragile ecosystems which can be easily disturbed by both human and natural forces. As few as 200 dune crossings by hikers can kill dune vegetation.^{159, 164} Shoreline hardening and the creation of groins, breakwalls, and piers which change the natural erosion and deposition of sand by water currents negatively impact dunes.^{165, 166} Heat from bonfires on dunes kills the roots of adjacent plants.¹⁶⁷ The lowering of lake levels and reduction in groundwater supplies that are predicted with climate change¹⁶⁸ will have negative impacts on dune ecosystems. Development pressure is expected to continue along the shorelines of the Great Lakes.¹⁶⁵

THEME: HUMAN/ECOSYSTEM INTERACTIONS

Key Finding 8

Theme Human/ecosystem interactions

Protected areas

National key finding

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

An analysis of protected areas in the Mixedwood Plains was conducted for ESTR using data from the Conservation Areas Reporting and Tracking System (CARTS) and the ecozone⁺ boundaries⁶ established for use in the project.¹⁶⁹ The CARTS database, maintained by the Canadian Council on Ecological Areas (CCEA), houses data on protected areas in Canada categorized using standardized categories developed by the International Union for the

Conservation of Nature (IUCN). The categories refer to the primary management objective of the protected area.

Prior to 1992 (the signing of the Convention on Biological Diversity), 0.7% of the ecozone⁺ was protected. By May 2009, protected areas in the Mixedwood Plains Ecozone⁺ covered 1.6%ⁱ of the landbase (**Error! Reference source not found.**) and totalled 1,887 km² (Figure 18), including¹⁷⁰:

- 843 km² in 172 protected areas (0.7% of the ecozone⁺) classified as IUCN categories I-IV, categories that include nature reserves, wilderness areas, and other parks and reserves managed for conservation of ecosystems and natural and cultural features, as well as those managed mainly for habitat and wildlife conservation;
- 1,044 km² in 283 protected areas (3.3% of the ecozone⁺) classified as IUCN categories VI, a category that focuses on sustainable use by established cultural tradition; and
- 0.16 km² in 12 protected areas (all established since 2000; <0.01% of the ecozone⁺) not classified by IUCN category.

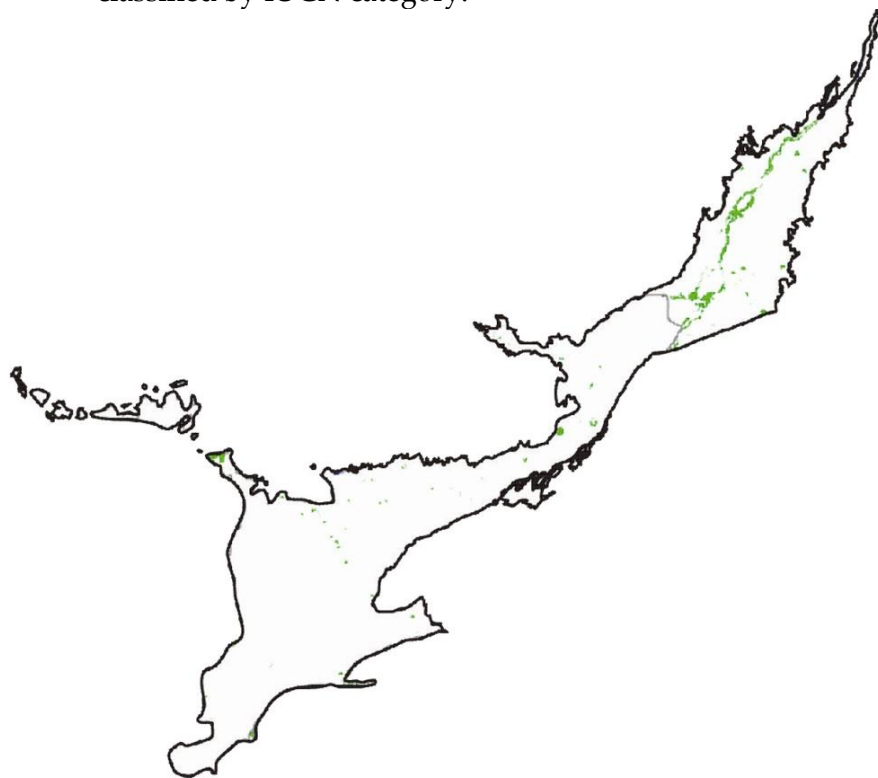


Figure 17. Distribution of protected areas in the Mixedwood Plains Ecozone⁺, May 2009.

Source: Environment Canada, 2009¹⁷¹ using data from the Conservation Areas Reporting and Tracking System (CARTS), v.2009.05, 2009;¹⁷² data provided by federal, provincial, and territorial jurisdictions

ⁱ An analysis by the Province of Ontario found that 1.8% of the ecozone was protected as of May 2009. Reasons for the discrepancy between this analysis and the ESTR analysis are not entirely known but likely reflect differing interpretations of the boundary of the Mixedwood Plains Ecozone⁺ by the federal and provincial governments. Regardless, both numbers show that the amount of protected areas in the Mixedwood Plains Ecozone⁺ is low relative to other ecozones⁺ in Canada and the Convention on Biological Diversity's target to protect 10% for each of the world's ecological regions.

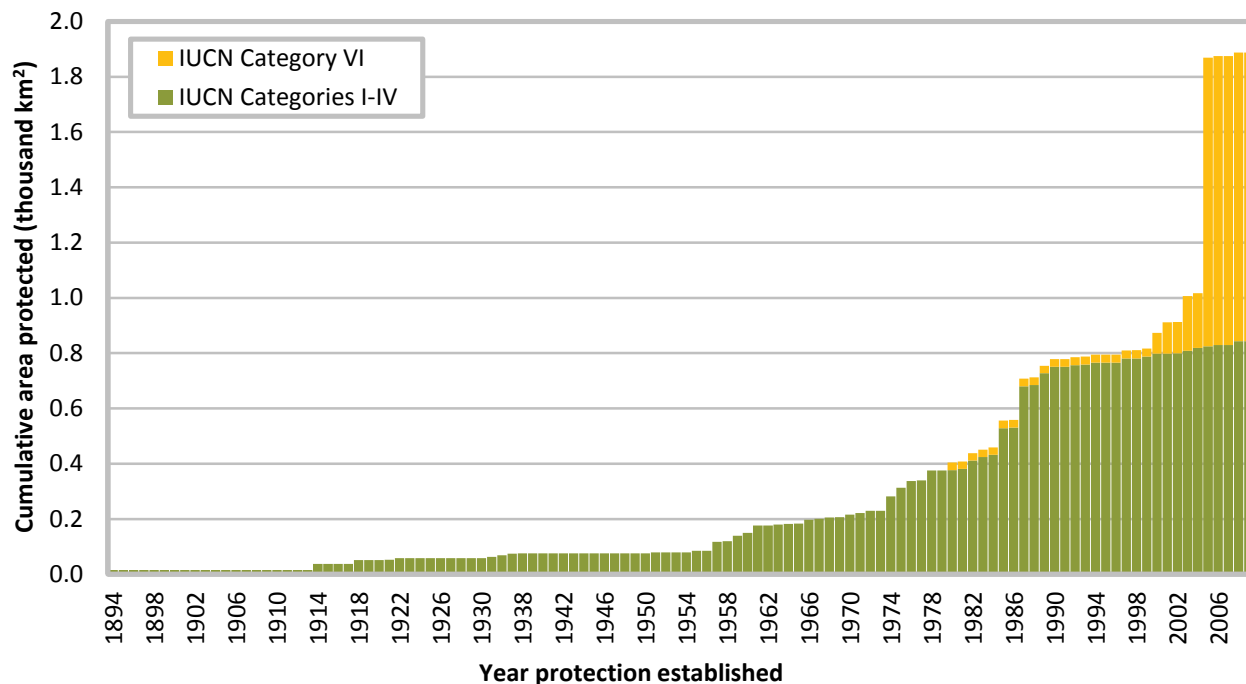


Figure 18. Growth of protected areas in the Mixedwood Plains Ecozone⁺, 1984–2009. Data provided by federal and provincial jurisdictions, updated to May 2009. Only legally protected areas are included. IUCN (International Union for Conservation of Nature) categories of protected areas are based on primary management objectives (see text for more information). Source: Environment Canada, 2009¹⁷¹ using data from the Conservation Areas Reporting and Tracking System (CARTS), v.2009.05, 2009¹⁷² data provided by federal and provincial jurisdictions

Based on the CARTS data, the amount of protected area in the Mixedwood Plains is the lowest of any of the terrestrial ecozone⁺ in Canada and well below the Convention on Biological Diversity’s target to protect 10% of each of the world’s ecological regions.

Because the Mixedwood Plains Ecozone⁺ is predominately a private land base with few government lands available for protection, growth in traditionally designated protected areas has been very difficult. Other regulatory approaches have and continue to be used to provide protection for lands significant to biodiversity conservation.¹⁷³ Protection is achieved through a number of designations and mechanisms with varying degrees of protection (see Evidence from Ontario and Evidence from Quebec sections below).

Evidence from Ontario

In the Ontario portion of the Mixedwood Plains, only those protected areas which are IUCN categories I–III have been categorized and submitted to the CARTS database. This means there are a large number of protected areas in Ontario which have not been classified which would likely be members of the IUCN categories IV–VI. Consequently, the number of protected areas for the Ontario portion of the ecozone⁺ is currently underestimated. (In contrast, in Quebec, all protected areas have been assigned an IUCN category.)

Historically, the first protected area within the Ontario portion of the Ecozone⁺ was Queen Victoria Niagara Falls Park established in 1887. The second oldest provincial park in Ontario, and the oldest in the Ontario portion of the ecozone⁺ is Rondeau Provincial Park which was established in 1894 on the north shore of Lake Erie. Growth of regulated protected areas has been slow and large gaps in representation or biodiversity protection still remain. The rate of protection started to increase in Ontario in the late 1960s and continued into the 1970s. Funding during this time period came from two sources: the Federal Agricultural and Rehabilitation (later Rural) Development Act (ARDA) and the Canada-Ontario Rideau-Trent-Severn (CORTS) committee (Killan 1993). Under ARDA, between 1967 and 1975, the federal government provided financial assistance, on a cost-sharing basis, to assist in underwriting the purchase and start-up costs of new provincial parks in economically depressed and declining rural areasⁱⁱ (Killan 1993). In 1975, the federal and Ontario governments accepted the CORTS committee's recommendations of acquiring both extended use and day-use parks along the Rideau and Trent Severn waterways. Most of the land acquisition undertaken along the Rideau system was expansion of existing parks and park reserves. The second major increase in the amount of protected areas in Ontario came in response to the Strategic Land Use Planning Program (SLUP) and the associated District Land Use Guidelines (DLUG) which were written between 1980 and 1983 (Killan 1993). The SLUP and DLUG programs were large scale planning efforts to accommodate the competing interests (e.g., forestry, tourism, protected areas, mining) on Ontario's Crown lands. Once the decisions were made in the SLUP and DLUG programs, approximately 26 new provincial parks or park additions were created in the Ontario portion of the ecozone between 1983 and 1989ⁱⁱⁱ.

A summary of key designations and mechanisms with their corresponding policy and level of protection are noted in Table 8 and described in further detail below.

ⁱⁱ Carillon, Charleston Lake, Awenda, and McRae Point Provincial Parks were created under ARDA.

ⁱⁱⁱ Black Creek, Fish Point, Komoka, Bass Lake, Cabot Head, Stoco Fen, James N. Allan and many other provincial parks were created (OMNR 1983)

Table 8. Ontario portion of the Mixedwood Plains Ecozone's diversity of protected areas related to legislation and general IUCN Classification^{iv}.

Designation/Mechanism	Legislation or Key Policy	Protection/ IUCN Classification
Federal and Provincial Sites		
National Parks ^{*v}	Canada National Parks Act (2000)	Fully Protected – IUCN II
Provincial Parks *	Provincial Parks and Conservation Reserves Act (2006)	Fully Protected – Nature Reserve – IUCN Ia; Natural Environment, Waterway and Recreation classes – IUCN II; Cultural Heritage IUCN III
Conservation Reserves*	Provincial Parks and Conservation Reserves Act (2006)	Fully Protected – IUCN II
Wilderness Area*	Wilderness Areas Act (1959)	Fully Protected for WA in MWP Ecozone is less than 260 ha – IUCN III
National Wildlife Areas*	Canada Wildlife Act 1994	Fully Protected - IUCN variable Ia; Ib; II; III or IV
Migratory Bird Sanctuaries*	Migratory Bird Convention Act (1994)	Fully Protected only if located within regulated designations such as National Wildlife Areas. If this is the case their IUCN classification can vary among IUCN categories Ia; II; III or IV.
Provincial Wildlife Management Areas	Fish and Wildlife Conservation Act (1997)	Fully Protected if in regulation – IUCN IV or V
National Historic Sites	Historic Sites and Monuments Act (1985) and the Canada National Parks Act (2000)	Fully protected – IUCN III
National Capital Commission's Greenbelt	National Capital Act	Fully protected within the Greenbelt are Core Natural Areas (IUCN Ia), Natural Area Buffers (IUCN II) and Natural Area Links (IUCN II).
Selected Provincial-Municipal Designations and Mechanisms		
Conservation Authority Lands	Conservation Authorities Act 1990	Fully protected for those lands within CA properties that are managed to protect biodiversity – IUCN variable from Ia; II; III or IV.
Provincially Significant Wetlands	Provincial Policy Statement	Fully protected under policy – IUCN Ia; III or IV
Areas of Natural and Scientific Interest (ANSI)	Provincial Policy Statement	Partially protected under policy for development and site alteration can occur. If fully protected under Official Plans IUCN 1a or III. Fully protected if a component of another protected designation e.g. provincial park.
Environmentally Sensitive Areas; Community Forests and/or other areas.	As defined in a municipal Official Plan or in a MNR plan or Conservation Authority plan	Too variable to provide level of protection or IUCN category. Site by site assessments would be required.

^{iv} IUCN follows Gray et al., 2009 and CARTs v.2009.05. Note within IUCN categories level of protection varies from fully to partially protect depending on the policies in place.

^v Denotes protected area classification present in the CARTS v.2009.05 database.

Federal and provincial sites

Within Ontario, regulated protected areas include national and provincial parks, conservation reserves, and wilderness areas. National parks (3) are a federal designation under the National Parks Act (2000) and represent 17,820 ha. The key provincial designations are provincial parks^{vi} (45,597 ha) and conservation reserves (2,632 ha), both designated under the Provincial Parks and Conservation Reserves Act (2006). Wilderness areas designated under the Wilderness Areas Act (1959) are considered fully protected with only one site (39 ha) of ten occurring outside existing provincial parks^{vii}. This suite of protected areas represents 66,088 ha or 0.7% of the ecozone^{viii} and fall within the IUCN categories Ia, II, or III.

A number of additional federal and provincial designations (2) and one conservation mechanism are dedicated to species and species population management within the ecozone⁺. Federally, National Wildlife Areas (NWAs) make up 5,143 ha with federal Migratory Bird Sanctuaries (MBSs) contributing another 5,026 hectares. Adding provincial Wildlife Management Areas (25,826 ha) (WMAs) results in a grand total of 35,995 ha, or 0.4%, of the ecozone⁺ for this general class of protected areas. Wildlife Management Areas are mechanisms for conservation of species, habitats and ecosystems. They provide full or partial protection via the Fish and Wildlife Conservation Act (1997) via land use planning direction on Crown land or via landowner agreements on private lands. Some WMAs have been captured within Conservation Authority lands or provincial parks and are subject to specific legislation and planning. National Wildlife Areas may qualify as IUCN category Ia, Ib, II, III, or IV and provincial WMAs as IUCN categories IV or V. MBSs qualify as an IUCN category only when part of a NWA.

Federal cultural/ historic areas such as National Historic Sites include the Trent-Severn waterway and the Rideau Canal (a UNESCO World Heritage Site). The majority of these are within the Mixedwood Plains Ecozone⁺ and contribute additional fully protected lands that make up to 0.01% of the ecozone. IUCN protected area classification is still not known for these heritage sites; however, depending on achievement of IUCN criteria and evaluation they may qualify as IUCN Category III protected areas.

Finally, National Capital Commission lands (about 10,000 ha) provide further direction for the management of biodiversity by including local and regional ecosystems within a 20,000 ha greenbelt. The National Capital Commission's greenbelt provides for partial and fully protected natural areas depending on the zone discussed. Three zones within the greenbelt—Core Natural Areas, Natural Area Buffers, and Natural Area Links—would qualify as fully protected. Some additional consideration in recognizing the entire greenbelt as an IUCN Category V may be warranted (Gray *et al.*, 2009).

^{vi} Total summary provided by MNR's State of Ontario's Protected Areas Report. Data presented includes cultural heritage, natural environment, nature reserve, waterway and recreational provincial parks with some protected areas overlapping ecozone boundaries.

^{vii} P. Kor, pers. comm. July 22, 2010 and SOPAR 2011.

^{viii} For this summary Ecozone means Ontario portion only.

Provincial-municipal designation and mechanisms

Other provincial and municipal site specific natural heritage area designations and conservation mechanisms include provincially significant Areas of Natural and Scientific Interest (ANSIs), Provincially Significant Wetlands (PSWs), significant woodlands, Conservation Authority (CA) Properties, Environmentally Sensitive Areas (ESAs), and community/municipal forests and open space lands that are managed for conservation. This group of natural heritage areas is very diverse in its level of protection ranging from full to partial protection, which is achieved through several interrelated and often complementary protection mechanisms. For example, MNR identifies (or confirms) whether wetlands are provincially significant (PSW) while protection may be afforded by a conservation authority regulation and a municipality designating the PSW in its Official Plan for protection. Other mechanisms such as zoning by-laws and site alteration by-laws may need to be in place to implement official plan policies and control land use. Ontario provides policy direction on land use planning for natural heritage interests (amongst a range of provincial interests) through the Provincial Policy Statement issued under the Planning Act. ANSIs, PSW, and CA properties include both full and partial protection. If fully protected they would be classified as IUCN 1a or III (ANSIs), 1a, II, or IV (PSW), and 1a, II, III, and IV (CA), but a site by site assessment is lacking and the level of custodial protection management is not uniform throughout the ecozone⁺. Private land adds an additional complication for these designations for private land features are not protected in perpetuity – so they are at risk of being lost over the medium to long term. Total hectares involved for identified ANSIs, PSWs, and CA properties approaches 900,000 ha, or 10.5%, of the ecozone⁺. Finally the Provincial Policy Statement provides municipalities an opportunity to recognize natural heritage systems (e.g., core natural heritage areas with linkages) within their planning processes and products. To date, identifying and protecting National Historic Sites in municipal Official Plans is still a rather new concept and requires a more concerned effort across the ecozone⁺ than has occurred in the past.

IUCN classification for ESAs, community forests, or partially protected areas is unknown with identification determined on a case-by-case basis. For example, ESAs encompass such designations as ANSIs but could also involve areas of local interest as well (e.g., bird nesting areas, deer wintering yards, recharge areas). The level of protection is determined by the policies within Official Plans and via restrictions in zoning by-laws that only apply when approvals under the Planning Act are being sought; therefore protection varies greatly across the ecozone⁺. To identify and maintain a certain IUCN level of protection, periodic site assessments of values and policies would have to occur as well as enhanced commitments to protection by landowners and governments.

Landscape-scale mechanisms

Previously discussed protection designations and mechanisms are enhanced through provincial direction captured in specific geographies that work at a landscape level. Land use plans such as the Greenbelt Plan (covering 728,450 ha), the Oak Ridges Moraine Plan (190,000 ha), and portions of the southern section of the Niagara Escarpment Plan and the Lake Simcoe Watershed Plan provide landscape level direction for municipalities for the planning and

management of their conservation lands. For the most part, these larger landscape level plans provide policy direction for full to partial protection to a broader range of natural heritage features and areas than what is provided solely by the PPS under previously mentioned designations and mechanisms. Unfortunately, some land use activities fall outside of the Planning Act and the Provincial Policy Statement. Such activities may negatively impacted NH areas and features regardless of the protection provided to these areas via planning mechanisms. Finally, a protection partnership among federal, provincial, regional, and local interests is found within the Rouge Park Alliance Partnership. This geography approaches a landscape scale and includes some 4,072 ha. This area may contain lands that could achieve IUCN categories Ia, II, III, and IV protected area status with the overall area being classified as category V.

Private landowner mechanisms

Private landowner mechanisms and contributions to natural heritage/biodiversity protection involve a significant suite of actions ranging from government programs with private landowners [Conservation Land Tax Incentive Program (CLTIP) and Managed Forest Tax Incentive Program (MFTIP)] to non-government organization lands (NGOs, such as the Nature Conservancy of Canada and Ontario Nature) to national private non-profit organizations (Ducks Unlimited) to Ontario Heritage Land Trust properties (a provincial government non-profit agency). Also existing within the ecozone are individual land trusts. Land trusts are charitable organizations that assist in achieving land/conservation agreements and/or are involved in stewardship of such agreements. Level of protection ranges from full to partial protection to sustainable forest management activities under MFTIP. The diversity of lands held and the diversity of objectives and mechanisms used make IUCN category identification difficult. Where full protection is achieved properties may qualify as IUCN Categories Ia, III, or IV. Private landowner mechanisms may reach 0.1% of the ecozone⁺.

Evidence from Quebec

In Quebec, significant protected areas were added in the years 1993, 2000, and 2005. Much of the recent increases have been due to the addition of Categories IV (“Habitat/Species Management Areas”) and VI (“Protected Areas with Sustainable Use of Natural Resources”) protected areas. In Quebec, protected areas are classified within 21 designation categories which all correspond to the broadly adopted IUCN protected area categories.¹⁷⁴ At present, protected areas are not listed per ecozone⁺, the provincial registry sums up the information per designation class for the entire territory.

The human footprint in the Quebec portion of the Mixedwood Plains Ecozone⁺ is evaluated at 62%, where agriculture alone occupies more than 50% of the territory.¹⁷⁵ In such a setting, it does not come as a surprise that the protected area network shows the lowest connectivity index out of 13 natural provinces. Habitat loss and fragmentation is one of the most important ecological issues in southern Quebec. Private land tenure hinders the implementation of an extended network for the conservation of key habitats. In spite of those considerations, the proportion of protected areas has increased by more than 1,400 km² from 2002 to 2009.¹⁷⁵ More

than 90% of protected areas are different wildlife habitats smaller than 10 km² that belong to IUCN category VI. The Quebec national parks (5) and Gatineau Park (National Capital Commission) contribute 77.8 and 361.3 km² respectively, while MBSs (12) and ecological reserves (15) maintain protection over 76.6 and 24.5 km², respectively. In order to improve the representativeness of different habitats, the ecozone⁺ would benefit from a better provision of mixedwood stands such as yellow birch–balsam fir–maple sugar, yellow birch–maple sugar, maple sugar–linden tree and black spruce stands.¹⁷⁵ An assessment of the present protected area network to secure species at risk habitats and improve plant and animal population recovery is also needed.

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.

The two most comprehensive national conservation programs, the Ecological Gifts Program (EGP) and the Natural Areas Conservation Program (NACP), have brought about significant environmental benefits in the ecozone⁺. Between 1995 and 2010, the EGP has allowed land trusts, conservation groups, municipalities, as well as provincial and federal departments to secure 13,057 ha on 339 properties in Ontario and 2,381 ha on 43 properties in Quebec, either as full title or as conservation easements. As of June 2011, the Nature Conservancy of Canada and partner groups, such as Ducks Unlimited Canada, had secured 7,199 ha through 87 conservation projects (5,441 ha in Ontario and 1,758 ha in Quebec) under the \$225 million NACP.

Habitats protected under these programs have to meet stringent ecological significance criteria.^{176, 177} The majority of the secured lands are wetlands or forested lands. Properties acquired through NACP and EGP protect 72 species listed under the federal *Species at Risk Act*, including shumard oak (*Quercus shumardii*; Special Concern), climbing prairie rose (*Rosa setigera*; Special Concern), blue ash (*Fraxinus quadrangulata*; Special Concern), American ginseng (*Panax quinquefolius*; Endangered), grey fox (*Urocyon cinereoargenteus*; Threatened), yellow-breasted chat (*Icteria virens*; Endangered), loggerhead shrike (*Lanius ludovicianus*; Endangered), peregrine falcon (*Falco peregrinus*; Special Concern), short-eared owl (*Asio flammeus*; Special Concern), least bittern (*Ixobrychus exilis*; Threatened), northern dusky salamander (*Desmognathus fuscus*; Endangered), eastern foxsnake (*Pantherophis gloydi*; Endangered), blue racer (*Coluber constrictor foxii*; Endangered), milksnake (*Lampropeltis triangulum*; Special Concern), Lake Erie watersnake (*Nerodia sipedon insularum*; Endangered), spiny softshell (*Apalone spinifera*; Threatened), and endemic species such as copper redhorse (*Moxostoma hubbsi*; Endangered) in the Richelieu River

and Victorin's gentian (*Gentianopsis virgata*; Threatened) as well as Victorin's spotted water-hemlock (*Cicuta maculata*; Special Concern) inhabiting the St. Lawrence tidal marshes.

Evidence from Ontario

With a high proportion of the Mixedwood Plains Ecozone⁺ in private ownership, voluntary stewardship activities are a crucial component of biodiversity conservation. Stewardship can include protection through easements and land securement, incentive programs, and restoration activities such as planting trees. Education and awareness activities such as nature interpretation centres and programs for youth can be seen as contributing to stewardship. Stewardship activities in the Mixedwood Plains involve a wide range of organizations and participants from the non-government sector, the agricultural sector, industry, First Nations, government, and private individuals.

Overall, stewardship in the Ontario portion of the Mixedwood Plains is best summarized by two long-term trends: increasing levels of public engagement; and the increasing scale of stewardship activities.

Stewardship activity has grown considerably in recent years as demonstrated by recent trends in participation levels in many stewardship programs. The provincially administered Managed Forest Tax Incentive Program and Conservation Land Tax Incentive Program provide property tax relief to participating properties. The Managed Forest Tax Incentive Program grew from just under 9,000 participating properties in 1998 to over 11,000 properties in 2008, covering more than 758,000 ha.¹⁷⁸ Likewise, the number of properties participating in Conservation Land Tax Incentive Program roughly doubled over the same timeframe, with current participation at 16,000 properties covering 216,000 ha (Figure 19).

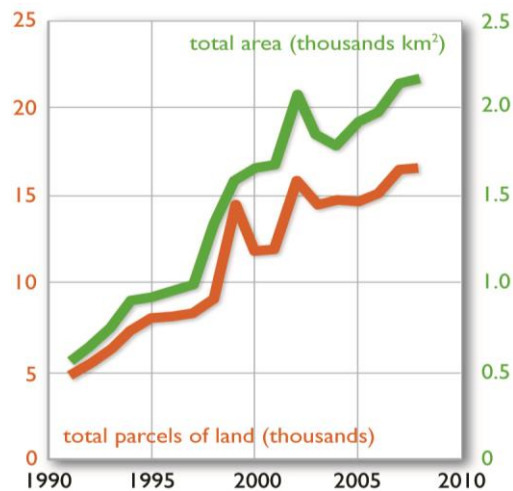


Figure 19. Growth of the Conservation Land Tax Incentive Program, 1991–2008.
Source: adapted from Ontario Ministry of Natural Resources, 2008¹⁸¹

Agricultural stewardship comprises a significant portion of the stewardship activity in the ecozone⁺ with 65% of all Ontario farms participating in the Environmental Farm Program with 12% of farms implementing Best Management Practices such as nutrient or riparian

management between 2005 and 2008.¹⁷⁹ Similarly, over the last 5 years, the number of projects completed by the Ontario Stewardship Program has increased by over 15%, with more than 650 projects completed in 2009.⁷⁰ New programs also aim to expand the stewardship sector. One example is the 50 Million Trees Program which fosters partnerships to support the planting of 50 million trees by 2020 to combat climate change.¹⁸⁰

Alongside this growth in stewardship participation, there has also been a shift towards landscape-scale stewardship initiatives which attempt to focus stewardship activities to priority areas and projects based on an overall conservation strategy. Examples include the Oak Ridges Moraine Conservation Plan¹⁸² and the Lake Simcoe Protection Plan,¹⁸³ both of which are supported by stewardship activities targeted to priority areas. Similarly, the Canada Ontario Agreement Respecting the Great Lakes Basin Ecosystem¹⁸⁴ supports stewardship projects that are linked to priority watersheds and outcomes such as restoring coastal habitats, improving water quality, and maintaining and enhancing fish populations. Other examples include the development of the Conservation Blueprint for the Great Lakes by the Nature Conservancy of Canada¹⁸⁵ and the community-led development of natural heritage systems facilitated by the Ontario Ministry of Natural Resources.

The last decade has also seen a growth in organizational coordination with the goals of fostering collaboration, developing guiding frameworks for stewardship activity, realizing efficiencies in implementation, and generating a higher profile for the sector as a whole.¹⁸⁶ This coordination takes place at the local level, facilitated by organizations such as Ontario Stewardship, individual Conservation Authorities or network organizations like the Carolinian Canada Coalition. At the provincial scale, the Stewardship Network of Ontario and the Biodiversity Education and Awareness Network support the implementation of stewardship engagement activities outlined in Ontario's Biodiversity Strategy.¹⁸⁷

While there has been significant growth in stewardship actions, the coordination of stewardship activities, and the number of people involved in stewardship, there is little sustained measurement of the cumulative outcome of the breadth of stewardship activities.¹⁸⁶ The adequacy of stewardship actions should be measured against the health and functionality of the ecosystem. The downward trends in the supply of many habitat types and declines in species richness outlined in this report suggest that the scale of current stewardship efforts is insufficient to offset both the area's historic biodiversity losses and current stressors on the ecosystem.^{146, 186, 188} Notwithstanding publications such as *How Much Habitat is Enough?*,¹⁸⁹ more effort is required to define what constitutes an adequate level of conservation and stewardship and tools to measure and compare the efficiency of the protection measures put in place. The development of meaningful targets and the monitoring of progress against those targets at the ecozone, ecodistrict, and watershed levels would assist in measuring the overall effectiveness of stewardship actions over time and help ensure future ecosystem functionality and the provision of ecosystem services.

Ecosystem conversion

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

The Mixedwood Plains Ecozone⁺ has undergone some of the most extensive changes in land cover of any ecozone⁺ in Canada. In 2011, 68% of the ecozone⁺ was agricultural land (second only to the Prairie Ecozone⁺ which has 87% agricultural land cover).⁸ Most of the land in the Quebec portion of the ecozone⁺ was cleared between 1800 and 1880 at a time associated with the first population peak in the area¹⁴ while the amount of cleared land in Ontario was at its maximum around 1920.¹⁸ (The changes in major natural biomes or ecosystems are discussed in Key Findings 1 through 7). In this section, the driving forces behind these changes, the expansion of urban areas, shoreline conversion, agricultural intensification, and loss of agricultural land, are discussed.

Expansion of urban areas

According to the 2006 Census of Canada, 53% of Canada's population was located in the Mixedwood Plains Ecozone⁺. The Windsor–Québec Axis, which runs through the core of the ecozone⁺, is considered the urban heartland of Canada.^{190,191} Between 1971 and 2006, the population of the Mixedwood Plains grew by 51%, which was higher than the population growth in the rest of Canada (42%).^{192,193} This increase in population is not equally distributed throughout the ecozone⁺. Census Canada data for the Ontario portion of the ecozone⁺ on population patterns and trends between 1951 and 2006 showed that by 2006, the area of sparsely populated (< 10 persons/km²) and rural land (10 to 25 persons/km²) had declined to 58% of the 1951 level, while the land area with urban population densities (60 to 400 persons/km²) had almost tripled. Growth was largest in the semi-urban category (25 to 60 persons/km²) (Figure 20). These trends are characteristic of urban deconcentration, a process in which population decline in the centre of cities is matched by population growth and expansion in suburban areas.¹⁹¹

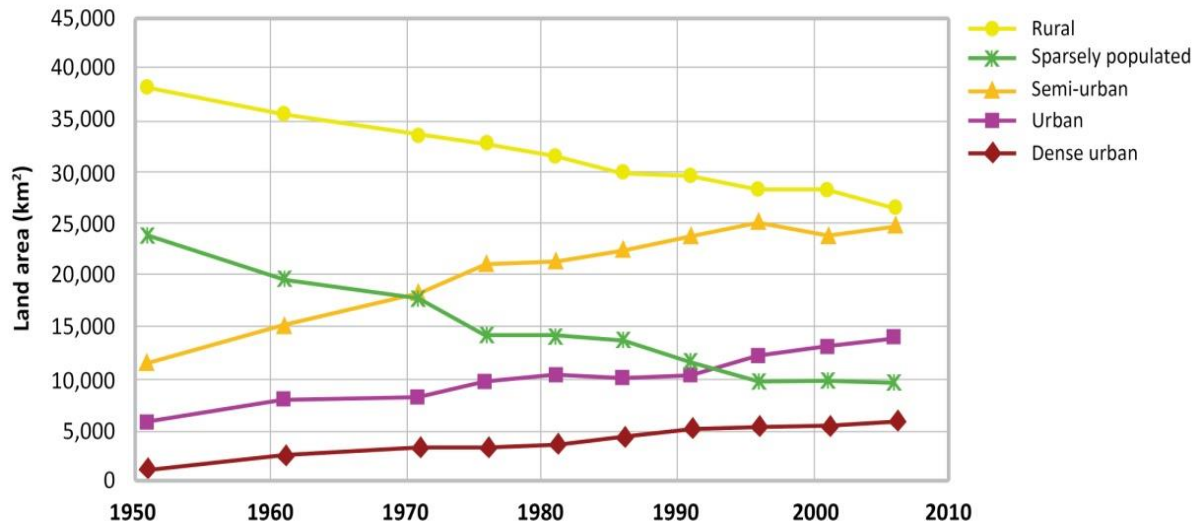


Figure 20. Trends in land area by population density class in the Ontario portion of the Mixedwood Plains Ecozone[†], 1951–2006.

Source: Census of Canada, 2010¹⁹⁴

Category definitions:¹⁹¹ dense urban (>400 persons/km²), urban (60–400 persons/km²), Semi-urban (25–60 persons/km²), rural (10–25 persons/km²), sparsely populated (< 10 persons/km²)

Analysis of land cover data confirms the census data. Comparing Landsat data from 1974 and 1990 with data from 2005, Ahern *et al.*⁸ found urban land cover increased by 667.1 km² (62.6%) in the Golden Horseshoe area of Ontario.⁸ This increase came from loss of agricultural land and, to a lesser extent, losses of forest cover (for discussion of impacts of habitat loss on interior forest birds (see Species of special economic, cultural, or ecological interest). The greatest expansion was centred on Toronto. There was relatively little growth in the Hamilton and Niagara regions between 1974 and 1990 but it appears to have accelerated between 1990 and 2005. The overall rate of urbanization in the Toronto–Hamilton–Niagara region was 20.3 km²/yr between 1974 and 1990, increasing to 22.8 km²/yr between 1990 and 2005.⁸ When land conversion was examined in the Toronto area alone, similar findings were observed with the most significant land use conversion from 1993 to 2007 being to urban uses, followed by conversion to golf courses and pits and quarries.¹⁹⁵

Analyses of landscape change in Quebec have consistently found urban cover increased from the 1950s to 2001.^{22, 25, 38, 196} In Quebec, urban growth has focused around Montréal and Québec with an increase in urban area of 227 km² or 20% (from 1,153 to 1,380 km²) between 1993 and 2001. Most of this expansion occurred on high quality fertile soils²⁵ at the expense of annual and perennial crop land and forested land.^{21, 25}

Urban expansion generally causes native species to have reduced survival and reproduction near homes¹⁹⁷ and native species richness often drops with increased urban density.¹⁹⁸ When urban trees from ten cities in southern Ontario were examined, it was found that urban trees had significantly lower mycorrhizal fungal colonization (mycorrhiza help the trees gain nutrients from the soil) than trees from rural environments, though it was not clear what was responsible for the difference.¹⁹⁹ Some species adapted to urban habitats are experiencing

declines. Loss of forest cover has been seen to cause both decreases in the populations of interior forest nesting birds (See Species of special economic, cultural, or ecological interest) and losses of large predators from many areas of the ecozone (See Food webs).

Shoreline conversion

Loss of natural shoreline has been an ongoing process since the arrival of European settlers as development in the ecozone⁺ was initially focused along shorelines.¹⁵ However, further shoreline conversion has also occurred more recently. When land use change was examined for the American portion of the Great Lakes, it was found that between 1992 and 2001, 2.5% of the Great Lakes watershed had experienced shoreline change. Changes due to new construction included a 33.5% increase in low-intensity development and a 7.5% increase in road area. Agricultural and forest land each experienced a 2.3% decrease in area and development was mostly concentrated near coastal areas.²⁰⁰ Most of the wetland loss was within 1 km of the shoreline.²⁰⁰

Similar data were not available for the Canadian portion of the Great Lakes, however, in a detailed study of 660.8 km of shoreline along southern Georgian Bay, the extent of shoreline alteration was mapped and assessed (Figure 21).²⁰¹ The highest levels of shoreline alteration occurred in the Town of Midland (51.7%), City of Owen Sound (39.1%), and Town of Collingwood (34.8%). Very little alteration has occurred in the Municipality of Northern Bruce Peninsula (1.2 %) which has a high percentage of shoreline in protected areas (including National and Provincial Parks, Nature Conservancy of Canada and provincial Nature Reserves) as well as rocky, steep terrain that restricts shoreline development. The high levels of alteration found in the towns of Midland and Collingwood (Figure 22) were associated with shorter weekend commuting distance from urban centres in the Greater Toronto Area, deeper soils, and flatter terrain.²⁰¹

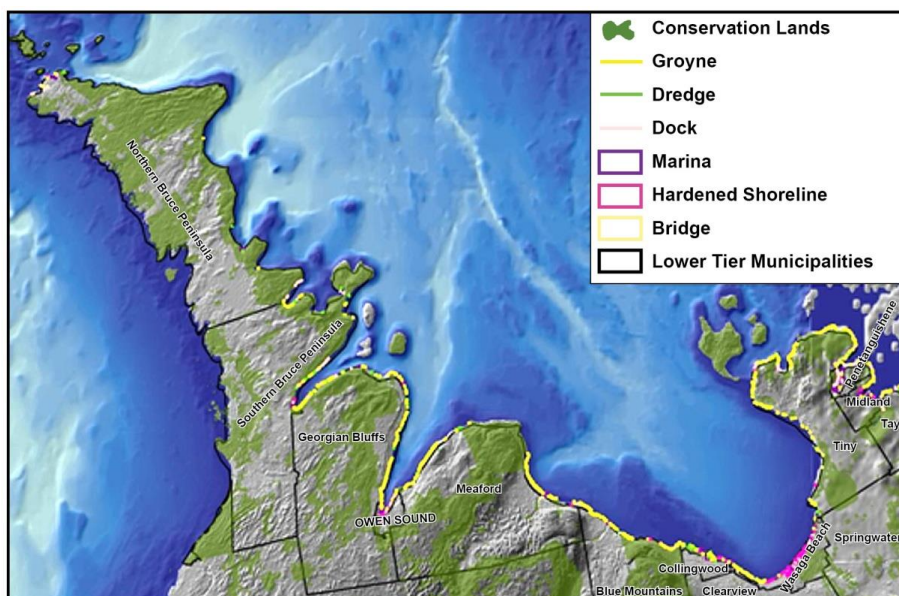


Figure 21. Shoreline alteration in southern Georgian Bay.

Source: Buck et al., 2010²⁰¹



Figure 22. Photos showing level of shoreline alteration in the Collingwood area of Ontario in 1954 (left) and 2008 (right).

Source: Buck et al., 2010²⁰¹

Loss of natural shoreline has been associated with changes in fish species composition.²⁰²⁻²⁰⁴ In a study of 62 coastal wetlands throughout the Great Lakes, the wetlands in Lake Erie and Lake Michigan with agricultural watersheds, turbid water, and little submerged vegetation were dominated by generalist, tolerant fish.²⁰⁴ The largely natural watershed of Lake Superior by comparison, had clear water, abundant submerged vegetation, and a diversity of fish species.²⁰⁴ Disturbed conditions were also associated with more non-native species.²⁰⁴ In Minnesota (just outside the ecozone⁺), both black crappies (*Poxmoxis ngromaculatus*) and largemouth bass (*Micropterus salmoides*) were more likely to nest near undeveloped shorelines than near developed ones.²⁰³ When fish communities were studied along the southeastern shoreline of Lake Ontario, it was found that fish abundance increased significantly with increases in submerged vegetation cover as did the frequency of smaller-bodied fish species. Large-bodied fish species such as common carp (*Cyprinus carpio*) were associated with areas with less submerged vegetation.²⁰⁵

Loss of agricultural land and agricultural intensification

Canada's most productive agricultural soils are found within the Mixedwood Plains Ecozone⁺. While the ecozone⁺ contains only 9% of Canada's agricultural land, it yields 38% of its agricultural production.^{206, 207} Based on census data from 1971 to 2006 for the Ontario portion of the ecozone⁺ (Figure 23), the total amount of agricultural land, the number of cattle, and the amount of improved pasture decreased, while cropland increased.²⁰⁸

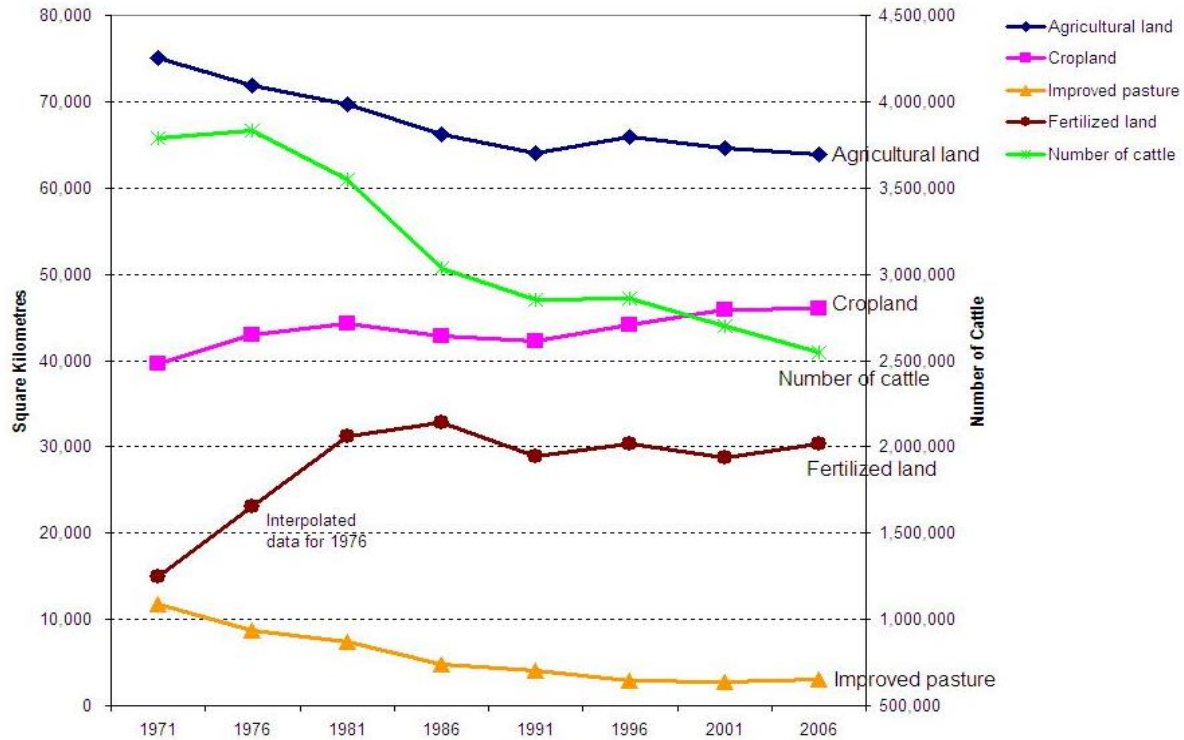


Figure 23. Trends in selected agricultural characteristics in the Ontario portion of the Mixedwood Plains Ecozone⁺, 1971–2006.

Source: Statistics Canada, 2008²⁰⁸

When the crops under production are examined for the ecozone⁺ there has been a major increase in soybean production (Figure 24) that reflects the introduction of varieties suitable for more northern climates.^{209, 210}

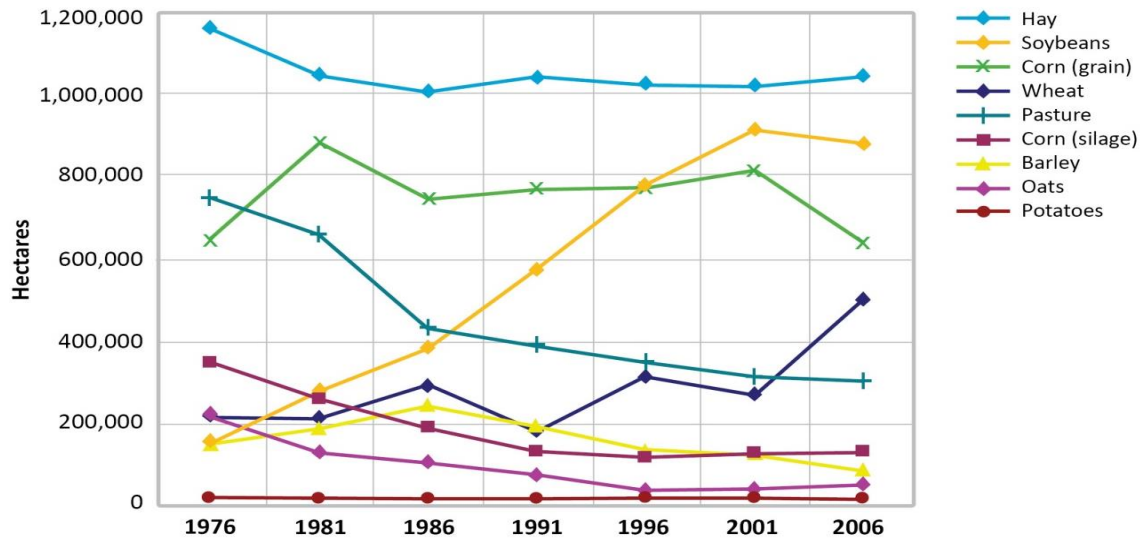


Figure 24. Trends in hectares planted by crop in the Ontario portion of the Mixedwood Plains Ecozone⁺, 1976–2006.

Source: Statistics Canada, 2008²⁰⁸

Based on land cover information derived from satellite imagery, between 1985 and 2005, the amount of agricultural land in the ecozone⁺ decreased by 0.13%.⁸ Losses are a result of growth in urbanization, the expansion of scattered non-farm rural residences, abandonment of marginal farmland, and re-growth of forest. Within the remaining farmland, agricultural intensification has reduced pasturelands and increased cropland. When landscape change was studied in the Quebec portion of the ecozone⁺, a large-scale transition from dairy-oriented farming activity to more intensive agricultural was observed.²⁵ Cover of annual crops increased by 7% from 1993 to 2001 with an associated decrease of 6% in cover of perennial crops.²⁵ The large increase in pig production is considered a potential explanation for this shift in land use. Corn is used as feed for these animals and 98% of all of the corn production in Quebec occurs in the Mixedwood Plains Ecozone⁺.²⁵ In addition, new corn hybrids have been developed which are suited to this region. The transition from perennial crops to annual crops was also seen over the long term (1950 to 1997) in southern Quebec.^{21, 22} A detailed study done in the Haut-Saint-Laurent area of the ecozone⁺ showed that agricultural practices intensified from 1958 to 1993, with the number of fields decreasing from 1964 to 1998 and an associated increase in average field size from 2.51 to 3.04 ha.

Agricultural intensification has been linked to an overall decrease in the suitability of agricultural land as wildlife habitat (see Agricultural landscapes as habitat), declines in birds of grasslands and open/agricultural lands (see Species of special economic, cultural, or ecological interest), and declines in bumblebees (see Species of special economic, cultural, or ecological interest).²¹¹

Loss of natural vegetation, fragmentation, and species loss have also been linked to the transmission of wildlife-borne diseases. The transmission of West Nile Virus and Lyme Disease have both been linked to losses of natural habitat and species diversity (See Conclusion: Human Well-being and Biodiversity: Constraint of infectious disease).

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.

The United Nations Convention on Biological Diversity recognises non-native invasive species as one of the greatest threats to global biodiversity.²¹² Invasive species can take many forms— aquatic or terrestrial plants (e.g., European frog-bit *Hydrocharis morsus-rane* and garlic mustard *Alliaria petiolata*), aquatic invertebrates (e.g., zebra mussel *Dreissena polymorpha*), fish species (e.g., round goby *Neogobius melanostomus* and rudd *Scardinius erythrophthalmus*) earthworms (*Lumbricus terrestris*), or forest pests (e.g., emerald ash borer *Agrilus planipennis* and Sirex

woodwasps *Sirex noctilio*). Comprehensive data on the distribution, spread, and invasion rates of many species groups (taxons) are not available.²¹³ Information is available for terrestrial plant species. In 2008, the Mixedwood Plains Ecozone⁺ had 139 non-native invasive plant species, the greatest number found in any ecozone⁺ in Canada (other ecozones⁺ with very high levels are the Atlantic Maritime Ecozone⁺ with 130 species, the Pacific Maritime Ecozone⁺ with 124 species, and the Boreal Shield Ecozone⁺ with 123 species).²¹⁴

The Mixedwood Plains has a long settlement history which has facilitated the introduction and spread of non-native species. Aboriginal peoples living in the ecozone⁺ likely transported animals and plants into the Great Lakes area, beginning a trend that accelerated with European settlement.²¹⁵ Invasion occurred through many mechanisms including unintentional releases, ship-related introductions, deliberate releases, entry via canals and water diversions, and movement along railroads and highways. As human activity and global trade has increased in the Great Lakes watershed, the rate of introduction of exotic species has also increased. Of the 185 known non-native species in the Great Lakes, 100 species (54%) entered the lakes in the period between 1959 and 2006.²¹⁶

Invasive species can have many impacts. They may compete with native species for food and habitat,²¹⁷⁻²²⁰ be novel predators,²²¹ be less nutritious prey,²²² and provide poorer quality habitat for wildlife.^{223, 224} A preliminary analysis of the 1998 Committee on the Status of Endangered Wildlife in Canada (COSEWIC) list of assessed species indicated that 25% of all endangered species, 31% of all threatened species, and 16% of all vulnerable species (now called species of special concern) in Canada were in some way at risk due to the impacts of invasive species.²²⁵ Later, Venter *et al.*²²⁶ indicated that introduced or alien species were threatening 22% of the species assessed by COSEWIC (as extinct, extirpated, endangered, threatened, or special concern).

Garlic mustard has been able to out-compete many of the native woody and herbaceous species found in the ecozone⁺ and the estimate of its spread rate in adjacent areas in the United States is 64,000 km² per year.²²⁷ No single mechanism explains the success of this species but a combination of plant traits, all slightly different from those of native plants, seems to confer garlic mustard with tremendous success in the new habitats it invades.^{227, 228}

The forests of the ecozone⁺ evolved without earthworms, so the introduction and establishment of these species alters natural functions. There are 15 species of lumbricid earthworms living in the ecozone⁺ considered to be invasive which arrived accidentally due to European settlement.^{229, 230} These worms are able to consume leaf litter much more quickly than naturally occurring decomposers thus altering nutrient cycling (carbon and nitrogen) and soil food web interactions.^{231, 232} Earthworms may also increase N₂O (nitrous oxide) emissions and could therefore contribute to production of greenhouse gases.²³³

Modelling of extinction rates of North American freshwater species has predicted a future extinction rate of 4% per decade due to a variety of threat factors including invasive species.²³⁴ A species that exemplifies the kind of change an invasive species can have on aquatic ecosystems is the zebra mussel (*Dreissena polymorpha*). The zebra mussel forms huge colonies and filters large quantities of plankton from the water column. The colonization of a waterbody

is followed by declines or complete losses of native mussel species.^{99, 235, 236} Zebra mussels are preyed upon by round goby in their native and introduced range and the spread of zebra mussels has facilitated the spread of the goby²²¹. Zebra mussels have been shown to bioaccumulate polycyclic aromatic hydrocarbons (PAHs), flouranthene, pyrene, chryses, benzoanthracene, PCB aroclor, arsenic, chromium, and barium.²³⁷ Accumulation of these contaminants, as well as type E botulism in zebra mussel tissue, is thought to represent a potentially realistic hazard to organisms (fish and birds) that feed on them.²³⁷ Between the time zebra mussels were first discovered in Lake St. Clair in 1989 and the year 2004, the estimated cost of their damage to drinking water treatment and electric power generation facilities within their North American range was \$267 million dollars with the annual costs around \$30,000/yr/facility.²³⁸

Figure 25 shows the distribution of zebra mussels across the Ontario portion of the ecozone⁺ in 2009.

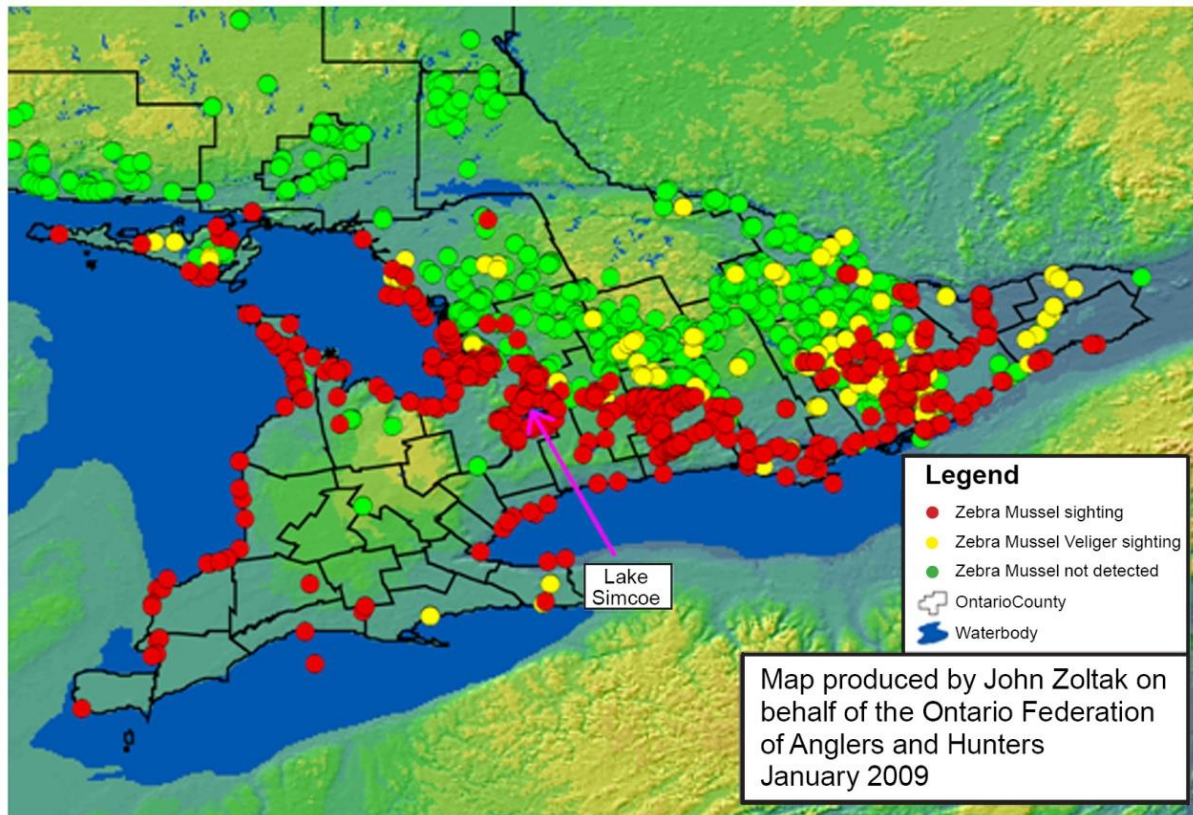


Figure 25. Distribution of zebra mussels throughout the Ontario portion of the Mixedwood Plains Ecozone⁺, 2009.

The distribution of this species is very extensive, which could facilitate the invasion of other aquatic invasive species, including the round goby.

Source: Ontario Federation of Anglers and Hunters, 2009²³⁹

Despite the overwhelming negative impact of invasive species on the ecozone⁺, there have been some good news stories. Studies of mussel populations in the Hudson River in adjacent New York State have shown populations of all four common native bivalves to have stabilized

or even recovered—although the zebra mussel population has not declined. How this has happened is not well understood, but it may provide some hope; even after an infestation, native bivalves can persist at population densities about an order of magnitude below their pre-invasion densities.²⁴⁰

Purple loosestrife (*Lythrum salicaria*) was choking wetlands across Ontario by the early 1990s. After extensive study, two species of *Galerucella* beetle were released as a biological control starting in 1992. While the beetles will never completely eradicate purple loosestrife from Ontario,²⁴¹⁻²⁴³ it is now considered controlled and densities of the plant and its ability to produce large quantities of seeds have been greatly reduced. Purple loosestrife has become a part of more naturally-functioning ecosystems.^{224, 239, 244, 245}

Since the Asian long-horned beetle (*Anoplophora glabripennis*) was first found in the Toronto/Vaughn area in 2003,²⁴⁶ eradication measures were taken and surveillance continues. Though not considered eradicated, there have been no new discoveries or detections of Asian long-horned beetle in Ontario since December 2007. If five years pass with no Asian long-horned beetles being detected, it will be considered eradicated.²⁴⁷

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.

Persistent, bioaccumulative, and toxic substances are long-lasting chemicals that can accumulate in wildlife and humans to levels that can be harmful to ecosystem and human health.²⁴⁸ Government regulations in the 1970s and 1980s banning use and restricting emissions of compounds such as polychlorinated biphenyls (PCBs), pesticides such as dichloro-diphenyl-trichloroethane (DDT), and heavy metals such as lead and mercury, have dramatically reduced the amounts of persistent, bioaccumulative, and toxic substances in the environment (e.g., Hites 2006²⁴⁸). Burdens remain, however, due to past use (from known and unknown contaminated sites), continued use (such as PCBs and mercury), and from by-products of other processes (e.g., Nizzetto *et al.* 2010²⁴⁹). However, newer in-use chemicals, such as polybrominated diphenylethers (PBDEs), which are flame retardants used in consumer and building products, can leach into air and wastewater and now exhibit increasing concentrations in the environment (e.g., Zhu and Hites 2004²⁵⁰). Some PBTs are subject to long-range transport from other areas to Ontario, and appear to be contaminating remote lakes and streams (e.g., Ma *et al.* 2005²⁵¹).

Evidence from Ontario

Ontario Ministry of the Environment monitors levels of persistent, bioaccumulative, and toxic substances in various environmental media such as air, water, sediment, and fish. This information is used, for example, to identify site-specific pollution problems, measure effectiveness of pollution reduction policies and management actions, and advise the public on the consumption of fish from a particular location.²⁵²

Concentrations of mercury (eg., Figure 26) and PCBs in sport fish from the inland lakes have generally declined in response to various regulatory actions.²⁵² However, depending on the location, size, and species of fish, current levels may result in some restrictions on fish consumption.²⁵² For most of the inland locations in Ontario, mercury remains a major substance of concern, and is the cause of more than 85% of fish consumption restrictions.²⁵²

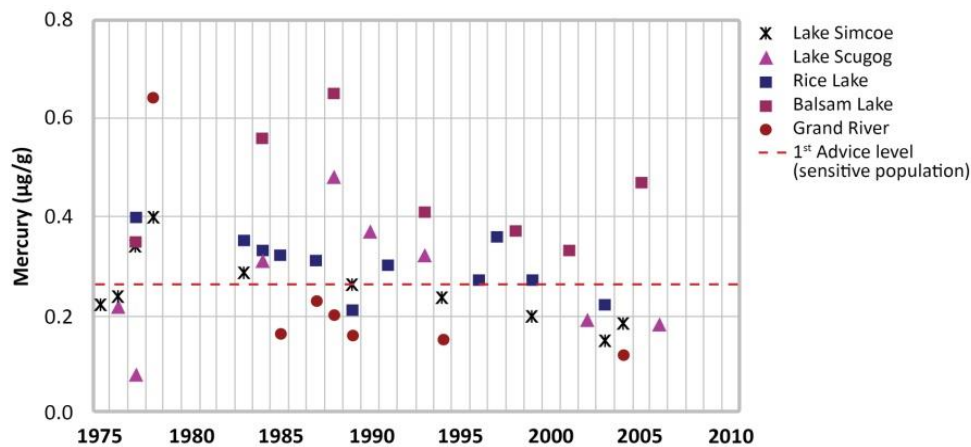


Figure 26. Concentration mercury in 50 cm walleye from Lake Simcoe, Lake Scugog, Rice Lake, Balsam Lake, and Grand River, 1975–2006.

Source: Data from Sport Fish Contaminant Monitoring Program of Ontario Ministry of the Environment²⁵³

Recently, Ontario Ministry of the Environment began to monitor levels of contaminants of emerging concern, such as PBDEs, polychlorinated naphthalenes, and perfluorinated compounds, in water and fish from selected inland locations. Currently, only limited data exist for these compounds. Although consumption guidelines for these compounds are still in development, it is thought that recent actions, such as ban on some compounds (e.g., Environment Canada 2006²⁵⁴), will eliminate the need for fish consumption restrictions due to their relatively low current levels.

Efforts to reduce impacts of sources of historical persistent, bioaccumulative, and toxic substances continue in the region as water, sediment, and young-of-the-year fish monitoring identifies localized areas with elevated concentrations. Remediation of several sites (e.g., Pottersburg Creek and Lake Clear) has resulted from these efforts.²⁵⁵

Although improvements in concentrations of some toxic substances such as PCBs and mercury in fish have occurred over the past 10 to 20 years,²⁵² stressors on biodiversity due to contaminants remain, as demonstrated by continued fish consumption restrictions due to concentrations of some past-use toxic substances.

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.

In lakes and streams, phosphorus is an essential nutrient for the growth of aquatic plants and algae, which provide food for aquatic animals. Sources of phosphorus to water include natural weathering of rocks, erosion of soils, decomposition of plants, and human activities such as the application of fertilizers, discharge of treated waste water, and leaching from septic systems. Excessive phosphorus inputs can result in eutrophication where there is too much plant and algae growth.

Evidence from Ontario

Water quality monitoring of phosphorus and other parameters is undertaken within several Ontario Ministry of the Environment programs. Streams and rivers are sampled through the Provincial Water Quality Monitoring Network by ministry and partner staff. In general, phosphorus levels have declined since the 1980s in Ontario rivers within the Mixedwood Plains.^{256, 257} However, as indicated in Figure 27, many Ontario Mixedwood Plains rivers and streams continue to exceed the interim Provincial Water Quality Objective of 30 µg/L of phosphorus, including 49% of 332 monitoring stations in the ecozone⁺. Elevated phosphorus levels in surface water generally occur where the soils are relatively nutrient rich and the land has been developed for a variety of agricultural and urban uses.

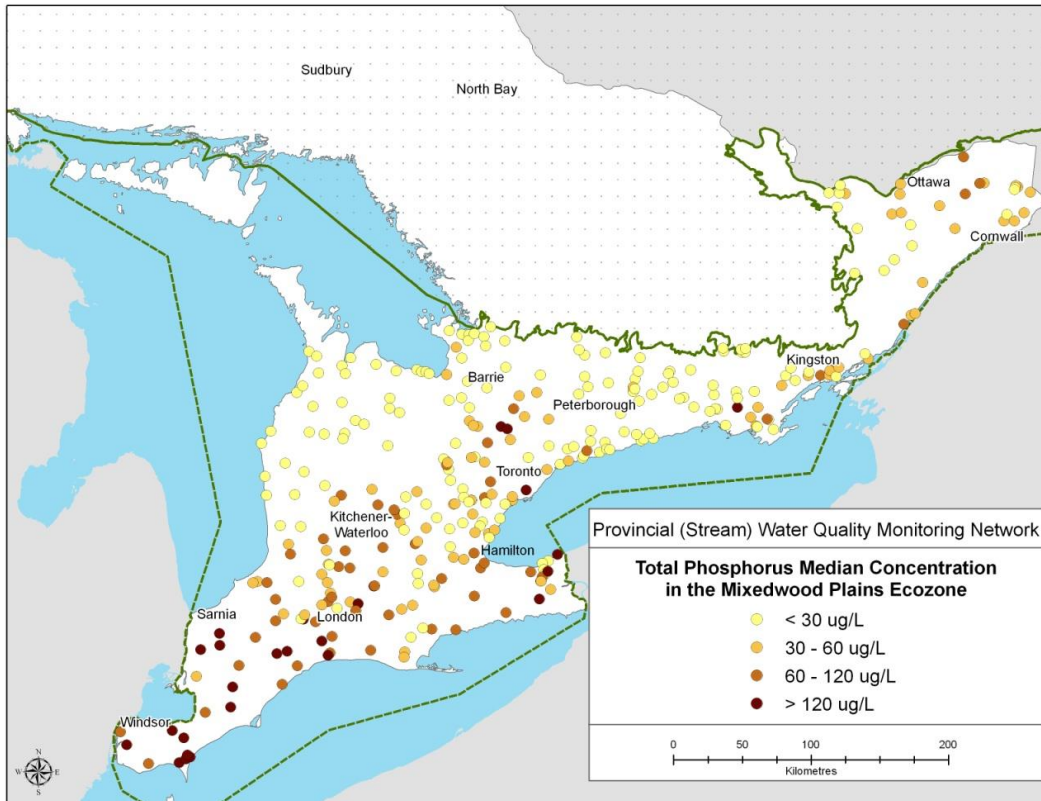


Figure 27. Median phosphorous concentrations in streams in the Ontario portion of the Mixedwood Plains Ecozone⁺, 2003-2007.

Source: data from the Provincial Water Quality Monitoring Network as cited in Kaltenecker and Todd, 2009²⁵⁸

An algal bloom is considered to be an excessive growth of algae in a lake or river.²⁵⁹ Favourable conditions for algal blooms include elevated nutrient concentrations (particularly phosphorus), warm temperatures, and shallow, slow moving water, although acidification and the invasion of lakes by dreissenid mussels (zebra mussel *Dreissena polymorpha* and quagga mussel *D. rostriformis bugensis*) have also been implicated.²⁶⁰⁻²⁶³ These growths of algae are a concern because some forms (cyanobacteria, also known as blue-green algae) can produce toxins that can impact human and animal health and can affect freshwater ecosystem processes.²⁶⁴

The Ontario Ministry of the Environment has compiled algal identification reports since 1994. These data indicate that the extent to which algal blooms, particularly cyanobacteria, are being reported in Ontario lakes and reservoirs has increased significantly between 1994 and 2009 (Figure 28). Although algal blooms can be natural phenomena in Ontario lakes, this trend has been attributed to increases in nutrient inputs to lakes, reservoirs, and rivers in some more developed areas, which promotes the growth of algae. Factors associated with climate warming, including warmer waters, reduced water column mixing, and lengthening of the ice-free season, may exacerbate bloom conditions.^{265, 266}

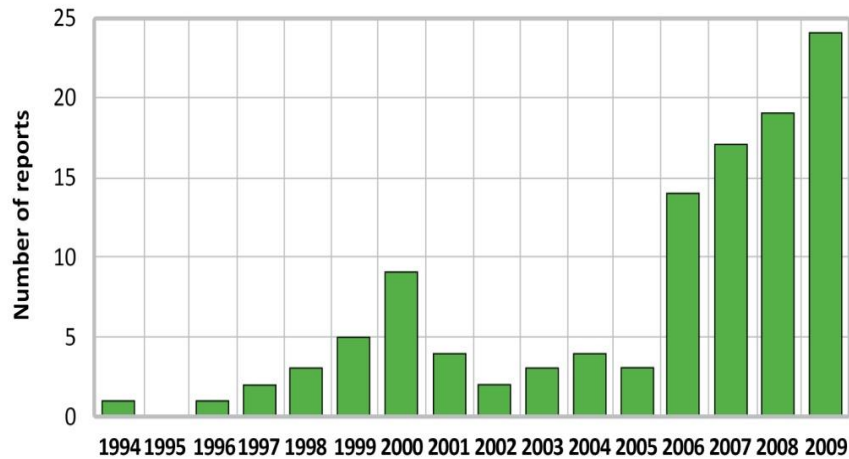


Figure 28. Total number of algal blooms in which dominance by cyanobacteria (blue-green algae) was confirmed in Ontario, 1994–2009.

Includes areas outside of the Mixedwood Plains Ecozone+.

Source: Winter et al., 2011²⁶⁷

Key Finding 13

Theme Human/ecosystem interactions

Acid deposition

National key finding

Thresholds related to ecological impact of acid deposition, including acid rain, are exceeded in some areas, acidifying emissions are increasing in some areas, and biological recovery has not kept pace with emission reductions in other areas.

Acid rain has three main components: weak carbonic acid, created when water reacts with atmospheric carbon dioxide; sulphuric acid, created when water reacts with sulphur from the burning of sulphur-containing coal and oil and the smelting of sulphide ores; and nitric acid, formed when water reacts with nitrogen oxides, mainly from the combustion of fossil fuels.

Due to the underlying geology of the Mixedwood Plains, most lakes are well buffered against acidity²⁶⁸ and the focus of research, therefore, has been on terrestrial systems. Direct impact from acid rain has been documented in high-elevation forests in northeastern North America as well as close to point sources such as the smelters in Sudbury, Ontario. At low elevations and in areas more distant from point sources, such as the Mixedwood Plains Ecozone+, the indirect effects of acidic deposition through soil acidification are of concern.²⁶⁹ To maintain the electrical neutrality of drainage waters, base cations – principally Ca²⁺ – are lost. The resulting acidification brings inorganic aluminum hydroxide (Al³⁺) and hydrogen ion (H⁺) into solution. The Al³⁺ impairs nutrient absorption, especially phosphorous uptake by the roots of almost all plants.²⁷⁰ The buffering capacity of soils and the tolerance of plant species to soil acidification vary greatly.²⁷¹

There are areas in the ecozone⁺ containing ultramafic rock, which is poor in calcium and potassium but rich in magnesium.²⁷² Recent acid-rain assessments^{268, 273} have indicated that some areas of the ecozone⁺ receive acid deposition in excess of their critical load.^{ix}

Although generally this ecozone⁺ is not highly affected by soil acidification, there are isolated regions which, due to their geologic history, have acid-sensitive soils.²⁷⁴⁻²⁷⁶ The Frontenac Arch is one of two physiographic areas within the ecozone⁺ with high levels of intact forest cover (see Intact landscapes and waterscapes); the area also has soils with low buffering capacity, which increases its susceptibility to forest health deterioration due to acidification.

Over the last 40 years, soil acidification due to long-range transport of atmospheric pollution has brought about a reduction in growth (10 p. 100) and recruitment (30 p. 100), and doubled the mortality rate in sugar maple stands (*Acer saccharum*) while promoting recruitment of American beech (*Fagus grandifolia*) in the northern part of the ecozone⁺.²⁷⁷ Application of lime in order to improve soil fertility and nutrition resulted in reduced dieback (factor of 4), doubled the growth rate, increased recruitment by 30 to 58% and reduced beech recruitment by 25%.²⁷⁷

Soil acidity trend data are not available for the ecozone⁺, however a study by Miller and Watmough²⁷⁶ examined the soil acidification and foliar nutrient status of Ontario's deciduous forests in 1986 and 2005. They found that mineral soil pH and exchangeable base cations were lower in 2005 but total sulphur, nitrogen, and cation exchange capacity had not changed from 1986. Foliar calcium levels were related to soil calcium levels and were lower in 2005.

Little is known about the impact of soil acidification on soil fauna, but changes in soil fauna have been reported in association with changes in soil pH. Increases in soil acidity have been found to be associated with changes in the soil collembolan (springtail) communities. As soil acidity increases, so does the abundance of collembolans associated with the duff and soil surface. As the acidity decreases, collembolans that stay in the upper mineral soil increase in dominance.²⁷⁸ As soil acidity decreases so does the diversity of symbiotic arbuscular mycorrhizal fungi. The quantity of colonization by mycorrhiza generally increases with pH.²⁷⁹

^{ix} **Critical load** is a quantitative estimate of the exposure to one or more pollutants, below which significant harmful effects on specified elements of the environment are not known to occur.

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.

Current trends

Climate change is considered by many to be one of the greatest threats to global ecosystems and biodiversity.^{280, 281} Predictions about our future climate are based on changes that are already being seen.

The Mixedwood Plains is well represented geographically with climate stations and Table 9 summarizes the significant trends in various climate variables for the ecozone⁺ from 1950 to 2007. This is one of the regions of Canada with the lowest increases in mean annual temperature over this time period.²⁸² Generally, the closer to a pole an area is, the greater the warming experienced.²⁸³ Nevertheless, the climate data showed significant trends for a few variables. There was an overall increase of 1.2°C in summer temperature, a 20% increase in fall precipitation, an overall increase in the number of days with precipitation in the spring, summer and fall, a 4.7% decrease in the ratio of snow to total precipitation, an increase in the number of growing degree days at some stations, and a decrease in snow depth at some monitoring stations (Table 9). Trends vary by season and station.

Table 9. Overview of climate trends for the Mixedwood Plains, 1950–2007.

Climate variable	Significant trends
Temperature (18 stations)	<ul style="list-style-type: none"> • Overall ↑ of 1.2°C in summer relative to base period (1961-1990) mean • No trend in spring, fall, or winter • Trends consistent across ecozone⁺
Precipitation (29 stations)	<ul style="list-style-type: none"> • Overall ↑ of 20% in total amount of precipitation in fall • No trend found in other seasons for total amount of precipitation although significant change was noted in some stations in some seasons • Overall ↑ in the number of days with precipitation in spring, summer, and fall • Overall ↓ of 4.7% in ratio of snow to total precipitation
Snow	<ul style="list-style-type: none"> • No trend in maximum annual snow depth or duration overall (16 stations) <ul style="list-style-type: none"> ○ 2 stations in the northeastern part of the ecozone⁺ in Quebec show ↓ of over 20 cm in maximum snow depth • No trend in number of days with >2cm on ground <ul style="list-style-type: none"> ○ ↓ of >10 days with >2cm of snow on the ground in 4 stations in southern Ontario from August to January and in 1 station in the St. Lawrence Lowlands February to July
Drought Severity Index	<ul style="list-style-type: none"> • No trend from 6 stations • No extreme or very wet or severe drought years • Stations not evenly distributed across ecozone⁺
Growing Season	<ul style="list-style-type: none"> • No trend in start, end, or length of the growing season overall <ul style="list-style-type: none"> ○ ↑ in number of growing degrees days at some stations

All trends reported are significant at $p < 0.05$

Source: additional data and analysis provided by the authors of Zhang et al., 2011²⁸²

Changes in timing of bird migration have already been recorded.²⁸⁴⁻²⁸⁶ A study at the Long Point Bird Observatory found that for every 1°C increase in spring temperature, median capture dates of migratory birds averaged across species was one day earlier.²⁸⁴ In a study of 78 songbird species from 1961 to 2006 in Pennsylvania (which is in the same Ecoregion of North America²⁸⁷), spring migration became significantly earlier over the 46 year period and autumn migration showed no overall change.²⁸⁵ When tree swallows were studied throughout North America, it was found that they are breeding earlier most likely due to a long-term increase in spring temperature.²⁸⁶

Changes are also being seen in mammal populations as the northern range limits of many species in the ecozone⁺ are limited by winter conditions.²⁸⁸ The average daily minimum temperatures in January and February have warmed by more than 2°C in the last 100 years which may be allowing the northward expansion of species such as the southern flying squirrel (*Glaucomys volans*), Virginia opossum (*Didelphis virginiana*), and little brown bat (*Myotis lucifugus*).²⁸⁹⁻²⁹¹ The increased abundance of fisher (*Martes pennanti*) may be associated with reduced snow depth.²⁹²

Predicted change

Aquatic systems are particularly vulnerable to climate change due to the impacts of increased temperature and evaporation combined with potential decreases in precipitation.²⁹³ Since fish are not able to regulate their body temperatures they are very dependent on water temperature to maintain important biochemical, physiological, and life history processes. Water temperature is a critical determinate of fish population growth, survival, and reproduction.²⁹⁴ If climatic warming occurs as projected, surface waters will be warmer for longer periods in spring, summer, and fall which will reduce the duration of winter conditions.²⁹⁵ At the same time, stratification periods will increase, with negative effects on deep water oxygen levels in late summer leading to increased risk of summer kill events for many aquatic species.²⁹⁵ The Mixedwood Plains has the highest diversity of freshwater fishes in Canada.^{117, 161} When fish communities were studied in 43 watersheds throughout the Ontario portion of the ecozone⁺ ²⁹⁶ it was found that currently cold-water fish species were present in 100% of watersheds and 38 of the 43 watersheds had cool-water fishes at more than 66% of the samples sites (Note: many watersheds in the ecozone⁺ have limited cold-water habitat even though all of the watersheds contain cold-water species). Analysis of the impact of projected warming on these watersheds and the 132 fish species within them (non-native species removed from analysis) showed reduced distribution of cold-water species and an increase in warm-water species.²⁹⁶ Even the least severe climate change scenario reduced cold-water fish species to only 67% of sites by 2025 (decrease of 33% of locations).²⁹⁶ Using the least severe scenario, an index of the likelihood of each watershed in southern Ontario retaining cold-water species after climate change was created. Most of the watersheds projected to retain cold-water species were in the northern portion of the ecozone (Bruce Peninsula, along the shore of Lake Huron, or bordering the edge of the Canadian Shield) while southwestern watersheds were likely to lose them.²⁹⁶ Modeling of the impact of climate change on brook trout (a cold-water species) in Canada showed a 49% decrease in distribution by 2050 with significant changes projected for the Mixedwood Plains,²⁹⁷ with the trout populations of smaller lakes considered to be at greater risk.²⁹⁸ There are many indirect or cascading effects associated with increased temperatures. The timing, size and duration of the spring freshet and the frequency and duration of droughts in southern Canada are predicted to change.²⁹⁹ Some warm-water species such as smallmouth bass (*Micropterus dolomieu*) are highly effective predators whose distribution is currently limited by temperature related effects.²⁹³ When the impact of increases in their distribution due to climate change were modeled,²⁹³ it was predicted that they would cause the extirpation of four common cyprinid species, the northern redbelly dace (*Phoxinus eos*), the finescale dace (*Phoxinus neogaeus*), the flathead minnow (*Pimephales promelas*) and the pearl dace (*Margariscus margarita*) in Ontario.

Many different responses are anticipated in terrestrial systems. Significant increases in plant diseases, such as Fomes root rot (*Heterobasidion annosum*), have been predicted, as well as declines of oak, ash, and maple forest.³⁰⁰ In agriculture, increases in common smut (*Ustilago maydis*) and cyst nematode (*Heterodera glycines*) have been predicted for corn, increases in bean yellow mosaic virus, potato leafroll virus, and cucumber mosaic virus have also been predicted.³⁰⁰ Hemlock woolly adelgid (*Adelges tsugae*), an insect pest of hemlock trees, is predicted to significantly increase in its range as it is currently temperature limited, while the

impact of *Armillaria* root rot, already wide spread, is predicted to increase due to increased stress caused by climate change.³⁰¹ Human diseases may also increase. For example, West Nile Virus and Lyme disease are expected to increase in Canada with the first expansions occurring within the Mixedwood Plains. With Lyme disease, modeling predicts a high probability of establishment in the southern areas of Ontario and Quebec³⁰² with the limit of spread in Ontario being a line within 130 km of North Bay. With West Nile Virus, the earlier onset of spring would prolong the time period in which spread to humans is likely to occur, while increased precipitation may increase mosquito breeding sites (mosquito's which bite both birds and humans are the vectors for West Nile Virus).³⁰³

When climate projections were done for the ecoregions of Ontario, it was found that novel climate conditions (previously non existing combinations of temperature and precipitation) may be created and that many of the currently existing climate conditions will disappear from the province.³⁰⁴ Most forest plant species living in highly fragmented landscapes show low or no ability to colonize new habitat patches; most move only a few metres per year.^{305, 306} In a study to examine tree species distributions under different climate scenarios in the Credit Valley, it was estimated that tree species would have to shift at the rate of 3,000 to 5,000 m/yr in order to keep pace with changing climate, yet most tree species are thought to be able to migrate only on the order of 50 to 300 m/yr.³⁰⁷ In another study looking at how tree species in Ontario would change under different climate scenarios (modeling to the year 2100), which in addition to climate took topography, soils, landuse, and fragmentation into account, it was found that the southern half of the province showed the highest degree of species turn-over and forest type change and was especially vulnerable to the effects of climate change.³⁰⁸ Throughout the ecozone⁺, due to potential changes in species distribution, forest types which we know today would be reduced and shifted, and many new species combinations and assemblages are likely to occur.³⁰⁸ In the same study, when limits were put on the rate of shift that species could achieve (to 1000 m/yr), the changes in forest cover were even more dramatic. Under all climate scenarios, tree species richness was lower than currently found throughout the province of Ontario, and large areas in the north as well as the south of the province would have forest types not currently found in the province.³⁰⁸ The high level of fragmentation found in this ecozone⁺ (see Forests, Grasslands, Wetlands, Lakes and rivers, Coastal, and Ice across biomes, as well as Ecosystem) will add an extra layer of complexity to species ability to move north and adapt to climate change. The ability of populations to redistribute in a shifting climate may be slowed or prevented in fragmented landscapes.³⁰⁹⁻³¹² Many modeling exercises make the assumption that species movement is possible due to the presence of natural vegetation. In southern Ontario where there often are large areas of urban and agricultural land, the potential for some species to change their distributions will be limited even further.

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.

Evidence from Ontario

Ecosystem services are the direct and indirect benefits that humans derive from healthy, functioning ecosystems. The loss or degradation of natural areas threatens to undermine future economic and social well-being by diminishing the natural foundations on which society is built. The Millennium Ecosystem Assessment has grouped ecosystem services into four comprehensive categories:

- *provisioning services* that provide essential raw materials such as food, water and fibre;
- *regulating services* that maintain essential life support services such as climate regulation and flood prevention;
- *supporting services* such as soil formation, nutrient cycling and pollination; and
- *cultural services* that provide recreational, aesthetic and spiritual benefits.²⁸¹

There is considerable global interest in applying ecosystem service concepts as a rationale for conservation and as a method to support the design of effective resource management policies.³¹³ Ecosystem services can be understood in biophysical terms, for example, the amount of forest required to sequester a specific amount of carbon. They can also be expressed in economic terms, for example, the estimated economic benefit of carbon sequestration of a given amount of forest.

The Mixedwood Plains Ecozone⁺ has undergone significant alteration in habitat since settlement. This has resulted in impacts on the flow of ecosystem services that can be supplied by the area's remaining natural features. The specific impacts have not been comprehensively or quantitatively measured, but trends in ecosystem services are driven by trends in ecosystem structure, function, and composition.^{281, 314} The transformation of the ecozone's forests, wetlands, and plains vegetation into agricultural and urban areas has impaired natural supporting ecosystem services such as soil formation, nutrient cycling, and pollination, as well as regulating services, such as water regulation and water supply.

A pilot study in eastern Ontario that was part of the National Agri-Environmental Standards Initiative found that a significant portion of the study area did not contain sufficient natural cover at the landscape level to provide full or partial pollination services to farm fields.³¹⁵ Although there has been evidence of improvement,^{106, 107} the loss of natural cover, urbanization, and the expansion of agriculture have affected the ecosystem services of water regulation,

quality, and supply. This is due to fragmentation and channelization of rivers and streams, dams and altered flow regimes, and elevated levels of sediments and nutrients.^{104, 105, 115, 122}

Even though the Mixedwood Plains Ecozone⁺ is highly disturbed, there are significant ecosystem service benefits provided within the area. Agriculture is the dominant provisioning service within the ecozone⁺. Although it occupies only 9% of Canada's land area, the Mixedwood Plains yields 38% of Canada's agricultural production.^{206, 207} Forests are important in both conventional economic terms and for their ecosystem services.³¹⁶ The network of forests and other natural areas in the ecozone⁺ are also important in combating climate change: they contribute to sequestration of carbon and allow for movement of plants and animals to new areas in response to a changing environment. Hunting and fishing are important components of the resource-based recreation economy; for example, recreational fishing alone in the Ontario portion of the Mixedwood Plains Ecozone⁺ accounted for \$570 million of spending on goods and services in Ontario in 2005.³¹⁷ There are also important ecosystem service benefits associated with the ecozone's⁺ protected areas including cultural, social, and spiritual benefits, as well as the direct economic benefits accruing from recreational use of parks.³¹⁸

A number of recent studies have utilized the valuation of ecosystem services to assess the indirect economic value of the remaining natural areas in southern Ontario. These studies have found that these areas "represent a significant, yet often uncounted, portion of the total economic value" of the landscape.³¹⁹ For example, a 2004 study estimated the annual indirect (uncounted) economic benefits from the ecosystem services of the Grand River watershed to be about the same value as the direct economic benefits that are counted from agricultural land within the watershed.³²⁰ Two studies completed in 2008 estimated the annual value of the measurable, but uncounted, ecosystem services of Ontario's Greenbelt and the Lake Simcoe Basin to be \$2.6 billion annually and \$975 million annually, respectively.^{321, 322}

A recent study assessed the ecosystem services for the entire Ontario portion of the Mixedwood Plains Ecozone⁺ using spatially-explicit economic valuation. The study conservatively estimates that the area's ecosystem services provide at least \$84 billion a year in economic benefits that are otherwise not counted.³¹⁹ Urban and suburban wetlands provide the ecosystem services of water filtration, water supply and flood attenuation, which provide at least \$40 billion annually.³¹⁹ Urban and suburban river systems provide ecosystem services estimated at \$236,000 per hectare per year, some of the greatest economic benefits for their size primarily because they benefit large human populations.³¹⁹

The study of ecosystem services and their valuation are still relatively new areas of research and there are a number of priorities for further investigation. These include:

- determining whether sufficient natural areas exist to provide the ecosystem services required by the ecozone's⁺ growing population;
- more rigorously identifying how the loss or rehabilitation of natural areas affects the supply of ecosystem services; and
- filling gaps in the ecosystem services valuation literature and reviewing how contextual factors such as scarcity and landscape configuration affect values.^{313, 319}

THEME: HABITAT, WILDLIFE, AND ECOSYSTEM PROCESSES

Theme Habitat, wildlife, and ecosystem processes

Intact landscapes and waterscapes

National key finding

Large tracts of relatively intact natural landscapes and waterscapes, where ecosystem processes are either known or presumed to be functioning properly, are found in many areas, but particularly in the north and west. This includes globally and nationally significant terrestrial, freshwater and marine movement corridors.

Evidence from Ontario

Landscapes

Due to the high level of fragmentation found in the Mixedwood Plains Ecozone⁺, areas of intact natural cover (landscapes and waterscapes) are quite small. In Ontario, the percentage of natural vegetation cover found in the ecozone⁺ ranges from a low of 18% in the Southwest, to a high of 57% in the Frontenac Arch and 51% in the Escarpment. The Eastern and Central physiographic areas have 37 and 35% natural vegetation respectively (Figure 29).¹⁶¹

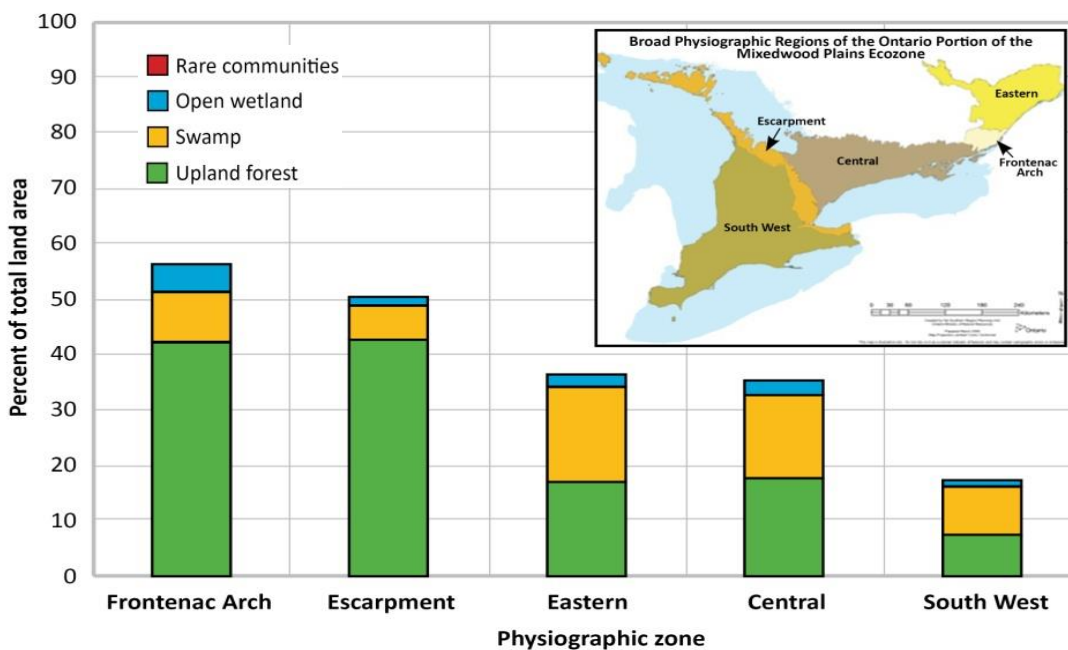


Figure 29. Percentage cover of natural vegetation in the Ontario portion of the Mixedwood Plains Ecozone⁺.

Represents all natural ecosystems (forest, wetlands, prairie savannah, etc.) found in the Ontario Portion of the Mixedwood Plains Ecozone⁺ by physiographic zone.

Source: Ontario Ministry of Natural Resources, 2010¹⁶¹

When the patch size distribution of forested lands within the Ontario portion of the ecozone⁺ was examined, the Escarpment and Frontenac Arch had 41 and 40% in patches greater than 200 ha, the Central and Eastern zones had 21 and 24% of their forest in patches greater than 200 ha, while only 5% of Southwestern Ontario had forest patches greater than 200 ha (Figure 30).¹⁶¹ When forest patch sizes are over 200 ha, research has shown that, generally, 80% of area-sensitive bird species find suitable habitat, however, when the forest patches are under 75 ha, they tend to be dominated by forest edge species.¹⁸⁹ Habitat for area sensitive forest bird species in Southwestern Ontario is severely limited in its supply. In addition, if upland forest is required for habitat, the situation is even more limited as there is only 1% cover of upland forest in Southwestern Ontario in patch size greater than 200 ha.¹⁶¹ When Global Forest Watch³²³ examined the Mixedwood Plains Ecozone⁺ they found that it had no area which fitted their definition of intact forest landscape (forest patches which were a minimum of 5,000 ha), however they did find 1.5% of the ecozone⁺ had forest patches which ranged from 1,000 ha to less than 5,000 ha. As forest cover is converted to other uses such as agriculture and urban lands, impacts can occur to stream ecosystems.³²⁴ Several studies in this ecozone⁺ have demonstrated that sensitive fish and macrobenthic invertebrate species are no longer found when development in upstream catchments exceeds a fairly low threshold. This effect can occur with as much as 50% forest cover still remaining.¹⁰⁰

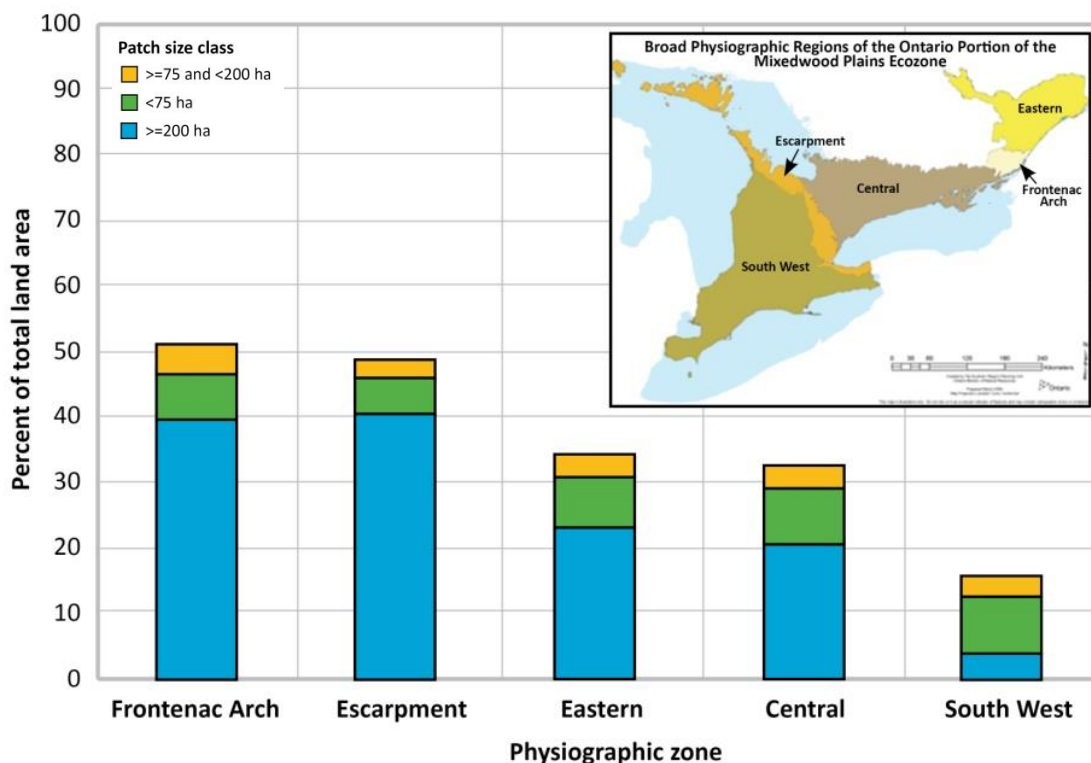


Figure 30. Percentage of forested lands in Ontario portion of the ecozone⁺ with patches <75 ha, ≥75 and <200 ha, and ≥200 ha).

Source: Ontario Ministry of Natural Resources, 2010¹⁶¹

The negative impact of roads on wildlife and ecosystems has been recognized as a major contributor to the global biodiversity crisis for many species.³²⁵⁻³²⁸ Thus, examining how “roaded” a landscape is provides another way to examine its level of intactness.³²⁹ The most densely roaded area of the Ontario portion of the ecozone⁺ is the Central physiographic area which has an average road density of 1.89 km/km² while the Frontenac Arch has the lowest average road density at 1.14 km/km². The vast majority of these roads within the ecozone⁺ are main thoroughfares and concession roads (Table 10).

Table 10. Road density by physiographic zone.

<i>Physiographic Region</i>	<i>Highways (km/km²)</i>	<i>Main Thoroughfares and Concession roads (km/km²)</i>	<i>Local Streets (km/km²)</i>	<i>Total by Physiographic Region (km/km²)</i>
Central	0.15	1.09	0.65	1.89
Escarpment	0.12	0.88	0.49	1.49
South West	0.09	1.05	0.27	1.41
Eastern	0.10	0.92	0.33	1.35
Frontenac Arch	0.11	0.92	0.11	1.14
Entire Mixedwood plains	0.11	1.02	0.40	1.53

Source: Ontario Ministry of Natural Resources, 2009³³⁰

When the amount of natural vegetation in patches greater than 200ha in size within the Ontario portion of the ecozone⁺ was assessed to determine how much was >100 m, >500 m, and >1000 m from a road, it was found that 45% of the existing natural vegetation occurred in patches larger than 200 ha more than 100 m from a road. At more than 1 km from a road, only 10% of the existing natural vegetation is found in patches greater than 200 ha. When broken down by physiographic area, the Escarpment had the greatest percentage of natural vegetation cover (27%) in patches over 200 ha more than 1 km from a road, followed by the Frontenac Arch at 14%, the Eastern and Central physiographic zones at 8 and 5%, and the Southwest had only 2% (Table 11).³³⁰

Table 11. Natural vegetation in Ontario portion of Mixedwood Plains Ecozone⁺

Physiographic Region	Percent of Land Area in Natural Cover	Percent Natural cover in patches ≥ 200 ha	Percent of Natural cover >100 m from roads	Percent Natural cover in Patches ≥ 200 ha that are >100 m from roads	Percent of Total Natural cover >500 m from roads	Percent Natural Cover in patches ≥ 200 ha in size >500 m from roads	Percentage of Total Natural Cover >1000 m from roads	Percentage Natural Cover in patches ≥ 200 ha in size >1000 m from roads.
Central	35%	68%	85%	43%	35%	19%	8%	5%
Eastern	37%	74%	88%	53%	43%	28%	12%	8%
Escarpment	51%	84%	89%	68%	54%	45%	30%	27%
Frontenac Arch	57%	83%	87%	64%	47%	35%	19%	14%
South West	18%	33%	86%	18%	35%	6%	4%	2%
Total Ontario Mixedwood Plains	30%	64%	87%	45%	41%	23%	13%	10%

Amount of Natural Vegetation (forests, wetlands, prairie-all natural ecosystem types) and patches ≥ 200 ha found at >100 m, >500 m and >1000 m from a road in the Ontario Portion of the Ecozone⁺. Source: Ontario Ministry of Natural Resources, 2009³³⁰

When examined spatially, it can be seen (Figure 31) that the majority of 200 ha patches in the Escarpment are found on Manitoulin Island and at the north end of the Bruce Peninsula, while at the southern end of the Escarpment there are no 200 ha patches more than 1 km from a road. The Southwest zone has very few patches more than 1 km from a road, the majority of which are located on Walpole Island. There are a few other widely scattered locations such as west of Chepstow and west of Badjeros.

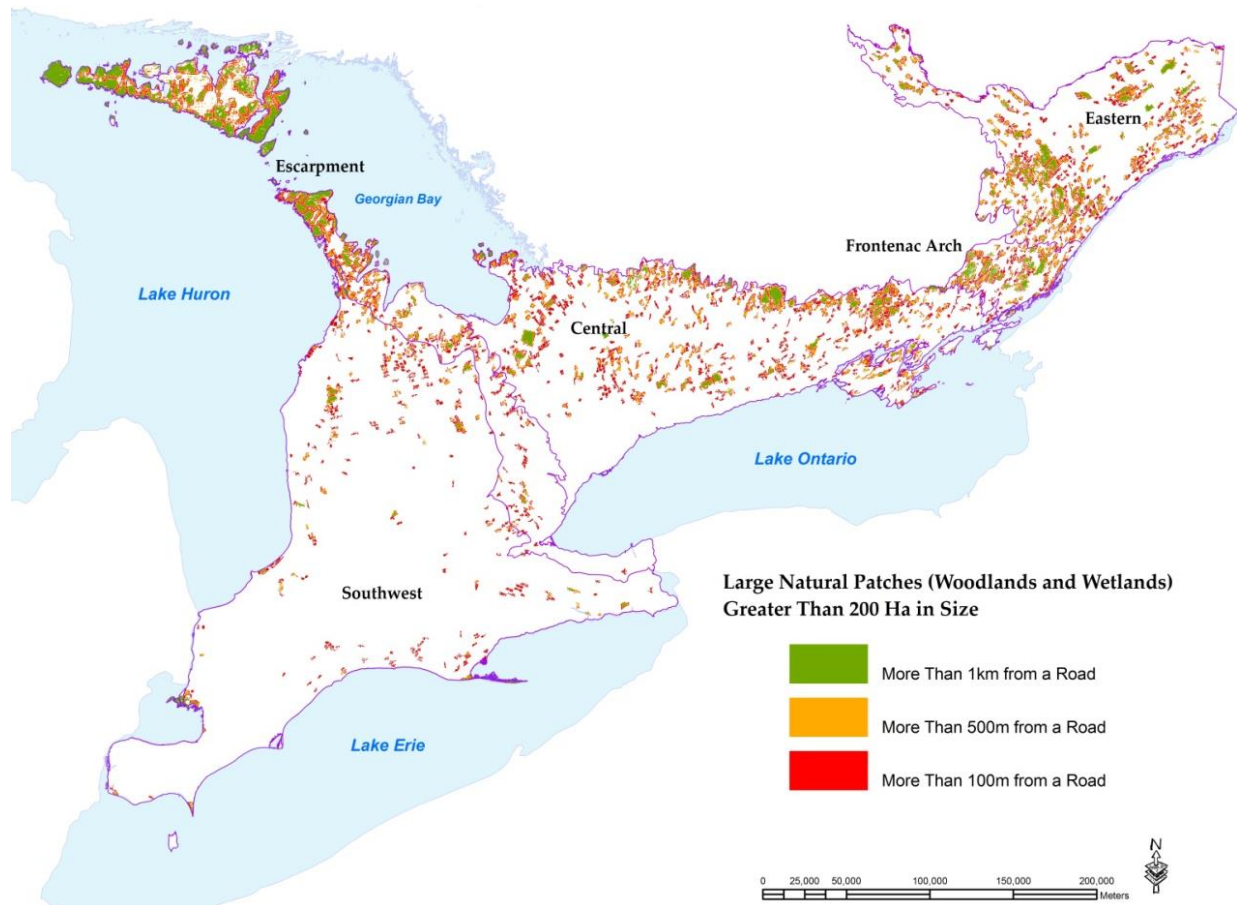


Figure 31. Proximity of large natural patches from roads in the Ontario portion of the Mixedwood Plains ecozone⁺.

Source: Ontario Ministry of Natural Resources, 2009³³⁰

The impact of roads varies greatly depending on the species in question, and the size and traffic level of the road. When roads are built, not only is natural cover lost, but roads can also act as barriers to movement and are often large sources of mortality.³³¹ Four lane highways have been found to impact moose corridors, grassland bird habitat usage, and cause road salt damage to distances up to 1 km.³³² When frog populations were studied along Hwy 401 (a four or more lane major highway), it was found that species richness was impacted to a distance of 450 to 800 m away with chorus frog populations being impacted to distances of 100 to 2400 m.³²⁵ Conversely, studies of logging roads, have shown impacts on plant species composition extending no more than 15 m from the road.³³³

Waterscapes

Fragmentation of aquatic systems with dams, weirs, and other barriers is a significant global biodiversity issue.^{116, 334, 335} The impacts of barriers on the movement of aquatic species causes loss of species diversity and ecosystem structure.^{116, 335, 336} In a global overview of dam-based impacts of large river systems, the entire Mixedwood Plains Ecozone was found to be highly impacted.¹¹⁶ When barriers to movement were examined in five watersheds in Central

physiographic region of Ontario, it could be seen that all five had barriers to aquatic species movement, however, there were large differences in the amount of fragmentation seen between watersheds. Wilmot and Oshawa creeks have relatively few barriers along their main channels, with Wilmot having the least number of barriers, while the Ganaraska River, Cobourg Creek, and Duffins Creek all have numerous barriers in their catchments making natural species movement very difficult (Figure 32). Though causal relationships cannot be drawn between barriers and productivity at this time, Wilmot Creek is recognized as the most productive cold-water stream running into Lake Ontario.^{337, 338}

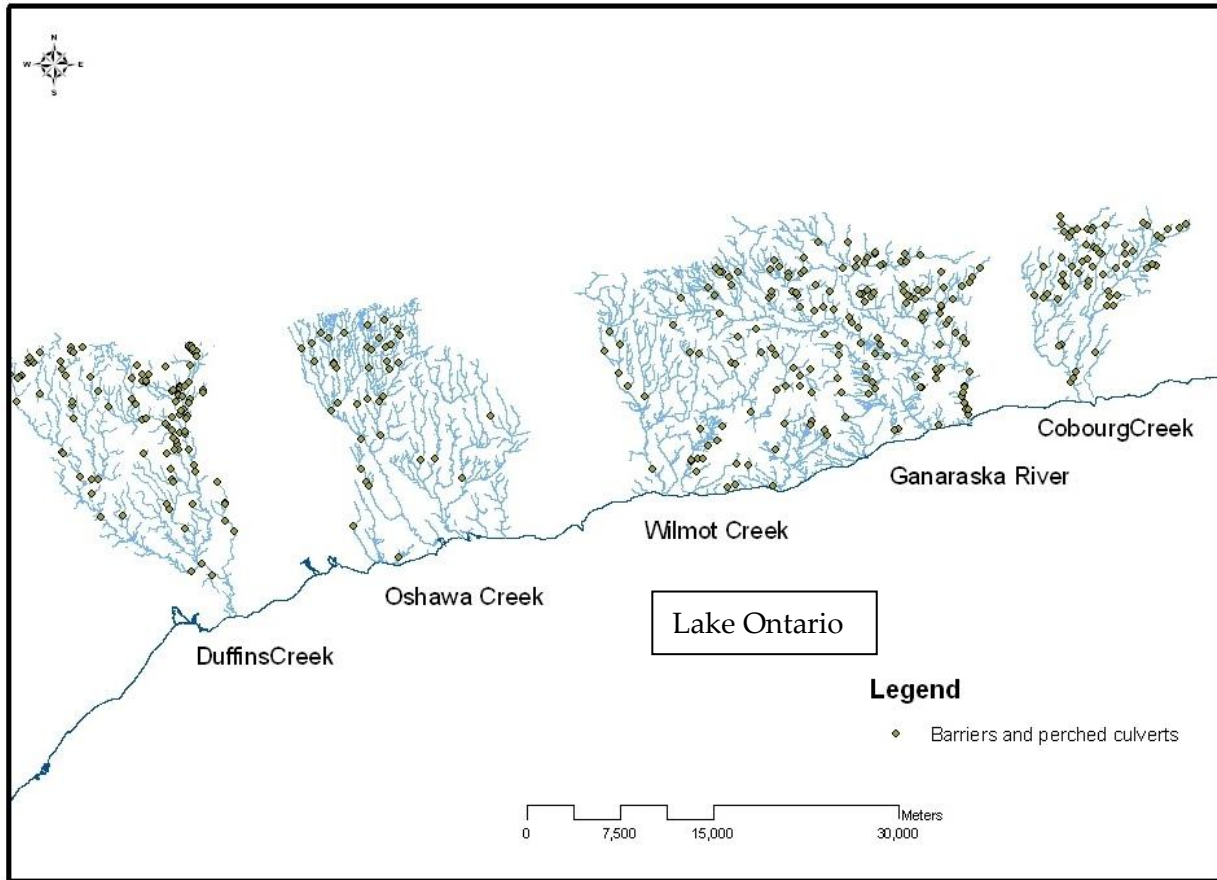


Figure 32. Extent of barriers to fish movement in five creek catchments in southern Ontario. Source: Ontario Ministry of Natural Resources, 2010³³⁹

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.

Agricultural land is the dominant land cover type in the Mixedwood Plains making up over 60% of the ecozone⁺.^{8, 340} Agricultural land use has been linked to species endangerment in the Mixedwood Plains Ecozone⁺.³⁴¹ A total of 355 terrestrial vertebrate species (birds 252, mammals 58, reptiles 24, and amphibians 21) use this agricultural land. With so much of the ecozone⁺ in agricultural land cover, the ability of that land to support wildlife is essential in preserving the biodiversity of the ecozone⁺.

When an index of wildlife habitat capacity of the agricultural land in the Mixedwood Plains was examined for the time period between 1986 and 2006, it was found to have declined significantly³⁴⁰ throughout the ecozone⁺ (a change from moderate to low capacity).³⁴⁰ Over the time period, habitat capacity decreased on 35.5% of agricultural land, increased on 19.9%, and was constant on 44.6% (Figure 33). This change was due in large part to the decrease in pasture and “all other land” (largely woodland and wetland) by 37.6 and 4.8% respectively.³⁴⁰

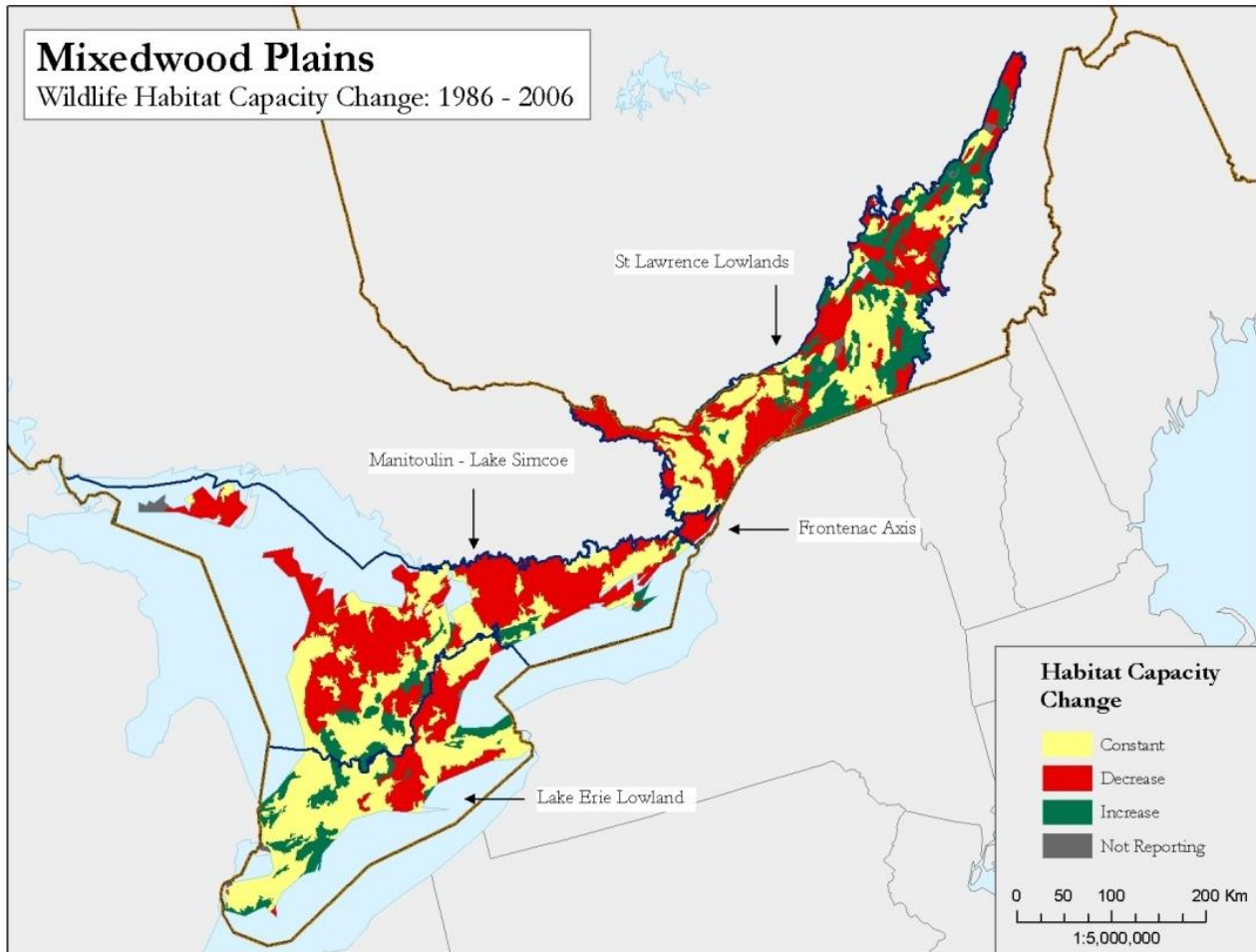


Figure 33. Changes in wildlife habitat capacity on agricultural land in the Mixedwood Plains Ecozone⁺ between 1986 and 2006.

ANOVA, Tukey HSD $p < 0.05$.

Source: Javorek and Grant, 2011³⁴⁰

During the study period, the amount of cropland expanded from 65 to 72% of the total amount of agricultural land. This represents an intensification of agriculture based primarily on the substantial increase in soybean production (6 to 16%).³⁴⁰ The changes in wildlife habitat capacity are presented in Figure 34.³⁴⁰

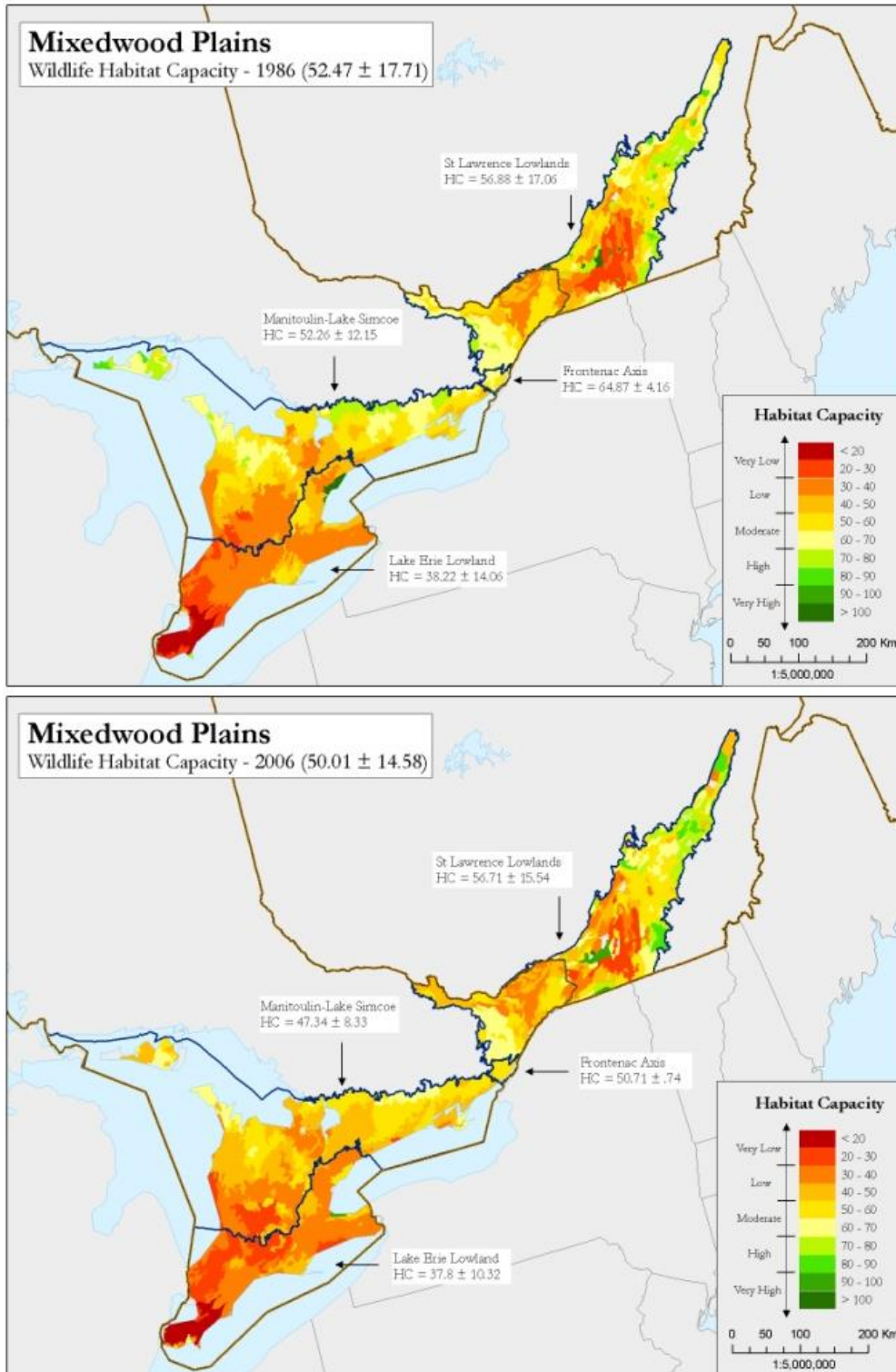


Figure 34. Wildlife habitat capacity on agricultural land in the Mixedwood Plains in 1986 (top) and 2006 (bottom).

Source: Javorek and Grant, 2011³⁴⁰

The major variability in the status of habitat capacity among regions in the Mixedwood Plains in 2006 primarily resulted from the amount and type of cropland, along with the relative share of pasture and natural/ semi-natural land. The Lake Erie Lowland reported the lowest habitat capacity as cropland comprised over 82% of agricultural land (Corn/ Soybean close to 50%) with only 13% “all of other land” and 2% unimproved pasture. The Lake Erie Lowland is part of the Southwest Physiographic zone (see Ecosystem conservation and Intact landscapes and waterscapes). The Southwest has only 8% cover of forest and 10% cover of wetlands. This low level of natural cover limits the ability of species to use the cropland for a single habitat requirement and have sufficient alternative land cover outside of the agricultural land base to meet their other habitat requirements, further compromising habitat potential. The higher habitat capacity in the Frontenac Axis, Manitoulin-Lake Simcoe, and Saint Lawrence Lowlands regions, was due to comparatively lower share of cropland (52, 66, and 66%, respectively) and greater “all other land” (21, 18, and 26%, respectively). These regions also have higher proportions of natural cover outside of the agricultural land base than the Lake Erie Lowlands, with percentages of natural cover ranging from 35 to 57%.¹⁶¹ This may mean that species which use agricultural land as part of their habitat may be able to find nearby natural land cover to complete their habitat requirements. The significantly higher “all other land” (woodland and wetland found on land defined as agricultural) component within the agricultural land base in the St. Lawrence Lowland was the main reason for this region reporting the highest habitat capacity on agricultural land in the Mixedwood Plains Ecozone⁺. This is interesting in light of the fact that St. Lawrence Lowland’s associated physiographic area, the Eastern physiographic zone (see Ecosystem Conversion Key Finding) does not have the highest percentage of natural land cover in the ecozone⁺ (33% in the Quebec portion and 37% in the Ontario portion), that is found in the Frontenac Arch (57%),¹⁶¹ indicating that higher wildlife capacity on the agricultural land base may not necessarily be linked with higher wildlife capacity in the landscape as a whole. There were other agricultural land use differences among these regions that impacted wildlife habitat capacity. Intensive Corn/Soybean production was considerably higher in Saint Lawrence Lowlands (32%) and Manitoulin-Lake Simcoe (30%) compared to the Frontenac Axis which had less than 1% Soybean and 17% Corn.³⁴⁰ The Frontenac Axis, had considerably more Unimproved Pasture (20%); the second most important cover type for wildlife, than did the St. Lawrence Lowlands (5%) and Manitoulin-Lake Simcoe (9%).³⁴⁰ This difference may be partly explained by the fact that the Frontenac Arch is an extension of the Canadian Shield that has shallow soils over bedrock that do not lend themselves to farming generally, or cropland in particular, to the same extent as the flat clay plain of the St. Lawrence Lowland.¹⁶¹

The impact of fragmentation on bird species has been discussed in the literature mostly in relation to forest bird species; however, agricultural intensification can also impact bird species populations. Jobin et al. (1996)³⁴² studied the farmland bird populations in the St. Lawrence valley using 24 years of Breeding Bird Surveys starting in the 1960s. They found that bird species diversity was higher in areas with diverse cover types than in those dominated by annual/ cash crops. Many species associated with dairy farming and perennial crop areas such as savannah sparrow (*Passerculus sandwichensis*), bobolink (*Dolichonyx oryzivorus*), brown-headed cowbird (*Molothrus ater*) and eastern meadowlark (*Sturnella magna*), showed decreasing population abundance between 1966 and 1990.³⁴²

When trends in the birds of open and grassland habitats were examined for the ecozone⁺ as a whole,³⁴³ it was found that both of these assemblages were experiencing declines. The grassland birds show dramatic declines particularly since the 1980s. Several species have lost 50% or more of their population over the last four decades, likely due to the combined effects of loss of marginal farmland to forest and more intensive use of remaining agricultural lands, where most of these birds nest and winter (Figure 35).³⁴³ Analysis of long-term data from several different bird surveys confirms significant declines in birds of grassland and open/agricultural habitats in the Mixedwood Plains".²¹³ This trend is not unique to the Mixedwood Plains as grassland birds are declining throughout North America.³⁴⁴

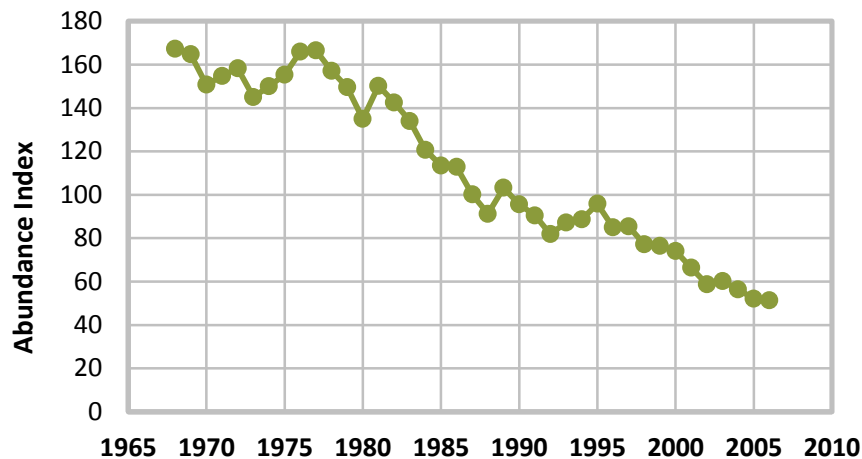


Figure 35. Annual indices of population change of grassland birds in the Mixedwood Plains Ecozone⁺
 Source: Downes et al., 2011³⁴³

The number of wind farms in Ontario has increased dramatically in the last few years and this trend is expected to continue. There are concerns that the presence of the wind turbines might result in lower nesting densities of bobolinks, eastern meadowlarks, and other grassland birds because of avoidance or abandonment of areas too close to the structures.^{345, 346} An even greater threat may be the increase in intensive agricultural practices in some areas, accompanied by loss of hedgerows.³⁴³

When birds of open or agricultural habitats were examined³⁴³ (Figure 36) declines were seen to include raptors, passerines, and short-distance and neotropical migrants, suggesting that problems on the breeding ground may be a common factor.³⁴³ Declines were seen in the aerial insectivores found in this assemblage, a group which is also declining nationally.^{347, 348} Loss of old-field habitat due to succession and the intensive use of remaining agricultural lands may be contributors.³⁴³

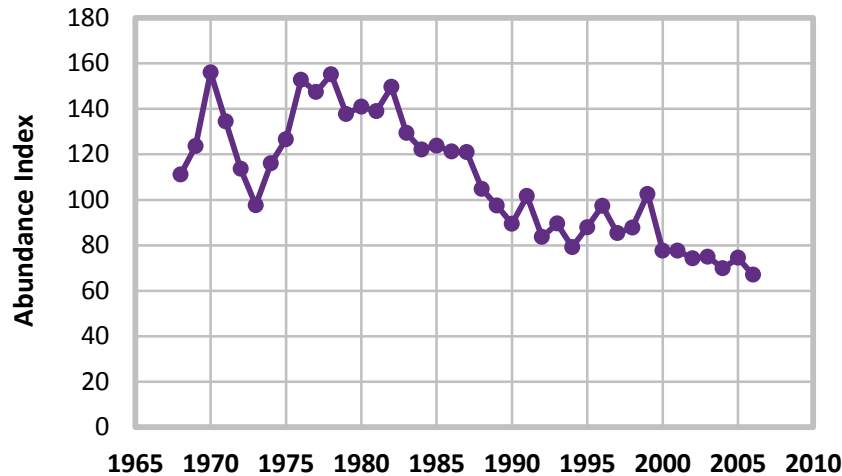


Figure 36. Annual indices of population change of open habitat birds in the Mixedwood Plains Ecozone⁺. Source: Downes et al., 2011³⁴³

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.

It is estimated that approximately 30,000 species live in the province of Ontario.¹⁴⁶ While the status of many species is well known, occurrence data for the majority of species is incomplete and their conservation status consequently obscure. For example, there is little information on how many fungi³⁴⁹ occur in the ecozone⁺, and while the occurrence of some insect orders, such as Lepidoptera (butterflies) and Odonata (dragonflies and damselflies) is well-known, knowledge of most invertebrate groups is generally poor. In 2005, the Canadian Endangered Species Conservation Council (CESCC) assessed the status of 4,217 Ontario's species through "Wild Species 2005".²⁵⁸ Though most of the assessed species groups comprise species with secure populations, the majority of both freshwater mussels and reptiles species fall into categories of conservation concern (Sensitive, May be at risk, At risk) (Figure 37).

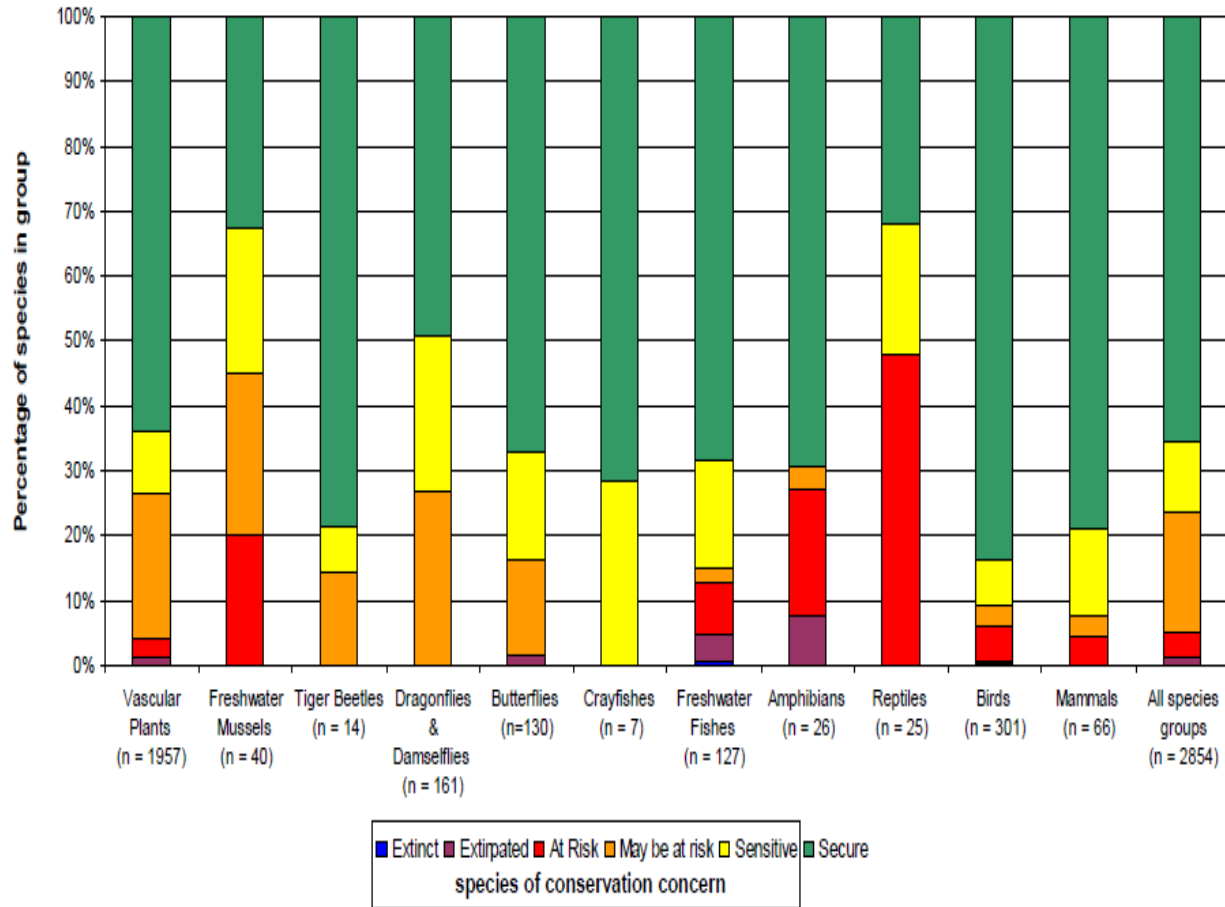


Figure 37. The number of Ontario native species which are secure or of conservation concern based on the General Status Rank categories, 2005.

Source: Ontario Biodiversity Council, 2010²¹³ based on original data from the Canadian Endangered Species Conservation Council 2006

Based on COSEWIC (Committee on the Status of Endangered Wildlife in Canada) at-risk categories and species that are tracked by provincial conservation data centres, there are 865 species of conservation concern in the Mixedwood Plains (Table 12). Approximately two thirds of the assessed species were vascular plants, and the taxon with the greatest number of species of conservation concern was vascular plants.

Table 12. Species of conservation concern in the Mixedwood Plains, 2009.

Taxon	Number of tracked species	COSEWIC			
		SC	THR	END	EXP
Mammals	12	2	1	1	
Birds	37	7	4	6	
Reptiles	24	4	10	5	1
Amphibians	12	1	3	3	1
Fish and Lampreys	45	13	7	5	1
Insects	74	0	0	1	1
Other Invertebrates	40	0	0	8	
Vascular Plants	584	11	19	39	2
Non-vascular Plants	37	3	3	1	
Total	865	41	47	69	6

Species tracked by the Ontario Natural Heritage Information Centre and Centre de données sur le patrimoine naturel du Québec are included as well as species identified as being at risk by the Committee on the Status of Endangered Wildlife in Canada (COSEWIC). SC= Special Concern, THR=Threatened, END=Endangered, EXP=Extirpated. The COSEWIC-listed species are a subset of the tracked species. The data are valid as of February 12, 2009.

When the number of species within a species group is taken into consideration, reptiles are proportionally the group of greatest concern, followed by mussels, amphibians, and fishes. Determining the most appropriate actions for conservation should be done based on more than just declining population trends,³⁵⁰ information such as abundance, breadth of range, rate of habitat loss, and whether the trend is part of a long term decline or if the species has a history of population fluctuation are all important factors.³⁵⁰ Declines in freshwater mussels, fishes, bumblebees, and reptiles and amphibians are presented in this key finding as examples of some of the changes in species populations occurring in the Mixedwood Plains.

Freshwater mussels

Southern Ontario has the highest diversity of freshwater mussels in Canada¹¹⁸ and all of the 41 species known to occur in Ontario are found in the Mixedwood Plains Ecozone⁺.³⁵¹ Most species of freshwater mussel have a specialized and unique life history strategy in that they require host fish for the dispersal of their larvae.³⁵² This relationship means that the recovery of rare mussel species is highly dependent on the host fish species.³⁵³ When mussel populations for the Great Lakes basin were examined from 1860 to 1996 (136 years) it was found that the number of species had been decreasing and that community composition had shifted,¹³² with the abundance of silt and pollution-tolerant species (subfamily Anodontinae) having decreased. Over the last two to three decades, four species of mussels have been lost from the Sydenham River, ten from the Thames River, nine from the Grand River, and there has been an almost complete collapse of the Great Lakes populations, likely due to the combined effects of intense agriculture, urban development, and the invading zebra mussel.³⁵⁴ Several refugia for mussels have been found in the Great Lakes at Metzger Marsh, Crane Creek Marsh, and Thompson Bay on Lake Erie in Ohio.³⁵⁵ The Lake St. Clair delta provides a refuge for the largest mussel

community in the lower Great Lakes and this site includes several species within its populations that have been listed as endangered or threatened in Canada and/or the State of Michigan making it an important refuge for the conservation of native mussels.³⁵⁵ It is believed that the offshore currents in the delta mitigate the ability of zebra mussel veligers to infest the native mussel species (zebra mussels will cling to the surface of native mussel species using them as substrate to grow on thus decreasing the survivorship of the native species) in the nearshore compared to offshore waters, thus creating a refuge for the native mussels.³⁵⁵ The highest diversity of freshwater mussels in Quebec is observed in the Mixed Wood Plain Ecozone; the Saint-François River harbors 12 species of the 23 species found in Quebec.³⁵⁶

Birds

When the results of the Breeding Bird Survey were examined from the 1970s to the 2000s, it was found that trends differed by habitat group. Birds of woodland habitat have fared best overall, while grassland birds and other birds of open/agricultural habitat have declined as a group since the 1970s (Table 13). Grassland birds showed the greatest decline of all groups with the abundance within the ecozone⁺ having dropped by over 60% since the 1970s.³⁴³

Table 13. Trends in abundance of landbirds for the Mixedwood Plains Ecozone⁺.

Species Assemblages	Trend (%/yr)	P	BBS Abundance Index				
			1970s	1980s	1990s	2000s	Change (%)
Forest Birds	1.1		50.6	56.9	64.2	67.3	33
Shrub/Successional	0.1		117.2	123.5	122.5	125.2	7
Grassland	-3.1	*	155.4	120.3	86.4	59.9	-61
Other Open	-1.8	*	133.8	124.9	90.4	74.8	-44
Urban/Suburban	-0.7	*	425.9	394.3	364.4	352.2	-17

P is the statistical significance: * indicates $P < 0.05$; *n* indicates $0.05 < P < 0.1$; no value indicates not significant

“Change” is the percent change in the average index of abundance between the first decade for which there are results (1970s) and the 2000s (2000–2006).

Source: Downes et al., 2011³⁴³

The general increase in birds of woodland habitats is likely a result of increases in forest cover that have occurred in some portions of the ecozone⁺ (see Forests). However, not all forest dwelling species are doing well; for example the Eastern wood pewee has declined by 55% since the 1970s.³⁴³ This species undertakes long-distant migration to South America and is also of one of many species that feed on flying insects that are experiencing declining populations. Some of the other species showing decline, such as veery (-31%), are interior forest nesters which tend to decline in abundance in forest patches with less than 20 ha of interior forest.³⁵⁷ Decreases in grassland birds have been attributed to agricultural intensification, loss of hedgerows, vegetation succession, and the increased use of chemical pesticides (see also Ecosystem conversion and Agricultural landscapes as habitat).³⁴³ Research from the United States also raises concern over the increase in wind turbines in grassland habitats and possible avoidance of areas close to turbines by species such as bobolinks and eastern meadowlark.³⁴⁵ Decreases in

birds of open/agricultural habitat are also attributed to habitat loss due to succession and intensification of use in remaining agricultural lands.

The decline in urban/suburban birds is less understood as these species are united by their tolerance of human presence. Declines in chimney swifts (-77%) are consistent with the declines in other aerial insectivores and with the loss of old-fashioned chimneys (due to capping and lining)³⁴³ but the declines in introduced species, such as house sparrow (-56%) and European starling (-35%), are harder to explain. In Europe, similar declines in house sparrow have been attributed to decreases in the numbers of chicks fledging due to decreases in the abundance of invertebrate prey.³⁵⁸ Other reasons for decline may be loss of nesting habitat and increases in pollution and predators.³⁴³

Significant declines in breeding populations of shorebirds were found between 1968 and 2006 in four of five species covered by the Breeding Bird Survey, with declines as high as 80% for spotted sandpiper and -64% for American woodcock.³⁵⁹ Wetland birds are also experiencing declines. Four of ten colonial waterbird species are declining in the Great Lakes. Great black backed gull is declining due to botulism and the common tern is probably declining due to competition with ring-billed gulls.³⁶⁰ Many marsh birds are also declining with the contributing factors including habitat loss and degradation, altered water levels, and invasive species.³⁶⁰

American black duck

Over 90% of the world population of American black ducks breed in eastern Canada³⁶¹ and the population declined by almost 50% between 1955 and 1985.³⁶² One of the most abundant ducks in eastern Canada, the population has been stable at about 450,000 since 1990, although declines continue in the Mixedwood Plains.^{363, 364} Causes for the decline are not clear but likely include habitat loss due to development and agriculture^{362, 365, 366} and displacement through competition with mallards³⁶⁷ which have been expanding in abundance and range.^{362, 365, 368} Population increases in other areas could be due to changes in management practices, such as increased hunting restrictions.³⁶⁹

Freshwater fish

The Mixedwood Plains has the highest diversity of freshwater fishes in Canada.¹¹⁷ The fish of this ecozone⁺ represent 97% of the total fish taxa for Ontario and 86% of the total for Quebec. Combined, the ecozone⁺ represents 78% of the total number of species for Canada.³⁷⁰ The majority of the rare fish species in the ecozone⁺ are fluvial specialists (flowing water obligates).^{371, 372} Comprehensive data are not available to allow for discussion of overall trends, but individual studies are available which provide some insights into the kinds of changes that are taking place within fish communities within the ecozone⁺.

Of the 21 species for which there is monitoring data for Lake Simcoe, seven species decreased in abundance between 1995 and 2003.³⁷³ Surveys of two tributaries of Lake Ontario in 2000 captured only 10 of 22 historical species in Carruthers Creek and only 28 of 50 historical species in Duffins Creek.¹²² In the Speed River (near Guelph Ontario), the ranges of cold-water species have contracted toward the headwaters while warm-water species have expanded their ranges upstream over the last 25 years.¹²¹ In the Grand River, brook trout populations have

disappeared or have been severely reduced in some reaches.¹⁰³ In a study of four shallow warm-water lakes in the Kawartha Lakes between 1980 and 2003,¹¹¹ consistent declines were found for walleye (*Sander vitreus vitreus*) populations while increasing trends were seen for smallmouth bass (*Micropterus dolomieu*) and largemouth bass (*Micropterus salmoides*) populations.

One of the fish species most at risk in the Ontario section of the ecozone⁺ is the reidside dace (*Clinostomus elongatus*), whose historic range included what is now the most heavily populated parts of southern Ontario. It is sensitive to alterations in flow regime, water temperature, and siltation, and its remaining populations are found in areas of rapid urban development. Its status was uplisted from threatened to endangered by COSEWIC in 2007.³⁷⁴

The copper redhorse (*Myxostoma hubbsi*) is the fish species facing the highest risks of extinction in the St. Lawrence Lowlands. The Richelieu (downstream of Chambly Basin) and Mille-îles Rivers and reaches of the St. Lawrence River connecting the latter represent the extent of the range for this rare and endemic species to Quebec. The COSEWIC declared the species *threatened* in 1987 and upgraded its status to *endangered* in 2004. The present population is estimated to a few hundred individuals. The recovery plan put in place in 2004 aims, amongst others, to improve natural reproduction by protecting and restoring its critical habitat, enhance recruitment through fish stocking and protect the species habitat through regulatory measures. The facts that the species reaches sexual maturity at age 10, spawns in late fall, has a weak recruitment and has a very restricted diet are all compounding factors acting on the vulnerability of the species. Significant protecting measures are needed to curb nutrients and toxic pollution originating from agricultural, municipal, and industrial activities as well as habitat destruction in order to avoid witness the extinction of this endemic species to the St. Lawrence Lowlands.³⁷⁵

Bumblebees

Throughout Europe and North America, declines in bumblebees have been documented.^{376, 377} In the vicinity of Guelph, Ontario, a comparison of bumblebee populations between the 1970s and 2004/06 revealed that 7 of the 14 species found in the 1970s were no longer present.³⁷⁷ One species, the rusty patched bumblebee (*Bombus affinis*) was found to have declined dramatically in abundance not only in southern Ontario but throughout its entire native range.³⁷⁷ The reasons for the decline are not well understood but possible explanations include habitat loss, pesticide use, introduction of disease from managed bees, and climate change. The rusty patched bumblebee was assessed as endangered by COSEWIC and listed as Endangered under Ontario's *Endangered Species Act*, 2007. Declines in bumblebees in the American midwest have been found to coincide with large-scale agricultural intensification.³⁷⁶ When the attributes of bee species experiencing decline were compared using three independent faunas in Britain, Ontario, and Sichuan, it was found that species with narrow climatic ranges, which occur close to the edges of those ranges, or which have queens that become active later in the season were the most susceptible to decline.³⁷⁸

Reptiles and amphibians

There are 26 native species of reptiles and 25 native species of amphibians found in the Mixedwood Plains Ecozone⁺. They are the most imperilled of all the assessed species groups. Of these 51 species, 26 (approximately 51%) were assessed as at risk by COSEWIC in 2008.¹¹ Of the 12 species found in Canada only in the Mixedwood Plains, all (100%) are at risk.^x Turtles appear to be in the greatest peril as seven of the eight native species (87.5%) found in the ecozone⁺ are at risk.^{xi} Snakes are similarly imperilled, with 11 of 17 (65%) of the species found in the ecozone⁺ assessed as at risk.¹¹

In both Ontario and Quebec, most amphibian monitoring is conducted by volunteer citizen based science programs. When data from the Marsh Monitoring Program for the Great Lakes basin (Canada and United States) were analyzed, statistically significant declining trends were detected for American toad, western chorus frog, green frog, and northern leopard frog (Figure 38). None of the commonly found species had a positive trend. Mink frog (not as common) exhibited a significantly increasing trend between 1995 and 2007.¹⁴⁷ Declines in chorus frog, green frog, and wood frog have also been reported by other authors.^{379, 380} In Quebec, western chorus frog has declined dramatically. Since 1950, this species has disappeared from more than 90% of its range in the Montérégie region. The major reason for this decline is habitat loss to urbanisation and agriculture. The species is also declining in the Outaouais region.³⁸¹

^x All species designated by COSEWIC were considered including those currently extirpated.

^{xi} The box turtle was not considered as it has not been determined whether it is a native species.

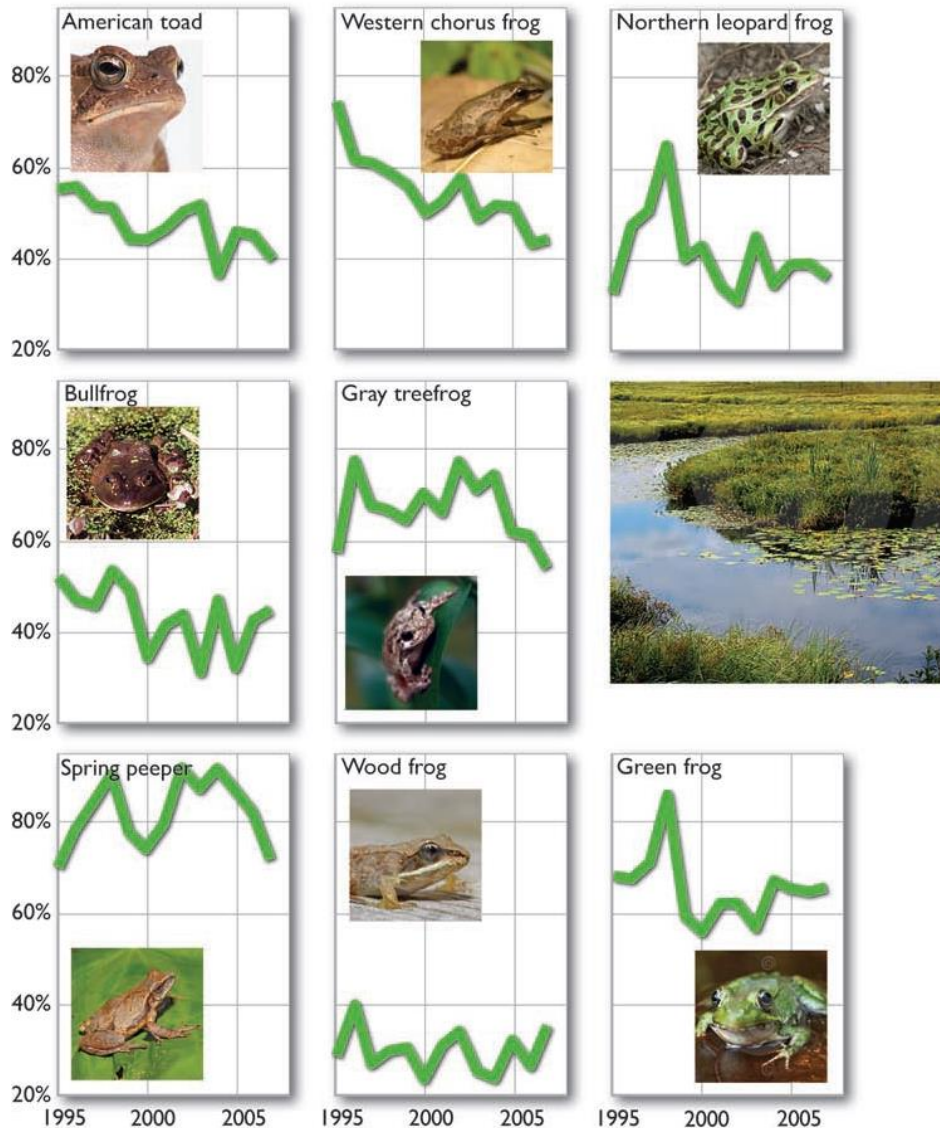


Figure 38. Amphibian trends in the Great Lakes Basin, 1995-2007.

Graphs depict change in the annual occurrence index that shows the percent of monitoring stations where the species was recorded from the Marsh Monitoring Program

Source: adapted from Archer et al. 2009¹⁴⁷

Photos: dreamstime.com: American toad, Spring peeper, Wood frog, and Green frog; and iStock.com: Western chorus frog, Northern leopard frog, Bullfrog, and Gray treefrog

The COSEWIC status reports for Massasauga rattlesnake (2008), blue racer (2002), eastern hog-nosed snake (2001), and wood turtle (2002) demonstrate dramatic range reductions and local extirpations in the Mixedwood Plains Ecozone⁺.³⁸²⁻³⁸⁵

There are many reasons for the declines in reptile and amphibian populations. As with most species in the ecozone⁺, one major factor is habitat loss and fragmentation.³⁸⁶ Road mortality is an issue for both reptiles and amphibians.^{325, 387, 388} Daigle and Jutras (2005),³⁸⁹ found that a wood turtle population declined by 50% in seven years and attribute that decline to habitat

modification, road mortality, and farm machinery mortality. Female turtles are particularly at risk as they are often hit by vehicles during their nesting migrations.^{390, 391}

Environmental pollutants are another cause of declines. Broad spectrum herbicides based on glyphosate have been found to kill between 68 and 86% of juvenile amphibians after one day.³⁹² High levels of PCBs, organochlorine pesticides, and dioxins/furans have been reported in turtles in Ontario.³⁹³

Chytridiomycosis (*Batrachochytrium dendrobatidis*- a fungal disease impacting amphibians) has had widespread impacts on amphibians worldwide, including the Mixedwood Plains. It has been found in a number of common amphibian species in 30 locations in the St. Lawrence River Valley of Quebec.³⁹⁴ More research is needed to determine the best ways to mitigate the impacts of chytridiomycosis, and to understand how influences such as habitat alteration, projected climate change, and exposure to chemical pollutants interact to cause the observed population impacts.

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.

Evidence from Ontario

Net primary productivity (NPP) is a measure of the amount of plant biomass per area produced over time. Factors that influence plant growth therefore also govern the amount of primary production in any given area.³⁹⁵ Large-scale estimates of terrestrial NPP are usually made using remotely sensed data and tend not to take into account the production of below-ground biomass; they therefore likely underestimate actual primary production.³⁹⁶

NPP estimates from satellite data reported for Canada range from a high of 700 grams of carbon per square meter per year ($\text{g C m}^{-2} \text{ year}^{-1}$) in the southeast part of Vancouver Island to a low in the far north of less than $1 \text{ g C m}^{-2} \text{ year}^{-1}$.³⁹⁷ The mean NPP for the Mixedwood Plains is estimated at $257 \text{ g C m}^{-2} \text{ year}^{-1}$, although forested areas within the Niagara Escarpment and Frontenac Arch (which have 43 percent forest cover) have values as high as $500 \text{ g C m}^{-2} \text{ year}^{-1}$ and, therefore, some of the highest NPP in the country. The mean NPP for the ecozone⁺ is reduced by the low production of crop lands (average NPP values of $220 \text{ g C m}^{-2} \text{ year}^{-1}$) and urban and industrial areas.

Hicke *et al.*, (2002)³⁹⁸ examined trends in North American net primary productivity derived from satellite observations from between 1982 and 1998. Most of the Mixedwood Plains (aside from an area in Ontario around Guelph and Midhurst) showed a positive trend of increasing

NPP of approximately $2 \text{ g C m}^{-2} \text{ yr}^{-1}$, with increases between 2 and 20%. The greatest increases were in the eastern Quebec portion of the ecozone⁺. These authors found that the maximum monthly trend in NPP was in August, September, or October for the Mixedwood Plains. Though this work is at a very coarse scale, it appears to demonstrate that those areas of the ecozone⁺ with cropland had maxima in August, while those with more forest cover had maxima in September or October. Hicke *et al.*, (2002)³⁹⁸ also found that over the 16-year study period, across North America in general, croplands had the largest mean increase in NPP followed by deciduous broadleaf forests. These cover types are common in the Mixedwood Plains. They attributed the increases in summer NPP found in the Mixedwood Plains area to an increased in precipitation in this part of the continent during the study period.

Estimates of NPP from physical, on-ground sampling are few for the Mixedwood Plains. Moore *et al.*, (2002)³⁹⁹, who studied Mer Bleue Bog near Ottawa, found that NPP varied at microsites within the bog. Bog-hummock NPP, for example, was estimated at $290 \text{ g C m}^{-2} \text{ year}^{-1}$ while bog-hollow NPP was $330 \text{ g C m}^{-2} \text{ year}^{-1}$. The average for the bog was about $302 \text{ g C m}^{-2} \text{ year}^{-1}$, while a nearby fen had an NPP of $360 \text{ g C m}^{-2} \text{ year}^{-1}$ (all vegetation strata combined). These values seem high relative to the numbers reported for cropland by Liu *et al.*, (2002),³⁹⁷ however bogs and fens have continuous vegetation cover and multiple strata of vegetation (mosses, herbs, shrubs and trees) and this may be responsible for the higher values for NPP from this bog/fen area compared to those reported for crop lands by Liu *et al.*, (2002).³⁹⁷

Though there has been little published on NPP that applies to this ecozone⁺, the following observations are offered:

- Natural ecosystems (at least in this ecozone⁺) generally have higher NPP than human-altered systems such as agricultural and urban areas; and
- Even ecosystems traditionally associated with slow growth, such as bogs and fens, have higher levels of NPP than human-altered systems.

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.

Since much of the Mixedwood Plains have been settled for at least two centuries, it is necessary to rely on historical accounts of disturbances to understand their former role in this landscape. Historically, insect outbreaks, fire, high wind speeds, and ice storms were the four main natural disturbance types that regulate forest dynamics in the ecozone⁺.

Fire

Reconstruction of pre-European vegetation and disturbance patterns from sediment analysis shows evidence of First Nations use of fire in this ecozone⁺ for both the clearing of agricultural land and for wildlife management.⁴⁰⁰ The extent to which fire was used by these early peoples is difficult to determine, but it is certain that the area burned would have been more than occurred from natural lightning strikes,⁴⁰¹ with areas as large as several square kilometres cleared around First Nation communities.¹² Estimates for the pre-settlement fire cycle range from 900 years^{402, 403} to 700 to 93,000 years.⁴⁰⁴ Post settlement, the cycle is estimated to be 5081 years.^{402, 403} If the Mixedwood Plains were dependent solely on stand-replacing fires as its main disturbance, early successional communities would virtually disappear from the landscape because of the very long cycle of major natural fires. Frequent surface fires are believed to have been the common fire type in the Mixedwood Plains⁴⁰⁵ and small scale gap disturbances were the normal disturbance agents driving species composition.

In Ontario today, all fires within the Mixedwood Plains receive full suppression either by municipal fire departments or the OMNR, depending on land tenure. No data is available on the area burned for the Ontario portion of the ecozone⁺⁴⁰⁶ and the ecozone⁺ no longer has a natural fire regime.

In Quebec, all fires within the ecozone⁺ also receive full suppression by the “Société de protection contre les incendies de forêts” or municipal fire departments. Data is available on forest fires for the time period between the first forest survey conducted from 1969 to 1975 and the third survey period occurring from 1990 to 1995.²³ Over this period, fire affected only 0.06% of the forest cover. Fire was the most important disturbance agent found between the first and the second (1981 to 1988) inventory periods as it represented 76% of the total area disturbed. Its importance decreased considerably during the period between the second and the third inventory when it represent only 14% of the total area disturbed.²³

Fire is a disturbance agent that creates unique site conditions for regeneration that are not duplicated by other natural (e.g. wind) forces or anthropogenic disturbances, such as forest harvesting.⁴⁰⁷⁻⁴⁰⁹ With the removal of fire as a disturbance agent, the amount of natural vegetation undergoing succession towards late successional stages may be increased above natural levels within protected areas where harvesting is not permitted. On the rest of the landscape, harvesting tends to limit the development of old growth stands. Fire removal may affect forest composition since tree species such as white pine, jack pine, and oaks species require fire for some of their regeneration processes.⁴¹⁰

Prairie and savannah communities are particularly vulnerable to fire removal as they succeed into other ecosystem types relatively quickly if they are not burned. These ecosystems are some of the very few communities in which prescribed burns are currently used as vegetation management tool in the Ontario portion of the ecozone⁺. Many prescribed burns occur on private land and without a reporting requirement; there is therefore no data available for them.⁴⁰⁶ Prescribed burns generally emulate surface fires since they are never allowed to occur under weather conditions which would result in stand-replacing fires. This is a positive influence for biodiversity in the Mixedwood Plains Ecozone⁺, since these surface fires were

likely the dominant type of fire in the system's natural state.^{405, 411} Although data are not available to quantify fire trends in the Mixedwood Plains, it appears that there is increasing recognition of the important ecological role of fire in ecosystems, and potentially better acceptance of using prescribed burns as a vegetation management tool, particularly for prairie and savannah communities.⁴⁰⁶ The ecological role of fire in the regeneration and disturbance of pine⁴¹² and oak^{413, 414} forest is well known. The use of fire to maintain these species could support biodiversity objectives.⁴¹²

Insect outbreaks

When the amount of forest land within the Ontario portion of the ecozone⁺ damaged by insects and diseases was examined for the period between 2001 and 2005, it was found that 14.8% had been damaged.⁴¹⁵ Almost all of that land, 98.2%, was impacted by single species infestations; only 1.8% was due to multiple species infestations. Forest tent caterpillar (*Malacosoma disstria*) and spruce budworm (*Christoneura fumiferana*) were responsible for about half of the damage in the Ontario portion of the ecozone⁺ (6.9%) while all other species combined to make up the remaining 7.9% of the impacted area.⁴¹⁵

In forests within Quebec's portion of the ecozone⁺, the area moderately or severely affected by insect infestations represented only 0.05% of the forest cover from the first (1969 to 1975) to the third inventory program (1990 to 1995).²³ While this disturbance type represented approximately 19% of the total disturbed area between the first and the second inventory program (1981 to 1988), it increased to 57% of the total disturbed area during the period from the second and the third inventory program.²³ In the northeastern North America, balsam fir (*Abies balsamea* (L.) Mill.) defoliation caused by spruce budworm outbreaks is one of the major natural disturbances leading to tree mortality in balsam fir and spruce stands.⁴¹⁶ Spruce budworm outbreaks occur with a recurrence cycle of approximately 30 years, and their effects on forest productivity cannot be compared with any other insect in eastern North America.^{416, 417} At the provincial scale, the last outbreak in Quebec (1975 to 1985) defoliated, on average, 14 million hectares annually⁴¹⁸ and destroyed annually 139 to 238 million m³ of softwood on public lands⁴¹⁹ leading to very important economic losses.

It is very difficult to know whether the levels of insect infestation by native species are higher than those experienced historically as no information exists to allow for comparison. The area infested by non-native invasive forest insects such as gypsy moth (*Lymantria dispar*), emerald ash borer (*Agrilus plannipennis*), Sirex woodwasps (*Sirex noctillo*) is in excess of natural disturbance levels as those species never occurred naturally within the ecozone⁺.¹⁶¹

Severe winds

Historically wind disturbance is considered to have been a larger disturbance in this ecozone⁺ than fire.^{32, 33, 404, 420} A surveyor's note reconstruction from northern Wisconsin⁴⁰⁴ found that heavy blow down was more prevalent than fire disturbance in pre-settlement forests (the vegetation in Wisconsin is part of the same international ecozone⁺) and that blow down patches were both smaller and more complex in shape than those associated with forest fire. The wind cycle was found to range from 450 to 10,500 years⁴⁰⁴ to 1210 years⁴²⁰. Wind cycles varied across

landscapes, with some areas having cycles several orders of magnitude longer than others depending on the substrate, forest species composition, climate, and storm patterns.⁴⁰⁴

Areas within the Mixedwood Plains are located in one of Canada's few "Tornado Alleys", where tornadoes occur at higher frequency than elsewhere in the country. A narrow corridor from extreme southwestern Ontario near Lake St. Clair, northeastward to Stratford, Shelburne, and Barrie, has been the location of many of Canada's worst tornadoes.⁴²¹⁻⁴²³ A portion of southeastern Quebec is similarly affected.

Many of the tree species found in the ecozone⁺ have rooting systems and morphologies that make them less susceptible to blow down.⁴²⁴ When wind throw was examined within the forested lands in the Ontario portion of the ecozone⁺, only 0.01% experienced wind throw between 2001 and 2005.¹⁶¹ A similar situation was observed in Quebec,²³ where it was found that from the first (1969 to 1975) to the third inventory program (1990 to 1996), the area affected by partial or total wind throw represented only 0.02% of the total forest area. The affected area increased over time with 0.025% of the forest affected between the second (1981 to 1988) inventory and the third, while only 0.003% was affected between the first and second inventories.²³ The Intergovernmental Panel on Climate Change⁴²⁵ has suggested that climate warming in this area will result in increased heat in the lower atmosphere, and therefore higher wind storm frequencies in the future.

Ice storms

Ice storms are another common disturbance of the forests of the ecozone⁺ occurring at 20 to 100 year intervals.²⁷ The 1998 ice storm damaged forests throughout eastern Ontario and southwestern Quebec. In southwestern Quebec the ice was 80 to 100mm thick and all but 3% of trees with a diameter of greater than 10 cm lost at least some of their crown branches and 35% lost at least half of their crown.²⁶ In eastern Ontario, the ice storm covered 604,000 km² ⁴²⁶ and was associated with an increase in patch isolation or fragmentation.²⁷ When the impacts of the ice storm on maple sugar production were studied in eastern Ontario, it was found that ice storm damage on sugar maple crowns had significant effects on sap sweetness and syrup production capacity for up to six years after the storm. After six years, trees with moderate and severe crown damage had recovered sufficiently to maintain root starch levels similar to trees that sustained light damage.⁴²⁶ Tree growth was also reduced for three years after the storm on moderately to severely damaged trees.⁴²⁶

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.

Evidence from Ontario

Human activities in the Mixedwood Plains Ecozone⁺ have led to a number of changes in the relationships among species. Through either the alteration of habitat availability and quality or harvest of species, humans have changed the relationships between predators and prey and thus the population dynamics of the species within the ecozone⁺. Habitat loss and fragmentation have huge impacts on predator-prey relationships⁴²⁷ but the nature of the change that occurs depends greatly on whether the predator is a specialist or generalist. Specialist predators rely on a narrow array of prey and when their prey's habitat is lost, there are serious impacts on that predator. If the predator is a generalist, it is assumed they can prey upon many species and are often better adapted to changes in the environment. A generalist predator may even benefit from habitat loss if the replacement habitat provides the predator with greater resources.^{427, 428} Though the number of mammal species found in the ecozone⁺ has actually increased since European settlement (due to introductions and range expansions), the biodiversity has decreased through the reduction of population size of many important species and the extirpation of others.⁴²⁹

Many of the large carnivores found originally throughout the Mixedwood Plains have been extirpated from some, or all of their previous range within the ecozone⁺. Wolverines (*Gulo gulo*) and cougars (*Felis concolor*) were extirpated from the ecozone⁺ shortly after European settlement due to habitat destruction and human persecution.⁴²⁹ Black bears (*Ursus americanus –an omnivore*), eastern wolf (*Canis lycaon*), Canada lynx (*Lynx canadensis*) and bobcat (*Lynx rufus*) are still found in those areas in the ecozone⁺ with significant forest cover,⁴²⁹ but no longer occur in much of the southern part of the ecozone⁺. Species such as European hare (*Lepus europaeus*), Norway rat (*Rattus norvegicus*), and house mouse (*Mus musculus*) were introduced by European settlers and are now naturalized species. Other species which were historically present and are tolerant of humans have benefited from human activities and have increased in number. The woodchuck (*Marmota monax*), raccoon (*Procyon lotor*), striped skunk (*Mephitis mephitis*), and eastern gray squirrel (*Sciurus carolinensis*) have benefited from the presence of humans and have increased in population.⁴²⁹ The northeastern coyote (*Canis latrans*) migrated here from the lower Michigan peninsula near Detroit into southern Ontario where hybridization with eastern wolves occurred.⁴³⁰ The hybridization has resulted in a larger body size and more wolf-like cranial features, probably allowing them to better hunt deer which facilitated their spread.⁴³⁰ In the absence of larger predators, the coyote⁴³¹ and red fox (*Vulpes vulpes*) have become primary predators in the ecozone⁺.

White-tailed deer (*Odocoileus virginianus*) are a species of edge habitats associated with environmental disturbances. With the fragmentation of landscape in the Mixedwood Plains creating habitat, an abundance of food associated with agriculture, milder winters, and the loss of large predators, deer have expanded their range in the ecozone⁺ and increased in density beyond historic levels.⁴³² In southern Ontario, as elsewhere, research has shown that high white-tailed deer densities alter forest plant communities and thereby affect habitat for other species. Under these conditions, the number of native plant species can be greatly reduced and spring flowers (ephemerals) are often reduced or absent.⁴³³ This relationship between spring flowers and deer grazing has led researchers to suggest that the height of the trilliums (*Trillium grandiflorum*) can be used to determine relative deer populations densities.⁴³⁴ Elk (*Cervus elaphus canadensis*), which were extirpated for the ecozone⁺ historically, have been re-introduced to the province of Ontario and have expanded their range into the Mixedwood Plains ecozone⁺.^{432, 435} In the Bancroft area where predation on elk is low, the reintroduced population has grown from 170 in 2001 to an estimated 500 in 2008.⁴³⁶

The population of double-crested cormorant (*Phalacrocorax auritus* –henceforth cormorant) provides an interesting example of how a generalist predator’s population can be influenced by changes in its relationship with the environment and other species.⁴³⁷ Cormorants are a native species of the Mixedwood Plains, and though very high numbers for this species were reported in other parts of Canada prior to the 1800s, it is difficult to determine their pre-settlement population levels within the ecozone⁺ due to lack of records.⁴³⁸ By the late 1800s and early 1900s, it is believed their populations were in decline due to persistent human persecution as the species was seen as competition for fisheries resources.⁴³⁸ The population partially recovered through at least the mid-1900s, but experienced a major decline throughout the 1950s to 1970s.⁴³⁸ By the late 1950s, a cormorant control program was initiated by the Ontario government due to concerns for recreational and commercial fisheries.⁴³⁷ Through the 1960s and early 1970s, cormorant populations experienced a dramatic decline due to reproductive failure. This was caused by eggshell thinning to the point that the eggs could not support the weight of adult during incubation.⁴³⁷ The thinning was caused by high levels of organochlorines (primarily DDT) in the Great Lakes being passed on to the cormorants through their diets.^{439, 440} New regulations, enhanced enforcement, and public awareness concerning toxic contaminants resulted in a ban on the use of DDT, significantly reducing levels of toxic chemicals and as a result cormorant reproductive success returned to relatively normal levels by the late 1970s.⁴³⁷ Recovery was also aided by enhanced over-winter survival of cormorants due to the consumption of catfish from the aquaculture industry in the southern United States.^{437, 441} At the same time alewife and rainbow smelt which are primary food sources for cormorants in the Great Lakes experienced significant population increases due to the decline of large predatory fish.^{437, 442}

Throughout the 1990s, cormorant populations on the Great Lakes continued to increase⁴³⁷ at a rate of about 29% per year.⁴⁴³ From 2000 to 2005, populations began to show signs of stabilization (Figure 39). A comparison of cormorant diets before and after the introduction of the invasive round goby (*Neogobius melanostomus*) demonstrated that cormorants switched from eating yellow perch (*Perca flavescens*), alewife, threespine stickleback (*Gasterosteus aculeatus*) and

smallmouth bass (*Micropterus dolomieu*) to eating dominantly round goby.⁴⁴³ Not only did the cormorants switch the species they were eating but they had to change their feeding method as the round gobies are located near the bottom of water bodies (benthic). The round gobies may be buffering predation of the native species previously consumed by cormorants.⁴⁴³

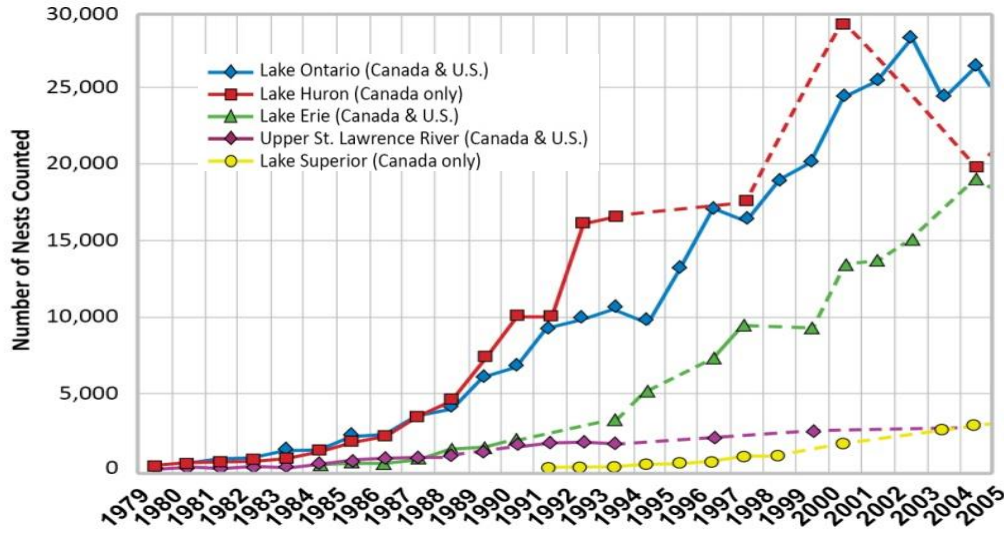


Figure 39. Great lakes-wide cormorant nest counts, 1979–2005.

Dashed line indicates projected nest counts for years with missing or incomplete data.

Source: Weseloh et al., 1995, 2002, and 2006, Canadian Wildlife Service, unpublished data, OMNR, unpublished data. Shieldcastle, unpublished data, as reported in, OMNR 2006⁴³⁷

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.

Evidence from Ontario

Despite being home to 53% of Canada’s population,⁴⁴⁴ and having a high level of access, the Mixedwood Plains has limited data with which to deliver a meaningful ecosystem assessment. Most of the data available for this ecozone+ was generated to answer specific research or management questions and was not part of a long term monitoring program. Generally, long

term, broad-scale monitoring programs which would provide data to support initiatives such as ESTR have not been designed, resourced, or implemented for this ecozone⁺.

At the landscape scale in the Ontario portion of the Mixedwood Plains, reporting is limited by the lack of a forest inventory (to allow monitoring of changes in tree species) and by the fact that no commitment has been made to the updating of the Southern Ontario Land Resource Inventory System (SOLRIS) which is a coarse scale land cover layer which would allow the tracking of broad scale landscape change over time. In addition to having only coarse grained, non-updated land cover data, there is little understanding of the amount and configuration of natural vegetation that is required to protect biodiversity and ecological services. The recent *State of Ontario's Biodiversity Report, 2010* used 25 indicators that related to the Mixedwood Plains ecozone⁺. Of those indicators, eight had high data confidence, 15 had medium data confidence, and two were not assessed either due to lack of data or the lack of analysis of existing long-term data.²¹³ At present, only 16 of those indicators will have data available in the future which will allow them to be re-examined.²¹³

For terrestrial species, much of our long term trend data comes from "citizen science". Bird and amphibian data such as that collected by the Breeding Bird Atlases, Breeding Bird Surveys, Christmas Bird Counts, Marsh Monitoring Program, Amphibian Road Call Count, and Frogwatch Canada are examples of such citizen science. The Ontario Federation of Anglers and Hunters runs two citizen science programs in partnership with the Ontario Ministry of Natural Resources both of which relate to invasive species: the Invading Species Watch program which specifically deals with testing of water samples for spiny water flea (*Bythotrephes longimanus*) and zebra mussel veligers (*Dreissena polymorpha*), and the Invading Species Awareness program which allows citizens to report sightings of invasive species.²³⁹ These programs, along with others like them, are able to provide scientifically reliable, long-term data over large areas^{445, 446} while allowing citizens to participate in the conservation of their local biodiversity.⁴⁴⁷ However, these programs are not able to cover the full breadth of monitoring that is required as they need to use data collection protocols which lend themselves to use by non-scientists.⁴⁴⁵ In addition to the citizen monitoring, many species at risk now have monitoring data being collected for them through the direction of their recovery team. Much of the SAR monitoring data collected in Ontario is stored at OMNR's Natural Heritage Information Centre, however there is no specific requirement for standardized monitoring protocols or the storage of the data in a centralized repository.⁴⁴⁸ Since most of the species found in Ontario are neither SAR, invasive species, or suitable for citizen monitoring, data which allows for the examination of broad scale, long term trends is not available for them.

There has been very little standardized species monitoring and inventory for aquatic species done in the Ontario portion of the ecozone⁺ since the 1980s.¹⁶¹ When hydrometric data was examined across Canada,⁴⁴⁹ it was found that in the lower St. Lawrence (southern Ontario west of the Lake Simcoe) 25% of the area was highly deficient while about 50% was deficient of gauging stations and that while the network appears dense, the large deficit areas suggest that the network was poorly designed. While the middle St. Lawrence, which stretches from the around Lake Simcoe to the Montréal area, had only 27% of its area with insufficient gauging stations which indicated a somewhat better situation in this area.⁴⁴⁹

Our understanding of how ecosystems function is also very limited. Primary information on carbon flux, primary productivity, nutrient cycling and loading, ground and surface water relations, and groundwater flow and quality are all lacking. Epizootics (white nose syndrome in bats being a key example, see Rapid change and thresholds) and cumulative impacts of human activities and contaminants have little base data and are poorly understood.¹⁶¹

The lack of primary ecological data also limits our abilities to do ecosystem valuation work. Many authors have identified the lack of data as a major impediment to the creation of accurate estimates of ecosystem goods and services values.^{319, 321, 450-452} Though there is an overall lack of data, grassland ecosystems (prairie, alvar, savannah) have even less information available about them than other ecosystem types.^{319, 453}

To further complicate matters, information on a single topic may be collected using different protocols between jurisdictions making analysis across boundaries highly problematic or impossible. Within the Ontario portion of the ecozone⁺, there are three federal departments, six OMNR Districts, about 30 Conservation Authorities, more than 200 municipalities, and an unknown number of non-governmental organizations, involved in environmental monitoring in some capacity.¹⁶¹ Currently, most organizations monitor only ecosystem trends directly related to their mandate and geographic jurisdiction, and then, only those that they can afford.¹⁶¹ A strategic ecosystem assessment framework is needed which incorporates broad scale inventory and monitoring programs at coarse and fine scales. Long-term monitoring requires long-term funding. The Environmental Commissioner of Ontario recently indicated that the amount of the provincial budget allocated to the environment (0.36% of the total) is not in line with public expectations of what should be spent.⁴⁵⁴ These jurisdictional issues along with lack of funding have lead to little monitoring information being available in the Ontario portion of the ecozone⁺.

Key Finding 22

Theme Science/policy interface

Rapid change and thresholds

National key finding

Growing understanding of rapid and unexpected changes, interactions, and thresholds, especially in relation to climate change, points to a need for policy that responds and adapts quickly to signals of environmental change in order to avert major and irreversible biodiversity losses.

Three diseases, white-nose syndrome (WNS – *Geomyces destructans sp. nov.*),⁴⁵⁵ chytridiomycosis (*Batrachochytrium dendrobatidis*), and viral hemorrhagic septicemia (VHSV Genotype IVb) which are currently impacting the Mixedwood Plains Ecozone⁺ provide striking examples of fast spreading, as yet poorly understood threats to our ecozone⁺'s ecological function and biodiversity.

White-nose syndrome (WNS- Figure 40) is a disease of hibernating, cave-roosting bats and was confirmed as occurring in Ontario in March 2010.⁴⁵⁶ WNS was first documented in cave near Albany, NY during the winter of 2006⁴⁵⁷ and since that time it has spread (Figure 41) and been responsible for the deaths of more than one million bats in the northeastern United States.⁴⁵⁸ Deaths from WNS often exceed 75% of the bats in infected hibernacula, but in some hibernacula, nearly 100% of the bats have been killed.^{458, 459} Bats with WNS may have visible rings of white fungus around their muzzles, and on their wing membranes and ears, the fungus penetrates the bat's tissues filling hair follicles and sebaceous glands.⁴⁵⁵ Affected individuals suffer severe weight loss and emaciated bats have been found outside of major hibernacula during winter, presumably searching for food (the bats would normally be hibernating).⁴⁵⁹ Species which have been impacted include the little brown bat (*Myotis lucifugus*), northern long-eared bat (*Myotis septentrionalis*), big brown bat (*Eptesicus fuscus*), and tri-colored bat (*Perimyotis subflavus*).⁴⁵⁵

Scientists are uncertain about where WNS came from, but, the disease causing fungus was recently identified in a bat from France⁴⁵⁸ which though obviously having the fungus appeared to have no ill effects. This led the researchers to suggest that the fungus may have been present in Europe for a long time and that bats there have an immunity to it. If turns out to be true, the fungus must somehow have been introduced to the United States and has now spread to Mixedwood Plains. The implications of WNS are extensive since more 13.5% of the ecozone's mammal diversity,⁴²⁹ and 20% of global mammalian diversity is in bats,⁴⁵⁸ and bats play an important ecological role in our ecozone⁺. A little brown bat, for example consumes about its own body weight in insects per night. If vast numbers of bats are lost, then massive amounts of insect biomass that would normally be consumed will be available to eat crops and have other ecological and economic impacts.⁴⁵⁹



Figure 40. Bats with white-nose syndrome, Craigmont Mine, Ontario
Photographer: Lesley Hale, OMNR Peterborough

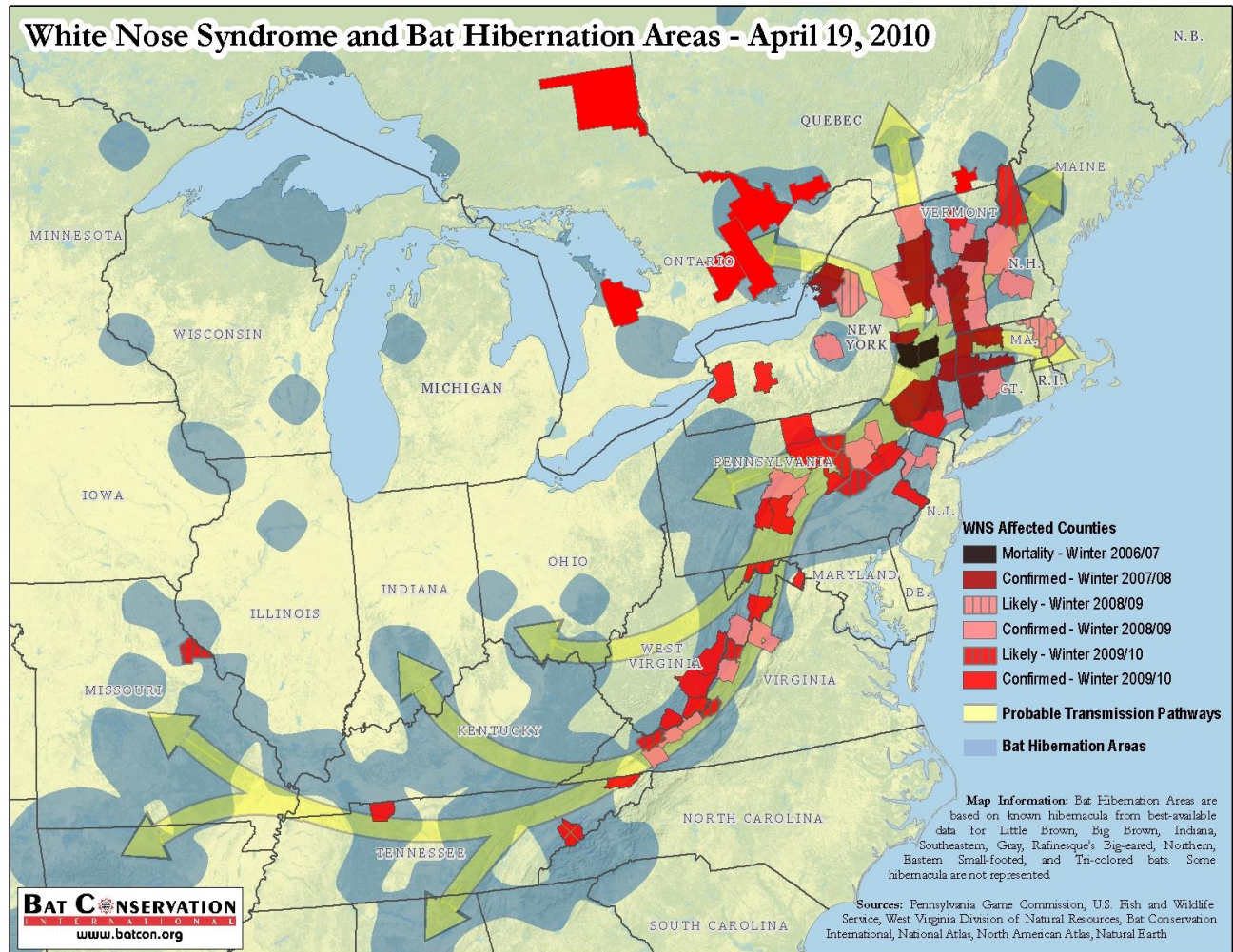


Figure 41. Spread of white-nose syndrome in bats.
Source: Szymanski et al., 2009⁴⁶⁰ Base map by Bat Conservation International

Chytridiomycosis (also known as frog fungus) has been found in more than 200 species of amphibians on five continents^{461, 462} and is considered a problem of central importance to biodiversity conservation. The disease was found to be present in 12 common amphibians from five Canadian provinces and seven American states, including 30 of 69 locations examined in the St. Lawrence River valley of Quebec.³⁹⁴ It is believed the fungus has its origin in Africa and that it was spread through the international trade of African clawed frogs (*Xenopus laevis*).^{461, 463} There is some evidence that our native species of bullfrog (*Rana catesbeiana*) is a potential carrier of the infection, which is lethal to many other amphibian species.⁴⁶⁴

Viral hemorrhagic septicemia (VHS) was identified in the 1960s and originally known as a disease of freshwater rainbow trout in Europe.⁴⁶⁵ The virus (viral hemorrhagic septicemia virus VHSV) was detected in the Pacific Northwest of North America in the late 1980s where it was found in sea-run chinook and coho salmon. It has since been detected in a variety of marine fish species.⁴⁶⁶ It emerged as a serious disease in Lake Ontario in 2005 as it was detected in a die-off that resulted in approximately 100 metric tonnes of dead freshwater drum (*Aplodinotus*

grunniens) in the Bay of Quinte.⁴⁶⁷ The virus was later found in an archived muskellunge (*Esox masquinongy*) sample from Lake St. Clair in 2003⁴⁶⁸ indicating that the virus has been present in the Great Lakes for several years. The virus is now known from multiple locations in all of the Great Lakes (although the detections in lake Superior are unconfirmed at the time of writing⁴⁶⁹) and has been detected in approximately 30 Great Lakes fish species. Many, but not all of these detections were from significant mortality events within the Great Lakes (Figure 42).⁴⁶⁶

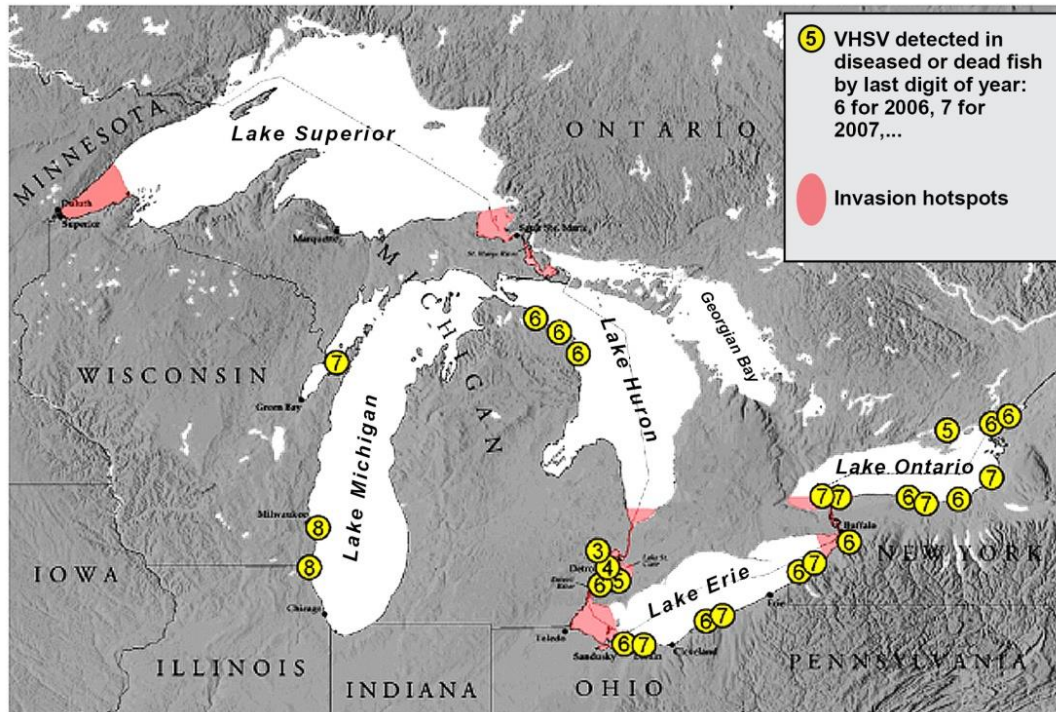


Figure 42. Distribution of Viral Hemorrhagic Septicemia Virus (VHSV) positive fish in the Great Lakes, 2003–2008.

Source Bain et al., 2010⁴⁶⁶

Sport fish are not the only group that can carry the virus, bait fish such as spottail shiner (*Notropis hudsonius*) have also been found with the virus⁴⁶⁶ and there is a concern the virus could spread through the transportation of bait fish. The virus destroys the endothelial cells, the cells lining the interior of the blood vessels and the vessels are unable to retain blood and hemorrhaging occurs. Other signs of the disease associated with VHS include, “pop-eye”, a distended abdomen, and discoloration and sores on the body. As a pathogen that is listed by the OIE (World Organization for Animal Health) as reportable, the finding of VHS in a new location has significant implications for trade both nationally and internationally.⁴⁶⁵ Questions remain about how the virus came to the Great Lakes and on how it is spread. Shipping has been implicated as a possible vector for the spread of VHSV but a recent paper⁴⁶⁶ found no current relationship between centres of shipping or boating activity, invasion hotspots (for non-native invasive species) and the occurrence of VHSV (Figure 43).

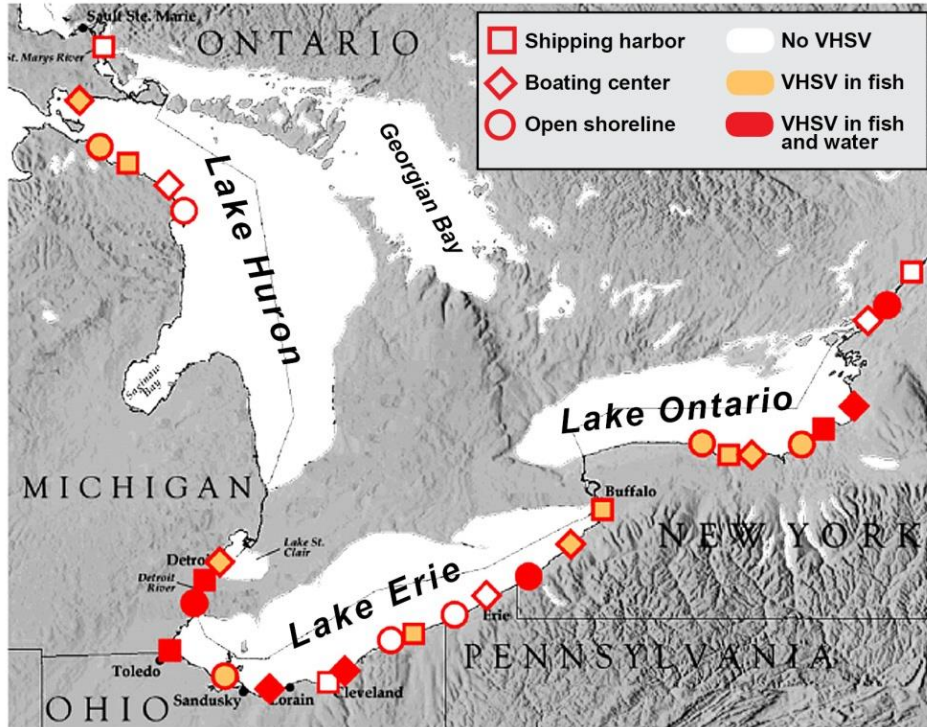


Figure 43. Distribution of VHSV positive fish and water and sites associated with shipping, boating, and open shorelines.

Source Bain et al., 2010⁴⁶⁶

Baine et al., (2010)⁴⁶⁶ concluded that VHSV was both enzootic (constantly present in fish populations but only occurring in a small number of cases) and epizootic (epidemic among populations of a single species in a particular region) though the infections they found in their broad survey of the Great Lakes were often subclinical (fish did not appear ill). Faisal and Schulz, (2010)⁴⁷⁰ found VHSV present in the leech *Myzobdella lugubris* which is widespread in both Lake Erie and Lake St. Clair and suggested that this species may be playing a role in the transmission of the virus. Recent trials on the use of iodophor disinfection on the eggs of walleye and northern pike (*Esox lucius*) have eliminated VHSV, although the authors reported that certain regimes reduced egg hatch.⁴⁷¹ Iodophor disinfection during gamete collection from salmonid and likely non-salmonid fishes immediately post fertilization may reduce VHSV transmission.⁴⁷¹

The swift spread and number of species impacted by these three diseases which are currently impacting the bat, frog, and fish populations of the Mixedwood Plains typify the kind of surprises, unexpected impacts, and interactions that wildlife managers and policy makers struggle to address.

CONCLUSION: HUMAN WELL-BEING AND BIODIVERSITY

The emphasis of the Ecosystem Status and Trends report for the Mixedwood Plains (Key Findings 1 to 22) has been on human impacts on the ecozone's biodiversity (structure, composition, and function) however, the biodiversity of the ecozone+ plays a critical role in determining the well-being of the humans that live within it. Maintenance of natural levels of biodiversity is necessary for proper ecosystem functioning and the provision of ecosystem services to humanity.⁴⁷²

Ecosystem services are the aspects of ecosystems utilized directly or indirectly to produce human well-being (see Ecosystem services for further detail).^{281, 473-475} These life supporting services are typically undervalued by society and our market economy.^{281, 475} Their value often goes unrecognized as our understanding of ecosystem services is still developing.⁴⁷⁶ They are worth billions of dollars per year, but need to be valued more accurately because their loss has massive economic impacts threatening health, food production, climate stability, and basic needs such as clean air and water.^{281, 319, 451, 477-479}

The most comprehensive review of the state of the planet and the resultant state of human well-being ever conducted is the Millennium Ecosystem Assessment. Established in 2001 as collaborative international program, it determined that human activities have changed most ecosystems and threaten the Earth's ability to support future generations.²⁸¹ The scale of change to our planet is great enough that the Stratigraphy Commission of the Geological Society of London has a working group trying to decide whether a new geologic time period, the Anthropocene will become a recognized time period of the Earth's geologic history in recognition of the extent of change that has taken place due to human activity.⁴⁸⁰ It has been suggested³¹⁴ that there are specific planetary boundaries within which humanity needs to operate in order to insure we avoid major human –induced environmental change at a global scale. Seven of these global boundaries have been established: CO₂ levels below 350 ppm, a less than 5% decrease from an ozone level of 290 Dobson units, nitrogen fixation of no more than 35 Tg N/yr, phosphorous inflow to the oceans of not more than ten times the amount from natural background weathering, consumption of freshwater of less than 4000 km³/yr, less than 15% of ice-free land as cropland, and a rate of species loss of less than 10 extinctions per million species/yr.³¹⁴ If we remain within these boundaries it is suggested that we are free to pursue long-term social and economic development without concern for environmental collapse. Globally we have already surpassed three of these boundaries (CO₂, nitrogen and species extinctions). It is not known where the Mixedwood Plains stands relative to most of these measures but it clearly exceeds the 15% of land in cropland as there is 68% cover of agricultural land in the ecozone+. The Mixedwood Plains is one of the smallest of Canada's ecozones+, has 53% of the country's human population⁴⁴⁴ yet still has one of the highest levels of plant species diversity in the country.¹³ With the human population expected to continue to increase, dominantly agricultural land cover (Agricultural landscapes as habitat), continued agricultural intensification and urban expansion (Ecosystem), high levels of invasive species and pollution (Invasive non-native species, Contaminants, Nutrient loading and algal blooms, and Acid

deposition), there is concern for the overall health of the ecosystems within the ecozone⁺ as well as concern about the implications for its human inhabitants.

The Ontario Biodiversity Council in partnership with the Ontario Ministry of Natural Resources has examined the state of Ontario's biodiversity through *Ontario's Biodiversity 2010 Highlights Report*. This report assesses the health of Ontario's biodiversity using 29 different indicators.²¹³ Of the 20 indicators that examine either pressures on biodiversity or the state of Ontario's biodiversity (direct measures of the ecosystem), the dominant trend was one of deterioration (8 of 20 indicators).²¹³ Many indicators showed that the threats to Ontario's biodiversity were most intense in the Mixedwood Plains ecozone.²¹³ Of the nine measures of conservation and sustainable use, most showed improvement (five of nine).²¹³ Though Ontario's ecosystems are not yet experiencing any improvements in condition, there has been improvement in conservation and stewardship. The key findings for the Mixedwood Plains are consistent with the *Ontario Biodiversity 2010* report as they show pressures on biodiversity through the issues of habitat loss and fragmentation (Theme: Biomes section, Ecosystem, and Intact landscapes and waterscapes), species loss (Agricultural landscapes as habitat, Species of special economic, cultural, or ecological interest, and Food webs) invasive species (Invasive non-native species), climate change (Ice across biomes and Climate change), and pollution (Contaminants, Nutrient loading and algal blooms, and Acid deposition) while showing improvements in stewardship (Stewardship).

Though all ecosystem services contribute to human health and well-being, there are three ecosystem services that have very direct links to human health: constraint of infectious diseases; provision of medicinal resources; and improved quality of life.⁴⁸¹

Constraint of infectious disease

Globally, evidence that high biodiversity can protect human health by reducing the risk of certain infectious diseases is growing.^{482, 483} When the global incidence of rodent-borne hemorrhagic fevers was examined,⁴⁸⁴ it was found that all the outbreaks occurred in highly disturbed habitats which had low biodiversity and that in each case the rodent host was a generalist/opportunistic species which did well in human disturbed areas. In Panama, experimentally induced decreases in small mammal diversity caused increases in hantavirus prevalence (hantavirus can infect humans) in the viral host small mammal population as well as an increase in the size of the host population.⁴⁸⁵ When the impacts of habitat fragmentation and species loss were examined in a field trial in Panama,⁴⁸⁶ it was found that habitat loss, fragmentation and species loss were altering hantavirus infection dynamics and that greater species diversity likely reduces the number of encounters between infected and susceptible hosts thus reducing the spread of the virus.⁴⁸⁶ Similar results were found an outbreak of hantavirus in central Bolivia.⁴⁸⁷

Both West Nile Virus (WNV – transmitted by mosquitoes) and Lyme disease (LD – transmitted by ticks) are found in the Mixedwood Plains and research into their dynamics reveal similar findings as to what is being discovered about biodiversity and the transmission of disease globally. When there is a high diversity of species for the disease bearing mosquitoes and ticks to feed upon, and most of the species are poor reservoirs for the diseases of concern, then there

is a very low infection rate of these diseases within the human population, however, when there are few species for the mosquitoes and ticks to feed upon, and those available are good reservoirs for the pathogens, there is a high rate of infection within the human population.⁴⁸⁸

In the case of WNV, some of the best reservoirs for the virus are common bird species such as American robin, American crow, house sparrow, blue jay, common grackle, and house finch, all of which are highly adapted to living in human modified environments. When the incidence of WNV and bird diversity were examined at the county level in the United States, it was found that as bird diversity went down, the incidence of WNV went up.⁴⁸⁸

The primary reservoirs of Lyme disease are white-footed mice, eastern chipmunks, short-tailed shrews, and masked shrews and all but the masked shrews are abundant in degraded and fragmented habitats. One of the major factors determining the species richness of terrestrial mammals in many areas is the actual size of the habitat area. When the prevalence of Lyme disease in ticks was examined relative to the size of forest habitat areas in Dutchess County New York State, it was found that as patch size decreased the rate of infection with Lyme disease increased,⁴⁸⁸ again indicating that decreased biodiversity is associated with increased disease.

A study of the prevalence of antimicrobial drug resistance in *E. coli* bacteria found in small mammals done in the Ottawa area,⁴⁸⁹ found that wild mammals living in the proximity of farms were generally more likely to harbour antimicrobial resistant bacteria (such as bacteria resistant to tetracycline) than wild mammals living in natural areas. These results suggest that the use of antimicrobial agents in farming, may have a impact on the amount of antimicrobial resistance seen in nature.⁴⁸⁹

Provision of medicinal resources

Plants have been used as a source of medicine throughout history and continue to serve as the basis for many pharmaceuticals used today.⁴⁹⁰ An example of a drug derived from a native species found within the Mixedwood Plains Ecozone⁺ is the cancer fighting drug "Taxol". Taxol can be derived from both the Canada Yew (*Taxus canadensis*) and the Pacific yew (*Taxus brevifolia*). Canada Yew is a common understory shrub found in the mature forests of the ecozone⁺. Once considered of little commercial interest, it is now prized by the pharmaceutical industry.⁴⁹¹

Plants are not the only sources of medicinal resources, mammal venom is also being investigated for potential medicinal use.⁴⁹² Though the scientific research has not been completed, patents have been issued for the use of soridicin^{493, 494} (the venom of the northern short-tailed shrew, *Blarina brevicauda*, which is found throughout the Mixedwood Plains) as an analgesic, a wrinkle treatment, a mechanism to immobilise muscles to treat neuromuscular diseases, and a treatment for excessive sweating.⁴⁹²

In a study of plants traditionally used by the Cree Nation of Quebec in the treatment of diabetes,⁴⁹⁵ three species (pitcher plant *Sarracenia purpurea*, Labrador tea *Rhododendron groenlandicum*, and black spruce *Picea mariana*) were found to be especially promising

candidates for in-depth analysis. All three of these species are found in many of Canada's ecozones⁺, including the Mixedwood Plains.

These are only a few examples of medicines derived from species which are part of the biodiversity of the Mixedwood Plains. Clearly, biodiversity loss decreases the supply of raw materials for drug discovery.^{483, 496}

Improved quality of life

The quality of our lives is also impacted by biodiversity. Many studies have shown positive psychological benefits associated with green space.⁴⁹⁷⁻⁵⁰⁰ Simply being able to see nature through a window has been associated with faster recovery rates in hospital,⁵⁰¹ lower levels of illness with inmates, lower heart rate,⁵⁰² higher job satisfaction,⁵⁰³ and better student test scores.⁵⁰⁴ Actually being in contact with nature⁵⁰⁴ has been shown to have a positive impact on blood pressure, cholesterol, outlook on life, and stress-reduction.⁵⁰⁵

A study done in the Netherlands⁴⁹⁸ found that people with a greener environment within a 1 to 3 km radius around their homes had better self perceived health than people living in a less green environment. The perceived general health of people living in less urban areas tended to be better. Analysis of the effects of green space in different age groups (youth 0 to 24, adults 25 to 65, and elderly 65 and older) showed that the health of all age groups benefited significantly from green space. When educational level was examined, people with lower education levels were more sensitive to the physical environmental characteristics.⁴⁹⁸ The degree of possible psychological benefit that a green space has seems to be related to the diversity of the area. In a study done in Sheffield England,⁴⁹⁷ it was found that the degree of psychological benefit was positively related to species richness of plants and to a lesser extent of birds. People's sense of identity and ability to reflect increased as plant diversity increased while their emotional attachment to their neighbourhood increased as bird diversity increased.⁴⁹⁷ People also appear to like green spaces much better than areas without vegetation. A study done in Chicago Illinois⁵⁰⁰ found that, on average, 90% more people used green spaces than barren spaces and on average 83% more individuals engaged in social activity in green versus barren spaces. For females, greener spaces were found to support proportionately more social activity than barren spaces and the location of the spaces (front, back, or side of the apartment building) was not related to the amount of social activity that took place.⁵⁰⁰

Given the wealth of evidence that human well-being is dependent on biodiversity, the question remains as to why humanity is allowing the biodiversity that sustains it to be negatively impacted. Research indicates that the extraction of raw materials from the environment and the dumping of wastes into the environment are grounded in the quest for minimizing costs of production to maximize profits.⁵⁰⁶ The assumption has been that stressing of the environment improves human well-being.⁵⁰⁶ There is increasing evidence that this is not true. In an analysis that examined 135 nations,⁵⁰⁶ it was found that if you controlled for physical and human capital, exploitation of the environment has no net positive effect on well-being (life expectancy at birth was used as the measure of well-being). When affluence was examined relative to happiness,⁵⁰⁷ it was found that growth in affluence for very low income countries can substantially improve well-being, but this benefit rapidly diminishes so that for affluent countries, further economic

growth does little to improve human well-being (a relationship of diminishing returns⁵⁰⁶). A study done in Illinois where people were asked whether they considered themselves a part of nature, and what nature was,⁵⁰⁸ yielded some very interesting and dissonant findings. Most participants (76.9%) considered themselves to be a part of nature, but interestingly 32.3% of these participants, as well as 63.6% of those who described themselves as separate from nature, perceived nature as an entity that does not involve humans. These two perceptions are at odds with each other. Most research has suggested that the more exposure people have to nature, the more connection they feel to it ⁵⁰⁸ and the study respondents who considered themselves part of nature talked about their experience with nature but defined nature specifically by the absence of humans. Dissonance is generally considered to be unpleasant and people relieve themselves of the contradictory perceptions by rationalizing or denying subsequent thoughts and behaviour.⁵⁰⁸ How this sort of dissonance is relieved could have resource management implications. If, in order to relieve the contradictory perception a path of greater levels of environmental responsibility is pursued, the outcome will be very different than, if the environmentally destructive behaviour is rationalized in order to relieve the dissonance.⁵⁰⁸

Significant challenges remain for the Mixedwood Plains Ecozone⁺ as its population increases, resources continue to be used, climate change impacts increase, and the ecosystem continues to be degraded. Moving from where we are, to where we need to be will require not only expanding our scientific understanding of the ecozone⁺, but finding mechanisms through which good stewardship is not seen as luxury but as essential for human well-being.

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