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Human Activity and the Environment 2021

Accounting for ecosystem change in Canada

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Correction Notice

The coral and sponge area was not correctly displayed on Map 2.3 Marine and coastal ecosystem extent: ecosystems and substrate, southern British Columbia coast. This map has been replaced.

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An HTML version is also available.

Cette publication est aussi disponible en français.

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Human Activity and the Environment 2021: Accounting for ecosystem change in Canada

Highlights

Human Activity and the Environment 2021: Accounting for ecosystem change in Canada provides some of the latest statistics on the extent and condition of Canada's ecosystems, as well as estimates of the supply and use of selected ecosystem services.

The increasing severity of global environmental issues are making it increasingly clear that economic and social health are dependent on maintaining ecosystems and the flows of services that they provide. But while today's decision-making can count on a wealth of robust socio-economic data, getting a complete picture of the state of Canada's ecosystems is difficult at the current time.

This report is the result of Statistics Canada's work to make comprehensive information on Canada's ecosystems more readily available. It is doing so by developing and implementing ecosystem accounts according to the new integrated and comprehensive statistical framework for ecosystem accounting adopted by the United Nations Statistical Commission. The System of Environmental-Economic Accounting – Ecosystem Accounting (SEEA – EA) takes a spatial approach to accounting, by organizing existing data on the location and size of ecosystem assets, tracking changes in their condition, measuring ecosystem services and linking this information to economic and human activity.

This work is an initial effort to provide as much information as possible about Canada's ecosystems. However, further work is needed to assess change on a long-term basis and develop quantitative measures and valuations to provide a more complete picture of the relationship between the economy, society and the environment and how we measure well-being and social progress. These issues will be the focus of further efforts as we embark on the development of a new Census of Environment program, which will provide access to a complete set of integrated environmental accounts and a wide range of regional-based information on issues stemming from rapid environmental change.

Selected highlights of the report are presented below. Further details on the results, analysis, sources, methodology, limitations and data gaps are available from the report.

Infographic Accounting for ecosystem change in Canada

ACCOUNTING FOR ECOSYSTEM CHANGE IN CANADA:

SELECTED FINDINGS FROM HUMAN ACTIVITY AND THE ENVIRONMENT, 2021

ECOSYSTEM TYPE	ECOSYSTEM EXTENT	CONDITIONS AND DRIVERS	SERVICES AND BENEFITS
SETTLEMENTS	**11%** Percentage growth of built-up and artificial surface area between 2000 and 2015	**76%** Percentage of population centre area classed as 'green' in the summer of 2019	**3.7 grams** Quantity of air pollutants filtered annually per square metre of urban tree cover
AGRO-ECOSYSTEMS	**64%** Proportion of Canada's directly modified land used for agriculture	**515 m** Longest average distance to a parcel of natural land, occurring in the Prairies	**$28.1 billion** Contribution of primary agriculture to GDP in 2018
FORESTS	**36%** Percentage of Canada's landmass covered by forest	**1%** Average percentage of total forest area harvested or burned annually between 1986 and 2019	**205 tonnes per hectare** Average amount of carbon stored in Canada's managed forests
WETLANDS	**11%** Percentage of Canada's landmass covered by organic wetland known as peatland	**1.7°C** Average annual increase in air temperature over peatlands from 1948 to 2016	**147 gigatonnes** Amount of carbon stored in Canada's boreal and subarctic peatlands
FRESHWATER	**13%** Percentage of inland area covered by freshwater	**3.3°C** Average increase in winter air temperature over freshwater from 1948 to 2016	**36.8 billion m^3** Amount of water used by industry and households in 2017
OCEANS	**5.75 million km^2** Area included in Canada's exclusive economic zone	**19%** Decline in 10-year average Arctic ice coverage between the 1980s and 2010s	**784,000 tonnes** Fish, shellfish and marine plants harvested in 2019
CANADA	**9%** Percentage of Canada's landmass is directly modified	**7°C** Largest average increase in winter air temperature in Canada from 1948 to 2016, occurring in northwestern Canada	**16.1 million** Number of visitors who enjoyed the nature of Canada's national parks in 2019

Source: Statistics Canada, 2022, "Accounting for ecosystem change in Canada," *Human Activity and the Environment, 2021*.

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Ecosystem extent and drivers of change

- Canada has some of the largest forest, tundra, prairie, wetland and freshwater ecosystems in the world, extending across 9.98 million km^2. Overall, approximately 36% of the country is covered by forest, 25% by arctic tundra, 4% by grassland including natural pasture or rangeland, 2% by permanent snow and ice cover and 28% by other natural and semi-natural areas such as woodland, shrubland, alpine tundra, barrenland, wetland and water. In 2016, 4% of the country was used for growing crops and tame or seeded pastures. Overall, 62,600 km^2 or about 0.6% of Canada's landscape consisted of settlement and human infrastructure in 2015, up 11% from 56,400 km^2 in 2000.
- Jurisdiction over the ocean includes 5.75 million km^2 within the limit of Canada's exclusive economic zone (EEZ). Close to half of this area is made up of areas with a maximum water depth of 200 m, supporting a diversity of marine life including fish and invertebrates that are important for major fisheries, as well as marine plants, such as phytoplankton, seagrasses and kelp, which play a key role in carbon storage.
- All areas of Canada's landmass have experienced increases in average annual and seasonal air temperatures from 1948 to 2016, but with important regional variations. The strongest temperature increases occurred across a vast region stretching across over 1.6 million km^2 of boreal and tundra ecosystems from Yellowknife to the Yukon–Alaska border. In this region, winter temperatures have increased by more than 5°C, with over 300,000 km^2 experiencing winter temperatures increases between 6°C and 7°C and almost 17,500 km^2, an area three times the size of Prince Edward Island, experiencing winter temperature increases greater than 7°C.
- In the Prairies, agricultural areas covering over 400,000 km^2 have experienced a 1.9°C increase in annual temperature and a 3.8°C increase in winter temperature from 1948 to 2016. These types of changes are driving a range of impacts on ecosystem conditions, including changes in snow and ice cover, glacier melt, permafrost thaw, freshwater flows, evapotranspiration, forest disturbance regimes, species migration, sea surface temperature, salinity and many other characteristics.

Ecosystem condition

- Total water storage change, estimated using gravity-based measurements from satellites, indicates that water storage decreased in many areas from 2002 to 2016, with the largest decreases in northern ecozones such as the Arctic Cordillera and Boreal Cordillera where large quantities of freshwater are stored in permafrost, glaciers and ice caps.
- Changes in precipitation and evapotranspiration will affect the availability of renewable water flows. Canada's average annual water yield was 3,514 km^3 or 0.35 m^3/m^2 from 1971 to 2014, equivalent to a depth of 350 mm across the extent of the country. Renewable freshwater production varies spatially across the country's diverse landscape and also varies temporally—monthly, seasonally and yearly. The lowest water yields occur in ecoprovinces across the Prairies.
- A new assessment of urban ecosystem condition used satellite imagery to assess the relative greenness of population centres in summer for three years. In 2019, 76% of the area of population centres in southern Canada had enough healthy vegetation to be classed as predominantly 'green' while the remaining urban areas had less vegetation and were classed as 'grey'. This percentage varied based on city size and region. In large urban population centres, an average of 70% of the total land area was classed as green, compared to 78% in medium population centres and 87% in small population centres.
- Ecosystem modification from human activity including changes in land cover and land use result in changes in ecosystem characteristics, functions and supply of ecosystem services. In 2016, 9% of Canada's terrestrial and freshwater area had been directly modified for agriculture, recent forest harvest or built-up area.
- Average annual sea surface temperatures from 2005 to 2017 have warmed compared with the 1981 to 2010 climate normal average for most areas of the Canadian EEZ. However, sea surface cooling is seen in parts of the Pacific and Hudson Bay over the same period. Average annual surface salinity from 2005 to 2017 has decreased against the climate normal salinity for many regions. These changes affect stratification of marine waters with further effects on nutrient availability and dissolved oxygen concentrations. These conditions also have cascading impacts on marine life, from the phytoplankton and zooplankton—microscopic aquatic plants and animals—at the bottom of the

marine food web, to fish and marine mammals. Species abundance data include stocks of fish and marine mammals managed by Fisheries and Oceans Canada and deemed economically, culturally or environmentally important. In 2019, 52 of these 176 stocks were deemed healthy, while the status of 29 stocks was assessed as cautious, 25 as critical and 70 as uncertain since there was insufficient data to classify the status.

- Sea ice is a defining characteristic of marine and coastal ecosystems across the Canadian Arctic and parts of the Atlantic Ocean. Total sea ice extent varies by season and over time; however, over the last fifty years, sea ice has decreased. The record minimum ice extent for Canada and the Arctic Ocean as a whole was set in the summer of 2012, followed in Canadian waters by 2011 and 1998 with the second and third lowest areas.
- Direct impacts and modifications to ocean ecosystems from human activity can include bottom trawling, species introduction, marine pollution and noise from shipping, as well as others that are not all easily quantified. Aquaculture and offshore oil production are regulated industries with activities occurring at specific sites allowing the area affected to be more easily tracked. Marine aquaculture sites for finfish and shellfish production cover an estimated 400 km^2 of coastal area. Licenses allowing for marine oil exploration within the EEZ cover 37,500 km^2, with an additional 21,000 km^2 covered by significant discovery licenses that indicate where production could in future be permitted. Oil production sites covering approximately 1,000 km^2 are located on the East Coast of Canada.
- In 2020, Canada had conserved 12.5% of its terrestrial and inland water areas and 13.8% of the EEZ through protected areas and other effective area-based conservation measures.

Supply and use of ecosystem services

- In 2019, Canada's forest and agricultural ecosystems supported the production of an estimated 141 million tonnes of timber and 149 million tonnes of agricultural goods, while freshwater, coastal and marine ecosystems produced 808 thousand tonnes of fish, shellfish and marine plants. Provisioning services also include the smaller quantities of flora and fauna that were foraged, hunted and harvested for recreational, commercial and subsistence use and the 36.8 billion m^3 of water extracted in 2017 by industries and households from rivers, lakes and groundwater. This total excludes use for hydro-electric generation.
- Regulating services include a large number of vital services provided by ecosystems. For example, they include the global climate regulation services provided through carbon sequestration and retention in ecosystems. Organic wetlands store large quantities of carbon—it is estimated that Canada's peatlands hold more than half the stocks of soil organic carbon in the country. Canada's managed forests store on average 205 tonnes of carbon per hectare in forest soils, trees, leaf litter and deadwood. While trees take up large amounts of carbon each year, managed forests were a net emitter of carbon in 2018 after accounting for emissions associated with harvesting and natural disturbances. In 2018, an estimated 3,500 kilotonnes of carbon were sequestered by trees in urban and agricultural areas. Ongoing research is occurring to estimate sequestration and storage of blue carbon—the carbon in marine plants and coastal sediment—in Canada's salt marshes, seagrass meadows and kelp forests.
- The average air pollutant removal per square metre of tree cover in 86 Canadian cities in 2010 was estimated to be 3.72 g/m^2/year for five common air pollutants, resulting in a small improvement in air quality. The total pollution removal value for these cities was estimated at $511 per hectare of urban tree cover.
- Cultural services can involve appreciation of and interactions with nature, as well as the contributions of ecosystems and biodiversity to well-being. For example, activities in nature including in public parks and green spaces provide valuable recreation services and may have positive effects on mental health. In 2019, 90% of households reported that they lived close to a park or public green space and many people engaged in recreational activities outdoors and in nature.

1.0 Introduction

Human Activity and the Environment 2021: Accounting for ecosystem change in Canada provides some of the latest statistics on the extent and condition of Canada's ecosystems, as well as estimates of the supply and use of selected ecosystem services.

The increasing severity of global environmental issues are making it increasingly clear that economic and social health are dependent on maintaining ecosystems and the flows of services that they provide. But while today's decision-making can count on very robust socio-economic data, getting a complete picture of the state of Canada's ecosystems is difficult at the current time.

This report is the result of Statistics Canada's work to start to make comprehensive information on Canada's ecosystems more readily available. It is doing so by developing and implementing ecosystem accounts according to the new integrated and comprehensive statistical framework for ecosystem accounting adopted by the United Nations Statistical Commission. The System of Environmental-Economic Accounting – Ecosystem Accounting (SEEA – EA) framework takes a spatial approach to accounting, by organizing existing data on the location and size of ecosystem assets, tracking changes in their condition, measuring ecosystem services and linking this information to economic and human activity.

According to the SEEA – EA:

> Ongoing ecosystem accounts will allow insight into important, overarching questions on the relationship between the economy, society, and the environment and how we measure well-being and social progress. For example:
>
> - What is the contribution of ecosystems and their services to the economy, social wellbeing, jobs and livelihoods?
> - How is the condition, health and integrity of ecosystems and biodiversity changing over time and where are the main areas of degradation and enhancement?
> - How can natural resources and ecosystems be best managed to ensure continued services and benefits such as energy, food supply, water supply, flood control, carbon storage and recreational opportunities?
> - How should conservation efforts be targeted?
> - What opportunities exist for the development of innovative incentive-based programs to conserve nature such as payment for ecosystem services?
> - What do estimates of a nation's wealth and economic potential look like once the state of its environment is considered?[1]

Ecosystem accounting takes a spatial approach to accounting, organizing data on the location and size of ecosystem assets, tracking changes in their condition, measuring ecosystem services and linking this information to economic and human activity. It is designed to answer important questions on the relationship between the economy, society and the environment and how we measure well-being and social progress.[2] Understanding, measuring and analyzing changes in the extent and condition of ecosystems and the impacts of these changes on ecosystem services allows for informed decision making that reflects a more comprehensive assessment of tradeoffs and impacts on human well-being.

This first effort to compile ecosystem accounts has uncovered data gaps and limitations in several areas. Data have been derived to present comprehensive and comparable statistics on ecosystems, with additional context from the literature. Further work and collaboration in identifying data priorities, data gathering and modeling are required to more fully report on Canada's ecosystems and ecosystem services. The Census of Environment has begun to address these issues, and will work to develop a trusted knowledge base on ecosystems. This will include ongoing data on how the extent and conditions of Canada's ecosystems are evolving over time.

1 United Nations, 2021, *System of Environmental-Economic Accounting* — Ecosystem Accounting, https://seea.un.org/ecosystem-accounting (accessed March 15, 2021).

2 United Nations, 2021.

The *Human Activity and the Environment* publications bring together data from many sources to present a statistical portrait of Canada's environment, with special emphasis on human activity and its relationship to natural elements—air, water soil, plants and animals. Each issue provides accessible and relevant information on an environmental issue of concern to Canadians.

The report is organized as follows:

Section 1 – Introduction

Section 2 – Ecosystem extent and drivers of change describes the extent of Canada's main terrestrial, freshwater, marine and coastal ecosystems, their defining characteristics, and changes in land use and climate that drive changes in these ecosystems and their condition.

Section 3 – Ecosystem condition presents data on selected abiotic, biotic and landscape and seascape ecosystem condition characteristics, including water storage and yield, ambient air quality, forest disturbance, urban greenness, landscape fragmentation and modification, sea surface temperature, salinity, species stock status, sea ice and seascape modification. Covering the whole range of condition characteristics for Canada's many ecosystems is beyond the scope of this report—selected measures were included based on data availability. Some measures of condition relate to geographic areas, while others are specific to individual ecosystem types.

Section 4 – Supply and use of ecosystem services presents data on selected provisioning, regulating and cultural ecosystem services provided by Canada's many ecosystems. Estimates are provided for the physical supply of provisioning services (e.g., crop production, fodder production, aquaculture production, wood production, wild animal harvests and water supply), regulating services (e.g., carbon sequestration and storage and air filtration) and use of recreation-related services.

Section 5 – Appendices

Methodology and data limitations

Glossary

Acknowledgements

Textbox: What you need to know about this report

This report brings together many different sources is to provide the most complete picture possible of Canada's ecosystems and changes in ecosystem condition and ecosystem services that will affect the health of the economy, society and human well-being. This has been accomplished through the use of ecosystem accounting, which involves the structured compilation of information on ecosystems such as forests, agro-ecosystems, wetlands, and marine and coastal areas, their condition or quality and the ecosystem services they provide, following the requirements of a coherent statistical framework.

The report is the result of Statistics Canada's ongoing work to develop and implement ecosystem accounts according to the new integrated and comprehensive statistical framework for ecosystem accounting described in the *System of Environmental-Economic Accounting–Ecosystem Accounting* (SEEA – EA) that has been adopted by the United Nations Statistical Commission.[3] While there are multiple components of these accounts, this report focuses on available data that align with the following core ecosystem accounts:

- Ecosystem extent accounts organize data on the size and location of different types of ecosystems. They provide information on the composition of ecosystems within a country and their change over time. Ecosystems are defined by the interaction of their biotic and abiotic components including climate, topography, soils, vegetation, soil moisture, hydrology and species. However, the use of data on land cover and land use provide an operational way to delineate ecosystems and assess change.

3 United Nations, 2021.

- Ecosystem condition accounts organize biophysical data on the quality of ecosystems and provide information on how ecosystem condition is changing over time. These accounts use a number of different variables or indicators to report on selected abiotic and biotic ecosystem condition characteristics (e.g., species, vegetation, landscape pattern, soil and water characteristics), organized into six classes: physical, chemical, compositional, structural and functional state or landscape and seascape characteristics. Ecosystem condition accounts cover the ecosystem types included in the extent accounts.
- Ecosystem services supply and use accounts report flows of ecosystem services supplied by ecosystems and used by economic units (e.g., households, industry). They provide insights on the ecosystem benefits used and enjoyed by people and which contribute to individual and societal well-being. These accounts can be compiled in physical or monetary terms.

For more information, see: Canadian System of Environmental-Economic Accounting – Ecosystem Accounts (5331)

This report provides a number of new assessment approaches to help measure progress against United Nations Sustainable Development Goals. It complements reporting for SDG 13 - Climate Action, 14 - Life Below Water and 15 - Life on Land.

Geographic units:

Much of the analysis on the extent and condition of terrestrial ecosystems is reported here at the ecoprovince level of the Ecological Land Classification, 2017 (Map 1.1). Canada's 53 ecoprovinces are characterized by major assemblages of structural or surface forms, faunal realms, vegetation, hydrology, soil and macro climate and are a subdivision of larger ecozones.

Data on marine and coastal ecosystem are reported by marine ecoregion, which are ecologically defined regions of Canada's oceans.[4]

Data on freshwater ecosystems are reported at the drainage region level of the Standard Drainage Area Classification, 2003, which aggregates sub-sub-drainage areas into 25 regions flowing into five ocean drainage areas.

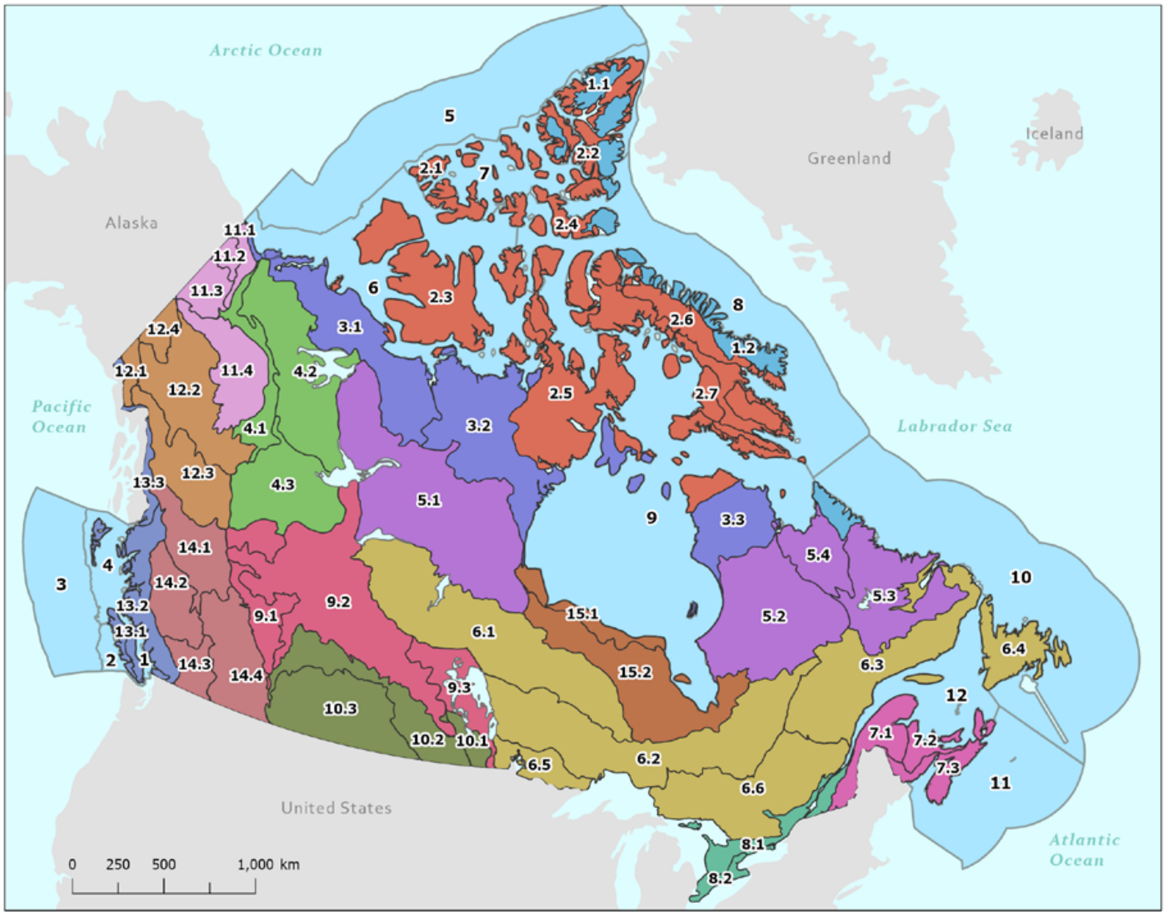
Urban-related data may be aggregated for population centres and for selected census metropolitan areas or census agglomerations.[5]

Data on ecosystem services are reported at the national level and by province, ecozone or population centre, where available.

4 Fisheries and Oceans Canada, 2016, *Federal Marine Bioregions*, https://open.canada.ca/data/en/dataset/23eb8b56-dac8-4efc-be7c-b8fa11ba62e9 (accessed January 29, 2019).

5 Statistics Canada, 2017, *Dictionary, Census of Population*, 2016, https://www12.statcan.gc.ca/census-recensement/2016/ref/dict/index-eng.cfm (accessed January 29, 2019).

Map 1.1
Ecozones, ecoprovinces and marine ecoregions of Canada



Arctic Cordillera
1.1 Northern Arctic Cordillera
1.2 Southern Arctic Cordillera

Northern Arctic
2.1 Sverdrup Islands
2.2 Ellesmere Basin
2.3 Victoria Lowlands
2.4 Parry Channel Plateau
2.5 Boothia–Foxe Shield
2.6 Baffin Uplands
2.7 Foxe–Boothia Lowlands

Southern Arctic
3.1 Amundsen Lowlands
3.2 Keewatin Lowlands
3.3 Ungava–Belcher

Taiga Plains
4.1 Mackenzie Foothills
4.2 Great Bear Lowlands
4.3 Hay–Slave Lowlands

Taiga Shield
5.1 Western Taiga Shield
5.2 Eastern Taiga
5.3 Labrador Uplands
5.4 Whale River Lowland

Boreal Shield
6.1 Western Boreal Shield
6.2 Mid-Boreal Shield
6.3 Eastern Boreal Shield
6.4 Newfoundland
6.5 Lake of the Woods
6.6 Southern Boreal Shield

Atlantic Maritime
7.1 Appalachian–Acadian Highlands
7.2 Northumberland Lowlands
7.3 Fundy Uplands

Mixedwood Plains
8.1 Great Lakes–St. Lawrence Lowlands
8.2 Huron–Erie Plains

Boreal Plains
9.1 Boreal Foothills
9.2 Central Boreal Plains
9.3 Eastern Boreal Plains

Prairies
10.1 Eastern Prairies
10.2 Parkland Prairies
10.3 Central Grassland

Taiga Cordillera
11.1 Northern Yukon Mountains
11.2 Old Crow–Eagle Plains
11.3 Ogilvie Mountains
11.4 Mackenzie–Selwyn Mountains

Boreal Cordillera
12.1 Wrangel Mountains
12.2 Northern Boreal Cordillera
12.3 Southern Boreal Cordillera
12.4 Western Boreal Cordillera

Pacific Maritime
13.1 Georgia Depression
13.2 Southern Coastal Mountains
13.3 Northern Coastal Mountains

Montane Cordillera
14.1 Northern Montane Cordillera
14.2 Central Montane Cordillera
14.3 Southern Montane Cordillera
14.4 Columbia Montane Cordillera

Hudson Plains
15.1 Hudson Bay Coastal Plains
15.2 Hudson–James Lowlands

Marine ecoregion
1 Strait of Georgia
2 Southern Shelf
3 Offshore Pacific
4 Northern Shelf
5 Arctic Basin
6 Western Arctic
7 Arctic Archipelago
8 Eastern Arctic
9 Hudson Bay Complex
10 Newfoundland-Labrador Shelves
11 Scotian Shelf
12 Gulf of St. Lawrence

Data quality and fitness for use

Data for this report were gathered from a variety of sources. There were data gaps and differences in definitions, spatial and temporal coverage and resolution and methods, all of which can increase uncertainty in the estimates and limit comparability across space and time.

This report provides a high-level overview of these issues by applying concepts from the newly adopted System of Environmental-Economic Accounting – Ecosystem Accounting framework. While this report presents some of the latest statistics available on many subjects, new data and improved methodologies will continue to be integrated to improve the quality of the ecosystem accounts.

Further details on the sources, methodology, limitations and data gaps are available in Appendix A.

2.0 Ecosystem extent and drivers of change

Canada is a vast country, the second largest in the world. Canada's terrestrial and freshwater area extends across 9.98 million km^2 while its jurisdiction over the ocean includes 5.75 million km^2 within the limit of its exclusive economic zone (EEZ), and a total of 7.1 million km^2 including jurisdiction over the seabed and subsoil of the extended continental shelf of the Arctic and Atlantic oceans.[6]

Many different ecosystems occupy Canada's land, freshwater and seascapes. Temperate and boreal forests, peatlands, tundra, alpine meadows, temperate grasslands, coastal wetlands and coral reefs can be delineated based on the interaction of biological communities of organisms and their environment. Characteristics such as climate, topography, soils, vegetation, wildlife and human activity interact and can be used to define the extent of terrestrial ecosystems at different scales. For marine and coastal ecosystems, climate, biota, currents, seafloor substrate, and horizontal and vertical zonation—the distance from the coast and depth in the water column—can be important components that help define ecosystem areas. Some of these characteristics are relatively fixed and change only slowly, but others can change rapidly, reflecting changes in land use and other pressures.

Human activity and land use change have greatly altered many of Canada's natural ecosystems. Major changes in Canada's landscapes occurred following European colonization including draining wetlands and clearing woodlands for agriculture and the establishment of settlements along waterways and rail lines, near harbours and on fertile lands. The loss of free-roaming plains bison to hunting and the opening of the Prairies to agriculture in the late 1800s altered the native grasslands and plains.[7] Natural forests have increasingly been converted to managed forests over the past century, with impacts on biodiversity and the loss of many old growth forests.[8]

Land use changes occur as a result of changes in patterns of human activity. Some examples include urban expansion into nearby agricultural, forest or wetland areas at the periphery of cities and the conversion of forests to agricultural land. Industrial activities such as forestry, mining and oil exploration can cause deforestation and ecosystem fragmentation in more remote areas of the country.[9] Human consumption and production activities also drive local and global ecosystem change.[10] For example, emissions released from human activities can affect the quality of air, water and land and influence the global climate system. Climate change is increasingly impacting ecosystem functions and the health and distribution of many plant and animal species across the country.[11]

This report brings together consistent statistics from many sources to map and describe the extent of Canada's ecosystems and changes in ecosystem condition and services that will affect the health of the economy, society and human well-being.

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6 Fisheries and Oceans Canada, 2018, *Oceans Collaboration*, https://www.dfo-mpo.gc.ca/oceans/collaboration/international-eng.html (accessed August 10, 2020); Fisheries and Oceans Canada, 2011, *Defining Canada's Maritime Zones*, Catalogue no. Fs23-571/2011E, http://publications.gc.ca/collections/collection_2012/mpo-dfo/Fs23-571-2011-eng.pdf (accessed August 10, 2020).

7 Wiken, E., et al., 1996, *A Perspective on Canada's Ecosystems*, Canadian Council on Ecological Areas, No. 14, Ottawa.

8 Waldron K., et al., 2020, "Ecological issues related to second-growth boreal forest management in eastern Quebec, Canada: Expert perspectives from a Delphi process," *Forest Ecology and Management,* Vol. 470-471, no. 118214, https://doi.org/10.1016/j.foreco.2020.118214 (accessed July 5, 2020); Didion, M., et al., 2007, "Forest age structure as indicator of boreal forest sustainability under alternative management and fire regimes: A landscape level sensitivity analysis," *Ecological Modelling*, Vol. 200, no. 1-2, https://doi.org/10.1016/j.ecolmodel.2006.07.011 (accessed July 5, 2020).

9 Statistics Canada, 2016, "The changing landscape of Canadian metropolitan areas," *Human Activity and the Environment*, Catalogue no. 16-201-X, https://www150.statcan.gc.ca/n1/pub/16-201-x/16-201-x2016000-eng.htm; Statistics Canada, 2018, "Forests in Canada," *Human Activity and the Environment,* Catalogue no. 16-201-X, https://www150.statcan.gc.ca/n1/pub/16-201-x/16-201-x2018001-eng.htm.

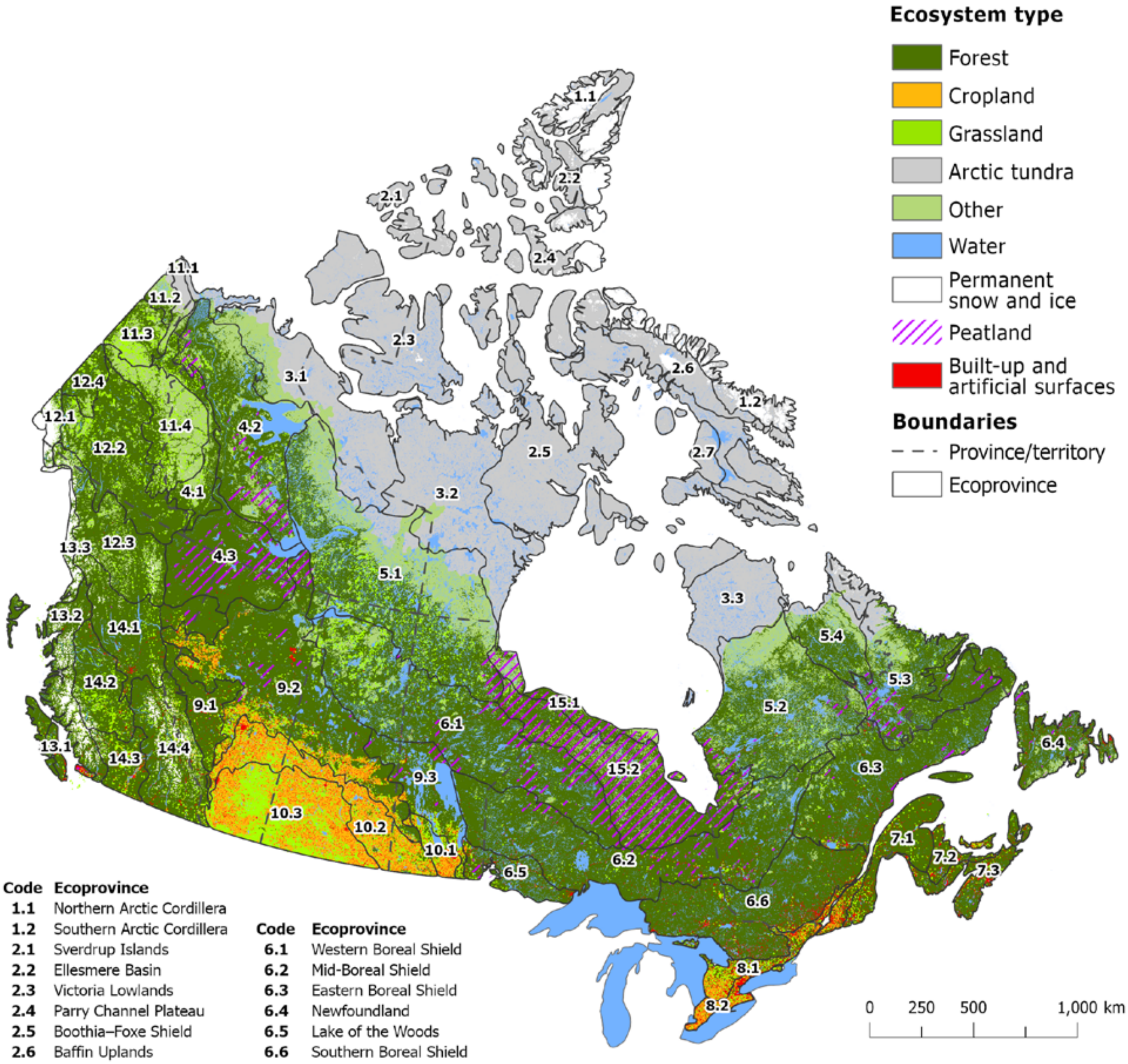
10 IPBES, 2019, *Summary for Policymakers of the Global Assessment Report on Biodiversity and Ecosystem Services of the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services*, S. Díaz, et al., (eds.), Bonn, Germany, https://doi.org/10.5281/zenodo.3553579 (accessed December 10, 2020); McGranahan, G., et al., 2005, "Chapter 27 Urban systems," *Ecosystems and Human Well-being: Current State and Trends*, Vol. 1, R. Hassan, R. Scholes and N. Ash, (eds.) Millennium Ecosystem Assessment, https://www.millenniumassessment.org/en/Condition.html (accessed December 15, 2018).

11 McKenney, D., et al., 2014, "Change and evolution in the plant hardiness zones of Canada," *BioScience,* Vol. 64, no. 4, pp. 341-350, https://doi.org/10.1093/biosci/biu016 (accessed April 20, 2020); Pitman, K., et al., 2020, "Glacier retreat and Pacific salmon," *BioScience*, Vol. 70, no. 3, pp. 220-236, https://doi.org/10.1093/biosci/biaa015 (accessed January 29, 2021); Rowland, E. L., et al., 2016, "Examining climate-biome ("cliome") shifts for Yukon and its protected areas," *Global Ecology and Conservation*, Vol. 8, pp. 1-17, https://doi.org/10.1016/j.gecco.2016.07.006 (accessed January 29, 2021); Beaubien, E. and A. Hamann, 2011, "Spring flowering response to climate change between 1936 and 2006 in Alberta, Canada," *BioScience*, Vol. 61, no. 7, pp. 514-524, https://doi.org/10.1525/bio.2011.61.7.6 (accessed February 10, 2021).

2.1 Terrestrial and freshwater ecosystems

Canada has some of the largest forest, tundra, prairie, wetland and freshwater ecosystems in the world (Map 2.1). Overall, approximately 36% of the country is covered by forest, 25% by arctic tundra, 4% by grassland including natural pasture or rangeland, 2% by permanent snow and ice cover and 28% by other natural and semi-natural areas such as woodland, shrubland, alpine tundra, barrenland, wetland and water (Table 2.1). In 2016, 4% of the country was used for growing crops and tame or seeded pastures and in 2015, 0.6% was covered by built-up and artificial surfaces used for settlements, transportation and other infrastructure.

Map 2.1
Terrestrial and freshwater ecosystem extent



Code	Ecoprovince
1.1	Northern Arctic Cordillera
1.2	Southern Arctic Cordillera
2.1	Sverdrup Islands
2.2	Ellesmere Basin
2.3	Victoria Lowlands
2.4	Parry Channel Plateau
2.5	Boothia–Foxe Shield
2.6	Baffin Uplands
2.7	Foxe–Boothia Lowlands
3.1	Amundsen Lowlands
3.2	Keewatin Lowlands
3.3	Ungava–Belcher
4.1	Mackenzie Foothills
4.2	Great Bear Lowlands
4.3	Hay–Slave Lowlands
5.1	Western Taiga Shield
5.2	Eastern Taiga
5.3	Labrador Uplands
5.4	Whale River Lowland

Code	Ecoprovince
6.1	Western Boreal Shield
6.2	Mid-Boreal Shield
6.3	Eastern Boreal Shield
6.4	Newfoundland
6.5	Lake of the Woods
6.6	Southern Boreal Shield
7.1	Appalachian–Acadian Highlands
7.2	Northumberland Lowlands
7.3	Fundy Uplands
8.1	Great Lakes–St. Lawrence
8.2	Huron–Erie Plains
9.1	Boreal Foothills
9.2	Central Boreal Plains
9.3	Eastern Boreal Plains
10.1	Eastern Prairies
10.2	Parkland Prairies
10.3	Central Grassland

Code	Ecoprovince
11.2	Old Crow–Eagle Plains
11.3	Ogilvie Mountains
11.4	Mackenzie–Selwyn Mountains
12.1	Wrangel Mountains
12.2	Northern Boreal Cordillera
12.3	Southern Boreal Cordillera
12.4	Western Boreal Cordillera
13.1	Georgia Depression
13.2	Southern Coastal Mountains

Code	Ecoprovince
13.3	Northern Coastal Mountains
11.1	Northern Yukon Mountains
14.1	Northern Montane Cordillera
14.2	Central Montane Cordillera
14.3	Southern Montane Cordillera
14.4	Columbia Montane Cordillera
15.1	Hudson Bay Coastal Plains
15.2	Hudson–James Lowlands

Notes: Ecosystem data here represent the latest comprehensive and comparable estimates for the country for the time period the data were developed. Data for built-up areas are from 2010. Peatlands are shown on the map where more than 50% of the soil landscape polygon is classified as peatland.
Sources: Beaudoin, A., et al., 2017, *Species composition, forest properties and land cover types across Canada's forests at 250 m resolution for 2001 and 2011,* Natural Resources Canada (NRCan), Canadian Forest Service, Laurentian Forestry Centre; Agriculture and Agri-Food Canada (AAFC), 2020, *Annual Crop Inventory, 2014-2016;* NRCan, Canada Centre for Mapping and Earth Observation, 2020, *2010 and 2015 Land Cover of North America at 30 metres,* Ed. 2.0, Commission for Environmental Cooperation (CEC), North American Land Change Monitoring System; Baldwin, K., et al., 2018, *Vegetation Zones of Canada: a Biogeoclimatic Perspective* [Map], Scale 1:5,000,000, NRCan, CFS; Tarnocai, C., I.M. Kettles, B. Lacelle, 2011, Peatlands of Canada, Geological Survey of Canada; AAFC, 2015, *Land Use, 1990, 2000 & 2010.*

Freshwater covers an estimated 1.3 million km^2—13% of the country's landscape including the Great Lakes. The area of these water courses and water bodies fluctuates depending on the season and weather conditions. For example, in summer, snowmelt contributes to the formation of shallow lakes in tundra areas, while in the Prairies, pothole wetlands that fill with water in the spring may disappear later in summer. Seasonal and inter-annual fluctuations can make it difficult to discern shifts in the extent of freshwater areas. The Great Lakes—the largest freshwater lake system in the world—straddle the Canada–United States border and cover an area of approximately 90,000 km^2 in Canada.[12]

Canada's boreal zone is a vast expanse of sub-arctic forest, woodland, heathland, grassland, wetland and water stretching across 5.5 million km^2 from Newfoundland and Labrador to the Yukon. The vegetation is shaped by the cold climate conditions, with winter temperatures that can consistently reach -40°C and below, and fire—the chief natural disturbance.[13] From north to south, boreal forests transition from forest-tundra zones, to open forests, to closed forest and cover close to 2.8 million km^2. Spruce (picea) are the dominant genus of trees in the boreal zone, with open spruce-lichen forests providing important habitat for caribou.[14] Other trees include cold-hardy varieties of poplar, birch, fir and pine.[15] Extensive organic wetland areas, known as peatlands, with sporadic and patchy permafrost areas,[16] have formed in lowland areas of the boreal zone, particularly surrounding Hudson Bay and Great Slave Lake. These bogs and fens, covered in sphagnum moss, lichens, shrubs and spruce trees, extend across approximately 1.1 million km^2 or about 11% of the total area of the country.

A greater diversity of vegetation is found in the cool temperate forests south of the boreal zone that collectively cover approximately 8% of the country. These include the largely coniferous rainforest, dry, montane and subboreal forests in coastal British Columbia and cordilleran British Columbia and Alberta; the Eastern mixed Great-–Lakes and St. Lawrence forests and deciduous Carolinian forests of Central Canada and southwestern Ontario; and the mixed Acadian forest in the Maritimes.[17]

Forests are affected by natural disturbances such as insect infestation, disease, fire and windthrow, as well as by timber harvesting, forest management practices and land use decisions. Much of Canada's temperate forest and the southern parts of the boreal forest are managed for timber production, with harvesting and regeneration timed to produce a sustainable forest yield as forests mature.[18] Overall, Canada's forest area is relatively stable—from 1990 to 2018, 0.4% of forests were deforested and converted to other uses, including agriculture, roads, hydro-electric reservoirs and urban areas.[19]

Tundra ecosystems are treeless areas of dwarf shrub and other low-lying sedges, mosses and lichen that have developed north of the boreal zone and in alpine regions at higher elevation. Arctic tundra experiences extremely low winter temperatures and low precipitation and has extensive permafrost soils that store vast amounts of organic carbon. In summer, the active or top layer of this soil thaws, developing into lakes and marshy areas and releasing methane and carbon from decomposing plant material. Arctic tundra, including rocky barrenland, covers an estimated 2.5 million

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12 International Boundary Commission, 2018, *Canada / United States of America Boundary Dataset*, http://www.internationalboundarycommission.org/en/maps-coordinates/coordinates.php (accessed February 2, 2021); Great Lakes Commission, 2012, *Great Lakes Boundaries*, https://www.glc.org/greatlakesgis (accessed February 2, 2021).

13 Brandt, J.P., 2009, "The extent of the North American boreal zone," *Environmental Reviews*, Vol. 17, https://doi.org/10.1139/A09-004 (accessed October 10, 2017); Brandt, J.P., et al., 2013, "An introduction to Canada's boreal zone: ecosystem processes, health, sustainability, and environmental issues," *Environmental Reviews*, Vol. 21, no. 4, https://doi.org/10.1139/er-2013-0040 (accessed October 10, 2017).

14 Federal, Provincial and Territorial Governments of Canada, 2010, *Canadian Biodiversity: Ecosystem Status and Trends 2010*, Canadian Councils of Resource Ministers, https://biodivcanada.chm-cbd.net/ecosystem-status-trends-2010/forests (accessed October 10, 2017).

15 Brandt, J.P., 2009; Canada's National Forest Inventory, 2013, Table 14.2. Area (1000 ha) of forest land by species group, age class and boreal zone in Canada, 2006 revised baseline, Version 3, December 2013, https://nfi.nfis.org/resources/general/summaries/en/html/BOR3_T14_LSAGE20_AREA_en.html (accessed June 18, 2020).

16 Tarnocai, C., 2009, "The impact of climate change on Canadian peatlands," *Canadian Water Resources Journal*, Vol. 34, no. 4, https://doi.org/10.4296/cwrj3404453 (accessed October 10, 2017); Statistics Canada, 2013, "Measuring ecosystem goods and services," *Human Activity and the Environment*, Catalogue no. 16-201-X; Smith, S., 2010, "Trends in permafrost conditions and ecology in northern Canada," *Canadian Biodiversity: Ecosystem Status and Trends 2010*, Technical Thematic Report No. 9, Canadian Councils of Resource Ministers, https://biodivcanada.chm-cbd.net/ecosystem-status-trends-2010/technical-report-9 (accessed June 18, 2020).

17 Natural Resources Canada, 2017, *Forest Classification*, https://www.nrcan.gc.ca/our-natural-resources/forests-forestry/sustainable-forest-management/measuring-reporting/forest-classification/13179#regions (accessed October 10, 2017); Rowe, J.S., 1972, *Forest Regions of Canada*, Department of the Environment, Canadian Forestry Service, Catalogue Fo47-1300, https://cfs.nrcan.gc.ca/pubwarehouse/pdfs/24040.pdf (accessed June 1, 2020); Baldwin, K., et al, 2018, *Vegetation Zones of Canada: A Biogeoclimatic Perspective*, Natural Resources Canada, Canadian Forest Service, http://cnvc-cnvc.ca/page.cfm?page=2306 (accessed June 1, 2020).

18 Natural Resources Canada, 2019, "Canada's forests: Managing for the future," *The State of Canada's Forests 2019*, https://www.nrcan.gc.ca/sites/www.nrcan.gc.ca/files/forest/sof2019/map/Map_EN_w1140px.jpg (accessed June 9, 2020).

19 Natural Resources Canada, 2020, *The State of Canada's Forests 2020*, https://www.nrcan.gc.ca/our-natural-resources/forests-forestry/state-canadas-forests-report/16496 (accessed December 8, 2020).

km^2 of Canada's North and additional areas of alpine tundra occur at elevation in the Rocky and Coast Mountains ranges. Areas of permanent snow and ice also occur in the Arctic Cordillera and at high elevation in Canadian mountain ranges, covering over 200,000 km^2 or about 2% of Canada's total area.[20]

Grassland ecosystems developed south of the boreal zone, in the Canadian Prairie provinces, east of the Rockies and in the dry valleys of southern interior British Columbia. The Prairies also include hundreds of thousands of small wetlands known as Prairie potholes that are important for local hydrology and provide habitat for waterfowl,[21] as well as wooded parkland areas that are a transition area between the grasslands and the boreal forest. The dominant grass and forb vegetation of these grasslands developed under cold and dry climate conditions and was maintained by fire and grazing. These ecosystems are among the most altered in North America, with little of the original grassland remaining.[22] Prairie grasslands developed fertile and humus-rich soils from the extensive plant root systems, though a significant proportion of this soil organic matter was lost during the conversion of grassland to agriculture,[23] now the dominant land use. Much of the wetland area has also been drained and converted to agricultural use. In 2016, 65% of the Parkland Prairies ecoprovince was used for arable agriculture,[24] followed by 60% in the Central Grassland and 54% in the Eastern Prairies, though additional grassland areas were used as natural pasture and rangeland.

Agriculture is also a major land use outside the Prairies, particularly in the Huron–Erie plains and Great Lakes–St. Lawrence Lowlands ecoprovinces, where arable land accounted for 58% and 39%, respectively, of the total area in 2016. It also contributed a significant but smaller share of the Central Boreal Plains ecoprovince (15%) and Eastern Boreal Plains (5%), the Northumberland Lowlands (7%) and Appalachian–Acadian Highlands (5%) in the Maritimes and Georgia Depression (5%) in British Columbia.

Humans are a part of Earth's ecosystems, exerting substantial pressures and influencing ecosystem processes and functions.[25] Urban development and industrial activity can dramatically alter the surrounding landscape. For example, land use change around cities is a direct driver of change causing permanent shifts from forest or agro-ecosystems to urban areas. Most settlement and human infrastructure is located in the south of the country, where the majority of people live (Table 2.2). Only seven ecoprovinces had a population of over one million people in 2016 and much of the country remains sparsely populated. Other built-up area is associated with resource extraction and industry use, including mines and oil and gas infrastructure.

In 2015, 62,600 km^2 of Canada's landscape was built-up and artificial surface associated with settlements and infrastructure, up 11% from 56,400 km^2 in 2000.[26]

Ecoprovinces with the highest percentage of built-up and artificial surfaces are the Huron-Erie Plains at 19%, Georgia Depression at 11% and the Great Lakes–St. Lawrence Lowlands at 10% in 2010. These three ecoprovinces include Montréal, Ottawa, Vancouver, Toronto and other large urban population centres and are home to over 62% of the

20 Natural Resources Canada, Canada Centre for Remote Sensing, U.S. Geological Survey and Comisión National para el Conocimiento y Uso de la Biodiversidad, Comisión National Forestal and Instituto National de Estadística y Geografía, 2020, *2010 and 2015 Land Cover of North America at 30 metres*, Ed. 2., North American Land Change Monitoring System, Commission for Environmental Cooperation (CEC), North American Land Change Monitoring System, http://www.cec.org/north-american-environmental-atlas/land-cover-30m-2015-landsat-and-rapideye/ (accessed December 9, 2020); Natural Resources Canada, 2019, Glaciers, https://www.nrcan.gc.ca/environment/science/indicators-change/glaciers/11005 (accessed October 13, 2020).

21 Statistics Canada, 2013, "Measuring ecosystem goods and services," *Human Activity and the Environment*, Catalogue no. 16-201-X, Millett, B., et al., 2009, "Climate trends of the North American Prairie Pothole Region, 1906-2000," *Climatic Change*, Vol. 93, pp. 243-267, https://doi.org/10.1007/s10584-008-9543-5 (accessed June 19, 2020); Fang, X., et al., 2007, *A Review of Canadian Prairie Hydrology: Principles, Modelling and Response to Land Use and Drainage Change*," Centre for Hydrology Report #2, University of Saskatchewan, https://research-groups.usask.ca/hydrology/documents/reports/chrpt02_prairie-hydrology-review_oct07.pdf (accessed December 3, 2020).

22 Federal, Provincial and Territorial Governments, 2010, *Canadian Biodiversity: Ecosystem Status and Trends, 2010*, Canadian Councils of Resource Ministers, Ottawa; Bailey, A.W., D. McCartney and M.P. Schellenberg, 2010, *Management of Canadian Prairie Rangeland*, Agriculture and Agri-Food Canada, Catalogue no. 10144, http://www.publications.gc.ca/site/eng/377157/publication.html (accessed December 10, 2020).

23 Canadian Society of Soil Science, 2020, "Chernozemic," *Soils of Canada*, https://soilsofcanada.ca/orders/chernozemic-soils.php (accessed June 8, 2020); Ogle, S.M., et al., 2018, "Delineating managed land for reporting national greenhouse gas emissions and removals to the United Nations framework convention on climate change," *Carbon Balance and Management*, Vol. 13, no. 9, https://doi.org/10.1186/s13021-018-0095-3 (accessed April 9, 2021); Wiken, E., et al., 1996.

24 Excludes natural land for pasture, wetlands and woodlands and other land (e.g., idle land, land occupied by farm buildings) on farms.

25 IPBES, 2019; Millennium Ecosystem Assessment, 2005, *Ecosystem and Human Well-being: Synthesis*, Island Press, Washington, DC. https://www.millenniumassessment.org/en/Synthesis.html (accessed December 15, 2018).

26 The 2015 ecoprovince estimates are not available for built-up and artificial surfaces.

population of Canada. Populations in urban areas rely heavily on ecosystem services generated elsewhere, as cities themselves occupy relatively little area while housing the majority of the population. In 2016, 81% of the population lived in population centres, the majority in large urban centres with a population greater than 100,000.[27]

The largest increases in built-up and artificial surfaces at the ecoprovince-level from 2000 to 2010 occurred in the Southern Boreal Shield, Central Boreal Plains and Great Lakes–St. Lawrence ecoprovinces. These three ecoprovinces accounted for more than half of the increase in built-up area over this period.

2.2 Marine and coastal ecosystems

Defining the extent of ecosystems in the ocean can be complicated. In all but the shallowest waters, surveying the ocean bottom in detail requires either diving or sending camera probes, though technologies such as sonar are increasingly being explored. Parts of the ocean are less well known than the surface of the moon because of the high pressures and almost freezing temperatures experienced at depth.[28] Canada's EEZ is approximately 5 km deep at its deepest, presenting a major challenge in mapping our ocean territory. Our knowledge about marine and coastal ecosystems—their locations, size and condition—is incomplete, particularly in arctic regions.

Measuring the depth of water above the seafloor—known as bathymetry—indicates the potential location of different types of ocean ecosystems. Sunlight, which plays a large role in determining where animals, plants and other biota live, will not penetrate much further than 200 m,[29] though small amounts may reach as deep as 1,000 m. Other bottom characteristics such as terrain ruggedness, slope and substrate can indicate favourable locations for different ocean habitats[30] and vegetation covers, as well as susceptibility to harm from changing ocean conditions, large storm events or human activities and modifications.

Areas with water depths down to 200 m, in particular shallower coastal areas, are the main regions of the ocean capable of supporting photosynthesizing plants. Many important ecosystems, such as saltmarshes, seagrass meadows and kelp forests are mainly found in coastal areas with water depths of 50 m or less (Map 2.2 and Table 2.3). While not all coastal ecosystems are fully mapped, estimates of saltmarsh extent indicate that at least 1,114 km^2 of these intertidal ecosystems exist, while seagrass meadows and kelp forests respectively cover an estimated 1,429 km^2 and 634 km^2 of seabed (Map 2.3 and Table 2.4). These ecosystems are biodiversity hot spots and important carbon sinks.[31]

27 Population centres have a population of at least 1,000 and a population density of 400 persons or more per square kilometre. All areas outside population centres are classified as rural areas. In 2016, large urban population centres with 100,000 persons or more accounted for 73% of the population centre total. Statistics Canada, 2017, Population and Dwelling Count Highlight Tables, 2016 Census, Catalogue no. 98-402-X2016001, https://www12.statcan.gc.ca/census-recensement/2016/dp-pd/hlt-fst/pd-pl/index-eng.cfm (accessed September 18, 2020).

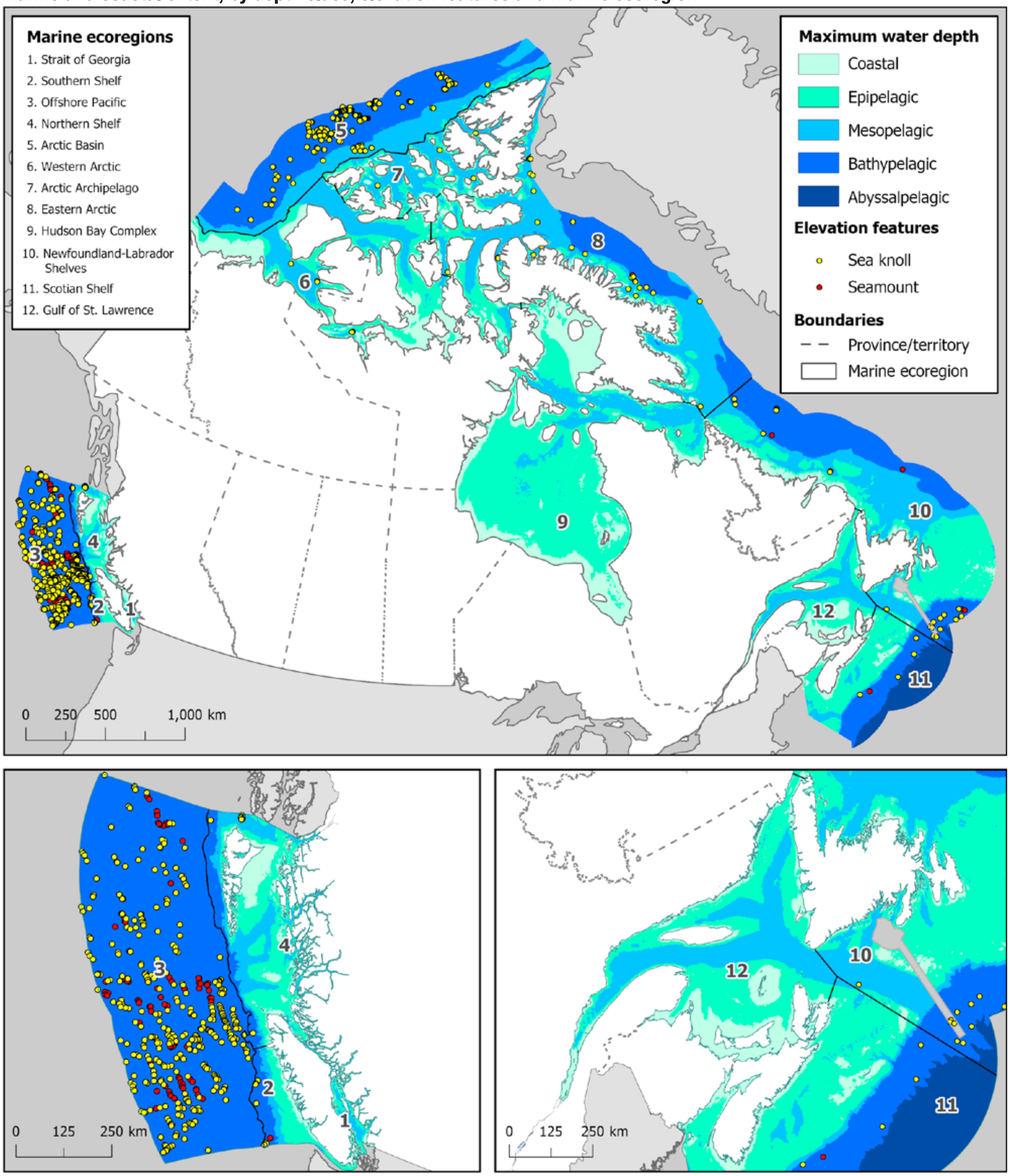
28 Copley, J., 2014, "Just How Little Do We Know about the Ocean Floor," *The Conversation UK*, October 9, 2014, https://theconversation.com/just-how-little-do-we-know-about-the-ocean-floor-32751 (accessed March 30, 2020).

29 National Oceanic and Atmospheric Administration, 2020, "How far does light travel in the ocean?," *Ocean Facts*, https://oceanservice.noaa.gov/facts/light_travel.html (accessed March 30, 2020).

30 Wölfl, A., et al., 2019, "Seafloor mapping – The challenge of a truly global ocean bathymetry," *Frontiers in Marine Science*, https://doi.org/10.3389/fmars.2019.00283 (accessed March 30 2020).

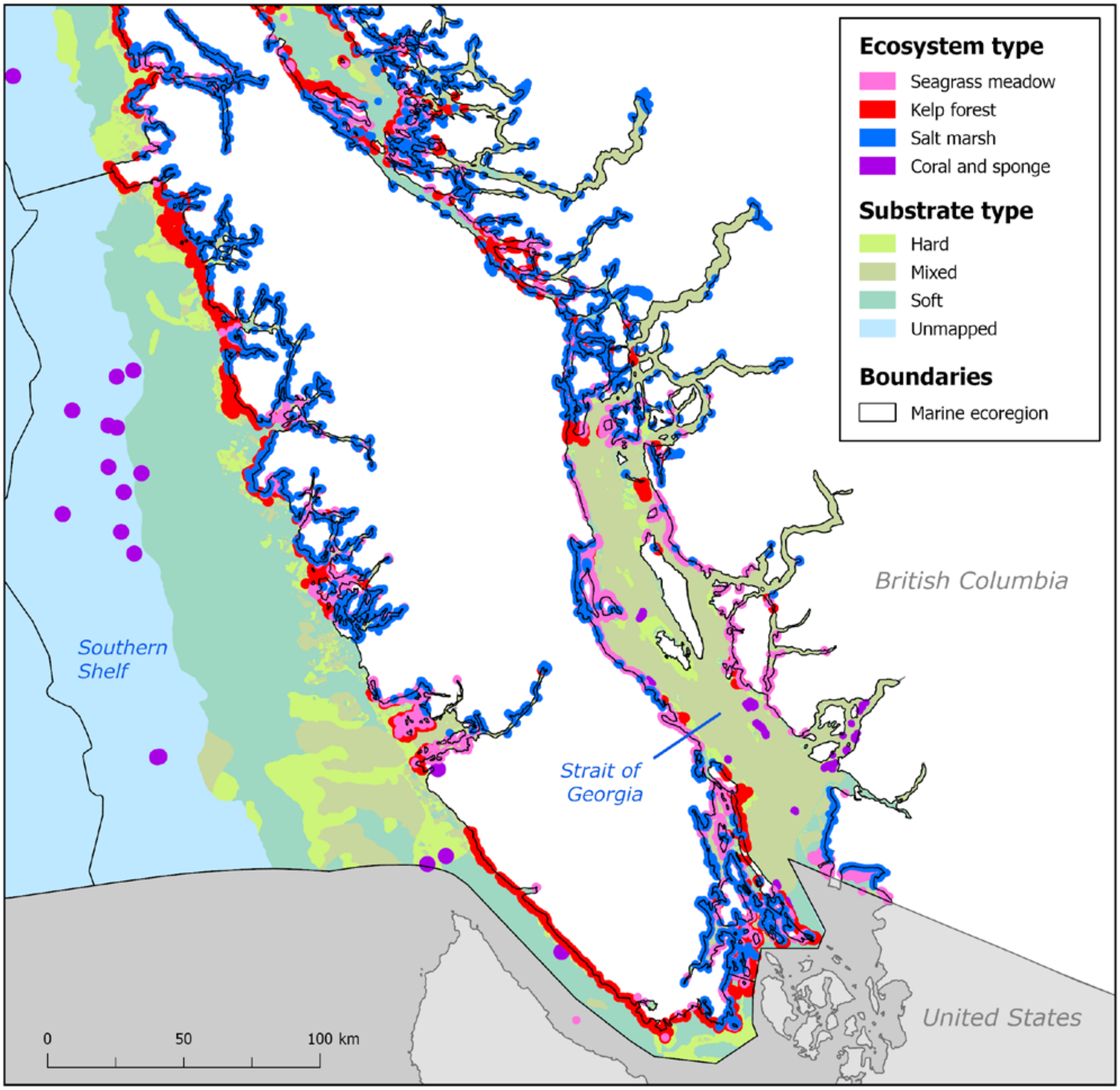
31 Commission for Environmental Cooperation (CEC), 2016, *North America's Blue Carbon: Assessing Seagrass, Salt Marsh and Mangrove Distribution and Carbon Sinks*, Montréal, Canada, 54pp, http://www3.cec.org/islandora/en/item/11664-north-america-s-blue-carbon-assessing-seagrass-salt-marsh-and-mangrove-en.pdf (accessed July 24, 2020); Krause-Jensen, D. and C.M. Duarte, 2016, "Substantial role of macroalgae in marine carbon sequestration," *Nature geosci*, Vol. 9, pp. 737-742, https://doi.org/10.1038/ngeo2790 (accessed July 26, 2020); Hyman, A. C., et al., 2019, "Long-term persistence of structured habitats; seagrass meadows as enduring hotspots of biodiversity and faunal stability," *Royal Society*, Vol. 286, no. 1912, https://doi.org/10.1098/rspb.2019.1861 (accessed July 26, 2020); National Oceanic and Atmospheric Administration, 2019, *What is Kelp Forest?*, https://oceanservice.noaa.gov/facts/kelp.html (accessed July 26, 2020)

Map 2.2
Marine and coastal extent, by depth class, elevation features and marine ecoregion



Notes: This map classifies areas of Canada's exclusive economic zone (EEZ) by their maximum water depth. Areas classed as coastal have a maximum depth of 50 m, the epipelagic class has depths from 50 m to 200 m, the mesopelagic class has depths from 200 m to 1,000 m, the bathypelagic class has depths of 1 km to 4 km and the abyssalpelagic class includes all areas with depths of more than 4 km.
Sources: GEBCO Compilation Group, 2015, *GEBCO 2014 Grid*, version 20150318; Yesson, C., et al., 2011 "The global distribution of seamounts based on 30-second bathymetry data." *Deep Sea Research Part1: Oceanographic Research Papers*, Vol 58, pp. 442-453.

Map 2.3
Marine and coastal ecosystem extent: ecosystems and substrate, southern British Columbia coast



Sources: McOwen, C., et. al., 2017, "A global map of saltmarshes," *Biodiversity Data Journal*, Vol. 5: e11764; B.C. Ministry of Forests, Lands, Natural Resources Operations and Rural Development, 2019, *Kelp Beds - Coastal Resource Information Management System (CRIMS), GeoBC;* Freiwald, A., et. al., 2017, "Global distribution of cold-water corals (version 5.0)," Fifth update to the dataset in Freiwald, et. al., 2004, by UNEP-WCMC, in collaboration with A. Freiwald and J. Guinotte, Cambridge (UK): UN Environment World Conservation Monitoring Centre; Fisheries and Oceans Canada, 2016, *Oceans Act Marine Protected Areas;* Fisheries and Oceans Canada, 2017, *Other Effective Area-Based Conservation Measures*; B.C. Ministry of Forests, Lands, Natural Resource Operations and Rural Development, 2019, *Eelgrasses - Coastal Resource Information Management System (CRIMS), GeoBC*; Personal communication with Brett Painter, Environment and Climate Change Canada, June 21, 2019; Personal communication with Heike Lotz, Dalhousie University, June 21, 2019; Personal communication with John Cristiani and Mary O'Connor, University of British Columbia, June 14, 2019; UNEP-WCMC and F.T. Short, 2018, *Global Distribution of Seagrasses (version 6.0),* Sixth update to the data layer used in Green and Short, 2003, Cambridge, (UK): UN Environment World Conservation Monitoring Centre; Gregr, E. J., J. Lessard and J. Harper, 2013, "Pacific data from a spatial framework for representing nearshore ecosystems," *Progress in Oceanography*, Vol. 1153, p. 189-201; Ministry of Forests, Lands, Natural Resource Operations and Rural Development, 1979, *Benthic Marine Ecounits - Coastal Resource Information Management System (CRIMS), GeoBC.*

Most of the world's major fisheries, such as herring, anchovy, sardine and cod, also occur in waters in the most shallow (epipelagic) depth range of 0 to 200 m. Almost 47% of the extent of Canada's EEZ has seafloor depths in this range, while another 25% can be classed as mesopelagic, with depths from 200 m to 1000 m. Waters at this depth have diminishing levels of light as depth increases and host a diverse range of species adapted to a low-light environment.

Areas with deeper (bathylpelagic) waters have depths between 1 km and 4 km. The seafloor in these areas receives no sunlight and experiences higher pressures and colder temperatures. Some cold-water corals grow at depths up to 2.5 km on the East Coast of Canada and can be hundreds of years old, though they can also be found in shallower waters on both the east and west coasts.[32] Coral reefs are important ecosystems for biodiversity, providing a home for a diverse population of fish and bottom dwellers. These reefs are fragile and susceptible to damage from human activities, such as fishing and oil extraction, as well as climate change due to the temperature requirements of some species.[33] Squid, large whales and octopuses can also be found at these depths. Slightly more than a quarter of Canada's EEZ has depths in this zone, in particular the Offshore Pacific and Arctic Basin marine ecoregions.

On the East Coast there are small areas of very deep (abyssalpelagic) waters with depths greater than 4 km in the offshore areas of the Scotian Shelf and Newfoundland Shelf marine ecoregions. These regions cover 2% of Canada's total EEZ. These deeper areas sometimes also have shallower regions known as sea knolls or seamounts that can occur in areas of high ruggedness and slope. Sea knolls and seamounts can be rich in biodiversity since the mixing of water and nutrients that occurs at these locations provides food for many species and are therefore a potential focus for conservation efforts.[34] The Pacific waters in Canada's EEZ have the highest proportion of rugged territory and thus a higher density of seamounts and sea knolls (Table 2.5).

Textbox: Impact of a changing climate on ecosystems and on ecosystem conditions

Climate is a key characteristic affecting the development of different ecosystems (Table 2.6 and 2.7). In Canada, warming temperatures and changing precipitation patterns have led to changes in the condition and functioning of ecosystems. Arctic tundra and boreal ecosystems are experiencing changing conditions including permafrost thaw and the development of thermokarst topography.[35] These changes affect the stability of roads and infrastructure in the North,[36] freshwater flows,[37] and greenhouse gas releases from thawing peatlands.[38] Forest ecosystems are experiencing changes in disturbance regimes and species ranges, including shrub densification in the transition between boreal and tundra ecosystems.[39]

32 Fisheries and Oceans Canada, 2019, *Oasis of the deep: Cold Water Corals of Canada*, http://www.science.gc.ca/eic/site/063.nsf/eng/h_EE39B64D.html (accessed February 21, 2020).

33 Fisheries and Oceans Canada, 2019; Smithsonian, 2018, *Deep Sea Corals*, https://ocean.si.edu/ecosystems/coral-reefs/deep-sea-corals (accessed May 28, 2020).

34 National Oceanic and Atmospheric Administration, n.d., "Why are seamounts 'hotspots' for biodiversity?," *Ocean Exploration Facts*, https://oceanexplorer.noaa.gov/facts/seamounts-biodiv.html (accessed March 30, 2020).

35 Derksen, C., et al., 2019, "Changes in snow, ice, and permafrost across Canada," *Canada's Changing Climate Report*, Bush, E. and D.S. Lemmen (eds.), Government of Canada, Ottawa, Ontario, pp. 194-260, https://changingclimate.ca/CCCR2019/chapter/5-0/ (accessed June 26, 2020); Turetsky, M.R., et al., 2020, "Carbon release through abrupt permafrost thaw," *Nature Geoscience*, Vol. 13, pp. 138-143, https://doi.org/10.1038/s41561-019-0526-0 (accessed February 10, 2021).

36 Derksen, C., et al., 2019.

37 Chesnokova, A., et al., 2020, "Linking mountain glacier retreat and hydrological changes in southwestern Yukon," *Water Resources Research*, Vol. 56, no.1, https://doi.org/10.1029/2019WR025706 (accessed February 10, 2021); Shugar, D., et al., 2017, "River piracy and drainage basin reorganization led by climate-driven glacier retreat," *Nature Geoscience*, Vol. 10, pp. 370-375, https://doi.org/10.1038/ngeo2932, (accessed February 10, 2021).

38 Tarnocai, C., 2009, "The impact of climate change on Canadian peatlands," *Canadian Water Resources Journal*, Vol. 34, no 4, pp. 453-466, https://doi.org/10.4296/cwrj3404453 (accessed October 10, 2017); Turetsky, M.R., et al., 2020, "Carbon release through abrupt permafrost thaw," *Nature Geoscience*, Vol. 13, pp. 138-143, https://doi.org/10.1038/s41561-019-0526-0 (accessed February 10, 2021).

39 Scholes, J. R., et al., 2014, "Terrestrial and inland water systems," *Climate Change 2014: Impacts, Adaptation, and vulnerability: Part A: Global and Sectoral Aspects*, Working Group II to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change, Field, C. B., et al. (eds.), https://www.ipcc.ch/site/assets/uploads/2018/02/WGIIAR5-Chap4_FINAL.pdf (accessed December 1, 2020); Natural Resources Canada, 2020, *Distribution of tree species*, https://www.nrcan.gc.ca/climate-change/impacts-adaptations/climate-change-impacts-forests/forest-change-indicators/distribution-tree-species/17778 (accessed July 27, 2020).

Changing snowfall patterns and glacier melt, as well as shorter snow and ice cover seasons, affect the timing and peak of streamflow, leading to reduced summer streamflows in some areas.[40] Temperature and precipitation changes can impact water availability for agriculture and household water use, and affect the frequency or severity of events such as drought, flood and fires. Increases in extreme events could have more localized impacts such as landslides, stormwater runoff in urban areas and sanitary sewer overflows into water bodies and the environment.[41] Changes in climate are also driving changes in Canada's oceans, with observed changes in physical and chemical characteristics such as sea surface temperature, salinity, density stratification, acidification, dissolved oxygen and sea level.[42] Over time, these types of changing conditions may be reflected in changes in the extent and location of different ecosystems.

From 1948 to 2016, all areas of Canada's landmass experienced increases in average annual and seasonal air temperatures (Map 2.4 and Table 2.8), but with important regional variations. Increasing temperatures are observed across ecosystems including forest, freshwater and peatland, as well as agricultural and urban ecosystems (Table 2.9).

The largest temperature increases in Canada occurred across a vast region of the northwest stretching from Yellowknife to the Yukon–Alaska border, an area that straddles the boreal and tundra zones and includes mountainous alpine terrain (Map 2.5). Within this region, almost 17,500 km^2—an area three times the size of Prince Edward Island—has been subjected to winter temperature increases greater than 7°C, while over 300,00 km^2 has experienced increases between 6°C and 7°C. In total, an area covering over 1.6 million km^2 has experienced winter temperature increases of greater than 5°C, which will affect approximately 732,000 km^2 of forest and 235,000 km^2 of peatland.[43]

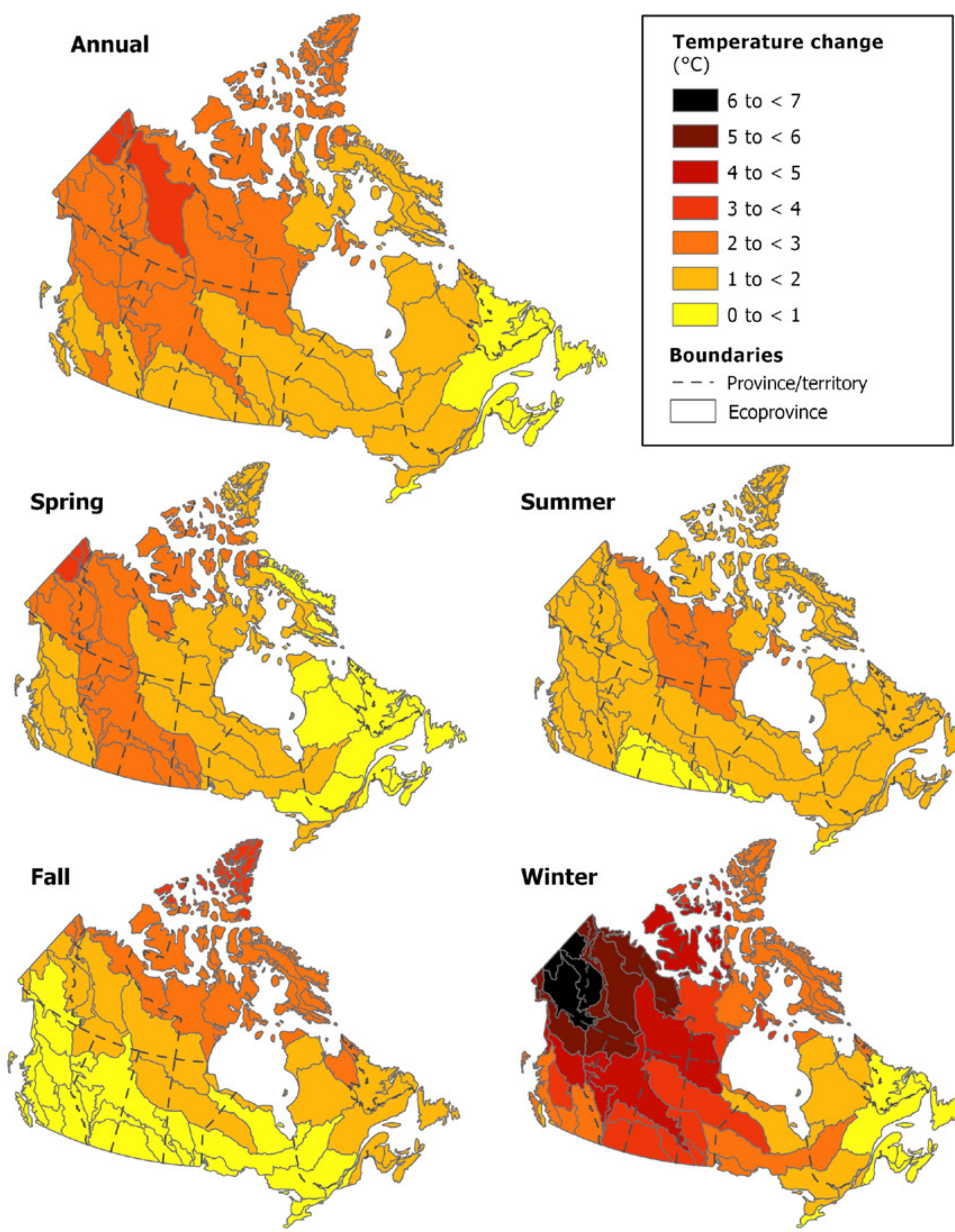
40 Bonsal, B.R., et al., 2019, "Changes in freshwater availability across Canada," *Canada's Changing Climate Report*, Bush, E. and D.S. Lemmen (eds.), Government of Canada, Ottawa, Ontario, pp. 261-342, https://changingclimate.ca/CCCR2019/chapter/6-0/ (accessed June 26, 2020).

41 Cloutier, C. et al., 2016, "Chapter 3: Potential impacts of climate change on landslides occurrence in Canada," *Slope Safety Preparedness for Impact of Climate Change*, Ho, K., S. Lacasse and L. Picarelli (eds.), 590 p., https://doi.org/10.1201/9781315387789 (accessed May 20, 2021); Fraser, R.H., et al., 2018, "Climate sensitivity of high Arctic permafrost terrain demonstrated by widespread ice-wedge thermokarst on Banks Island," *Remote Sensing*, Vol. 954, https://doi.org/10.3390/rs10060954 (accessed May 20, 2021); United States Environmental Protection Agency, 2016, *Climate Adaptation and Stormwater Runoff*, https://www.epa.gov/arc-x/climate-adaptation-and-stormwater-runoff (accessed May 20, 2021); Metro Vancouver, 2018, *Study of the Impacts of Climate Change on Precipitation and Stormwater Management*, http://www.metrovancouver.org/services/liquid-waste/LiquidWastePublications/Climatechangeimpactsprecipitationstormwater2050-2100%E2%80%93Technical-brief-2018.pdf (accessed May 20, 2021).

42 Greenan, B.J.W., et al., 2019, "Changes in oceans surrounding Canada," *Canada's Changing Climate Report*, Bush, E. and D.S. Lemmen (eds.), Government of Canada, Ottawa, Ontario, https://changingclimate.ca/CCCR2019/chapter/7-0/ (accessed June 26, 2020).

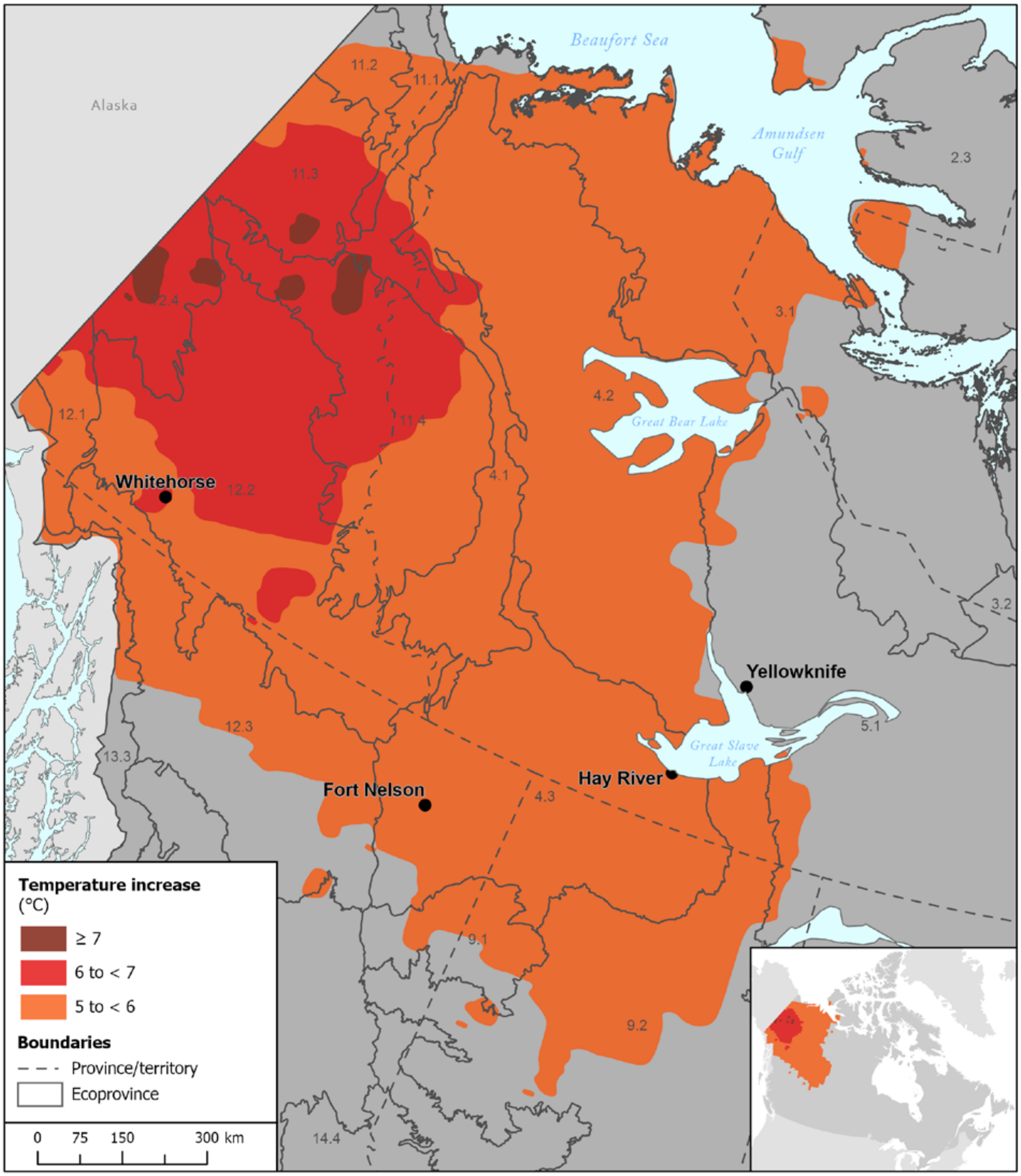
43 Statistics Canada, Environment and Energy Statistics Division, 2021, special tabulation.

Map 2.4
Temperature change, annual and all seasons, by ecoprovince, 1948 to 2016



Notes: Temperature change (1948 to 2016) refers to the linear trend of temperature departures from the 1961 to 1990 climate normal. Caution should be exercised when analyzing change results in the North because of lower climate station densities. Significance levels are not available. Winter data are from December to February with other seasons following sequentially.
Sources: Environment and Climate Change Canada (ECCC), *Canadian Gridded Temperature and Precipitation Anomalies (CANGRD)*; ECCC, *Climate Trends and Variations Bulletin.*

Map 2.5
Winter temperature increase greater than 5°C, northwestern Canada, 1948 to 2016



Notes: Temperature change (1948 to 2016) refers to the linear trend of temperature departures from the 1961 to 1990 climate normal. Caution should be exercised when analyzing change results in the North because of lower climate station densities. Significance levels are not available. Winter data are from December to February.
Sources: Environment and Climate Change Canada (ECCC), *Canadian Gridded Temperature and Precipitation Anomalies (CANGRD)*; ECCC, *Climate Trends and Variations Bulletin.*

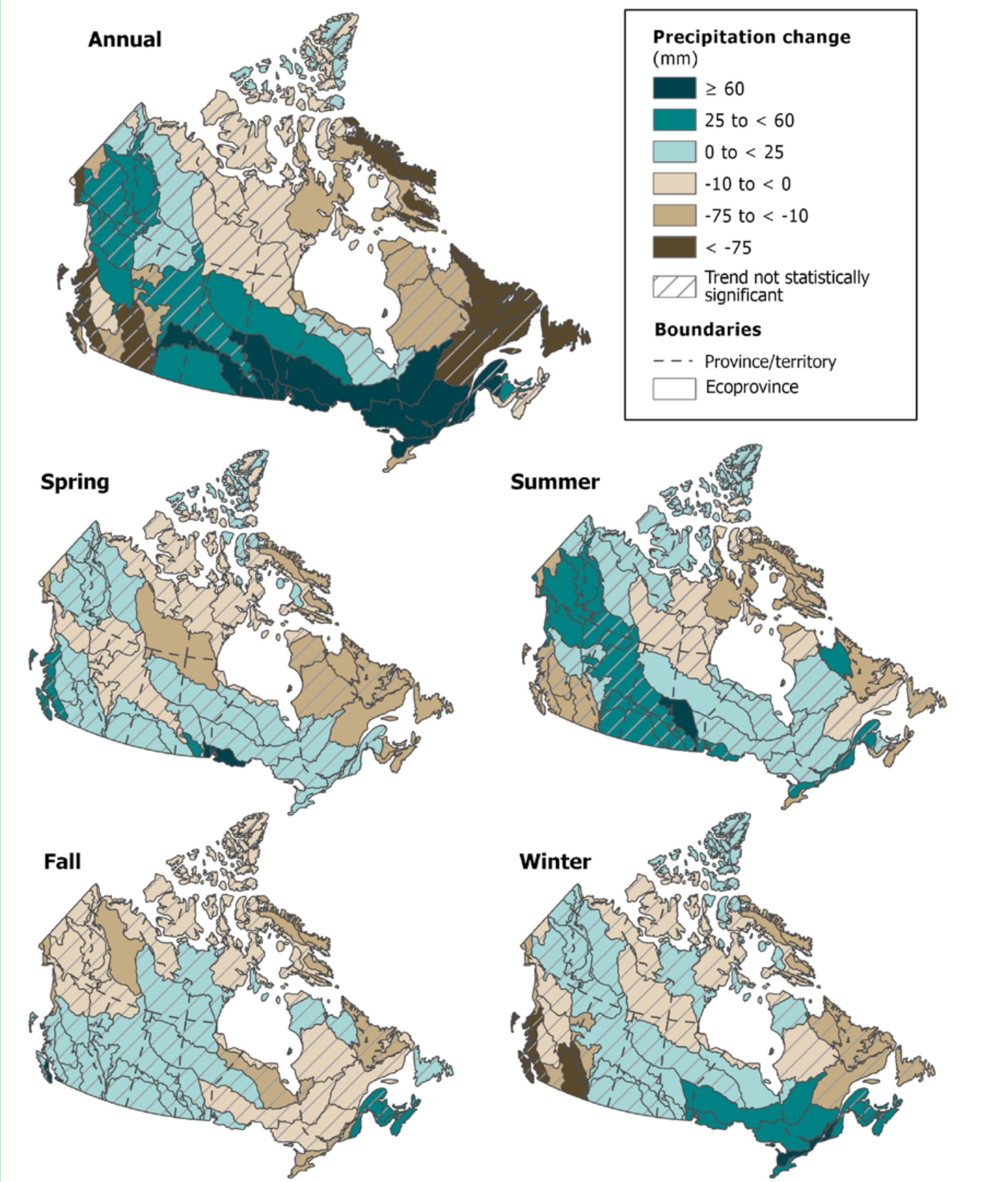
In the Prairies, agricultural areas accounting for over 400,000 km^2 have experienced a 1.9°C increase in average annual temperature and a 3.8°C increase in winter temperature from 1948 to 2016, presenting new challenges and opportunities for food production.[44] Freshwater ecosystems are also influenced—in half of Canada's ecoprovinces, freshwater ecosystems have been exposed to annual temperature increases of 2°C or greater, with even larger winter temperature increases. These changes impact flow regimes and habitat for fish and other aquatic life.

Precipitation patterns—including rainfall and snowfall—are highly variable across Canada, with differences in the type, amount and timing of precipitation received in different areas. From 1979 to 2016, trends show average annual precipitation increased in eleven ecoprovinces, particularly those located in the Boreal Shield and the Prairies, and decreased in six (Map 2.6 and Table 2.8).[45] Much of Ontario and southern Quebec showed an increase in winter precipitation of between 18 mm and 62 mm between 1979 and 2016, including the Mid-Boreal Shield, Southern Boreal Shield, Great Lakes–St. Lawrence Lowlands, Huron–Erie Plains and Hudson–James Lowlands ecoprovinces. Over the same time period, much of the southern Yukon and northern British Columbia, including the Mackenzie–Selwyn Mountains, Northern Boreal Cordillera and Southern Boreal Cordillera ecoprovinces, showed an increase in summer precipitation of between 26 mm and 36 mm.

44 This area represents the total area of farms in the Prairies ecozone, from the *Interpolated Census of Agriculture*, 2011. Agriculture and Agri-Food Canada, 2016, Interpolated Census of Agriculture, https://open.canada.ca/data/en/dataset/1dee8513-5c73-43b6-9446-25f7b985cd00 (accessed December 3, 2020).

45 Statistical significance is assessed at the 90% and the 95% confidence levels.

Map 2.6
Precipitation change, annual and all seasons, by ecoprovince, 1979 to 2016



Notes: Statistically significant linear trends are presented at the 90% confidence interval or above. Caution should be used when analyzing trends in the North because of lower climate station densities. Winter data are from December to February with other seasons following sequentially.
Sources: Statistics Canada, Environment and Energy Statistics Division, 2021, special tabulation based on Wang, S., Y. Yang, Y. Luo and A. Rivera, 2013, "Spatial and seasonal variations in evapotranspiration over Canada's landmass," *Hydrology and Earth System Sciences*, Vol. 17, no. 9, pp. 3561-3575; Wang, S., et al., 2014, "A national-scale assessment of long-term water budget closures for Canada's watersheds," *Journal of Geophysical Research: Atmospheres*, Vol. 119, pp. 8712–8725.

Evapotranspiration (ET) is the combination of evaporation from land and water surfaces and transpiration from plants and is one of the key processes of the water cycle. ET is governed by land cover, water supply, net solar radiation, air temperature, humidity and wind speed. Along with information on precipitation, ET provides an indicator of water availability.[46] Potential evapotranspiration (PET) represents the evapotranspiration that would occur without limitations on water supply, that is, if more water were available. When interpreted alone or with other measures of the water cycle like precipitation or ET, it can contribute to an understanding of aridity and drought, water stress and deficits, and stress on vegetation.[47] Persistent changes can signal changes in the water cycle, energy budget and ecosystems.[48] These variables are estimated by applying models to climate data or by using a combination of models and satellite data. ET and PET are typically higher during the summer and lower during the winter.

Most ecoprovinces have experienced an upward trend in ET and PET between 1979 and 2016, but rates vary from one ecoprovince to another (Table 2.10). Large increases in ET are observed between 1979 and 2016 in the Appalachian–Acadian Highlands and in the south-central British Columbian ecoprovinces of the Northern Montane Cordillera and Central Montane Cordillera, but also in the Eastern Prairies.[49] The largest increases in PET for the same time period occurred near the East Coast and in southern British Columbia, in particular the Eastern Boreal Shield, Appalachian–Acadian Highlands, Columbia Montane Cordillera, Southern Montane Cordillera and Georgia Depression ecoprovinces.

46 Wang, S., et al., 2013, “Spatial and seasonal variations in evapotranspiration over Canada’s landmass,” *Hydrology and Earth System Sciences*, Vol. 17, pp. 2561-3575, https://doi.org/10.5194/hess-17-3561-2013 (accessed December 1, 2020).

47 Fisher, J. B., et al., 2017, ”The future of evapotranspiration: Global requirements for ecosystem functioning, carbon and climate feedbacks, agricultural management, and water resources,” *Water Resources Research*, Vol. 53, pp. 2618–2626, https://doi.org/10.1002/2016WR020175 (accessed May 12, 2021); Lemordant, L., et al., 2018, “Critical impact of vegetation physiology on the continental hydrologic cycle in response to increasing CO_2,” *Proceedings of the National Academy of Sciences*, Vol. 115, pp. 4093-4098; https://doi.org/10.1073/pnas.1720712115 (accessed May 12, 2021).

48 Hember, R.A., N.C. Coops and D. L Spittlehouse, 2017, “Spatial and temporal variability of potential evaporation across North American Forests,” *Hydrology*, https://cfs.nrcan.gc.ca/publications?id=38902 (accessed May 12, 2021).

49 Statistical significance is assessed at the 90% and the 95% confidence levels.

Table 2.1
Terrestrial and freshwater ecosystem extent, by type and ecoprovince (Part 1)

Ecoprovince	Code	Total area	Total area		Peatland
			Land	Freshwater	
		km²			
Canada	...	**9,978,923**	..	..	**1,135,608**
Total, area outside Ecological Land Classification	...	**99,176**	..	..	..
Total, Ecological Land Classification	...	**9,879,747**	**8,644,654**	**1,235,093**	**1,135,608**
Northern Arctic Cordillera	1.1	113,667	112,625	1,041	0
Southern Arctic Cordillera	1.2	129,758	123,306	6,452	146
Sverdrup Islands	2.1	65,520	62,650	2,870	0
Ellesmere Basin	2.2	129,117	124,957	4,159	0
Victoria Lowlands	2.3	429,668	370,563	59,105	916
Parry Channel Plateau	2.4	134,422	129,945	4,477	2
Boothia–Foxe Shield	2.5	546,492	472,764	73,727	2,285
Baffin Uplands	2.6	131,350	119,793	11,558	0
Foxe–Boothia Lowlands	2.7	80,387	67,263	13,125	1,245
Amundsen Lowlands	3.1	308,466	254,569	53,897	12,180
Keewatin Lowlands	3.2	383,489	304,554	78,935	2,661
Ungava–Belcher	3.3	158,527	122,042	36,485	813
Mackenzie Foothills	4.1	86,572	83,262	3,311	5,872
Great Bear Lowlands	4.2	340,206	265,135	75,071	73,989
Hay–Slave Lowlands	4.3	235,507	214,896	20,612	88,301
Western Taiga Shield	5.1	635,379	470,061	165,319	63,869
Eastern Taiga	5.2	394,475	311,732	82,742	26,967
Labrador Uplands	5.3	250,152	202,643	47,508	37,027
Whale River Lowland	5.4	114,641	95,599	19,042	9,350
Western Boreal Shield	6.1	524,821	426,918	97,904	140,863
Mid-Boreal Shield	6.2	500,600	433,169	67,431	106,239
Eastern Boreal Shield	6.3	354,666	310,752	43,914	24,827
Newfoundland	6.4	111,239	98,981	12,258	22,674
Lake of the Woods	6.5	71,646	59,817	11,829	11,971
Southern Boreal Shield	6.6	319,993	282,250	37,743	13,360
Appalachian–Acadian Highlands	7.1	94,951	92,222	2,729	2,115
Northumberland Lowlands	7.2	35,629	34,390	1,239	2,704
Fundy Uplands	7.3	71,086	67,191	3,894	6,559
Great Lakes–St. Lawrence Lowlands	8.1	88,174	83,385	4,789	3,633
Huron–Erie Plains	8.2	24,724	24,139	585	308
Boreal Foothills	9.1	124,690	122,257	2,433	15,631
Central Boreal Plains	9.2	483,992	450,567	33,425	96,469
Eastern Boreal Plains	9.3	130,770	89,071	41,700	27,680
Eastern Prairies	10.1	32,872	28,955	3,916	128
Parkland Prairies	10.2	177,448	167,605	9,844	333
Central Grassland	10.3	254,376	242,144	12,232	0
Northern Yukon Mountains	11.1	26,893	26,442	450	71
Old Crow–Eagle Plains	11.2	20,760	18,925	1,835	1,713
Ogilvie Mountains	11.3	60,089	59,018	1,070	1,770
Mackenzie–Selwyn Mountains	11.4	159,487	156,172	3,314	383
Wrangel Mountains	12.1	24,471	23,830	641	0
Northern Boreal Cordillera	12.2	239,038	229,570	9,469	5,310
Southern Boreal Cordillera	12.3	168,162	159,889	8,273	1,105
Western Boreal Cordillera	12.4	38,797	37,597	1,200	160
Georgia Depression	13.1	19,470	18,429	1,040	465

Table 2.1
Terrestrial and freshwater ecosystem extent, by type and ecoprovince (Part 1)

			Total area		
		Total area	Land	Freshwater	Peatland
Ecoprovince	Code	km²			
Southern Coastal Mountains	13.2	158,751	151,029	7,722	6,142
Northern Coastal Mountains	13.3	31,881	30,944	937	488
Northern Montane Cordillera	14.1	141,283	133,129	8,154	5,225
Central Montane Cordillera	14.2	106,009	100,245	5,764	5,658
Southern Montane Cordillera	14.3	59,034	56,469	2,566	348
Columbia Montane Cordillera	14.4	180,331	172,464	7,867	698
Hudson Bay Coastal Plains	15.1	64,090	56,965	7,124	44,221
Hudson–James Lowlands	15.2	311,730	291,363	20,368	260,735

.. not available for a specific reference period
… not applicable

Notes: This table presents land cover and land use data at the ecoprovince level of the Ecological Land Classification (ELC) as a proxy for an ecosystem type classification. Ecosystem extent estimates are compiled using numerous sources based on satellite imagery, ground and photo plots and soil and respondent surveys. Source data are available at different resolutions, with varying levels of uncertainty. Data have been derived by rescaling and/or averaging across years to provide the best estimate for the time period. While these estimates provide information on the extent of Canadian ecosystems at a point in time, unless otherwise noted, they are not suitable for assessing change. Areas outside the ELC include the Canadian portion of the Great Lakes and other residual areas along shorelines. Other natural and semi-natural area is unclassified area calculated based on subtraction of all other ecosystem type classes from the total area of Canada. For more information about definitions, sources and methods, see Appendix A.

Sources: Agriculture and Agri-Food Canada (AAFC), 2013, *Terrestrial Ecoprovinces of Canada*, https://open.canada.ca/data/en/dataset/98fa7335-fbfe-4289-9a0e-d6bf3874b424 (accessed December 2, 2020); Natural Resources Canada (NRCan), 2014, *Atlas of Canada National Scale Data 1:1,000,000 – Waterbodies,* https://open.canada.ca/data/en/dataset/e9931fc7-034c-52ad-91c5-6c64d4ba0065 (accessed December 9, 2020); NRCan, Canada Centre for Mapping and Earth Observation (CCMEO), 2018, *Lakes, Rivers and Glaciers in Canada – CanVec Series – Hydrographic Features, 50K*, https://open.canada.ca/data/en/dataset/9d96e8c9-22fe-4ad2-b5e8-94a6991b744b (accessed December 2, 2020); Tarnocai, C., I.M. Kettles and B. Lacelle, 2011, *Peatlands of Canada, Geological Survey of Canada*, https://geoscan.nrcan.gc.ca/starweb/geoscan/servlet.starweb?path=geoscan/fulle.web&search1=R=288786 (accessed March 16, 2020); National Forest Inventory, 2021, *First remeasurement standard reports, (2007-2017): Table 4.1. Area (1000 ha) of forest and non-forest land by terrestrial ecozone in Canada*, https://nfi.nfis.org/resources/general/summaries/t1/en/NFI/html/NFI_T4_FOR_AREA_en.html (accessed August 13, 2021); *Beaudoin, A., et al., 2017, Species composition, forest properties and land cover types across Canada's forests at 250 m resolution for 2001 and 2011*, NRCan, Canadian Forest Service (CFS), Laurentian Forestry Centre, https://doi.org/10.23687/ec9e2659-1c29-4ddb-87a2-6aced147a990 (accessed March 31, 2019); Brandt, J.P., 2009, "The extent of the North American boreal zone," *Environmental Reviews*, Vol. 27, no. 1, pp. 101-161, http://cfs.nrcan.gc.ca/publications/?id=29569 (accessed June 15, 2017); AAFC, 2020, *Annual Crop Inventory, 2014-2016*, https://open.canada.ca/data/en/dataset/ba2645d5-4458-414d-b196-6303ac06c1c9 (accessed December 3, 2020); NRCan, CCMEO, 2020, *2010 and 2015 Land Cover of North America at 30 metres*, Ed. 2.0, Commission for Environmental Cooperation (CEC), North American Land Change Monitoring System, http://www.cec.org/north-american-land-change-monitoring-system/ (accessed December 9, 2020); AAFC, 2016, *Interpolated Census of Agriculture*, https://open.canada.ca/data/en/dataset/1dee8513-5c73-43b6-9446-25f7b985cd00 (accessed December 3, 2020); Baldwin, K., et al., 2018, *Vegetation Zones of Canada: a Biogeoclimatic Perspective* [Map], Scale 1:5,000,000, NRCan, CFS, https://open.canada.ca/data/en/dataset/22b0166b-9db3-46b7-9baf-6584a3acc7b1 (accessed October 26, 2020); AAFC, 2015, *Land Use, 1990, 2000 & 2010*, https://open.canada.ca/data/en/dataset/18e3ef1a-497c-40c6-8326-aac1a34a0dec (accessed June 1, 2020); Environment and Climate Change Canada, 2020, *CRF Tables*, Canada's National Inventory Submissions 2018 to the UNFCCC, https://unfccc.int/process-and-meetings/transparency-and-reporting/reporting-and-review-under-the-convention/greenhouse-gas-inventories-annex-i-parties/submissions/national-inventory-submissions-2018#fn1 (accessed April 30, 2020).

Table 2.1
Terrestrial and freshwater ecosystem extent, by type and ecoprovince (Part 2)

		Ecosystem types - Natural and semi-natural area						
		Forest, 2017			Grassland and natural pasture, 2015	Arctic tundra, 2015	Permanent snow and ice, 2015	Other natural and semi-natural area
		Total	Boreal	Non-boreal				
Ecoprovince	Code	km²						
Canada	…	**3,635,411**	**2,791,877**	**843,534**	**403,745**	**2,468,836**	**210,305**	**2,761,975**
Total, area outside Ecological Land Classification	…	..	..	..	..	..	..	**99,176**
Total, Ecological Land Classification	…	**3,635,411**	**2,791,877**	**843,534**	**403,745**	**2,468,836**	**210,305**	**2,662,799**
Northern Arctic Cordillera	1.1	0	0	0	0	19,246	94,420	0
Southern Arctic Cordillera	1.2	0	0	0	0	92,517	37,234	0
Sverdrup Islands	2.1	0	0	0	0	65,068	451	0
Ellesmere Basin	2.2	0	0	0	0	119,727	9,387	0
Victoria Lowlands	2.3	0	0	0	0	428,375	1,260	0
Parry Channel Plateau	2.4	0	0	0	0	127,563	6,851	0
Boothia–Foxe Shield	2.5	0	0	0	0	545,428	1,041	0
Baffin Uplands	2.6	0	0	0	0	123,828	7,521	0
Foxe–Boothia Lowlands	2.7	0	0	0	0	80,245	129	0
Amundsen Lowlands	3.1	8,038	8,038	0	37	230,209	2	70,114
Keewatin Lowlands	3.2	6,403	6,403	0	60	367,826	1	9,174
Ungava–Belcher	3.3	1,619	1,619	0	17	156,886	0	0
Mackenzie Foothills	4.1	42,063	42,063	0	8,761	8	23	35,689
Great Bear Lowlands	4.2	132,081	132,081	0	12,654	582	83	194,651
Hay–Slave Lowlands	4.3	178,366	178,366	0	2,402	0	0	54,247
Western Taiga Shield	5.1	193,371	193,371	0	47,673	51,219	0	343,076
Eastern Taiga	5.2	128,427	128,427	0	7,292	7,275	0	251,310
Labrador Uplands	5.3	125,150	125,150	0	4,032	15,737	140	104,987
Whale River Lowland	5.4	38,761	38,761	0	495	17,966	17	57,381
Western Boreal Shield	6.1	313,868	313,868	0	36,136	0	0	174,316
Mid-Boreal Shield	6.2	373,393	370,317	3,076	9,415	0	0	115,236
Eastern Boreal Shield	6.3	250,497	243,829	6,668	7,614	0	0	93,958
Newfoundland	6.4	67,410	67,410	0	3,121	0	0	39,351
Lake of the Woods	6.5	51,186	13,321	37,865	619	0	0	17,346
Southern Boreal Shield	6.6	268,746	80,952	187,793	2,889	0	0	40,229
Appalachian–Acadian Highlands	7.1	83,129	14,327	68,802	4,488	0	0	345
Northumberland Lowlands	7.2	27,222	0	27,222	2,190	0	0	2,197
Fundy Uplands	7.3	56,100	0	56,100	2,395	0	0	7,690
Great Lakes–St. Lawrence Lowlands	8.1	31,396	0	31,396	13,427	0	0	0
Huron–Erie Plains	8.2	2,634	0	2,634	2,539	0	0	493
Boreal Foothills	9.1	97,869	96,242	1,626	2,334	0	0	20,583
Central Boreal Plains	9.2	283,486	281,001	2,486	17,030	0	0	105,657
Eastern Boreal Plains	9.3	59,165	56,145	3,020	6,199	0	0	57,966
Eastern Prairies	10.1	2,870	151	2,720	5,625	0	0	5,370
Parkland Prairies	10.2	6,779	368	6,411	23,014	0	0	25,198
Central Grassland	10.3	5,590	0	5,590	78,771	0	0	9,813
Northern Yukon Mountains	11.1	1,661	1,661	0	1,017	16,162	1	8,049
Old Crow–Eagle Plains	11.2	5,327	5,327	0	502	2,971	0	11,954
Ogilvie Mountains	11.3	20,283	20,283	0	14,971	0	6	24,771
Mackenzie–Selwyn Mountains	11.4	36,730	36,730	0	25,355	0	501	96,869
Wrangel Mountains	12.1	1,639	1,388	251	928	0	10,720	11,183
Northern Boreal Cordillera	12.2	111,315	111,173	143	22,168	0	102	105,145
Southern Boreal Cordillera	12.3	59,178	58,485	692	11,040	0	2,534	95,331
Western Boreal Cordillera	12.4	13,768	13,768	0	6,161	0	2	18,810
Georgia Depression	13.1	14,398	0	14,398	106	0	46	1,775

Table 2.1
Terrestrial and freshwater ecosystem extent, by type and ecoprovince (Part 2)

		Ecosystem types - Natural and semi-natural area						
		Forest, 2017			Grassland and natural pasture, 2015	Arctic tundra, 2015	Permanent snow and ice, 2015	Other natural and semi-natural area
		Total	Boreal	Non-boreal				
Ecoprovince	Code	km²						
Southern Coastal Mountains	13.2	95,757	0	95,757	1,379	0	13,543	47,589
Northern Coastal Mountains	13.3	6,205	369	5,837	129	0	14,363	11,173
Northern Montane Cordillera	14.1	99,065	21,055	78,010	1,646	0	1,744	37,843
Central Montane Cordillera	14.2	71,038	0	71,038	3,123	0	1,129	28,967
Southern Montane Cordillera	14.3	39,457	0	39,457	1,759	0	456	15,378
Columbia Montane Cordillera	14.4	108,050	13,507	94,543	3,835	0	6,598	60,214
Hudson Bay Coastal Plains	15.1	12,758	12,758	0	2,632	0	0	48,681
Hudson–James Lowlands	15.2	103,162	103,162	0	5,765	0	0	202,695

.. not available for a specific reference period
… not applicable

Notes: This table presents land cover and land use data at the ecoprovince level of the Ecological Land Classification (ELC) as a proxy for an ecosystem type classification. Ecosystem extent estimates are compiled using numerous sources based on satellite imagery, ground and photo plots and soil and respondent surveys. Source data are available at different resolutions, with varying levels of uncertainty. Data have been derived by rescaling and/or averaging across years to provide the best estimate for the time period. While these estimates provide information on the extent of Canadian ecosystems at a point in time, unless otherwise noted, they are not suitable for assessing change. Areas outside the ELC include the Canadian portion of the Great Lakes and other residual areas along shorelines. Other natural and semi-natural area is unclassified area calculated based on subtraction of all other ecosystem type classes from the total area of Canada. For more information about definitions, sources and methods, see Appendix A.

Sources: Agriculture and Agri-Food Canada (AAFC), 2013, *Terrestrial Ecoprovinces of Canada*, https://open.canada.ca/data/en/dataset/98fa7335-fbfe-4289-9a0e-d6bf3874b424 (accessed December 2, 2020); Natural Resources Canada (NRCan), 2014, *Atlas of Canada National Scale Data 1:1,000,000 – Waterbodies,* https://open.canada.ca/data/en/dataset/e9931fc7-034c-52ad-91c5-6c64d4ba0065 (accessed December 9, 2020); NRCan, Canada Centre for Mapping and Earth Observation (CCMEO), 2018, *Lakes, Rivers and Glaciers in Canada – CanVec Series – Hydrographic Features, 50K*, https://open.canada.ca/data/en/dataset/9d96e8c9-22fe-4ad2-b5e8-94a6991b744b (accessed December 2, 2020); Tarnocai, C., I.M. Kettles and B. Lacelle, 2011, *Peatlands of Canada, Geological Survey of Canada*, https://geoscan.nrcan.gc.ca/starweb/geoscan/servlet.starweb?path=geoscan/fulle.web&search1=R=288786 (accessed March 16, 2020); National Forest Inventory, 2021, *First remeasurement standard reports, (2007-2017): Table 4.1. Area (1000 ha) of forest and non-forest land by terrestrial ecozone in Canada*, https://nfi.nfis.org/resources/general/summaries/t1/en/NFI/html/NFI_T4_FOR_AREA_en.html (accessed August 13, 2021); *Beaudoin, A., et al., 2017, Species composition, forest properties and land cover types across Canada's forests at 250 m resolution for 2001 and 2011*, NRCan, Canadian Forest Service (CFS), Laurentian Forestry Centre, https://doi.org/10.23687/ec9e2659-1c29-4ddb-87a2-6aced147a990 (accessed March 31, 2019); Brandt, J.P., 2009, "The extent of the North American boreal zone," *Environmental Reviews*, Vol. 27, no. 1, pp. 101-161, http://cfs.nrcan.gc.ca/publications/?id=29569 (accessed June 15, 2017); AAFC, 2020, *Annual Crop Inventory, 2014-2016*, https://open.canada.ca/data/en/dataset/ba2645d5-4458-414d-b196-6303ac06c1c9 (accessed December 3, 2020); NRCan, CCMEO, 2020, *2010 and 2015 Land Cover of North America at 30 metres*, Ed. 2.0, Commission for Environmental Cooperation (CEC), North American Land Change Monitoring System, http://www.cec.org/north-american-land-change-monitoring-system/ (accessed December 9, 2020); AAFC, 2016, *Interpolated Census of Agriculture*, https://open.canada.ca/data/en/dataset/1dee8513-5c73-43b6-9446-25f7b985cd00 (accessed December 3, 2020); Baldwin, K., et al., 2018, *Vegetation Zones of Canada: a Biogeoclimatic Perspective* [Map], Scale 1:5,000,000, NRCan, CFS, https://open.canada.ca/data/en/dataset/22b0166b-9db3-46b7-9baf-6584a3acc7b1 (accessed October 26, 2020); AAFC, 2015, *Land Use, 1990, 2000 & 2010*, https://open.canada.ca/data/en/dataset/18e3ef1a-497c-40c6-8326-aac1a34a0dec (accessed June 1, 2020); Environment and Climate Change Canada, 2020, *CRF Tables*, Canada's National Inventory Submissions 2018 to the UNFCCC, https://unfccc.int/process-and-meetings/transparency-and-reporting/reporting-and-review-under-the-convention/greenhouse-gas-inventories-annex-i-parties/submissions/national-inventory-submissions-2018#fn1 (accessed April 30, 2020).

Table 2.1
Ecosystem extent, by type and ecoprovince (Part 3)

		Ecosystem types - Intensive use area					
		Arable			Built-up and artificial surfaces		
		2001	2011	2016	2000	2010	2015
Ecoprovince	Code	km²					
Canada	...	**445,782**	**425,299**	**437,945**	**56,398**	**60,706**	**62,641**
Total, area outside Ecological Land Classification	...	..	..	..	..	..	..
Total, Ecological Land Classification	...	**445,782**	**425,299**	**437,945**	**56,398**	**60,706**	**62,641**
Northern Arctic Cordillera	1.1	0	0	0	0	0	..
Southern Arctic Cordillera	1.2	0	0	0	7	7	..
Sverdrup Islands	2.1	0	0	0	2	2	..
Ellesmere Basin	2.2	0	0	0	2	2	..
Victoria Lowlands	2.3	0	0	0	34	34	..
Parry Channel Plateau	2.4	0	0	0	8	8	..
Boothia–Foxe Shield	2.5	0	0	0	23	23	..
Baffin Uplands	2.6	0	0	0	2	2	..
Foxe–Boothia Lowlands	2.7	0	0	0	13	13	..
Amundsen Lowlands	3.1	0	0	0	67	67	..
Keewatin Lowlands	3.2	0	0	0	25	25	..
Ungava–Belcher	3.3	0	0	0	3	5	..
Mackenzie Foothills	4.1	0	0	0	30	30	..
Great Bear Lowlands	4.2	0	0	0	155	155	..
Hay–Slave Lowlands	4.3	24	23	46	426	446	..
Western Taiga Shield	5.1	0	0	0	39	41	..
Eastern Taiga	5.2	0	0	0	158	171	..
Labrador Uplands	5.3	0	0	0	88	105	..
Whale River Lowland	5.4	0	0	0	15	20	..
Western Boreal Shield	6.1	0	9	20	448	482	..
Mid-Boreal Shield	6.2	470	727	668	1,765	1,888	..
Eastern Boreal Shield	6.3	1,024	1,292	1,297	1,167	1,300	..
Newfoundland	6.4	60	64	96	1,222	1,261	..
Lake of the Woods	6.5	1,425	1,454	1,462	997	1,033	..
Southern Boreal Shield	6.6	3,040	3,331	3,236	4,096	4,893	..
Appalachian–Acadian Highlands	7.1	4,731	4,661	4,573	2,155	2,417	..
Northumberland Lowlands	7.2	2,284	2,322	2,403	1,501	1,619	..
Fundy Uplands	7.3	1,826	1,935	1,898	2,798	3,004	..
Great Lakes–St. Lawrence Lowlands	8.1	34,455	34,225	34,120	8,520	9,231	..
Huron–Erie Plains	8.2	14,244	13,806	14,287	4,562	4,771	..
Boreal Foothills	9.1	3,125	3,328	3,014	868	890	..
Central Boreal Plains	9.2	76,759	71,507	72,254	4,827	5,566	..
Eastern Boreal Plains	9.3	7,102	6,582	6,584	838	857	..
Eastern Prairies	10.1	18,417	17,073	17,655	1,308	1,352	..
Parkland Prairies	10.2	119,471	109,291	116,106	6,180	6,351	..
Central Grassland	10.3	153,373	149,081	153,674	6,372	6,528	..
Northern Yukon Mountains	11.1	0	0	0	4	4	..
Old Crow–Eagle Plains	11.2	0	0	0	8	8	..
Ogilvie Mountains	11.3	0	0	0	58	58	..
Mackenzie–Selwyn Mountains	11.4	0	0	0	31	31	..
Wrangel Mountains	12.1	0	0	0	2	2	..
Northern Boreal Cordillera	12.2	0	0	6	302	303	..
Southern Boreal Cordillera	12.3	0	0	0	73	79	..
Western Boreal Cordillera	12.4	0	0	0	54	54	..
Georgia Depression	13.1	854	870	967	2,039	2,178	..

Table 2.1
Ecosystem extent, by type and ecoprovince (Part 3)

		Ecosystem types - Intensive use area					
		Arable			Built-up and artificial surfaces		
		2001	2011	2016	2000	2010	2015
Ecoprovince	Code	km²					
Southern Coastal Mountains	13.2	34	49	115	346	367	..
Northern Coastal Mountains	13.3	0	0	0	11	11	..
Northern Montane Cordillera	14.1	534	667	491	454	493	..
Central Montane Cordillera	14.2	896	1,173	1,315	413	437	..
Southern Montane Cordillera	14.3	876	1,053	988	903	997	..
Columbia Montane Cordillera	14.4	757	779	672	883	961	..
Hudson Bay Coastal Plains	15.1	0	0	0	10	19	..
Hudson–James Lowlands	15.2	0	0	0	86	108	..

.. not available for a specific reference period
… not applicable

Notes: This table presents land cover and land use data at the ecoprovince level of the Ecological Land Classification (ELC) as a proxy for an ecosystem type classification. Ecosystem extent estimates are compiled using numerous sources based on satellite imagery, ground and photo plots and soil and respondent surveys. Source data are available at different resolutions, with varying levels of uncertainty. Data have been derived by rescaling and/or averaging across years to provide the best estimate for the time period. While these estimates provide information on the extent of Canadian ecosystems at a point in time, unless otherwise noted, they are not suitable for assessing change. Areas outside the ELC include the Canadian portion of the Great Lakes and other residual areas along shorelines. Other natural and semi-natural area is unclassified area calculated based on subtraction of all other ecosystem type classes from the total area of Canada. For more information about definitions, sources and methods, see Appendix A.

Sources: Agriculture and Agri-Food Canada (AAFC), 2013, *Terrestrial Ecoprovinces of Canada*, https://open.canada.ca/data/en/dataset/98fa7335-fbfe-4289-9a0e-d6bf3874b424 (accessed December 2, 2020); Natural Resources Canada (NRCan), 2014, *Atlas of Canada National Scale Data 1:1,000,000 – Waterbodies,* https://open.canada.ca/data/en/dataset/e9931fc7-034c-52ad-91c5-6c64d4ba0065 (accessed December 9, 2020); NRCan, Canada Centre for Mapping and Earth Observation (CCMEO), 2018, *Lakes, Rivers and Glaciers in Canada – CanVec Series – Hydrographic Features, 50K*, https://open.canada.ca/data/en/dataset/9d96e8c9-22fe-4ad2-b5e8-94a6991b744b (accessed December 2, 2020); Tarnocai, C., I.M. Kettles and B. Lacelle, 2011, *Peatlands of Canada, Geological Survey of Canada*, https://geoscan.nrcan.gc.ca/starweb/geoscan/servlet.starweb?path=geoscan/fulle.web&search1=R=288786 (accessed March 16, 2020); National Forest Inventory, 2021, *First remeasurement standard reports, (2007-2017): Table 4.1. Area (1000 ha) of forest and non-forest land by terrestrial ecozone in Canada*, https://nfi.nfis.org/resources/general/summaries/t1/en/NFI/html/NFI_T4_FOR_AREA_en.html (accessed August 13, 2021); *Beaudoin, A., et al., 2017, Species composition, forest properties and land cover types across Canada's forests at 250 m resolution for 2001 and 2011*, NRCan, Canadian Forest Service (CFS), Laurentian Forestry Centre, https://doi.org/10.23687/ec9e2659-1c29-4ddb-87a2-6aced147a990 (accessed March 31, 2019); Brandt, J.P., 2009, "The extent of the North American boreal zone," *Environmental Reviews*, Vol. 27, no. 1, pp. 101-161, http://cfs.nrcan.gc.ca/publications/?id=29569 (accessed June 15, 2017); AAFC, 2020, *Annual Crop Inventory, 2014-2016*, https://open.canada.ca/data/en/dataset/ba2645d5-4458-414d-b196-6303ac06c1c9 (accessed December 3, 2020); NRCan, CCMEO, 2020, *2010 and 2015 Land Cover of North America at 30 metres*, Ed. 2.0, Commission for Environmental Cooperation (CEC), North American Land Change Monitoring System, http://www.cec.org/north-american-land-change-monitoring-system/ (accessed December 9, 2020); AAFC, 2016, *Interpolated Census of Agriculture*, https://open.canada.ca/data/en/dataset/1dee8513-5c73-43b6-9446-25f7b985cd00 (accessed December 3, 2020); Baldwin, K., et al., 2018, *Vegetation Zones of Canada: a Biogeoclimatic Perspective* [Map], Scale 1:5,000,000, NRCan, CFS, https://open.canada.ca/data/en/dataset/22b0166b-9db3-46b7-9baf-6584a3acc7b1 (accessed October 26, 2020); AAFC, 2015, *Land Use, 1990, 2000 & 2010*, https://open.canada.ca/data/en/dataset/18e3ef1a-497c-40c6-8326-aac1a34a0dec (accessed June 1, 2020); Environment and Climate Change Canada, 2020, *CRF Tables*, Canada's National Inventory Submissions 2018 to the UNFCCC, https://unfccc.int/process-and-meetings/transparency-and-reporting/reporting-and-review-under-the-convention/greenhouse-gas-inventories-annex-i-parties/submissions/national-inventory-submissions-2018#fn1 (accessed April 30, 2020).

Table 2.2
Population, by ecoprovince, 2016

Ecoprovince	Code	Land area	Total population	Population density	Population in population centres1	Population centre share of total population1
		km²	persons	persons/km²	persons	percentage
Canada	**…**	**8,644,654**	**35,151,728**	**4.1**	**28,576,355**	**81.3**
Northern Arctic Cordillera	1.1	112,625	0	0.0	0	…
Southern Arctic Cordillera	1.2	123,306	1,651	0.0	0	0.0
Sverdrup Islands	2.1	62,650	0	0.0	0	…
Ellesmere Basin	2.2	124,957	0	0.0	0	…
Victoria Lowlands	2.3	370,563	4,089	0.0	2,816	68.9
Parry Channel Plateau	2.4	129,945	2,614	0.0	0	0.0
Boothia–Foxe Shield	2.5	472,764	17,192	0.0	9,847	57.3
Baffin Uplands	2.6	119,793	0	0.0	0	…
Foxe–Boothia Lowlands	2.7	67,263	3,525	0.1	0	0.0
Amundsen Lowlands	3.1	254,569	3,785	0.0	2,119	56.0
Keewatin Lowlands	3.2	304,554	7,561	0.0	4,955	65.5
Ungava–Belcher	3.3	122,042	6,347	0.1	2,350	37.0
Mackenzie Foothills	4.1	83,262	700	0.0	0	0.0
Great Bear Lowlands	4.2	265,135	6,256	0.0	2,078	33.2
Hay–Slave Lowlands	4.3	214,896	14,941	0.1	6,094	40.8
Western Taiga Shield	5.1	470,061	27,466	0.1	18,884	68.8
Eastern Taiga	5.2	311,732	9,075	0.0	2,967	32.7
Labrador Uplands	5.3	202,643	4,715	0.0	0	0.0
Whale River Lowland	5.4	95,599	5,467	0.1	1,353	24.7
Western Boreal Shield	6.1	426,918	80,933	0.2	28,589	35.3
Mid-Boreal Shield	6.2	433,169	271,519	0.6	157,219	57.9
Eastern Boreal Shield	6.3	310,752	386,762	1.2	255,447	66.0
Newfoundland	6.4	98,981	492,519	5.0	286,698	58.2
Lake of the Woods	6.5	59,817	203,121	3.4	122,052	60.1
Southern Boreal Shield	6.6	282,250	1,581,203	5.6	913,173	57.8
Appalachian–Acadian Highlands	7.1	92,222	860,248	9.3	418,670	48.7
Northumberland Lowlands	7.2	34,390	639,389	18.6	323,423	50.6
Fundy Uplands	7.3	67,191	1,105,911	16.5	610,479	55.2
Great Lakes–St. Lawrence Lowlands	8.1	83,385	10,059,562	120.7	8,453,277	84.0
Huron–Erie Plains	8.2	24,139	8,324,391	344.8	7,873,584	94.6
Boreal Foothills	9.1	122,257	87,670	0.7	41,907	47.8
Central Boreal Plains	9.2	450,567	695,800	1.5	322,881	46.4
Eastern Boreal Plains	9.3	89,071	139,801	1.6	49,172	35.2
Eastern Prairies	10.1	28,955	914,493	31.6	792,530	86.7
Parkland Prairies	10.2	167,605	2,500,002	14.9	2,082,262	83.3
Central Grassland	10.3	242,144	2,021,842	8.3	1,756,526	86.9
Northern Yukon Mountains	11.1	26,442	0	0.0	0	…
Old Crow–Eagle Plains	11.2	18,925	221	0.0	0	0.0
Ogilvie Mountains	11.3	59,018	5	0.0	0	0.0
Mackenzie–Selwyn Mountains	11.4	156,172	108	0.0	0	0.0
Wrangel Mountains	12.1	23,830	73	0.0	0	0.0
Northern Boreal Cordillera	12.2	229,570	33,454	0.1	21,732	65.0
Southern Boreal Cordillera	12.3	159,889	2,487	0.0	0	0.0
Western Boreal Cordillera	12.4	37,597	1,913	0.1	0	0.0
Georgia Depression	13.1	18,429	3,544,749	192.5	3,310,895	93.4
Southern Coastal Mountains	13.2	151,029	135,380	0.9	73,160	54.0
Northern Coastal Mountains	13.3	30,944	1,011	0.0	0	0.0
Northern Montane Cordillera	14.1	133,129	123,637	0.9	83,022	67.1
Central Montane Cordillera	14.2	100,245	69,195	0.7	24,867	35.9
Southern Montane Cordillera	14.3	56,469	537,455	9.5	396,655	73.8
Columbia Montane Cordillera	14.4	172,464	208,007	1.2	118,120	56.8
Hudson Bay Coastal Plains	15.1	56,965	1,475	0.0	0	0.0
Hudson–James Lowlands	15.2	291,363	12,008	0.0	6,552	54.6

… not applicable
1. The term 'population centre' was introduced for the 2011 Census and replaced the term 'urban area.' All areas outside population centres are classified as rural areas.
Source: Statistics Canada, *Table 38-10-0047-01*, https://doi.org/10.25318/3810004701-eng (accessed September 18, 2020).

Table 2.3
Marine and coastal extent, by depth class and marine ecoregion

	Maximum water depth class[1]					
	Coastal epipelagic	Epipelagic	Mesopelagic	Bathypelagic	Abyssalpelagic	Total
Marine ecoregion	km²					
Total exclusive economic zone	**812,532**	**1,866,901**	**1,459,181**	**1,485,749**	**122,533**	**5,746,894**
Strait of Georgia	3,273	3,173	2,522	2	0	8,970
Southern Shelf	4,132	11,176	4,583	8,267	0	28,158
Offshore Pacific	3	15	211	315,495	0	315,724
Northern Shelf	23,423	39,737	25,109	13,060	0	101,328
Arctic Basin	142	13,117	224,802	513,992	0	752,053
Western Arctic	177,824	189,473	172,497	0	0	539,793
Arctic Archipelago	43,739	91,959	133,099	0	0	268,797
Eastern Arctic	77,149	154,899	362,773	187,819	0	782,639
Hudson Bay Complex	343,386	759,653	141,606	0	0	1,244,644
Newfoundland-Labrador Shelves	49,994	350,532	287,743	344,977	8,410	1,041,656
Scotian Shelf	25,963	145,984	28,277	102,137	114,123	416,485
Gulf of St. Lawrence	63,504	107,183	75,959	0	0	246,646

Note: This table classifies areas of Canada's exclusive economic zone (EEZ) by their maximum water depth. Areas classed as coastal epipelagic have a maximum depth of 50 m, the epipelagic class has depths from 50 m to 200 m, the mesopelagic class has depths of 200 m to 1000 m, the bathypelagic class has depths of 1 km to 4 km, and the abyssalpelagic class includes all areas with depths of more than 4 km. Within each area, the water column from the water surface to the seafloor is similarly divided into vertical zones. For example, areas classed as abyssalpelagic will have waters that are within the epipelagic, mesopelagic and bathypelagic zones.
Source: GEBCO Compilation Group, 2015, *GEBCO_2014 Grid*, version 20150318, www.gebco.net (accessed December 5, 2018).

Table 2.4
Marine and coastal ecosystem extent, by marine ecoregion

	Ecosystem type				
	Salt marsh	Seagrass meadow	Kelp forest	Cold coral and sea sponge reef	Area unassigned
Marine ecoregion	km²				
Estimated minimum total	**1,114**	**1,429**	**634**	**293,353**	**5,451,558**
Strait of Georgia	64	252	77	33	8,637
Southern Shelf	75	94	126	177	27,776
Offshore Pacific	..	..	..	12[4]	315,710
Northern Shelf	599	371	431	2,610	97,799
Arctic Basin	..	..	..	..	752,425
Western Arctic	..[1]	1	..	..	539,588
Arctic Archipelago	..	..	..	..	268,633
Eastern Arctic	..[1]	1	..[2]	55,542	727,291
Hudson Bay Complex	..[1]	274	..[2]	757	1,243,656
Newfoundland-Labrador Shelves	..[1]	21	..[2]	110,321	931,315
Scotian Shelf	178	49	..[2,3]	80,742	335,497
Gulf of St. Lawrence	198	364	..[2,3]	43,160	203,232

.. not available for a specific reference period

1. Salt marsh is known to occur in this marine ecoregion. However, the area was unavailable and is not included in this estimate.
2. Kelp beds are known to occur in this marine ecoregion. However, the area was unavailable and is not included in this estimate. Point data for kelp can be found in Wilson K.L., M.A. Skinner and H.K. Lotze, 2019, "Projected 21st-century distribution of canopy-forming seaweeds in the Northwest Atlantic with climate change," *Diversity and Distributions,* Vol. 25, no. 4, pp. 582-602, https://doi.org/10.1111/ddi.12897 (accessed May 22, 2020).
3. Kelp was observed pre- and post-2000, but decreases have occurred as a result of warming waters. Bernier, R.Y., R.E. Jamieson and A.M. Moore (Eds.), 2018, "State of the Atlantic Ocean synthesis report," *Can.Tech. Rep. Fish. Aquat. Sci.* 3167:iii+149p. Kelp was historically found in the southern Gulf of St. Lawrence, but is now uncommon. The Eastern shore Islands of the Scotian Shelf have dense kelp beds, Fisheries and Oceans Canada, 2019, "Ecological Importance," *Eastern Shore Islands: Area of Interest (AOI)*, https://www.dfo-mpo.gc.ca/oceans/aoi-si/easternshore-ilescoteest-eng.html (accessed September 29, 2020).
4. Coldwater coral is known to occur in the Offshore Pacific Seamounts and Vents Marine Protected Area and SGaan Kinghlas-Bowie Seamount Marine Protected Area. However, the area within these protected areas was unavailable and is not included in this estimate.

Notes: Salt marsh, seagrass meadow, kelp forest and cold coral and sea sponge reef areas are underestimated because of the difficulty of fully mapping Canada's marine regions. Some seagrass and cold water coral area estimates have been derived from point data. The total marine and coastal area covered by this table includes some small inlets and shallow bays that are excluded from other tabulations and small overlaps between ecosystem types may occur. For more information, see Appendix A.

Sources: McOwen, C., et al., 2017, "A global map of saltmarshes," *Biodiversity Data Journal,* Vol. 5: e11764, https://doi.org/10.3897/BDJ.5.e11764 and http://data.unepwcmc.org/datasets/43 (v.6) (accessed September 20, 2019); British Columbia Ministry of Forests, Lands, Natural Resource Operations and Rural Development, 2019, *Kelp Beds - Coastal Resource Information Management System (CRIMS)*, GeoBC, https://catalogue.data.gov.bc.ca/dataset/kelp-beds-coastal-resource-information-management-system-crims (accessed April 4, 2019); Freiwald, A., et al., 2017, ""Global distribution of cold-water corals (version 5.0),"" Fifth update to the dataset in Freiwald, et al., 2004, by UNEP-WCMC, in collaboration with A. Freiwald and J. Guinotte, Cambridge (UK): UN Environment World Conservation Monitoring Centre, http://data.unep-wcmc.org/datasets/3 (accessed June 3, 2019); Kenchington, E., et al., 2018, *Delineation of Coral and Sponge Significant Benthic areas in Eastern Canada Using Kernel Density Analyses and Species Distribution Models*, https://data.mendeley.com/datasets/hnp4xr2sy3 (accessed May 14, 2019); Fisheries and Oceans Canada, 2016, *Oceans Act Marine Protected Areas*, https://open.canada.ca/data/en/dataset/a1e18963-25dd-4219-a33f-1a38c4971250 (accessed September 9, 2019); Fisheries and Oceans Canada, 2017, *Other Effective Area-Based Conservation Measures*, https://open.canada.ca/data/en/dataset/44769543-7a23-4991-a53f-c2cf7c7a946f (accessed September 9, 2019); B.C. Ministry of Forests, Lands, Natural Resource Operations and Rural Development, 2019, *Eelgrasses - Coastal Resource Information Management System (CRIMS)*, GeoBC, https://catalogue.data.gov.bc.ca/dataset/eelgrasses-coastal-resource-information-management-system-crims (accessed April 4, 2019); Fisheries and Oceans Canada, 2019, *Eelgrass inventory in James Bay, Chaleur Bay, Estuary and Gulf of St. Lawrence*, https://open.canada.ca/data/en/dataset/c9ab948f-5009-4dbc-9129-2f6e373f17f6 (accessed September 30, 2019); Personal communication with Brett Painter, Environment and Climate Change Canada, June 21, 2019; Personal communication with Heike Lotz, Dalhousie University, June 21, 2019; Personal communication with John Cristiani and Mary O'Connor, University of British Columbia, June 14, 2019; Personal communication with Amanda Bates and Jasmin Schuster, Memorial University (February 10, 2020), Personal communication with Arnault LeBris, Memorial University (May 20, 2020); UNEP-WCMC and F.T. Short, 2018, *Global distribution of seagrasses (version 6.0)*, Sixth update to the data layer used in Green and Short, 2003, Cambridge, (UK): UN Environment World Conservation Monitoring Centre, http://data.unep-wcmc.org/datasets/7 (accessed September 30, 2020).

Table 2.5
Marine and coastal terrain ruggedness, slope and substrate, by marine ecoregion and depth class (Part 1)

	Terrain ruggedness[1]					Slope percentage[2]			
	Level	Nearly level	Slightly rugged	Intermediately rugged	Moderately to extremely rugged	Level	Undulating	Rolling	Hilly
	0 to 80	81 to 116	117 to 161	162 to 239	240 to 4,367	0 to 0.5	0.5 to 5	5 to 30	Greater than 30
Marine ecoregion and depth class	km²								
Strait of Georgia									
Coastal	1,464	510	417	355	528	238	1,312	1,604	119
Epipelagic	1,389	605	450	332	397	17	1,419	1,684	53
Mesopelagic	1,776	304	149	88	205	34	1,714	678	97
Bathypelagic	0	0	0	0	2	0	0	0	2
Southern Shelf									
Coastal	3,313	229	166	197	225	606	2,782	723	21
Epipelagic	10,722	200	98	66	90	3,895	6,886	392	3
Mesopelagic	1,368	915	924	874	502	39	1,297	3,207	41
Bathypelagic	2,989	1,401	1,291	1,371	1,216	81	3,010	5,043	133
Offshore Pacific									
Coastal	0	0	2	0	1	0	0	3	0
Epipelagic	0	1	1	7	6	0	0	15	0
Mesopelagic	14	10	14	28	145	0	20	135	56
Bathypelagic	260,078	19,287	12,601	11,458	12,071	52,160	210,975	50,703	1,657
Northern Shelf									
Coastal	16,368	1,538	1,341	1,523	2,650	8,134	8,834	6,077	378
Epipelagic	34,432	1,971	1,092	910	1,333	8,747	26,060	4,747	183
Mesopelagic	17,478	1,944	1,842	1,763	2,083	4,714	12,761	7,290	343
Bathypelagic	3,562	2,120	2,237	2,826	2,316	29	3,499	9,249	282
Arctic Basin									
Coastal	130	8	2	1	0	14	117	10	0
Epipelagic	12,955	108	40	14	0	4,580	8,370	167	0
Mesopelagic	216,406	5,750	1,934	632	80	83,661	131,504	9,638	0
Bathypelagic	481,786	18,843	8,026	3,896	1,440	109,235	369,028	35,653	75
Western Arctic									
Coastal	175,799	1,112	492	292	129	123,568	51,974	2,280	2
Epipelagic	187,044	1,776	447	165	40	89,912	96,642	2,919	0
Mesopelagic	170,974	1,130	314	71	8	84,445	86,289	1,763	0
Arctic Archipelago									
Coastal	35,875	2,571	1,741	1,656	1,895	7,504	27,684	8,192	359
Epipelagic	84,291	4,243	1,988	1,013	425	15,945	66,576	9,406	32
Mesopelagic	125,709	4,247	1,847	1,003	292	31,358	92,015	9,712	14
Eastern Arctic									
Coastal	60,239	4,924	3,675	3,656	4,656	17,494	42,395	16,318	941
Epipelagic	145,499	4,479	2,237	1,545	1,139	49,809	94,168	10,728	194
Mesopelagic	339,700	11,467	6,471	3,400	1,734	136,062	200,213	26,160	338
Bathypelagic	184,388	2,452	728	225	26	58,270	124,735	4,814	0
Hudson Bay Complex									
Coastal	340,711	1,550	683	360	82	266,025	74,862	2,497	1
Epipelagic	758,450	779	309	100	15	596,649	161,593	1,411	0
Mesopelagic	140,566	792	173	63	11	62,041	78,370	1,195	0
Newfoundland-Labrador Shelves									
Coastal	41,944	3,445	2,149	1,481	974	12,012	30,791	7,104	87
Epipelagic	343,377	4,081	1,757	977	339	222,157	121,774	6,598	3
Mesopelagic	267,163	9,491	6,199	3,676	1,213	116,714	150,599	20,371	58
Bathypelagic	305,044	21,486	10,286	5,615	2,547	34,129	271,198	39,349	303
Abyssalpelagic	7,445	583	250	102	30	182	7,265	964	0

Table 2.5
Marine and coastal terrain ruggedness, slope and substrate, by marine ecoregion and depth class (Part 1)

	Terrain ruggedness[1]					Slope percentage[2]			
	Level	Nearly level	Slightly rugged	Intermediately rugged	Moderately to extremely rugged	Level	Undulating	Rolling	Hilly
	0 to 80	81 to 116	117 to 161	162 to 239	240 to 4,367	0 to 0.5	0.5 to 5	5 to 30	Greater than 30
Marine ecoregion and depth class	km²								
Scotian Shelf									
Coastal	25,671	212	62	18	1	11,707	13,982	275	0
Epipelagic	144,773	934	222	46	9	71,910	72,950	1,124	0
Mesopelagic	20,284	2,189	1,980	2,318	1,506	8,219	12,024	7,952	81
Bathypelagic	73,622	10,707	6,786	6,241	4,781	406	73,374	28,228	128
Abyssalpelagic	113,773	266	69	13	2	28,400	85,405	318	0
Gulf of St. Lawrence									
Coastal	61,752	893	401	284	174	38,939	22,932	1,625	7
Epipelagic	105,949	845	240	118	30	49,461	56,598	1,124	0
Mesopelagic	75,729	190	31	5	4	37,681	38,080	198	0

. not available for any reference period

1. Terrain ruggedness calculated using the method in Riley, Shawn J., et al., 1999, "A terrain ruggedness index that quantifies topographic heterogeneity," *Intermountain Journal of Sciences*, Vol. 5, no. 1-4.
2. Slope was calculated from the bathymetry using ArcGis, slope classifications match broader class from http://www.env.gov.bc.ca/esd/distdata/ecosystems/Soil_Data/Legends/SlopeClassLegend.pdf
3. Data was not obtained for Atlantic and Arctic regions with the exception of the Gulf of St Lawrence. Classification of sediment substrate differed between sources—sediment for the Gulf of St. Lawrence was redefined as follows: sand sediment as soft, pelite and glacial drift as hard, and everything else as mixed.
4. Low-resolution maps that do not include the required level of detail exist; other data sets may be available for smaller regions, but were not obtained.

Note: Areas classed as coastal have a maximum depth of 50 m, the epipelagic class has depths from 50 m to 200 m, the mesopelagic class has depths from 200 m to 1,000 m, the bathypelagic class has depths of 1 km to 4 km and the abyssalpelagic class includes all areas with depths of more than 4 km.

Sources: GEBCO Compilation Group, 2015, GEBCO_2014 Grid, version 20150318, www.gebco.net (accessed December 5, 2018); Gregr, E. J., J. Lessard and J. Harper, 2013, "Pacific data from A spatial framework for representing nearshore ecosystems," *Progress in Oceanography*, Vol. 1153, p. 189-201; B.C. Ministry of Forests, Lands, Natural Resource Operations and Rural Development, 1979, *Benthic Marine Ecounits - Coastal Resource Information Management System (CRIMS)*, GeoBC, https://catalogue.data.gov.bc.ca/dataset/benthic-marine-ecounits-coastal-resource-information-management-system-crims (accessed August 19, 2019); Loring, D. H. and D. J. G. Nota, 1973, "Morphology and sediments of the Gulf of St. Lawrence," *Bull. Fish. Res. Bd. Can.,* Vol. 182, https://open.canada.ca/data/en/dataset/8c269a91-d3a2-4f49-943d-6b2401c42cba (accessed November 20, 2019).

Table 2.5
Marine and coastal terrain ruggedness, slope and substrate, by marine ecoregion and depth class (Part 2)

	Substrate type[3]			
	Soft	Mixed	Hard	Unavailable[4]
Marine ecoregion and depth class	km²			
Strait of Georgia				
Coastal	1,129	1,413	555	177
Epipelagic	387	2,347	416	24
Mesopelagic	28	2,440	52	2
Bathypelagic	0	2	0	0
Southern Shelf				
Coastal	1,295	1,527	1,148	162
Epipelagic	7,591	1,582	1,815	189
Mesopelagic	1,430	102	4	3,047
Bathypelagic	6	.	.	8,262
Offshore Pacific				
Coastal	.	.	.	3
Epipelagic	.	.	.	15
Mesopelagic	.	.	.	211
Bathypelagic	.	.	224	315,271
Northern Shelf				
Coastal	10,520	5,053	6,276	1,575
Epipelagic	20,572	5,501	12,989	675
Mesopelagic	7,872	3,131	8,527	5,578
Bathypelagic	.	.	74	12,986

Table 2.5
Marine and coastal terrain ruggedness, slope and substrate, by marine ecoregion and depth class (Part 2)

	Substrate type[3]			
	Soft	Mixed	Hard	Unavailable[4]
Marine ecoregion and depth class	km²			
Arctic Basin				
Coastal	.	.	.	142
Epipelagic	.	.	.	13,117
Mesopelagic	.	.	.	224,802
Bathypelagic	.	.	.	513,992
Western Arctic				
Coastal	.	.	.	177,824
Epipelagic	.	.	.	189,473
Mesopelagic	.	.	.	172,497
Arctic Archipelago				
Coastal	.	.	.	43,739
Epipelagic	.	.	.	91,959
Mesopelagic	.	.	.	133,099
Eastern Arctic				
Coastal	.	.	.	77,149
Epipelagic	.	.	.	154,899
Mesopelagic	.	.	.	362,773
Bathypelagic	.	.	.	187,819
Hudson Bay Complex				
Coastal	.	.	.	343,386
Epipelagic	.	.	.	759,653
Mesopelagic	.	.	.	141,606
Newfoundland-Labrador Shelves				
Coastal	1	.	.	49,993
Epipelagic	.	.	.	350,532
Mesopelagic	.	.	.	287,743
Bathypelagic	.	.	.	344,977
Abyssalpelagic	.	.	.	8,410
Scotian Shelf				
Coastal	.	.	.	25,964
Epipelagic	.	.	.	145,984
Mesopelagic	.	.	.	28,277
Bathypelagic	.	.	.	102,137
Abyssalpelagic	.	.	.	114,123
Gulf of St. Lawrence				
Coastal	27,537	14,960	6,665	14,342
Epipelagic	43,424	17,349	40,033	6,378
Mesopelagic	3,610	901	66,106	5,342

. not available for any reference period

1. Terrain ruggedness calculated using the method in Riley, Shawn J., et al., 1999, "A terrain ruggedness index that quantifies topographic heterogeneity," *Intermountain Journal of Sciences*, Vol. 5, no. 1-4.
2. Slope was calculated from the bathymetry using ArcGis, slope classifications match broader class from http://www.env.gov.bc.ca/esd/distdata/ecosystems/Soil_Data/Legends/SlopeClassLegend.pdf
3. Data was not obtained for Atlantic and Arctic regions with the exception of the Gulf of St Lawrence. Classification of sediment substrate differed between sources—sediment for the Gulf of St. Lawrence was redefined as follows: sand sediment as soft, pelite and glacial drift as hard, and everything else as mixed.
4. Low-resolution maps that do not include the required level of detail exist; other data sets may be available for smaller regions, but were not obtained.

Note: Areas classed as coastal have a maximum depth of 50 m, the epipelagic class has depths from 50 m to 200 m, the mesopelagic class has depths from 200 m to 1,000 m, the bathypelagic class has depths of 1 km to 4 km and the abyssalpelagic class includes all areas with depths of more than 4 km.

Sources: GEBCO Compilation Group, 2015, GEBCO_2014 Grid, version 20150318, www.gebco.net (accessed December 5, 2018); Gregr, E. J., J. Lessard and J. Harper, 2013, "Pacific data from A spatial framework for representing nearshore ecosystems," *Progress in Oceanography*, Vol. 1153, p. 189-201; B.C. Ministry of Forests, Lands, Natural Resource Operations and Rural Development, 1979, *Benthic Marine Ecounits - Coastal Resource Information Management System (CRIMS)*, GeoBC, https://catalogue.data.gov.bc.ca/dataset/benthic-marine-ecounits-coastal-resource-information-management-system-crims (accessed August 19, 2019); Loring, D. H. and D. J. G. Nota, 1973, "Morphology and sediments of the Gulf of St. Lawrence," *Bull. Fish. Res. Bd. Can.,* Vol. 182, https://open.canada.ca/data/en/dataset/8c269a91-d3a2-4f49-943d-6b2401c42cba (accessed November 20, 2019).

Table 2.6
Average annual, average annual maximum and minimum monthly and variability of temperature and precipitation by ecoprovince, 1979 to 2016

Ecoprovince	Code	Average annual temperature	Average maximum monthly temperature	Average minimum monthly temperature	Temperature variability	Average annual precipitation	Average maximum monthly precipitation	Average minimum monthly precipitation	Precipitation variability
			°C		CV	mm	km³		CV
Canada	**...**	**-4.3**	**13.0**	**-23.1**	**5.70**	**545.8**	**25.4**	**4.8**	**0.58**
Northern Arctic Cordillera	1.1	-21.3	0.7	-38.7	0.66	207.3	4.3	0.8	0.55
Southern Arctic Cordillera	1.2	-12.5	4.0	-29.4	0.93	402.6	7.1	1.8	0.41
Sverdrup Islands	2.1	-18.1	3.3	-35.9	0.78	78.5	1.3	0.1	0.96
Ellesmere Basin	2.2	-19.7	2.8	-37.7	0.74	142.3	3.8	0.5	0.66
Victoria Lowlands	2.3	-14.9	5.8	-33.1	0.94	115.3	10.6	0.9	0.83
Parry Channel Plateau	2.4	-15.9	5.2	-34.4	0.88	173.7	5.1	0.4	0.82
Boothia–Foxe Shield	2.5	-12.3	7.5	-31.8	1.10	271.3	26.1	3.2	0.61
Baffin Uplands	2.6	-12.8	5.1	-30.7	0.97	307.6	7.3	0.9	0.64
Foxe–Boothia Lowlands	2.7	-11.9	7.3	-30.8	1.11	233.3	3.7	0.3	0.74
Amundsen Lowlands	3.1	-10.4	10.0	-29.6	1.36	200.1	11.6	1.5	0.68
Keewatin Lowlands	3.2	-11.6	10.3	-32.2	1.30	244.4	17.9	1.8	0.68
Ungava–Belcher	3.3	-7.2	9.1	-26.2	1.70	489.7	12.8	1.9	0.55
Mackenzie Foothills	4.1	-5.9	13.9	-26.8	2.45	351.0	5.6	0.8	0.67
Great Bear Lowlands	4.2	-6.6	14.4	-28.0	2.30	268.3	15.9	2.5	0.60
Hay–Slave Lowlands	4.3	-1.7	16.0	-22.4	7.84	399.2	18.3	2.1	0.72
Western Taiga Shield	5.1	-6.7	14.1	-28.1	2.22	345.7	36.4	5.8	0.58
Eastern Taiga	5.2	-4.3	12.7	-24.4	2.98	718.6	44.7	7.8	0.51
Labrador Uplands	5.3	-3.3	12.4	-21.0	3.51	906.4	29.6	8.8	0.34
Whale River Lowland	5.4	-5.4	11.5	-24.7	2.32	671.7	11.7	2.3	0.48
Western Boreal Shield	6.1	-1.7	16.9	-23.3	8.06	537.6	47.3	7.3	0.57
Mid-Boreal Shield	6.2	0.5	17.1	-19.7	24.49	794.7	56.9	13.3	0.43
Eastern Boreal Shield	6.3	-0.6	14.7	-18.4	19.27	1,029.9	46.6	14.8	0.33
Newfoundland	6.4	3.7	15.8	-8.6	2.21	1,339.1	18.4	7.1	0.29
Lake of the Woods	6.5	2.4	18.7	-17.8	5.13	700.7	9.1	1.1	0.63
Southern Boreal Shield	6.6	3.2	18.2	-15.2	3.57	998.8	42.6	14.0	0.32
Appalachian–Acadian Highlands	7.1	3.1	17.7	-13.4	3.38	1,160.7	14.9	4.3	0.35
Northumberland Lowlands	7.2	5.1	19.0	-10.0	1.91	1,204.8	5.7	1.7	0.36
Fundy Uplands	7.3	6.0	18.5	-7.3	1.45	1,382.1	13.4	4.1	0.35
Great Lakes–St. Lawrence Lowlands	8.1	6.0	20.0	-10.5	1.72	1,038.8	12.2	4.1	0.32
Huron–Erie Plains	8.2	8.4	21.5	-6.4	1.13	937.8	3.4	0.9	0.37
Boreal Foothills	9.1	1.2	14.4	-15.3	8.24	533.0	13.4	1.4	0.71
Central Boreal Plains	9.2	0.7	16.7	-19.1	17.85	446.4	41.0	5.2	0.68
Eastern Boreal Plains	9.3	0.9	18.4	-20.4	14.13	509.5	12.8	1.4	0.69
Eastern Prairies	10.1	2.8	19.7	-18.2	4.61	535.5	3.6	0.3	0.72
Parkland Prairies	10.2	2.5	18.0	-16.9	4.80	457.0	17.2	1.7	0.72
Central Grassland	10.3	3.9	18.9	-14.4	2.83	373.3	20.5	1.9	0.75
Northern Yukon Mountains	11.1	-10.8	9.3	-29.1	1.28	161.1	1.1	0.1	0.97
Old Crow–Eagle Plains	11.2	-9.4	9.8	-27.4	1.42	144.6	0.8	0.0	1.10
Ogilvie Mountains	11.3	-8.3	11.0	-28.1	1.67	166.2	2.6	0.1	1.12
Mackenzie–Selwyn Mountains	11.4	-8.0	10.6	-27.6	1.67	309.5	10.3	1.1	0.77
Wrangel Mountains	12.1	-5.2	7.8	-20.0	1.83	640.0	1.6	0.3	0.44
Northern Boreal Cordillera	12.2	-3.8	12.5	-23.7	3.26	314.2	14.2	1.6	0.67
Southern Boreal Cordillera	12.3	-2.1	10.6	-17.7	4.45	512.8	13.5	2.2	0.50
Western Boreal Cordillera	12.4	-5.2	12.2	-25.7	2.53	217.1	2.2	0.1	1.04
Georgia Depression	13.1	8.4	16.5	0.7	0.64	2,036.5	7.4	0.6	0.68

Table 2.6
Average annual, average annual maximum and minimum monthly and variability of temperature and precipitation by ecoprovince, 1979 to 2016

Ecoprovince	Code	Average annual temperature	Average maximum monthly temperature	Average minimum monthly temperature	Temperature variability	Average annual precipitation	Average maximum monthly precipitation	Average minimum monthly precipitation	Precipitation variability
		°C			CV	mm	km^3		CV
Southern Coastal Mountains	13.2	5.0	13.3	-3.6	1.12	1,947.0	50.1	8.7	0.52
Northern Coastal Mountains	13.3	0.7	10.5	-10.9	10.31	1,089.9	4.0	0.9	0.45
Northern Montane Cordillera	14.1	1.1	12.8	-13.5	8.18	618.1	12.8	2.8	0.44
Central Montane Cordillera	14.2	2.7	13.5	-10.3	2.88	622.9	9.6	2.3	0.42
Southern Montane Cordillera	14.3	3.7	15.0	-8.1	2.05	675.1	6.1	1.1	0.47
Columbia Montane Cordillera	14.4	1.0	12.5	-11.6	8.06	964.6	25.6	6.0	0.42
Hudson Bay Coastal Plains	15.1	-4.4	14.4	-25.4	3.12	502.2	5.5	0.8	0.62
Hudson–James Lowlands	15.2	-1.7	16.0	-22.6	7.91	629.2	31.4	5.9	0.52

… not applicable

Notes: Variability is measured by using a coefficient of variation (CV) that allows the comparison of all months in all years of the 38-year time period. The CV of the data is a measure of the dispersion or variation in the monthly values over the period 1979 to 2016. It is defined as the ratio of the standard deviation of the monthly values to the mean. A higher CV indicates that the monthly data are more variable. The CV calculated for temperature is based on absolute degrees using kelvin (K). To convert precipitation measured in depth in mm to a volume per area in m^3/m^2, divide by 1000.

Sources: Wang, S., Y. Yang, Y. Luo and A. Rivera, 2013, "Spatial and seasonal variations in evapotranspiration over Canada's landmass," *Hydrology and Earth System Sciences*, Vol. 17, no. 9, pp. 3561-3575, https://doi.org/10.5194/hess-17-3561-2013 (accessed December 1, 2020); Wang, S., et al., 2014, "A national-scale assessment of long-term water budget closures for Canada's watersheds," *Journal of Geophysical Research: Atmospheres,* Vol. 119, pp. 8712–8725, https://doi.org/10.1002/2014JD021951 (accessed February 1, 2021).

Table 2.7
Average annual, average annual maximum and minimum monthly and variability of evapotranspiration and potential evapotranspiration by ecoprovince, 1979 to 2016

Ecoprovince	Code	Average annual evapotrans-piration	Average maximum monthly evapotrans-piration	Average minimum monthly evapotrans-piration	Evapotrans-piration variability	Average annual potential evapotrans-piration	Average maximum monthly potential evapotrans-piration	Average minimum monthly potential evapotrans-piration	Potential evapotrans-piration variability
		mm	km³		CV	mm	km³		CV
Canada	**...**	**257**	**18.86**	**0.36**	**1.10**	**561**	**43.05**	**-1.86**	**1.23**
Northern Arctic Cordillera	1.1	89	4.37	-0.44	1.76	154	9.41	-1.00	2.04
Southern Arctic Cordillera	1.2	113	4.32	-0.36	1.32	227	11.36	-0.88	1.66
Sverdrup Islands	2.1	72	1.73	-0.16	1.54	295	7.26	-0.38	1.67
Ellesmere Basin	2.2	97	4.88	-0.37	1.66	265	16.33	-0.92	1.86
Victoria Lowlands	2.3	105	14.49	-1.41	1.47	328	51.59	-4.00	1.67
Parry Channel Plateau	2.4	120	6.19	-0.62	1.69	265	15.70	-1.34	1.90
Boothia–Foxe Shield	2.5	125	18.08	-1.47	1.29	315	63.71	-3.88	1.64
Baffin Uplands	2.6	121	4.90	-0.47	1.42	246	13.27	-1.10	1.76
Foxe–Boothia Lowlands	2.7	135	3.10	-0.25	1.37	295	8.75	-0.58	1.67
Amundsen Lowlands	3.1	142	12.49	-0.77	1.33	404	40.25	-2.85	1.53
Keewatin Lowlands	3.2	149	15.10	-0.73	1.25	394	50.43	-2.42	1.52
Ungava–Belcher	3.3	101	3.92	-0.72	1.26	388	20.14	-1.64	1.50
Mackenzie Foothills	4.1	200	4.62	0.03	1.18	515	11.20	-0.43	1.26
Great Bear Lowlands	4.2	176	14.77	0.01	1.20	499	45.37	-2.24	1.31
Hay–Slave Lowlands	4.3	320	17.50	0.52	1.07	647	33.74	-1.38	1.09
Western Taiga Shield	5.1	141	22.66	-0.76	1.14	495	85.83	-5.05	1.31
Eastern Taiga	5.2	150	13.09	0.34	0.89	508	50.90	-2.42	1.18
Labrador Uplands	5.3	205	11.13	0.65	0.84	515	31.21	-1.08	1.10
Whale River Lowland	5.4	114	3.04	-0.15	1.00	436	13.68	-0.91	1.29
Western Boreal Shield	6.1	275	34.38	1.33	1.02	649	75.18	-3.34	1.06
Mid-Boreal Shield	6.2	400	43.88	3.47	0.88	731	74.24	-0.65	0.91
Eastern Boreal Shield	6.3	311	23.10	2.59	0.77	639	47.84	-0.45	0.96
Newfoundland	6.4	373	9.03	0.99	0.78	793	16.07	1.18	0.73
Lake of the Woods	6.5	470	7.92	0.30	0.98	848	11.74	-0.08	0.88
Southern Boreal Shield	6.6	521	38.74	2.76	0.92	797	50.68	0.03	0.85
Appalachian–Acadian Highlands	7.1	488	12.19	0.40	1.07	756	14.74	-0.29	0.93
Northumberland Lowlands	7.2	535	4.98	0.20	1.04	907	6.14	0.14	0.82
Fundy Uplands	7.3	522	9.19	0.54	0.95	969	12.67	0.79	0.74
Great Lakes–St. Lawrence Lowlands	8.1	485	12.28	0.05	1.13	873	15.12	-0.22	0.85
Huron–Erie Plains	8.2	556	3.81	0.01	1.04	1005	4.47	0.00	0.76
Boreal Foothills	9.1	425	12.14	0.42	0.98	718	18.25	-0.77	0.98
Central Boreal Plains	9.2	378	47.72	0.52	1.15	720	74.15	-3.35	1.04
Eastern Boreal Plains	9.3	397	11.54	0.13	1.15	767	21.47	-0.75	1.02
Eastern Prairies	10.1	450	4.39	-0.06	1.33	841	5.94	-0.21	1.01
Parkland Prairies	10.2	411	23.35	-0.31	1.35	819	31.25	-1.20	1.02
Central Grassland	10.3	349	26.27	-0.19	1.21	905	47.72	-1.50	0.95
Northern Yukon Mountains	11.1	141	1.19	-0.05	1.39	415	3.43	-0.20	1.48
Old Crow–Eagle Plains	11.2	136	0.92	-0.03	1.41	453	2.82	-0.17	1.43
Ogilvie Mountains	11.3	151	2.72	-0.03	1.31	473	7.53	-0.32	1.31
Mackenzie–Selwyn Mountains	11.4	175	7.52	-0.13	1.24	462	19.77	-1.04	1.35
Wrangel Mountains	12.1	136	0.60	-0.02	1.22	353	1.84	-0.12	1.42
Northern Boreal Cordillera	12.2	207	12.27	0.42	1.08	536	29.70	-1.44	1.17
Southern Boreal Cordillera	12.3	221	8.98	0.25	1.03	531	21.06	-1.37	1.18
Western Boreal Cordillera	12.4	181	1.84	0.03	1.17	542	4.88	-0.15	1.16
Georgia Depression	13.1	598	2.38	0.20	0.77	805	3.08	-0.09	0.87

Table 2.7
Average annual, average annual maximum and minimum monthly and variability of evapotranspiration and potential evapotranspiration by ecoprovince, 1979 to 2016

Ecoprovince	Code	Average annual evapotrans-piration	Average maximum monthly evapotrans-piration	Average minimum monthly evapotrans-piration	Evapotrans-piration variability	Average annual potential evapotrans-piration	Average maximum monthly potential evapotrans-piration	Average minimum monthly potential evapotrans-piration	Potential evapotrans-piration variability
		mm	km³		CV	mm	km³		CV
Southern Coastal Mountains	13.2	392	12.12	1.27	0.74	659	20.83	-0.75	0.92
Northern Coastal Mountains	13.3	203	1.09	0.00	1.05	455	2.91	-0.26	1.26
Northern Montane Cordillera	14.1	365	10.81	0.84	0.86	616	18.46	-1.16	1.06
Central Montane Cordillera	14.2	352	7.73	0.61	0.82	668	14.55	-0.52	0.95
Southern Montane Cordillera	14.3	420	5.82	0.32	0.89	746	9.48	-0.53	0.97
Columbia Montane Cordillera	14.4	417	16.85	1.04	0.86	693	27.65	-1.83	1.02
Hudson Bay Coastal Plains	15.1	206	3.31	0.06	1.04	544	8.23	-0.25	1.13
Hudson–James Lowlands	15.2	306	22.74	1.26	0.96	632	42.57	-1.07	1.00

… not applicable

Notes: Evapotranspiration is the process of evaporation from land surfaces and transpiration from plants. It is controlled by surface water availability and by meteorological variables such as net solar radiation, air temperature and humidity and wind speed. Potential evapotranspiration represents the evapotranspiration that would occur without limitations on water supply, and is therefore linked to the amount of energy available to generate evapotranspiration in a specific area and is independent of water supply. Variability is measured by using a coefficient of variation (CV) that allows the comparison of all months in all years of the 38-year time period. The CV of the data is a measure of the dispersion or variation in the monthly values over the period 1979 to 2016. It is defined as the ratio of the standard deviation of the monthly values to the mean. A higher CV indicates that the monthly data are more variable.

Sources: Wang, S., Y. Yang, Y. Luo and A. Rivera, 2013, "Spatial and seasonal variations in evapotranspiration over Canada's landmass," *Hydrology and Earth System Sciences,* Vol. 17, no. 9, pp. 3561-3575, https://doi.org/10.5194/hess-17-3561-2013 (accessed December 1, 2020); Wang, S., et al., 2014, "A national-scale assessment of long-term water budget closures for Canada's watersheds," *Journal of Geophysical Research: Atmospheres,* Vol. 119, pp. 8712–8725, https://doi.org/10.1002/2014JD021951 (accessed February 1, 2021); Li, Z., S. Wang, and J. Li, 2020, "Spatial variations and long-term trends of potential evapotranspiration in Canada," *Scientific Reports*, Vol. 10, no. 22089, https://doi.org/10.1038/s41598-020-78994-9 (accessed February 3, 2021); Wang, S., et al., 2014, "Assessment of water budget for sixteen large drainage basins in Canada," *Journal of Hydrology*, Vol. 512, pp. 1-15, https://doi.org/10.1016/j.jhydrol.2014.02.058 (accessed December 11, 2020).

Table 2.8
Temperature and precipitation change, by ecoprovince

Ecoprovince	Code	Annual temperature change, 1948 to 2016	Season of largest temperature change, 1948 to 2016	Temperature change for season of largest change, 1948 to 2016	Annual precipitation change, 1979 to 2016	Season of largest precipitation change, 1979 to 2016	Precipitation change for season of largest change, 1979 to 2016
		°C	season	°C	mm	season	mm
Northern Arctic Cordillera	1.1	2.2	Fall	3.2	4.7[E]	Summer[E]	4.5[E]
Southern Arctic Cordillera	1.2	1.6	Winter	2.2	-99.9*	Fall*	-30.7*
Sverdrup Islands	2.1	2.4	Fall	3.4	5.7[E]	Spring**	1.9**
Ellesmere Basin	2.2	2.1	Fall	3.3	-0.5[E]	Fall[E]	-4.0[E]
Victoria Lowlands	2.3	2.6	Winter	4.1	-2.9[E]	Spring[E]	-2.2[E]
Parry Channel Plateau	2.4	2.1	Fall	2.9	-0.8[E]	Fall[E]	-3.5[E]
Boothia–Foxe Shield	2.5	1.9	Winter	2.8	-31.1*	Summer[E]	-19.2[E]
Baffin Uplands	2.6	1.7	Winter	2.4	-77.2*	Summer*	-31.4*
Foxe–Boothia Lowlands	2.7	1.8	Winter	2.7	-4.8[E]	Summer[E]	-10.7[E]
Amundsen Lowlands	3.1	3.0	Winter	5.0	-9.8[E]	Fall[E]	-6.8[E]
Keewatin Lowlands	3.2	2.3	Winter	3.9	-3.9[E]	Fall[E]	11.1[E]
Ungava–Belcher	3.3	1.4	Summer	1.9	-33.4[E]	Spring[E]	-13.6[E]
Mackenzie Foothills	4.1	2.8	Winter	5.7	37.5[E]	Summer*	37.8*
Great Bear Lowlands	4.2	3.0	Winter	5.4	7.4[E]	Summer[E]	16.5[E]
Hay–Slave Lowlands	4.3	2.6	Winter	5.3	24.6[E]	Summer[E]	30.7[E]
Western Taiga Shield	5.1	2.2	Winter	4.0	-10.0[E]	Spring*	-11.3*
Eastern Taiga	5.2	1.3	Summer	1.8	-74.9[E]	Spring[E]	-20.9[E]
Labrador Uplands	5.3	0.8	Fall	1.6	-98.2*	Spring[E]	-32.2[E]
Whale River Lowland	5.4	1.2	Fall	2.0	-43.1[E]	Summer*	47.1*
Western Boreal Shield	6.1	1.7	Winter	3.2	39.2**	Summer**	24.9**
Mid-Boreal Shield	6.2	1.3	Winter	2.1	60.7**	Winter*	25.3*
Eastern Boreal Shield	6.3	0.8	Summer	1.2	-75.2[E]	Spring**	-39.7**
Newfoundland	6.4	0.7	Summer	1.3	-125.0*	Spring**	-52.9**
Lake of the Woods	6.5	1.7	Winter	2.7	122.5*	Spring*	66.3*
Southern Boreal Shield	6.6	1.0	Winter	1.2	66.1*	Winter*	56.6*
Appalachian–Acadian Highlands	7.1	0.9	Summer	1.1	107.4[E]	Winter[E]	42.1[E]
Northumberland Lowlands	7.2	0.9	Summer	1.3	58.3[E]	Winter[E]	53.5[E]
Fundy Uplands	7.3	0.9	Summer	1.4	-0.9[E]	Spring*	-51.1*
Great Lakes–St. Lawrence Lowlands	8.1	1.1	Winter	1.3	77.0**	Winter*	62.3*
Huron–Erie Plains	8.2	0.9	Spring	1.1	-29.1[E]	Winter*	45.6*
Boreal Foothills	9.1	2.0	Winter	4.5	-12.0[E]	Winter[E]	-12.5[E]
Central Boreal Plains	9.2	2.3	Winter	4.5	34.1[E]	Summer[E]	28.7[E]
Eastern Boreal Plains	9.3	2.0	Winter	3.6	105.0*	Summer*	67.7*
Eastern Prairies	10.1	1.7	Winter	3.1	135.2*	Spring*	51.2*
Parkland Prairies	10.2	1.9	Winter	3.7	67.1*	Summer**	26.0**
Central Grassland	10.3	1.9	Winter	3.8	55.7**	Summer[E]	26.7[E]
Northern Yukon Mountains	11.1	3.2	Winter	5.2	15.7[E]	Summer[E]	12.4[E]
Old Crow–Eagle Plains	11.2	3.2	Winter	5.2	-2.0[E]	Fall[E]	-8.5[E]
Ogilvie Mountains	11.3	3.3	Winter	6.4	5.2[E]	Summer[E]	6.4[E]
Mackenzie–Selwyn Mountains	11.4	2.8	Winter	6.1	44.3*	Summer*	34.9*
Wrangel Mountains	12.1	2.5	Winter	5.7	-130.9*	Summer[E]	-38.0[E]
Northern Boreal Cordillera	12.2	2.5	Winter	6.1	28.7[E]	Summer**	25.8**
Southern Boreal Cordillera	12.3	2.1	Winter	5.1	27.0[E]	Summer**	36.1**
Western Boreal Cordillera	12.4	3.0	Winter	6.7	-23.5[E]	Summer[E]	-12.9[E]
Georgia Depression	13.1	1.5	Summer	1.8	-23.2[E]	Winter[E]	-95.8[E]

Table 2.8
Temperature and precipitation change, by ecoprovince

Ecoprovince	Code	Annual temperature change, 1948 to 2016	Season of largest temperature change, 1948 to 2016	Temperature change for season of largest change, 1948 to 2016	Annual precipitation change, 1979 to 2016	Season of largest precipitation change, 1979 to 2016	Precipitation change for season of largest change, 1979 to 2016
		°C	season	°C	mm	season	mm
Southern Coastal Mountains	13.2	1.7	Winter	2.4	-77.1[E]	Winter**	-108.9**
Northern Coastal Mountains	13.3	2.1	Winter	4.5	-3.7[E]	Summer[E]	49.7[E]
Northern Montane Cordillera	14.1	2.1	Winter	4.3	35.2*	Summer[E]	24.4[E]
Central Montane Cordillera	14.2	1.9	Winter	3.2	-0.1[E]	Fall[E]	14.0[E]
Southern Montane Cordillera	14.3	2.0	Winter	2.6	-38.7[E]	Summer[E]	-57.6[E]
Columbia Montane Cordillera	14.4	1.7	Winter	3.0	-95.9[E]	Winter*	-82.9*
Hudson Bay Coastal Plains	15.1	1.4	Winter	2.5	-13.7[E]	Fall[E]	-8.0[E]
Hudson–James Lowlands	15.2	1.2	Winter	2.0	16.6[E]	Winter**	17.6**

… not applicable
* significantly different from reference category ($p < 0.05$)
** significantly different from reference category ($p < 0.10$)
[E] use with caution

Notes: To convert precipitation measured in depth in mm to a volume per area in m^3/m^2 to, divide by 1000. Trends in precipitation are reported for linear trends to the 90% confidence interval or above. Caution should be used when analyzing trends in the northern Arctic islands and along the Yukon–Alaska border because of lower climate station densities. Levels of significance are not provided for temperature trends as these trends were generated by Environment and Climate Change Canada.

Sources: Environment and Climate Change Canada (ECCC), *Canadian Gridded Temperature and Precipitation Anomalies (CANGRD)*, https://open.canada.ca/data/en/dataset/3d4b68a5-13bc-48bb-ad10-801128aa6604#wb-auto-6 (accessed May 15, 2020); ECCC, *Climate Trends and Variations Bulletin*, https://www.canada.ca/en/environment-climate-change/services/climate-change/science-research-data/climate-trends-variability/trends-variations.html (accessed May 15, 2020); Statistics Canada, Environment and Energy Statistics Division, 2021, special tabulation based on Wang, S., Y. Yang, Y. Luo and A. Rivera, 2013, "Spatial and seasonal variations in evapotranspiration over Canada's landmass," *Hydrology and Earth System Sciences,* Vol. 17, no. 9, pp. 3561-3575, https://doi.org/10.5194/hess-17-3561-2013 (accessed December 1, 2020); Wang, S., et al., 2014, "A national-scale assessment of long-term water budget closures for Canada's watersheds," *Journal of Geophysical Research: Atmospheres*, Vol. 119, pp. 8712–8725, https://doi.org/10.1002/2014JD021951 (accessed February 1, 2021).

Table 2.9
Temperature change, by ecosystem type, land cover or land use and ecoprovince, 1948 to 2016 (Part 1)

		Forest			Freshwater			Peatland
Ecoprovince	Code	Annual temperature change, 1948 to 2016	Season of largest temperature change, 1948 to 2016	Temperature change for season of largest change, 1948 to 2016	Annual temperature change, 1948 to 2016	Season of largest temperature change, 1948 to 2016	Temperature change for season of largest change, 1948 to 2016	Annual temperature change, 1948 to 2016
		°C	season	°C		season	°C	
Northern Arctic Cordillera	1.1	...	...	...	2.2	Fall	3.4	...
Southern Arctic Cordillera	1.2	...	...	...	1.4	Fall	2.1	1.1
Sverdrup Islands	2.1	...	...	...	2.4	Fall	3.5	...
Ellesmere Basin	2.2	...	...	...	2.1	Fall	3.4	...
Victoria Lowlands	2.3	...	...	...	2.6	Winter	4.3	2.6
Parry Channel Plateau	2.4	...	...	...	2.1	Fall	2.8	2.2
Boothia–Foxe Shield	2.5	...	...	...	2.0	Winter	3.0	1.5
Baffin Uplands	2.6	...	...	...	1.6	Winter	2.3	...
Foxe–Boothia Lowlands	2.7	...	...	...	1.8	Winter	2.6	1.7
Amundsen Lowlands	3.1	3.1	Winter	5.2	3.0	Winter	4.9	3.1
Keewatin Lowlands	3.2	2.3	Winter	3.8	2.3	Winter	3.9	2.1
Ungava–Belcher	3.3	1.4	Summer	2.2	1.4	Summer	2.1	1.4
Mackenzie Foothills	4.1	2.8	Winter	5.7	3.0	Winter	5.9	2.9
Great Bear Lowlands	4.2	3.0	Winter	5.4	3.0	Winter	5.3	3.0
Hay–Slave Lowlands	4.3	2.5	Winter	5.3	2.7	Winter	5.4	2.6
Western Taiga Shield	5.1	2.2	Winter	4.0	2.3	Winter	4.1	1.9
Eastern Taiga	5.2	1.2	Summer	1.9	1.3	Summer	2.0	1.2
Labrador Uplands	5.3	0.7	Fall	1.4	0.9	Fall	1.7	0.8
Whale River Lowland	5.4	1.2	Fall	2.1	1.2	Fall	2.1	1.2
Western Boreal Shield	6.1	1.7	Winter	3.2	1.8	Winter	3.4	1.6
Mid-Boreal Shield	6.2	1.3	Winter	2.1	1.3	Winter	2.1	1.3
Eastern Boreal Shield	6.3	0.8	Summer	1.2	0.8	Fall	1.2	0.8
Newfoundland	6.4	0.7	Summer	1.2	0.7	Summer	1.2	0.7
Lake of the Woods	6.5	1.7	Winter	2.7	1.7	Winter	2.7	1.7
Southern Boreal Shield	6.6	1.0	Winter	1.2	1.0	Winter	1.2	1.0
Appalachian–Acadian Highlands	7.1	0.8	Summer	1.1	0.9	Summer	1.1	0.8
Northumberland Lowlands	7.2	0.9	Summer	1.3	0.9	Summer	1.3	0.9
Fundy Uplands	7.3	0.9	Summer	1.4	0.9	Summer	1.4	0.9
Great Lakes–St. Lawrence Lowlands	8.1	1.1	Winter	1.3	1.1	Winter	1.3	1.1
Huron–Erie Plains	8.2	0.9	Spring	1.1	0.9	Spring	1.2	0.9
Boreal Foothills	9.1	2.1	Winter	4.5	2.0	Winter	4.5	2.0
Central Boreal Plains	9.2	2.3	Winter	4.6	2.3	Winter	4.5	2.4
Eastern Boreal Plains	9.3	2.0	Winter	3.6	1.9	Winter	3.5	2.0
Eastern Prairies	10.1	1.7	Winter	3.1	1.8	Winter	3.1	1.8
Parkland Prairies	10.2	1.9	Winter	3.6	2.0	Winter	3.9	1.9
Central Grassland	10.3	1.9	Winter	3.9	1.9	Winter	3.9	...
Northern Yukon Mountains	11.1	3.3	Winter	5.9	3.2	Winter	5.2	3.2
Old Crow–Eagle Plains	11.2	3.2	Winter	5.3	3.2	Winter	5.1	3.2
Ogilvie Mountains	11.3	3.3	Winter	6.2	3.3	Winter	6.4	3.3
Mackenzie–Selwyn Mountains	11.4	2.7	Winter	6.1	2.8	Winter	6.1	2.3
Wrangel Mountains	12.1	2.6	Winter	6.0	2.5	Winter	5.8	...
Northern Boreal Cordillera	12.2	2.4	Winter	6.0	2.4	Winter	6.0	2.4
Southern Boreal Cordillera	12.3	2.1	Winter	5.1	2.1	Winter	5.2	2.0
Western Boreal Cordillera	12.4	3.0	Winter	6.7	2.9	Winter	6.7	2.9
Georgia Depression	13.1	1.5	Summer	1.7	1.5	Summer	1.7	1.5

Table 2.9
Temperature change, by ecosystem type, land cover or land use and ecoprovince, 1948 to 2016 (Part 1)

		Forest			Freshwater			Peatland
Ecoprovince	Code	Annual temperature change, 1948 to 2016	Season of largest temperature change, 1948 to 2016	Temperature change for season of largest change, 1948 to 2016	Annual temperature change, 1948 to 2016	Season of largest temperature change, 1948 to 2016	Temperature change for season of largest change, 1948 to 2016	Annual temperature change, 1948 to 2016
		°C	season	°C		season	°C	
Southern Coastal Mountains	13.2	1.7	Winter	2.4	1.7	Winter	2.5	1.7
Northern Coastal Mountains	13.3	1.9	Winter	3.9	2.0	Winter	4.2	1.9
Northern Montane Cordillera	14.1	2.1	Winter	4.3	2.2	Winter	4.4	2.2
Central Montane Cordillera	14.2	1.9	Winter	3.2	2.0	Winter	3.3	1.9
Southern Montane Cordillera	14.3	2.0	Winter	2.6	2.0	Winter	2.6	1.9
Columbia Montane Cordillera	14.4	1.7	Winter	2.9	1.7	Winter	2.8	1.8
Hudson Bay Coastal Plains	15.1	1.4	Winter	2.5	1.5	Winter	2.6	1.4
Hudson–James Lowlands	15.2	1.2	Winter	1.9	1.2	Winter	1.9	1.2

… not applicable

Notes: This table provides temperature trend data for various classes of ecosystem, land cover or land use. These areas represented by the forest and the farm area classes differ from areas reported in Table 1. Each class is treated independently from other classes and overlaps exist. Caution should be used when analyzing trends in the northern Arctic islands and along the Yukon–Alaska border because of lower climate station densities.

Sources: Statistics Canada, Environment and Energy Statistics Division, 2021, special tabulation based on Environment and Climate Change Canada (ECCC), *Canadian Gridded Temperature and Precipitation Anomalies (CANGRD)*, https://open.canada.ca/data/en/dataset/3d4b68a5-13bc-48bb-ad10-801128aa6604#wb-auto-6 (accessed May 15, 2020); ECCC, *Climate Trends and Variations Bulletin*, https://www.canada.ca/en/environment-climate-change/services/climate-change/science-research-data/climate-trends-variability/trends-variations.html (accessed May 15, 2020); Beaudoin, A., et al., 2017, *Species composition, forest properties and land cover types across Canada's forests at 250m resolution for 2001 and 2011*, Natural Resources Canada (NRCan), Canadian Forest Service, Laurentian Forestry Centre, https://doi.org/10.23687/ec9e2659-1c29-4ddb-87a2-6aced147a990 (accessed March 31, 2019); Tarnocai, C., I.M. Kettles and B. Lacelle, 2011, *Peatlands of Canada*, Geological Survey of Canada, https://geoscan.nrcan.gc.ca/starweb/geoscan/servlet.starweb?path=geoscan/fulle.web&search1=R=288786 (accessed March 16, 2020); NRCan, Canada Centre for Mapping and Earth Observation (CCMEO), 2018, *Lakes, Rivers and Glaciers in Canada – CanVec Series – Hydrographic Features, 50K*, https://open.canada.ca/data/en/dataset/9d96e8c9-22fe-4ad2-b5e8-94a6991b744b (accessed December 2, 2020); Agriculture and Agri-Food Canada (AAFC), 2016, *Interpolated Census of Agriculture*, https://open.canada.ca/data/en/dataset/1dee8513-5c73-43b6-9446-25f7b985cd00 (accessed December 3, 2020); AAFC, 2015, *Land Use, 1990, 2000 & 2010*, https://open.canada.ca/data/en/dataset/18e3ef1a-497c-40c6-8326-aac1a34a0dec (accessed June 1, 2020); NRCan, CCMEO, 2020, *2010 and 2015 Land Cover of North America at 30 metres,* Ed. 2.0, Commission for Environmental Cooperation (CEC), North American Land Change Monitoring System (accessed December 9, 2020); NRCan, 2017, *Topographic Data of Canada - CanVec Series*, https://open.canada.ca/data/en/dataset/8ba2aa2a-7bb9-4448-b4d7-f164409fe056 (accessed December 9, 2020); Statistics Canada, 2017, *Road Network File*, 2016, https://www150.statcan.gc.ca/n1/en/catalogue/92-500-X (accessed December 21, 2020).

Table 2.9
Temperature change, by ecosystem type, land cover or land use and ecoprovince, 1948 to 2016 (Part 2)

		Agricultural area			Built-up and artificial surfaces			Linear features
Ecoprovince	Code	Annual temperature change, 1948 to 2016	Season of largest temperature change, 1948 to 2016	Temperature change for season of largest change, 1948 to 2016	Annual temperature change, 1948 to 2016	Season of largest temperature change, 1948 to 2016	Temperature change for season of largest change, 1948 to 2016	Annual temperature change, 1948 to 2016
		°C	season	°C		season	°C	
Northern Arctic Cordillera	1.1	…	…	…	.	.	.	.
Southern Arctic Cordillera	1.2	…	…	…	1.8	Winter	2.6	1.8
Sverdrup Islands	2.1	…	…	…	.	.	.	.
Ellesmere Basin	2.2	…	…	…	1.0	Fall	3.4	1.0
Victoria Lowlands	2.3	…	…	…	2.6	Winter	4.0	2.6
Parry Channel Plateau	2.4	…	…	…	2.0	Winter	2.7	2.1
Boothia–Foxe Shield	2.5	…	…	…	1.6	Winter	2.4	1.7
Baffin Uplands	2.6	…	…	…	.	.	.	.
Foxe–Boothia Lowlands	2.7	…	…	…	2.0	Winter	2.9	1.9
Amundsen Lowlands	3.1	…	…	…	2.9	Winter	4.6	3.2
Keewatin Lowlands	3.2	…	…	…	1.8	Winter	3.5	1.9
Ungava–Belcher	3.3	…	…	…	1.3	Summer	2.2	1.4
Mackenzie Foothills	4.1	…	…	…	.	.	.	3.1
Great Bear Lowlands	4.2	…	…	…	.	.	.	3.0
Hay–Slave Lowlands	4.3	2.4	Winter	5.3	2.4	Winter	5.2	2.5
Western Taiga Shield	5.1	…	…	…	1.9	Winter	3.7	2.7
Eastern Taiga	5.2	…	…	…	1.2	Summer	1.9	1.2

Table 2.9
Temperature change, by ecosystem type, land cover or land use and ecoprovince, 1948 to 2016 (Part 2)

		Agricultural area			Built-up and artificial surfaces			
								Linear features
Ecoprovince	Code	Annual temperature change, 1948 to 2016	Season of largest temperature change, 1948 to 2016	Temperature change for season of largest change, 1948 to 2016	Annual temperature change, 1948 to 2016	Season of largest temperature change, 1948 to 2016	Temperature change for season of largest change, 1948 to 2016	Annual temperature change, 1948 to 2016
		°C	season	°C		season	°C	
Labrador Uplands	5.3	…	…	…	0.9	Fall	1.7	0.9
Whale River Lowland	5.4	…	…	…	1.2	Fall	2.0	1.2
Western Boreal Shield	6.1	2.0	Winter	3.7	1.8	Winter	3.5	1.7
Mid-Boreal Shield	6.2	1.0	Summer	1.3	1.2	Winter	1.8	1.2
Eastern Boreal Shield	6.3	0.9	Winter	1.4	0.8	Fall	1.2	0.8
Newfoundland	6.4	0.7	Fall	1.2	0.7	Summer	1.2	0.7
Lake of the Woods	6.5	1.7	Winter	3.0	1.7	Winter	2.7	1.7
Southern Boreal Shield	6.6	1.1	Winter	1.3	1.0	Winter	1.3	1.0
Appalachian–Acadian Highlands	7.1	1.0	Summer	1.2	0.9	Summer	1.1	0.9
Northumberland Lowlands	7.2	0.8	Summer	1.2	0.9	Summer	1.3	0.9
Fundy Uplands	7.3	0.9	Summer	1.3	0.9	Summer	1.4	0.9
Great Lakes–St. Lawrence Lowlands	8.1	1.1	Winter	1.3	1.1	Winter	1.3	1.1
Huron–Erie Plains	8.2	0.9	Spring	1.1	0.9	Spring	1.2	0.9
Boreal Foothills	9.1	1.9	Winter	4.2	2.0	Winter	4.3	2.1
Central Boreal Plains	9.2	2.1	Winter	4.3	2.2	Winter	4.4	2.2
Eastern Boreal Plains	9.3	1.8	Winter	3.3	1.9	Winter	3.4	1.9
Eastern Prairies	10.1	1.7	Winter	3.1	1.7	Winter	3.2	1.7
Parkland Prairies	10.2	1.9	Winter	3.8	1.9	Winter	3.8	1.9
Central Grassland	10.3	1.9	Winter	3.8	1.9	Winter	3.8	1.9
Northern Yukon Mountains	11.1	…	…	…	3.3	Winter	5.8	3.3
Old Crow–Eagle Plains	11.2	…	…	…	3.2	Winter	5.3	3.2
Ogilvie Mountains	11.3	…	…	…	3.3	Winter	6.6	3.3
Mackenzie–Selwyn Mountains	11.4	…	…	…	2.5	Winter	5.8	2.6
Wrangel Mountains	12.1	…	…	…	2.4	Winter	5.6	2.7
Northern Boreal Cordillera	12.2	…	…	…	2.1	Winter	5.5	2.5
Southern Boreal Cordillera	12.3	…	…	…	2.0	Winter	5.1	2.1
Western Boreal Cordillera	12.4	…	…	…	3.0	Winter	6.7	3.0
Georgia Depression	13.1	1.5	Summer	1.7	1.5	Summer	1.8	1.5
Southern Coastal Mountains	13.2	1.9	Winter	2.8	1.7	Winter	2.5	1.7
Northern Coastal Mountains	13.3	…	…	…	1.9	Winter	3.5	2.0
Northern Montane Cordillera	14.1	2.1	Winter	3.7	2.1	Winter	4.0	2.1
Central Montane Cordillera	14.2	2.0	Winter	3.3	2.0	Winter	3.3	1.9
Southern Montane Cordillera	14.3	2.1	Winter	2.7	2.0	Winter	2.6	2.0
Columbia Montane Cordillera	14.4	1.7	Winter	3.0	1.7	Winter	2.7	1.7
Hudson Bay Coastal Plains	15.1	…	…	…	1.5	Winter	2.8	1.5
Hudson–James Lowlands	15.2	…	…	…	1.2	Winter	1.9	1.2

. not available for any reference period
… not applicable

Notes: This table provides temperature trend data for various classes of ecosystem, land cover or land use. These areas represented by the forest and the farm area classes differ from areas reported in Table 1. Each class is treated independently from other classes and overlaps exist. Caution should be used when analyzing trends in the northern Arctic islands and along the Yukon–Alaska border because of lower climate station densities.

Sources: Statistics Canada, Environment and Energy Statistics Division, 2021, special tabulation based on Environment and Climate Change Canada (ECCC), *Canadian Gridded Temperature and Precipitation Anomalies (CANGRD)*, https://open.canada.ca/data/en/dataset/3d4b68a5-13bc-48bb-ad10-801128aa6604#wb-auto-6 (accessed May 15, 2020); ECCC, *Climate Trends and Variations Bulletin*, https://www.canada.ca/en/environment-climate-change/services/climate-change/science-research-data/climate-trends-variability/trends-variations.html (accessed May 15, 2020); Beaudoin, A., et al., 2017, *Species composition, forest properties and land cover types across Canada's forests at 250m resolution for 2001 and 2011*, Natural Resources Canada (NRCan), Canadian Forest Service, Laurentian Forestry Centre, https://doi.org/10.23687/ec9e2659-1c29-4ddb-87a2-6aced147a990 (accessed March 31, 2019); Tarnocai, C., I.M. Kettles and B. Lacelle, 2011, *Peatlands of Canada*, Geological Survey of Canada, https://geoscan.nrcan.gc.ca/starweb/geoscan/servlet.starweb?path=geoscan/fulle.web&search1=R=288786 (accessed March 16, 2020); NRCan, Canada Centre for Mapping and Earth Observation (CCMEO), 2018, *Lakes, Rivers and Glaciers in Canada – CanVec Series – Hydrographic Features, 50K*, https://open.canada.ca/data/en/dataset/9d96e8c9-22fe-4ad2-b5e8-94a6991b744b (accessed December 2, 2020); Agriculture and Agri-Food Canada (AAFC), 2016, *Interpolated Census of Agriculture*, https://open.canada.ca/data/en/dataset/1dee8513-5c73-43b6-9446-25f7b985cd00 (accessed December 3, 2020); AAFC, 2015, *Land Use, 1990, 2000 & 2010*, https://open.canada.ca/data/en/dataset/18e3ef1a-497c-40c6-8326-aac1a34a0dec (accessed June 1, 2020); NRCan, CCMEO, 2020, *2010 and 2015 Land Cover of North America at 30 metres*, Ed. 2.0, Commission for Environmental Cooperation (CEC), North American Land Change Monitoring System (accessed December 9, 2020); NRCan, 2017, *Topographic Data of Canada - CanVec Series*, https://open.canada.ca/data/en/dataset/8ba2aa2a-7bb9-4448-b4d7-f164409fe056 (accessed December 9, 2020); Statistics Canada, 2017, *Road Network File*, 2016, https://www150.statcan.gc.ca/n1/en/catalogue/92-500-X (accessed December 21, 2020).

Table 2.10
Evapotranspiration and potential evapotranspiration change, by ecoprovince, 1979 to 2016

Ecoprovince	Code	Annual evapotrans-piration change, 1979 to 2016	Season of largest evapotrans-piration change, 1979 to 2016	Evapotrans-piration change for season of largest change, 1979 to 2016	Annual potential evapotrans-piration change, 1979 to 2016	Season of largest potential evapotrans-piration change, 1979 to 2016	Potential evapotrans-piration change for season of largest change, 1979 to 2016
		mm	season	mm		season	mm
Northern Arctic Cordillera	1.1	15.0*	Summer*	12.1*	28.9*	Summer*	26.8*
Southern Arctic Cordillera	1.2	0.8[E]	Summer**	-6.0**	-6.9[E]	Summer**	-21.8**
Sverdrup Islands	2.1	4.1**	Fall*	4.3*	23.2*	Summer[E]	10.0[E]
Ellesmere Basin	2.2	3.2[E]	Spring*	2.6*	33.4*	Summer*	31.8*
Victoria Lowlands	2.3	0.0[E]	Fall**	2.5**	32.3*	Summer*	23.1*
Parry Channel Plateau	2.4	-1.3[E]	Summer[E]	-2.6[E]	26.9*	Summer*	26.4*
Boothia–Foxe Shield	2.5	3.9[E]	Spring*	3.0*	26.5*	Summer**	19.2**
Baffin Uplands	2.6	-0.1[E]	Summer[E]	-3.5[E]	-14.3[E]	Summer[E]	-18.8[E]
Foxe–Boothia Lowlands	2.7	2.8[E]	Spring[E]	2.5[E]	13.5[E]	Summer[E]	10.6[E]
Amundsen Lowlands	3.1	4.8[E]	Spring**	3.9**	10.4[E]	Spring[E]	8.0[E]
Keewatin Lowlands	3.2	5.0[E]	Fall**	3.4**	21.0[E]	Summer[E]	13.2[E]
Ungava–Belcher	3.3	-36.2*	Summer*	-33.7*	36.3*	Summer*	17.1*
Mackenzie Foothills	4.1	14.9*	Summer*	8.3*	25.0*	Summer**	12.3**
Great Bear Lowlands	4.2	5.1[E]	Spring[E]	2.6[E]	11.8[E]	Spring[E]	10.3[E]
Hay–Slave Lowlands	4.3	28.4*	Summer[E]	12.8[E]	19.1[E]	Spring**	13.1**
Western Taiga Shield	5.1	-20.4*	Summer*	-18.7*	12.9[E]	Spring[E]	7.3[E]
Eastern Taiga	5.2	14.5*	Fall*	6.3*	51.8*	Spring*	19.0*
Labrador Uplands	5.3	20.3*	Summer*	13.5*	49.3*	Summer*	19.8*
Whale River Lowland	5.4	5.2**	Summer[E]	3.7[E]	27.4*	Spring*	15.2*
Western Boreal Shield	6.1	10.6[E]	Fall*	6.7*	3.5[E]	Fall*	9.4*
Mid-Boreal Shield	6.2	16.7[E]	Fall*	14.6*	21.9[E]	Fall*	20.8*
Eastern Boreal Shield	6.3	43.3*	Summer*	21.2*	68.0*	Fall*	24.8*
Newfoundland	6.4	23.7*	Summer[E]	13.5[E]	40.6*	Fall*	22.1*
Lake of the Woods	6.5	21.3[E]	Fall*	17.4*	15.6[E]	Fall*	19.5*
Southern Boreal Shield	6.6	46.6*	Fall*	24.8*	38.0*	Fall*	24.1*
Appalachian–Acadian Highlands	7.1	76.7*	Summer*	34.4*	64.2*	Fall*	23.6*
Northumberland Lowlands	7.2	35.9*	Fall*	17.4*	29.1**	Fall*	16.8*
Fundy Uplands	7.3	27.7*	Fall*	14.7*	17.2[E]	Fall*	14.2*
Great Lakes–St. Lawrence Lowlands	8.1	34.5*	Spring**	15.1**	56.5*	Fall*	27.8*
Huron–Erie Plains	8.2	16.6[E]	Summer[E]	-16.9[E]	54.1*	Fall*	28.0*
Boreal Foothills	9.1	22.6**	Fall*	12.6*	42.2*	Fall*	18.6*
Central Boreal Plains	9.2	27.5*	Summer*	15.9*	13.4**	Fall**	10.7**
Eastern Boreal Plains	9.3	17.3[E]	Fall*	15.6*	-31.1[E]	Summer*	-43.3*
Eastern Prairies	10.1	63.5*	Summer*	40.3*	-22.6[E]	Summer**	-35.9**
Parkland Prairies	10.2	48.1*	Summer*	41.6*	1.5[E]	Fall*	19.4*
Central Grassland	10.3	45.5*	Summer*	33.3*	23.1[E]	Fall*	29.9*
Northern Yukon Mountains	11.1	-0.5[E]	Summer[E]	-5.8[E]	6.6[E]	Spring[E]	7.5[E]
Old Crow–Eagle Plains	11.2	-15.3[E]	Summer[E]	-18.4[E]	11.2**	Spring[E]	7.3[E]
Ogilvie Mountains	11.3	-1.0[E]	Summer[E]	-2.5[E]	14.0*	Spring[E]	9.3[E]
Mackenzie–Selwyn Mountains	11.4	16.7*	Summer*	10.7*	25.9*	Summer*	17.9*
Wrangel Mountains	12.1	11.0[E]	Spring*	5.0*	44.6**	Summer*	28.1*
Northern Boreal Cordillera	12.2	24.3*	Summer*	13.9*	28.1*	Summer*	14.7*
Southern Boreal Cordillera	12.3	20.6*	Summer*	12.4*	28.9*	Spring[E]	10.4[E]
Western Boreal Cordillera	12.4	12.3[E]	Summer[E]	7.1[E]	24.6*	Summer*	13.2*
Georgia Depression	13.1	42.2[E]	Summer*	27.6*	59.1*	Summer*	26.9*

Table 2.10
Evapotranspiration and potential evapotranspiration change, by ecoprovince, 1979 to 2016

Ecoprovince	Code	Annual evapotranspiration change, 1979 to 2016	Season of largest evapotranspiration change, 1979 to 2016	Evapotranspiration change for season of largest change, 1979 to 2016	Annual potential evapotranspiration change, 1979 to 2016	Season of largest potential evapotranspiration change, 1979 to 2016	Potential evapotranspiration change for season of largest change, 1979 to 2016
		mm	season	mm		season	mm
Southern Coastal Mountains	13.2	33.2**	Summer*	18.1*	49.6*	Spring*	14.3*
Northern Coastal Mountains	13.3	27.0*	Summer*	14.4*	48.2*	Spring*	28.8*
Northern Montane Cordillera	14.1	57.1*	Summer*	33.4*	33.5*	Fall*	11.6*
Central Montane Cordillera	14.2	54.3*	Summer*	30.2*	49.0*	Summer*	17.3*
Southern Montane Cordillera	14.3	32.4*	Spring*	15.7*	64.4*	Summer*	29.3*
Columbia Montane Cordillera	14.4	51.7*	Summer*	17.1*	65.0*	Spring*	21.4*
Hudson Bay Coastal Plains	15.1	7.4E	Fall*	4.2*	11.4E	Fall*	12.5*
Hudson–James Lowlands	15.2	9.8E	Fall*	7.7*	9.5E	Fall*	15.9*

… not applicable
E use with caution
* significantly different from reference category ($p < 0.05$)
** significantly different from reference category ($p < 0.10$)

Notes: To convert evapotranspiration measured in depth in mm to volume per area in m^3/m^2 to divide by 1000. Trends in evapotranspiration and potential evapotranspiration are reported for linear trends to the 90% confidence interval or above. Caution should be used when analyzing trends in the northern Arctic islands and along the Yukon–Alaska border because of lower climate station densities.

Sources: Statistics Canada, Environment and Energy Statistics Division, 2021, special tabulation based on Wang, S., Y. Yang, Y. Luo and A. Rivera, 2013, "Spatial and seasonal variations in evapotranspiration over Canada's landmass," *Hydrology and Earth System Sciences*, Vol. 17, no. 9, pp. 3561-3575, https://doi.org/10.5194/hess-17-3561-2013 (accessed December 1, 2020); Wang, S., et al., 2014, "A national-scale assessment of long-term water budget closures for Canada's watersheds," *Journal of Geophysical Research: Atmospheres*, Vol. 119, pp. 8712–8725, https://doi.org/10.1002/2014JD021951 (accessed February 1, 2021); Li, Z., S. Wang and J. Li, 2020, "Spatial variations and long-term trends of potential evapotranspiration in Canada," *Scientific Reports*, Vol. 10, no. 22089, https://doi.org/10.1038/s41598-020-78994-9 (accessed February 3, 2021).

3.0 Ecosystem condition

Human activities can have a far-reaching impact on ecosystem condition,[50] which relates to the quality of ecosystems and influences their ability to provide ecosystem services. In ecosystem accounting, the assessment of ecosystem condition includes measuring the state and changes over time of many different abiotic, biotic and landscape and seascape characteristics.

3.1 Terrestrial and freshwater ecosystem condition

Canada's diversity of ecosystems, ranging from northern wildernesses, to urban, industrial and agricultural landscapes across the south, can face vastly different pressures from human activity. For example, these pressures may be related to activities that affect land use, pollution emissions and climate change. Some of the key ecosystem condition characteristics for terrestrial and freshwater ecosystems presented in this section relate to abiotic characteristics such as water availability and air quality; biotic characteristics covering forest disturbance and urban greenness; and landscape characteristics on fragmentation and degree of modification. There are many other aspects of ecosystem condition; however, data for many other characteristics have not yet been compiled for Canada at a national scale or by ecosystem type.

Freshwater resources

Canada has abundant freshwater resources, with water held in lakes, wetlands, glaciers, snow and aquifers and runoff flowing into lakes, rivers and streams. These freshwater resources are integral to the functioning of terrestrial and aquatic ecosystems and provide essential benefits to humans.[51]

Total water storage change is an estimate of the change in water stored in the environment as groundwater, soil moisture, surface water, snow and ice estimated using gravity-based measurements from satellites. These changes occur as a result of changing climate conditions, such as increasing temperatures causing glacier melt and changing precipitation patterns.

The largest decreases[52] in water storage from 2002 to 2016 were in ecoprovinces located in the Arctic Cordillera and Northern Arctic, as well as the Boreal Cordillera in the Yukon and northern British Columbia (Map 3.1), where large quantities of freshwater are frozen in permafrost, glaciers and ice caps.[53] For example, in the Northern Arctic Cordillera, water storage has been decreasing at an average rate of 105 mm per year, followed by the Southern Arctic Cordillera (-103 mm/year) and the Ellesmere Basin (-96 mm/year) (Table 3.1).

The decline in water storage in these areas is consistent with observations on temperature increases, permafrost thaw and glacier retreat.[54] The largest temperature increases in Canada are measured in the northwest, driving major changes in ecosystems in the region. For example, thinning alpine glaciers have an impact on water availability in the Prairies, since meltwater from glaciers is a contributor to summer streamflows. Meltwater from ice caps in the Canadian Arctic contributes to global sea level rise and influences salinity levels.[55]

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50 Wiken, E., et al., 1996, *A Perspective on Canada's Ecosystems*, Canadian Council on Ecological Areas, No. 14, Ottawa.

51 Statistics Canada, 2017, "Freshwater in Canada," *Human Activity and the Environment*, Catalogue no. 16-201-X https://www150.statcan.gc.ca/n1/pub/16-201-x/16-201-x2017000-eng.htm; Strayer, D.L. and S.E. Findlay, 2010, "Ecology of freshwater shore zones," *Aquatic Sciences*, Vol. 72, no. 2, https://doi.org/10.1007/s00027-010-0128-9 (accessed July 23, 2020).

52 Statistical significance is assessed at the 90% and the 95% confidence levels.

53 Natural Resources Canada, 2019, *Glaciers*, https://www.nrcan.gc.ca/environment/science/indicators-change/glaciers/11005 (accessed October 13, 2020).

54 Wang, S. and J. Li, 2016, "Terrestrial water storage climatology for Canada from GRACE satellite observations in 2002-2014," *Canadian Journal of Remote Sensing*, Vol. 42, no. 3, pp. 190-202, https://doi.org/10.1080/07038992.2016.1171132 (accessed December 17, 2020); Derksen C., et al., 2019, "Changes in snow, ice, and permafrost across Canada," *Canada's Changing Climate Report*, Bush, E. and D.S. Lemmen (eds.), https://changingclimate.ca/CCCR2019/chapter/5-0/ (accessed June 26, 2020).

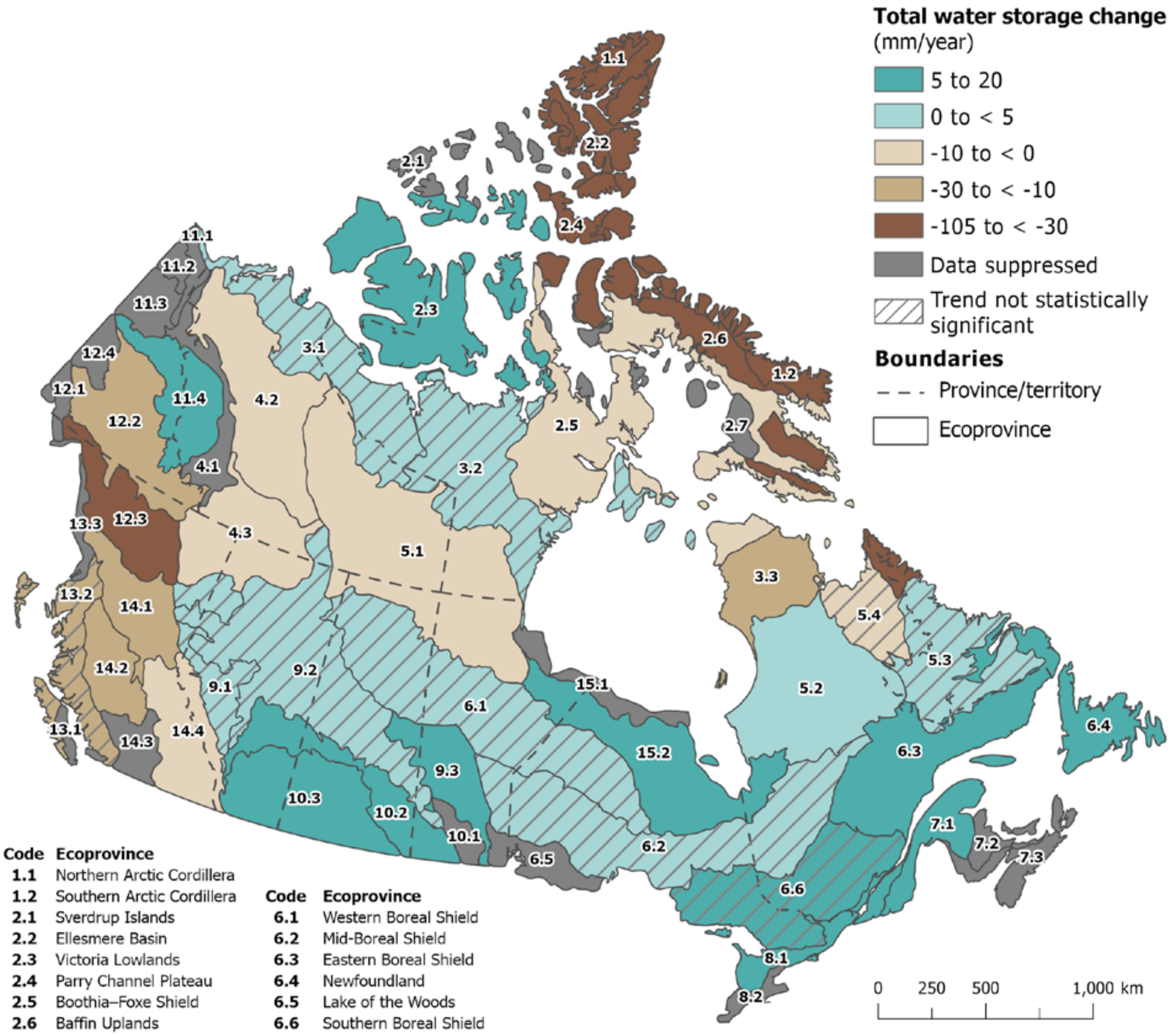
55 Frederikse, Thomas et al., 2020, "The causes of sea-level rise since 1900," *Nature*, Vol. 584, pp. 393-397, https://doi.org/10.1038/s41586-020-2591-3 (accessed April 26, 2021); Greenan, B.J.W., et al., 2019, "Changes in oceans surrounding Canada," *Canada's Changing Climate Report*, Bush, E. and D.S. Lemmen (eds.), Government of Canada, Ottawa, Ontario, https://changingclimate.ca/CCCR2019/chapter/7-0/ (accessed June 26, 2020).

While decreases in water storage occurred in the north, increases[56] occurred in the Eastern Boreal Plains (+19 mm/year), Central Grassland (+12 mm/year) and Parkland Prairies (+11 mm/year) ecoprovinces and in the Appalachian–Acadian Highlands (+15 mm/year) on the East Coast. These increases generally align with increasing precipitation trends and in the Prairies also reflect the recovery of groundwater storage following depletion from the historic 2001 drought across western Canada.[57]

56 Statistical significance is assessed at the 90% and the 95% confidence levels.

57 Wang, S., et al., 2015, "Long-term water budget imbalances and error sources for cold region drainage basins," *Hydrological Processes*, Vol. 29, no. 9, pp. 2125–2136, https://doi.org/10.1002/hyp.10343 (accessed March 23, 2021).

Map 3.1
Annual total water storage change, by ecoprovince, 2002 to 2016



Code	Ecoprovince
1.1	Northern Arctic Cordillera
1.2	Southern Arctic Cordillera
2.1	Sverdrup Islands
2.2	Ellesmere Basin
2.3	Victoria Lowlands
2.4	Parry Channel Plateau
2.5	Boothia–Foxe Shield
2.6	Baffin Uplands
2.7	Foxe–Boothia Lowlands
3.1	Amundsen Lowlands
3.2	Keewatin Lowlands
3.3	Ungava–Belcher
4.1	Mackenzie Foothills
4.2	Great Bear Lowlands
4.3	Hay–Slave Lowlands
5.1	Western Taiga Shield
5.2	Eastern Taiga
5.3	Labrador Uplands
5.4	Whale River Lowland

Code	Ecoprovince
6.1	Western Boreal Shield
6.2	Mid-Boreal Shield
6.3	Eastern Boreal Shield
6.4	Newfoundland
6.5	Lake of the Woods
6.6	Southern Boreal Shield
7.1	Appalachian–Acadian Highlands
7.2	Northumberland Lowlands
7.3	Fundy Uplands
8.1	Great Lakes–St. Lawrence
8.2	Huron–Erie Plains
9.1	Boreal Foothills
9.2	Central Boreal Plains
9.3	Eastern Boreal Plains
10.1	Eastern Prairies
10.2	Parkland Prairies
10.3	Central Grassland

Code	Ecoprovince
11.2	Old Crow–Eagle Plains
11.3	Ogilvie Mountains
11.4	Mackenzie–Selwyn Mountains
12.1	Wrangel Mountains
12.2	Northern Boreal Cordillera
12.3	Southern Boreal Cordillera
12.4	Western Boreal Cordillera
13.1	Georgia Depression
13.2	Southern Coastal Mountains

Code	Ecoprovince
13.3	Northern Coastal Mountains
11.1	Northern Yukon Mountains
14.1	Northern Montane Cordillera
14.2	Central Montane Cordillera
14.3	Southern Montane Cordillera
14.4	Columbia Montane Cordillera
15.1	Hudson Bay Coastal Plains
15.2	Hudson–James Lowlands

Notes: Total water storage change is an estimate of the change in water stored in the environment as groundwater, soil moisture, surface water, snow and ice. Caution must be used in interpreting total water storage change results because of the level of uncertainty in the models, the short length of the time series, and the coarse resolution of the data. Data were suppressed for smaller ecoprovinces using a threshold of approximately 90,000 km^2. Statistically significant linear trends are presented at the 90% confidence interval or above.

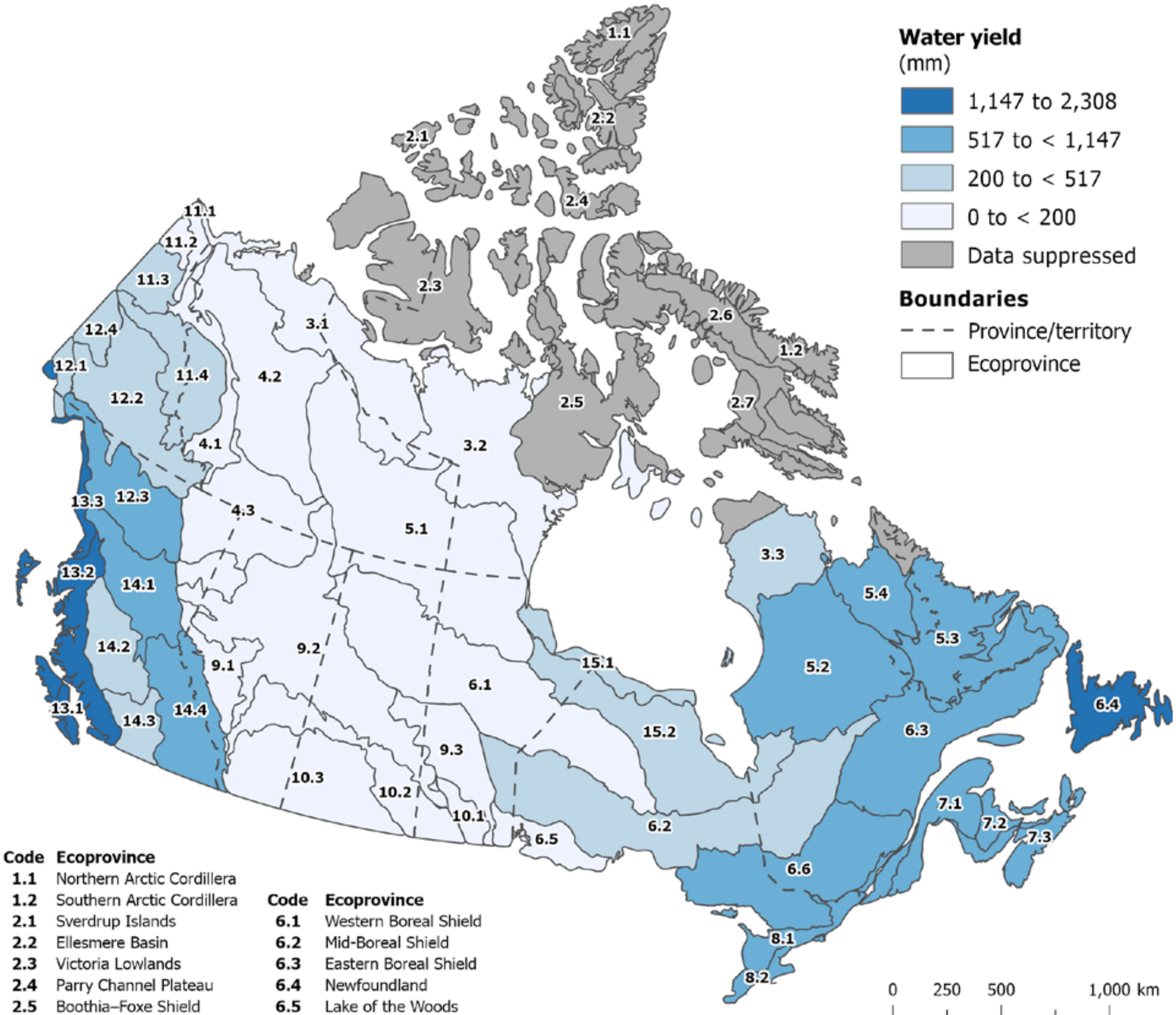
Sources: Statistics Canada, Environment and Energy Statistics Division, 2021, special tabulation based on Wang, S., et al., 2014, "Assessment of water budget for sixteen large drainage basins in Canada," *Journal of Hydrology,* Vol. 512, pp. 1-15; Wang, S. and J. Li, 2016, "Terrestrial water storage climatology for Canada from GRACE satellite observations in 2002-2014," *Canadian Journal of Remote Sensing,* Vol. 42, no. 3, pp. 190-202; Li, J., S. Wang and F. Zhou, 2016, "Time series analysis of long-term terrestrial water storage over Canada from GRACE satellites using principal component analysis," *Canadian Journal of Remote Sensing,* Vol. 42, no. 3, pp. 161-170.

Canada's average annual water yield was 3,514 km^3 from 1971 to 2014, equivalent to a depth of 350 mm across the extent of the country. This renewable freshwater production varies spatially across the country's diverse landscape and also varies temporally—monthly, seasonally and yearly.

From 1971 to 2014, ecoprovinces within the Pacific Maritime ecozone in British Columbia had the highest average annual water yield per unit area (Map 3.2 and Table 3.1). Within the Pacific Maritime ecozone, the Southern Coastal Mountains ecoprovince had the highest water yield per area at 2,308 mm, followed by the neighbouring Georgia Depression (1,696 mm) and Northern Coastal Mountains (1,652 mm). Other ecoprovinces with high water yields per area were Newfoundland (1,147 mm) and the Fundy Uplands (986 mm).

The lowest water yields were found in the Prairies and the Boreal Plains ecozones, which cover most of Alberta, Saskatchewan and Manitoba. At the ecoprovince level, the lowest yields were found in the Central Grassland (20 mm), the Parkland Prairies (42 mm), the Eastern Prairies (68 mm) and the Central Boreal Plains (83 mm).

Map 3.2
Average annual water yield per area, by ecoprovince, 1971 to 2014



Code	Ecoprovince
1.1	Northern Arctic Cordillera
1.2	Southern Arctic Cordillera
2.1	Sverdrup Islands
2.2	Ellesmere Basin
2.3	Victoria Lowlands
2.4	Parry Channel Plateau
2.5	Boothia–Foxe Shield
2.6	Baffin Uplands
2.7	Foxe–Boothia Lowlands
3.1	Amundsen Lowlands
3.2	Keewatin Lowlands
3.3	Ungava–Belcher
4.1	Mackenzie Foothills
4.2	Great Bear Lowlands
4.3	Hay–Slave Lowlands
5.1	Western Taiga Shield
5.2	Eastern Taiga
5.3	Labrador Uplands
5.4	Whale River Lowland

Code	Ecoprovince
6.1	Western Boreal Shield
6.2	Mid-Boreal Shield
6.3	Eastern Boreal Shield
6.4	Newfoundland
6.5	Lake of the Woods
6.6	Southern Boreal Shield
7.1	Appalachian–Acadian Highlands
7.2	Northumberland Lowlands
7.3	Fundy Uplands
8.1	Great Lakes–St. Lawrence
8.2	Huron–Erie Plains
9.1	Boreal Foothills
9.2	Central Boreal Plains
9.3	Eastern Boreal Plains
10.1	Eastern Prairies
10.2	Parkland Prairies
10.3	Central Grassland

Code	Ecoprovince
11.2	Old Crow–Eagle Plains
11.3	Ogilvie Mountains
11.4	Mackenzie–Selwyn Mountains
12.1	Wrangel Mountains
12.2	Northern Boreal Cordillera
12.3	Southern Boreal Cordillera
12.4	Western Boreal Cordillera
13.1	Georgia Depression
13.2	Southern Coastal Mountains

Code	Ecoprovince
13.3	Northern Coastal Mountains
11.1	Northern Yukon Mountains
14.1	Northern Montane Cordillera
14.2	Central Montane Cordillera
14.3	Southern Montane Cordillera
14.4	Columbia Montane Cordillera
15.1	Hudson Bay Coastal Plains
15.2	Hudson–James Lowlands

Notes: Water yield is an estimate of freshwater runoff. Data were suppressed at the ecoprovince level for the North.

Sources: Statistics Canada, Environment and Energy Statistics Division, 2021, *Table 38-10-0091-01;* Spence, C. and A. Burke, 2008, "Estimates of Canadian Arctic Archipelago runoff from observed hydrometric data," *Journal of Hydrology,* Vol. 362, pp. 247-259.

Ambient air quality

Ambient air quality varies by region, city, and neighbourhood since it reflects the quantity and location of air pollutant emissions and meteorological conditions such as wind speed, wind direction, temperature and precipitation.[58] Air emissions can result from human sources including motor vehicles, power generating plants, oil and gas production, industrial facilities and fertilizer use. In addition to having impacts on human health, emissions can also affect ecosystems, for example through acid deposition on forests.[59] Natural sources of air pollutants include forest fires, dust, lightning and even trees,[60] which can release pollen and volatile organic compounds (VOCs).

Canadian Ambient Air Quality Standards (CAAQS)[61] exist for fine particulate matter ($PM_{2.5}$), ground level ozone (O_3), sulphur dioxide (SO_2) and nitrogen dioxide (NO_2) and are a driver for air quality management across the country. In 2016, average ambient concentrations of $PM_{2.5}$ were 6.4 $\mu g/m^3$, 32.5 ppb for ground-level ozone, 7.8 ppb for nitrogen dioxide, 1.0 ppb for sulphur dioxide and 58.4 ppb carbon for volatile organic compounds. Between 2002 and 2016, average annual and peak ambient air concentrations of SO_2 and NO_2, as well as average concentrations of VOCs decreased (Chart 3.1 and 3.2).[62] While peak O_3 concentrations decreased, the average annual concentrations remained stable. No long-term trends were found for $PM_{2.5}$, whose concentrations remained relatively stable.

Average ambient levels of pollutants varied by region and urban area (Table 3.2). Higher concentrations of $PM_{2.5}$ were detected in the urban areas of Windsor, Québec City and Regina in 2016. For ozone, the regional average ambient levels ranged from 26.6 ppb of O_3 in British Columbia to 37.5 ppb of O_3 in southern Ontario in 2016, with urban areas in Ontario having among the highest concentrations. Ambient air concentrations for SO_2 and NO_2 were lowest in Atlantic Canada (0.6 ppb of SO_2 and 3.1 ppb of NO_2) and highest in southern Quebec for SO_2 (1.7 ppb) and British Columbia for NO_2 (9.2 ppb).

58 Canadian Council of Ministers of the Environment, 2017, *Canada's Air*, https://ccme.ca/en/air-quality-report (accessed February 14, 2020); Evans, G., 2019, *Near-Road Air Pollution Pilot Study Final Report*, http://hdl.handle.net/1807/96917 (accessed February 27, 2020); Cakmak, S., et al., 2018, "Associations between long-term $PM_{2.5}$ and ozone exposure and mortality in the Canadian Census Health and Environment Cohort (CANCHEC), by spatial synoptic classification zone," *Environment International*, Vol. 111, https://doi.org/10.1016/j.envint.2017.11.030 (accessed February 27, 2020).

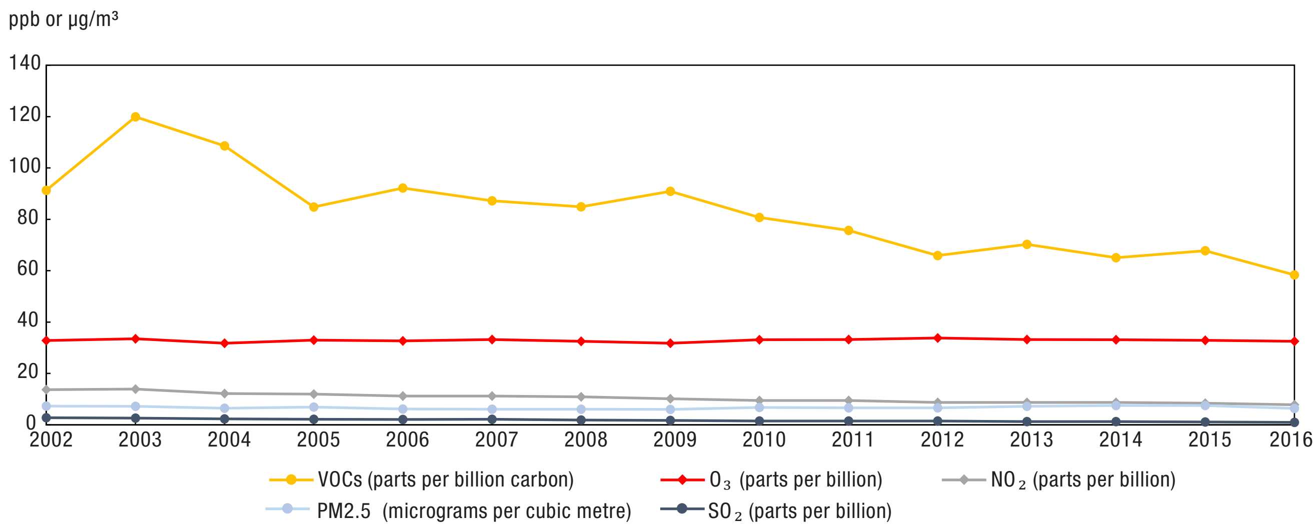
59 Carou, S., et al., 2008, *A National Picture of Acid Deposition Critical Loads for Forest Soils in Canada*, Report prepared for the CCME Acid Rain Task Group, p. 1–8, https://central.bac-lac.gc.ca/.item?id=PN1412&op=pdf&app=Library (accessed December 17, 2021); Fraser, G. A., et al., 1985, *The Potential Impact of the Long Range Transport of Air Pollutants on Canadian Forests: Report of a Scientific Opinion Survey*, Information Report E-X-36, http://cfs.nrcan.gc.ca/pubwarehouse/pdfs/24756.pdf (accessed October 16, 2017).

60 California Air Resources Board, 2012, *Trees and Air Quality*, https://ww2.arb.ca.gov/sites/default/files/classic//cc/capandtrade/offsets/CARB_2012_trees_and_air_quality.pdf (accessed February 20, 2020); Environment and Climate Change Canada, 2016, *Common air pollutants: ground-level ozone*, https://www.canada.ca/en/environment-climate-change/services/air-pollution/pollutants/common-contaminants/ground-level-ozone.html (accessed February 20, 2020).

61 The Canadian Air Quality Standards (CAAQS) were developed by the Canadian Council of Ministers of the Environment as outdoor air quality targets that are to drive air quality management across Canada, under the *Canadian Environmental Protection Act*. See: Canadian Council of Ministers of the Environment, 2017.

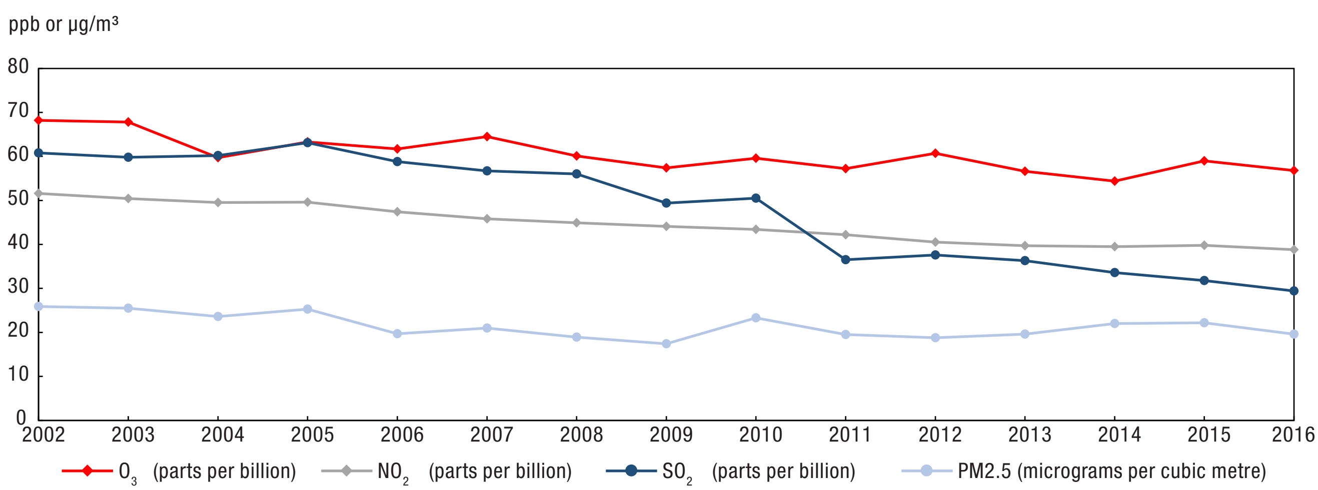
62 Ambient air quality concentrations are averaged from monitoring station data. These stations are spread across the country, but are more concentrated in urban areas. For more information about the methodology and included stations, see: Environment and Climate Change Canada, 2018, *Canadian Environmental Sustainability Indicators: Air quality*, https://www.canada.ca/en/environment-climate-change/services/environmental-indicators/air-quality.html#def (accessed May 8, 2020).

Chart 3.1
Average ambient air quality, Canada, 2002 to 2016



Notes: Ambient air quality concentrations are averaged from monitoring station data. These stations are spread across the country, but are more concentrated in urban areas. For more information about the methodology and included stations, see the CESI Air Quality Indicator.
Sources: Environment and Climate Change Canada, 2018, "Air Quality," *Canadian Environmental Sustainability Indicators*, https://www.canada.ca/en/environment-climate-change/services/environmental-indicators/air-quality.html (accessed May 11, 2020), based on data from the National Air Pollutant Surveillance Program, https://www.canada.ca/en/environment-climate-change/services/air-pollution/monitoring-networks-data/national-air-pollution-program.html.

Chart 3.2
Peak ambient air quality, Canada, 2002 to 2016



Notes: Ambient air quality concentrations are averaged from monitoring station data. These stations are spread across the country, but are more concentrated in urban areas. For more information about the methodology and included stations, see the CESI Air Quality Indicator.
Sources: Environment and Climate Change Canada, 2018, "Air Quality," *Canadian Environmental Sustainability Indicators*, https://www.canada.ca/en/environment-climate-change/services/environmental-indicators/air-quality.html (accessed May 11, 2020), based on data from the National Air Pollutant Surveillance Program, https://www.canada.ca/en/environment-climate-change/services/air-pollution/monitoring-networks-data/national-air-pollution-program.html.

Forest condition

There are many different variables that can be used to track the condition of forest ecosystems. For example, forest biodiversity and composition (e.g., genus, species), structure (e.g., age class, biomass), timber stocks, natural disturbances and harvesting are important measures of the biotic condition of forests.[63] Natural disturbances, including wildfire, insect and disease outbreaks, landslides and windthrow, are important ecosystem processes that affect and shape forests. These disturbances can occur on a local to extensive geographical scale and effects may be limited to small reductions in tree health or growth, but can also result in significant mortality.

The areas affected by natural disturbances fluctuate widely from year to year and by region. For example, outbreaks of insects, such as spruce budworm, forest tent caterpillar and mountain pine beetle, can be short lived or may last for many years. These pests can reduce tree growth, damage trees and lead to increased mortality. In 2018, approximately 5% of forest area experienced moderate or severe insect infestations causing defoliation and tree mortality.[64]

The 2017 and 2018 fire seasons were particularly severe in British Columbia, while 2019 was a more severe year in Alberta.[65] From 1986 to 2019, the total area affected by forest fires in Canada ranged from a low of 6,264 km^2 in 2001 to a high of 70,951 km^2 in 1995.[66] On average, the area burned each year represents less than 1% of forest area, with the largest proportion of forest fires in unmanaged forest areas that have limited or no access and no active fire suppression. Over the period from 1986 to 2019, forest fires have burned large areas across the boreal zone, particularly in the Western Boreal Shield and Western Taiga Shield ecoprovinces (Map 3.3 and Table 3.3).

Similarly, forest harvesting affects a small proportion of the country's forests, but these activities are more localized in temperate forests and in the southern parts of the boreal zone.[67] On average, the area harvested each year represents less than 0.3% of the total forest area. In 2018, the area harvested totalled 7,472 km^2, up from the low of 6,132 km^2 set in 2009 following the 2008 financial crisis and U.S. housing market crash.[68]

63 Montréal Process Working Group, 2015, "Criteria and indicators for the conservation and sustainable management of temperate and boreal forests," *The Montréal Process*, Fifth Edition, https://www.montrealprocess.org/documents/publications/techreports/MontrealProcessSeptember2015.pdf (accessed October 27, 2020).

64 National Forestry Database, 2020, *Forest insects*, http://nfdp.ccfm.org/en/data/insects.php (accessed July 15, 2020).

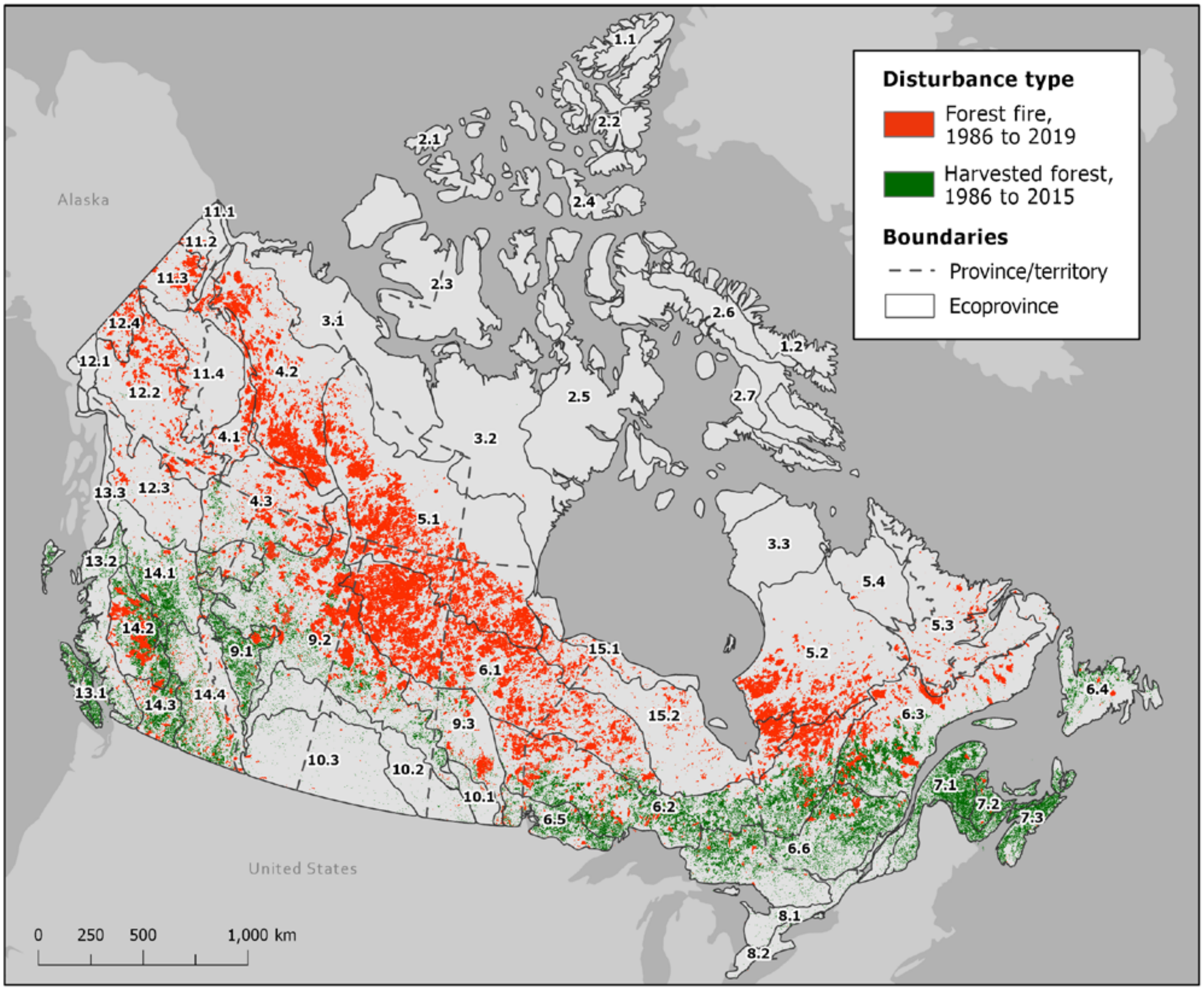
65 Wang, J. and K. Strong, 2019, "British Columbia's forest fires, 2018," *Environment Fact Sheets*, Catalogue no. 16-508-X, https://www150.statcan.gc.ca/n1/pub/16-508-x/16-508-x2019002-eng.htm (accessed May 5, 2021). National Forestry Database, 2020, Forest fires, http://nfdp.ccfm.org/en/data/fires.php (accessed May 7, 2021).

66 National Forestry Database, 2020; Statistics Canada 2018, "Forests in Canada," *Human Activity and the Environment*, Catalogue no. 16-201-X https://www150.statcan.gc.ca/n1/pub/16-201-x/16-201-x2018001-eng.htm (accessed July 15, 2020).

67 Natural Resources Canada, 2019, "Canada's forests: Managing for the future," *The State of Canada's Forests 2019*, https://www.nrcan.gc.ca/sites/www.nrcan.gc.ca/files/forest/sof2019/map/Map_EN_w1140px.jpg (accessed June 9, 2020).

68 National Forestry Database, 2020, Harvest, http://nfdp.ccfm.org/en/data/harvest.php (accessed July 15, 2020).

Map 3.3
Forest fire and harvesting



Code	Ecoprovince	Code	Ecoprovince	Code	Ecoprovince	Code	Ecoprovince
1.1	Northern Arctic Cordillera	4.3	Hay–Slave Lowlands	8.1	Great Lakes–St. Lawrence	12.4	Western Boreal Cordillera
1.2	Southern Arctic Cordillera	5.1	Western Taiga Shield	8.2	Huron–Erie Plains	13.1	Georgia Depression
2.1	Sverdrup Islands	5.2	Eastern Taiga	9.1	Boreal Foothills	13.2	Southern Coastal Mountains
2.2	Ellesmere Basin	5.3	Labrador Uplands	9.2	Central Boreal Plains	13.3	Northern Coastal Mountains
2.3	Victoria Lowlands	5.4	Whale River Lowland	9.3	Eastern Boreal Plains	11.1	Northern Yukon Mountains
2.4	Parry Channel Plateau	6.1	Western Boreal Shield	10.1	Eastern Prairies	14.1	Northern Montane Cordillera
2.5	Boothia–Foxe Shield	6.2	Mid-Boreal Shield	10.2	Parkland Prairies	14.2	Central Montane Cordillera
2.6	Baffin Uplands	6.3	Eastern Boreal Shield	10.3	Central Grassland	14.3	Southern Montane Cordillera
2.7	Foxe–Boothia Lowlands	6.4	Newfoundland	11.2	Old Crow–Eagle Plains	14.4	Columbia Montane Cordillera
3.1	Amundsen Lowlands	6.5	Lake of the Woods	11.3	Ogilvie Mountains	15.1	Hudson Bay Coastal Plains
3.2	Keewatin Lowlands	6.6	Southern Boreal Shield	11.4	Mackenzie–Selwyn Mountains	15.2	Hudson–James Lowlands
3.3	Ungava–Belcher	7.1	Appalachian–Acadian Highlands	12.1	Wrangel Mountains		
4.1	Mackenzie Foothills	7.2	Northumberland Lowlands	12.2	Northern Boreal Cordillera		
4.2	Great Bear Lowlands	7.3	Fundy Uplands	12.3	Southern Boreal Cordillera		

Notes: Harvest data are identified by 30 m Landsat remote sensing. Fire data are taken from the *National Burned Area Composite*, part of the Fire Monitoring, Accounting and Reporting System, based on the integration of data from fine and coarse resolution satellite data from Natural Resources Canada and Provincial, Territorial and Parks Canada Agencies. These data differ from the harvesting and burned area totals reported in the National Forestry Database, which are based on different methodologies.
Sources: Natural Resources Canada, Canadian Forest Service, 2020, *National Burned Area Composite (NBAC)*; Guindon, L., et al., 2017, *Canada Landsat Disturbance (CanLaD): a Canada-wide Landsat-based 30-m resolution product of fire and harvest detection and attribution since 1984.*

Urban greenness

The presence and health of trees and other vegetation are also important characteristics of ecosystem condition in urban areas. Satellite imagery can be used to track the relative greenness of cities and towns over time.[69] The level of urban greenness depends on natural environmental conditions, for example climate, as well as differences in local land use.[70] Urbanization processes can result in significant reductions in the quantity of 'green' areas that have more vegetation and related increases in 'grey' areas that are predominantly covered by buildings, impervious surfaces, bare soil and low-density vegetation (Figure 3.1). Increases in greenness seen over longer periods in urban areas can be linked to the introduction or maturation of vegetation in yards and gardens. Interannual variations in urban vegetation quantity and condition can also be related to natural factors such as drought, insects or disease.

Figure 3.1
Example of urban pixels classed as green or grey

Green **Grey**

Note: The green or grey class is based on the MODIS NDVI value.

In 2019, 76% of the area of population centres in southern Canada was classed as green in summer (Table 3.4). This percentage varied based on city size and regional differences. In large urban population centres, an average of 70% of the total land area was classed as green, compared to 78% in medium population centres and 87% in small population centres. In general, the proportion of green area in population centres in 2019 was lower than in 2001. Approximately three-quarters of large urban (77%) and medium (71%) population centres experienced this drop in greenness levels, despite widespread drought conditions across the Canadian south-west and an abnormally dry summer in Ontario and Quebec in 2001.[71] In comparison, 35% of small population centres experienced a drop in greenness, while 33% saw no change in greenness levels.

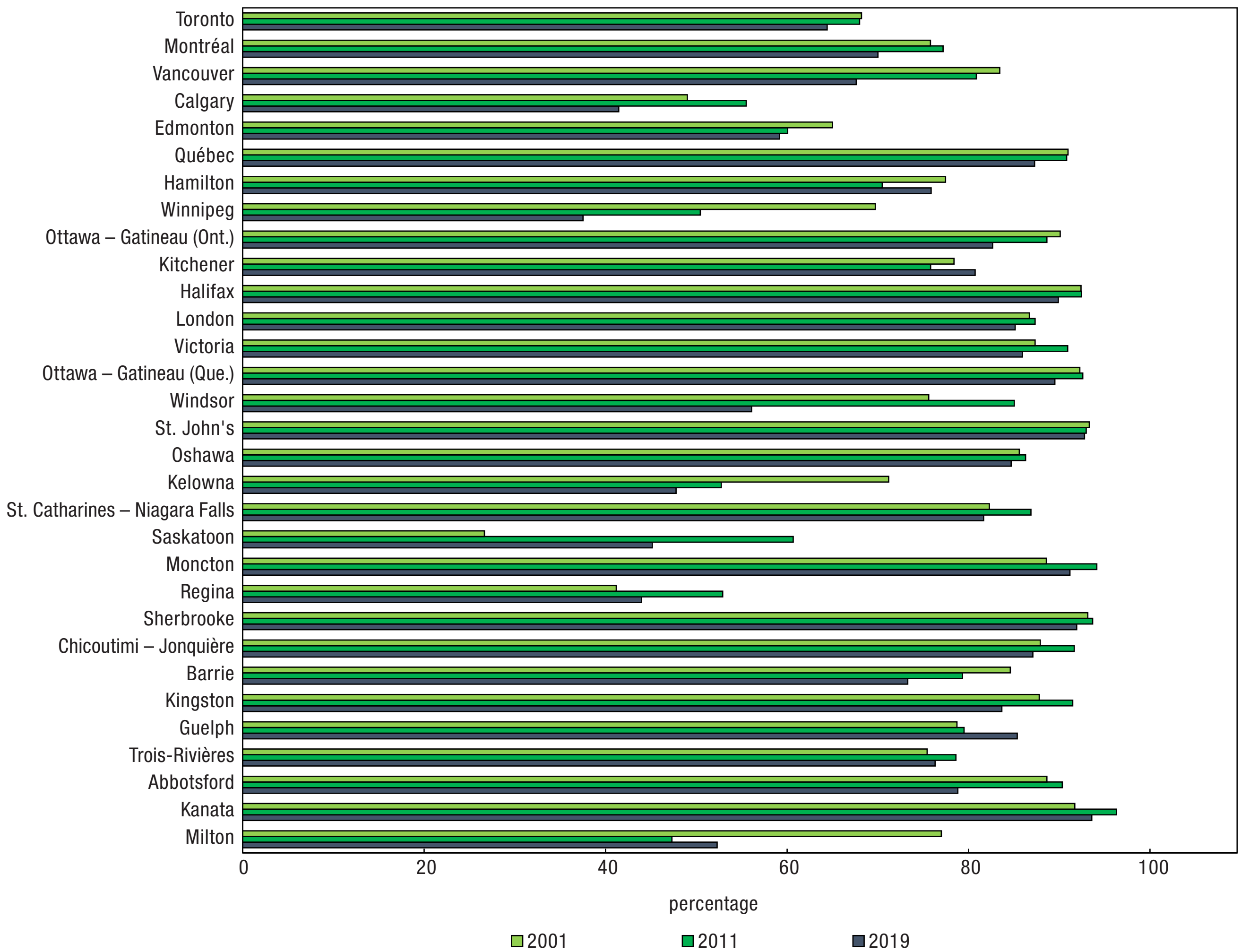
69 Estimates of greenness presented here are based on the normalized difference vegetation index (NDVI) from MODIS. For more information, see Appendix A. Corbane et al., (2020) have proposed greenness, as measured using NDVI, as a proxy indicator to measure progress towards United Nations Sustainable Development Goal (SDG) Target 11.7. Corbane, C., et al., 2020, "The grey-green divide: multi-temporal analysis of greenness across 10,000 urban centres derived from the Global Human Settlement Layer (GHSL)," *International Journal of Digital Earth*, 2020, Vol. 13, no. 1, pp. 101-118. https://doi.org/10.1080/17538947.2018.1530311 (accessed September 21, 2020).

70 Nowak, D. J., et al., 1996, "Measuring and analyzing urban tree cover," *Landscape and Urban Planning*, Vol. 36, no. 1, https://doi.org/10.1016/S0169-2046(96)00324-6 (accessed September 18, 2020).

71 Wheaton, E., et al., 2008, "Dry times: hard lessons from the Canadian drought of 2001 and 2002," *The Canadian Geographer*, Vol. 52, no. 2, https://onlinelibrary.wiley.com/doi/full/10.1111/j.1541-0064.2008.00211.x (accessed September 18, 2020); Statistics Canada, 2002, "The western Canadian drought of 2001 – how dry was it?, *Vista on the Agri-Food Industry and the Farm Community*, Catalogue no. 21-004-XIE, http://publications.gc.ca/Collection/Statcan/21-004-X/21-004-XIE2002103.pdf (accessed September 18, 2020); Hogg, E.H., J.P. Brandt and M. Michaelian, 2008, "Impacts of a regional drought on the productivity, dieback, and biomass of western Canadian aspen forests," *Canadian Journal of Forest Research*, Vol. 38, no. 6, https://doi.org/10.1139/X08-001 (accessed September 18, 2020).

Winnipeg, Milton, Kelowna, Windsor and Vancouver experienced the largest decreases in the share that was classed as green from 2001 to 2019 (Chart 3.3). These larger decreases in greenness may have been driven by the contributions of urbanization and moderate drought conditions in 2019. For example, Milton experienced population growth of 350% from 2001 to 2016.[72] However, decreases in Winnipeg and Windsor may also have been amplified by the impact of the emerald ash borer—an exotic invasive insect that has had a large impact on trees in some regions.[73]

Chart 3.3
Urban greenness, by large urban population centre, 2001, 2011 and 2019



Notes: Estimates of population centre greenness are based on the Normalized Difference Vegetation Index (NDVI) from MODIS. Large urban population centres are presented here in order by size of land area, from largest to smallest. For more information, see Appendix A.
Source: Statistics Canada, 2020, *Corrected representation of the NDVI using historical MODIS satellite images* (250 m resolution) from 2000 to 2019, https://open.canada.ca/data/en/dataset/dc700f75-19d8-4913-9846-78615ca93784 (accessed April 29, 2020).

72 Statistics Canada, Environment and Energy Statistics Division, special tabulation from the Census of Population, using 2016 population centre boundaries.

73 Natural Resources Canada, 2020, *Emerald Ash Borer*, https://www.nrcan.gc.ca/our-natural-resources/forests-forestry/wildland-fires-insects-disturban/top-forest-insects-diseases-cana/emerald-ash-borer/13377 (accessed September 18, 2020); Epp, B., 2018, *Emerald Ash Borer Management in Manitoba*, Manitoba Sustainable Development, http://www.cif-ifc.org/wp-content/uploads/2018/10/ReducedFileSize-3-EAB-Manitoba-Brad-Epp.pdf (accessed September 21, 2020); City of Winnipeg, 2020, *Emerald Ash Borer (EAB)*, https://www.winnipeg.ca/PublicWorks/parksOpenSpace/UrbanForestry/EmeraldAsh.stm (accessed September 21, 2020).

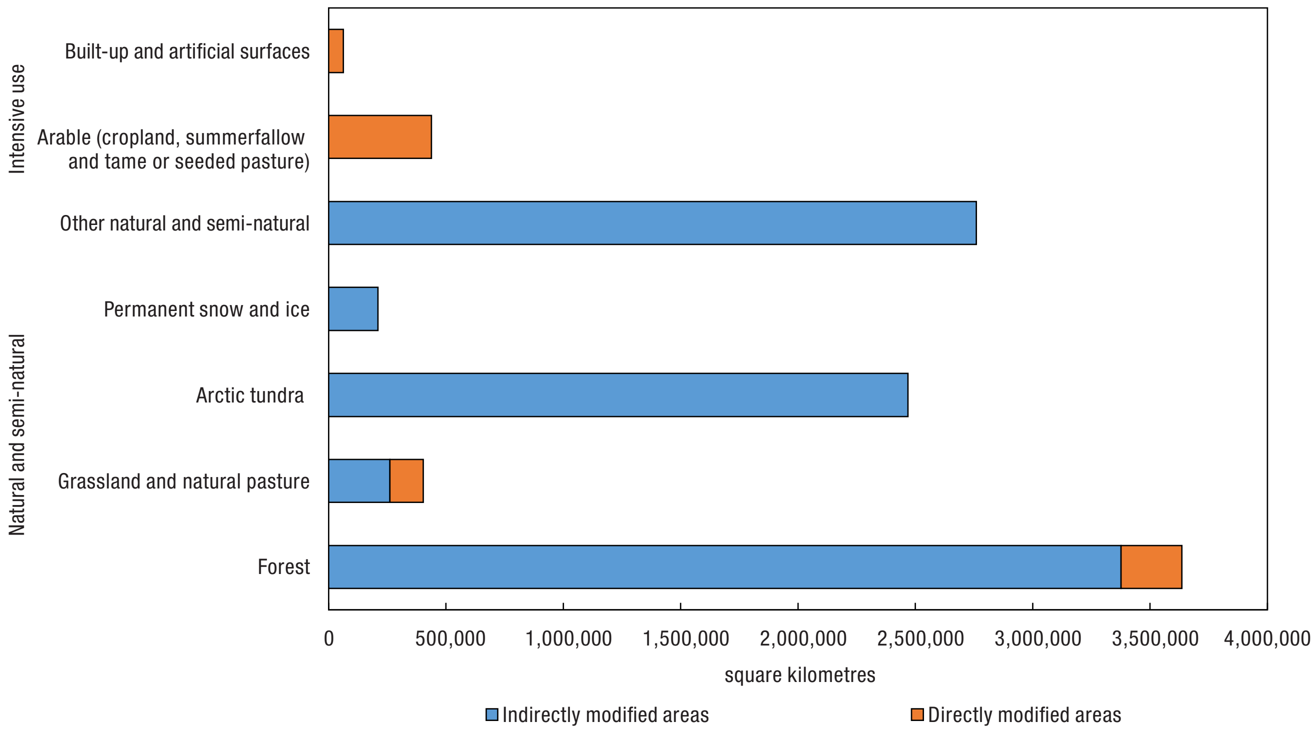
Landscape condition characteristics

Human activities have an impact on ecosystem characteristics, functions and the supply of ecosystem goods and services. For example, changing land cover and land use can affect water regulation, habitat provision and pollination services. The degree of modification lies on a continuum. For example, agro-ecosystems have been modified from natural ecosystems through tillage, drainage, introduction of different species and use of chemical inputs, but still maintain important ecosystem functions such as nutrient cycling and pollination.[74] Heavily built areas with a large proportion of artificial surfaces and lower proportion of natural and semi-natural areas are considered the most modified ecosystems.

In 2016, 9% of Canada's landmass had been directly modified for agricultural production, recent forest harvesting (since 1986) or urban and industrial development (Chart 3.4). The majority of this area was used for agriculture (64%), followed by forest harvesting (29%) and built-up area (7%). Other areas including old growth and regenerating forests, tundra, grassland and other ecosystems are considered indirectly modified. These areas may have been modified from their original condition through historic logging or dam construction, may be actively managed for timber production or may be affected by acid deposition and climate change, but retain many characteristics of natural and semi-natural ecosystems.

74 Power, A. G., 2010, "Ecosystem services and agriculture: Tradeoffs and synergies," *Philosophical Transactions of the Royal Society B*, Vol. 365, https://doi.org/10.1098/rstb.2010.0143 (accessed January 26, 2021).

Chart 3.4
Directly modified and indirectly modified areas, by ecosystem type, 2016



Notes: All areas of Canada are directly or indirectly modified by human activity. Directly modified land includes areas used for agriculture (e.g., cropland, pasture, summerfallow), recent forest harvest (1986 to 2015) and built-up and artificial surface. For more information on methodology, see Appendix A.
Sources: National Forest Inventory, 2021, *First remeasurement standard reports, (2007-2017): Table 4.1. Area (1000 ha) of forest and non-forest land by terrestrial ecozone in Canada*, https://nfi.nfis.org/resources/general/summaries/t1/en/NFI/html/NFI_T4_FOR_AREA_en.html (accessed August 13, 2021); Guindon, L., et al., 2017, C*anada Landsat Disturbance (CanLaD): a Canada-wide Landsat-based 30-m resolution product of fire and harvest detection and attribution since 1984*, https://doi.org/10.23687/add1346b-f632-4eb9-a83d-a662b38655ad (accessed July 20, 2020), Data files downloaded from https://opendata.nfis.org/mapserver/nfis-change_eng.html (accessed July 20, 2020); Agriculture and Agri-Food Canada (AAFC), 2020, *Annual Crop Inventory, 2014-2016,* https://open.canada.ca/data/en/dataset/ba2645d5-4458-414d-b196-6303ac06c1c9 (accessed December 3, 2020); Natural Resources Canada (NRCan), Canada Centre for Mapping and Earth Observation (CCMEO), 2020, *2010 and 2015 Land Cover of North America at 30 metres*, Ed. 2.0, Commission for Environmental Cooperation (CEC), North American Land Change Monitoring System, http://www.cec.org/north-american-environmental-atlas/land-cover-2010-landsat-30m/ (accessed December 3, 2020); AAFC, 2016, *Interpolated Census of Agriculture*, https://open.canada.ca/data/en/dataset/1dee8513-5c73-43b6-9446-25f7b985cd00 (accessed December 9, 2020); AAFC, 2015, *Land Use, 2010*, https://open.canada.ca/data/en/dataset/18e3ef1a-497c-40c6-8326-aac1a34a0dec (accessed June 1, 2020); Baldwin, K., et. al., 2018, *Vegetation Zones of Canada: a Biogeoclimatic Perspective* [Map], Scale 1:5,000,000, NRCan, Canadian Forest Service, https://open.canada.ca/data/en/dataset/22b0166b-9db3-46b7-9baf-6584a3acc7b1 (accessed October 26, 2020); Environment and Climate Change Canada, 2020, *CRF Tables*, Canada's National Inventory Submissions 2018 to the UNFCCC, https://unfccc.int/process-and-meetings/transparency-and-reporting/reporting-and-review-under-the-convention/greenhouse-gas-inventories-annex-i-parties/submissions/national-inventory-submissions-2018#fn1 (accessed April 30, 2020).

Habitat and landscape fragmentation refers to the division of natural and semi-natural ecosystems into smaller and more isolated patches. Farm fields, forest cut blocks and built-up and artificial surfaces have transformed the natural landscape. Linear features such as roads, rail lines, transmission lines and cutlines divide landscapes into smaller patches and are often the first encroachments of human activity into an area.[75] Larger cities and densely populated areas generally have higher linear feature densities as a result of demand for road, water, waste and communication infrastructure. Increased fragmentation can affect an ecosystem's ability to function, for example, by reducing its capacity to support species abundance and richness or ability to provide ecosystem services such as flood attenuation, pollination, or erosion prevention.

In 2016, the smallest natural and semi-natural patch sizes and longest distance to natural and semi-natural patch were found in ecoprovinces across the Prairies and the Mixedwood Plains ecozones where the majority of the country's agricultural activity takes place (Table 3.5). The Central Grassland and Parkland Prairies ecoprovinces had the smallest

75 European Environment Agency / Federal Office for the Environment, 2011, *Landscape fragmentation in Europe: Joint EEA-FOEN report*, https://www.eea.europa.eu/publications/landscape-fragmentation-in-europe (accessed February 2, 2021); Forman. R., et al., 2003, *Road Ecology: Science and Solutions*, Island Press.

average natural and semi-natural patches at 1.0 km^2 and 1.1 km^2, followed by the Huron–Erie Plains (1.1 km^2) and the Great Lakes–St. Lawrence Lowlands (1.3 km^2). The longest average distance to a natural and semi-natural patch was in the Central Grassland (515 m), followed by the Eastern Prairies (508 m) and the Huron–Erie Plains (331 m).

Linear feature density was highest in the Huron–Erie Plains ecoprovince (2,769 m/km^2), the Great Lakes–St. Lawrence Lowlands (1,815 m/km^2) and the Georgia Depression (1,692 m/km^2), which include Canada's largest population centres including Montréal, Toronto and Vancouver.

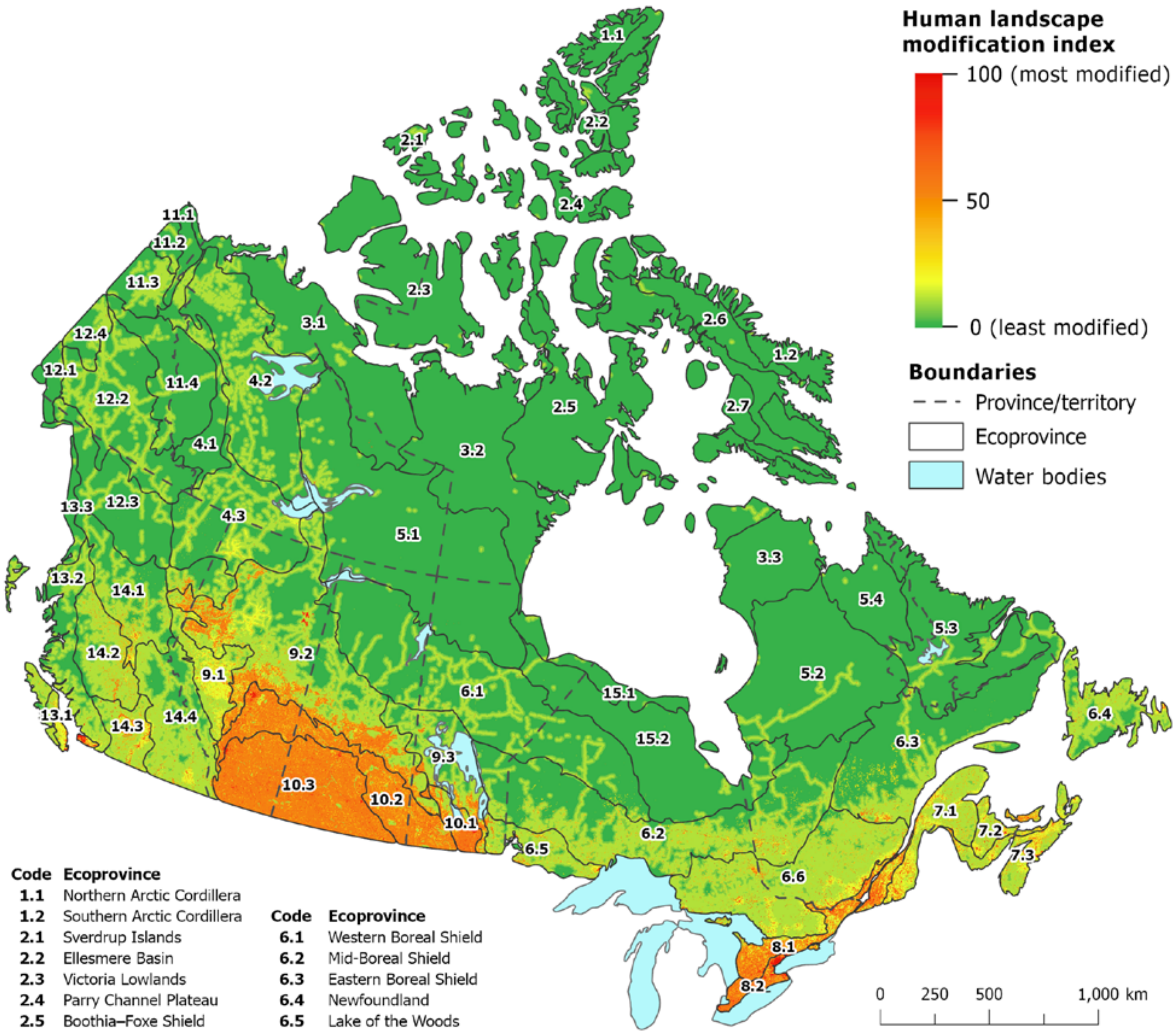
The human landscape modification index (HLMI) integrates data on land use, natural and semi-natural patch size and linear features to provide a measure of the degree to which an area has been modified from its natural state (Maps 3.4 and 3.5). Higher HLMI scores indicate a higher degree of modification from the natural ecosystem state and occur where grassland, wetland and forest ecosystems have been converted to agroecosystems and urban centres and where there is more landscape fragmentation. Conversely, lower HLMI scores indicate lower rates of modification and where ecosystem functions are more likely to be closer to their natural state. The highest HLMI score was found in the Huron–Erie Plains in southern Ontario. The lowest HLMI scores are found in the North since much of the landscape remains intact with few direct modifications.[76]

Human activities also affect freshwater ecosystems. The construction of dams or bridges and water withdrawal for agricultural and industrial use or drinking water production result in direct impacts on the flow of rivers and streams. Nutrient emissions from wastewater treatment plants or farm runoff have direct impacts on water quality. Carbon emissions from human activity indirectly affect freshwater ecosystems as a result of long-term changes in the water cycle and water temperatures. The human freshwater influences index is an overall ranking of drainage regions based on individual rankings of selected anthropogenic variables that affect freshwater ecosystems (Map 3.6).[77] By combining multiple influencing factors, this index helps convey the cumulative effects of human activities on freshwater ecosystems. The higher rankings for drainage regions in the south reflect the large number of influences associated with higher population densities and landscape conversion, while warming temperatures are the major influence on freshwater ecosystems in the North.

76 The HLMI provides a proxy measure that can be used to report on progress towards the United Nations Sustainable Development Goal (SDG) Target 15.3 Combat desertification, restore degraded land and soil and strive to achieve a land degradation-neutral world.

77 The HFII provides a proxy measure that can be used to report on progress towards the United Nations Sustainable Development Goal (SDG) Target 6.6. Protect and restore water-related ecosystems.

Map 3.4
Human landscape modification index, 2011



Code	Ecoprovince
1.1	Northern Arctic Cordillera
1.2	Southern Arctic Cordillera
2.1	Sverdrup Islands
2.2	Ellesmere Basin
2.3	Victoria Lowlands
2.4	Parry Channel Plateau
2.5	Boothia–Foxe Shield
2.6	Baffin Uplands
2.7	Foxe–Boothia Lowlands
3.1	Amundsen Lowlands
3.2	Keewatin Lowlands
3.3	Ungava–Belcher
4.1	Mackenzie Foothills
4.2	Great Bear Lowlands
4.3	Hay–Slave Lowlands
5.1	Western Taiga Shield
5.2	Eastern Taiga
5.3	Labrador Uplands
5.4	Whale River Lowland

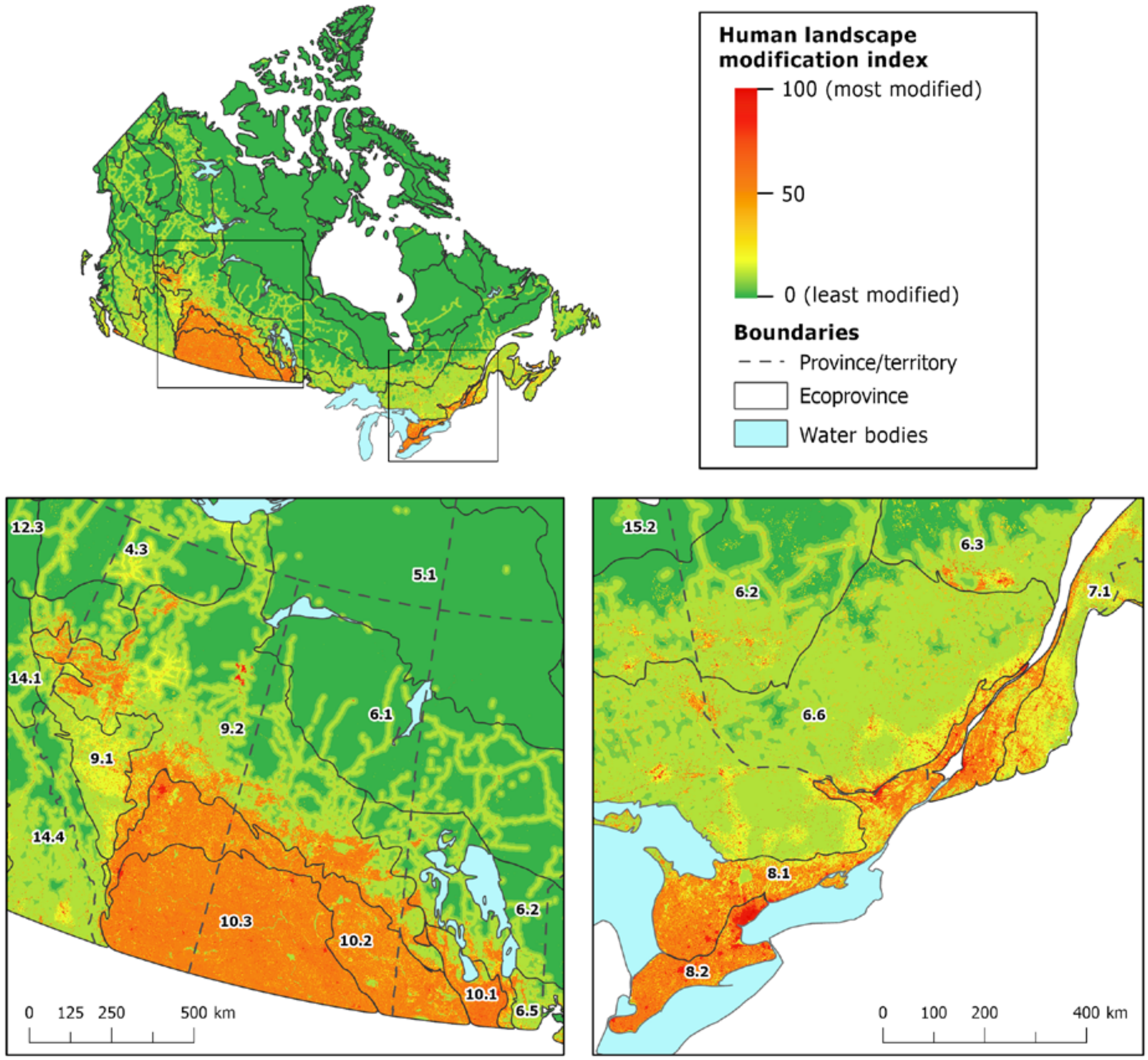
Code	Ecoprovince
6.1	Western Boreal Shield
6.2	Mid-Boreal Shield
6.3	Eastern Boreal Shield
6.4	Newfoundland
6.5	Lake of the Woods
6.6	Southern Boreal Shield
7.1	Appalachian–Acadian Highlands
7.2	Northumberland Lowlands
7.3	Fundy Uplands
8.1	Great Lakes–St. Lawrence
8.2	Huron–Erie Plains
9.1	Boreal Foothills
9.2	Central Boreal Plains
9.3	Eastern Boreal Plains
10.1	Eastern Prairies
10.2	Parkland Prairies
10.3	Central Grassland

Code	Ecoprovince
11.2	Old Crow–Eagle Plains
11.3	Ogilvie Mountains
11.4	Mackenzie–Selwyn Mountains
12.1	Wrangel Mountains
12.2	Northern Boreal Cordillera
12.3	Southern Boreal Cordillera
12.4	Western Boreal Cordillera
13.1	Georgia Depression
13.2	Southern Coastal Mountains

Code	Ecoprovince
13.3	Northern Coastal Mountains
11.1	Northern Yukon Mountains
14.1	Northern Montane Cordillera
14.2	Central Montane Cordillera
14.3	Southern Montane Cordillera
14.4	Columbia Montane Cordillera
15.1	Hudson Bay Coastal Plains
15.2	Hudson–James Lowlands

Notes: The human landscape modification index (HLMI) is a composite index used to measure direct human modifications to the landscape based on the degree that an area has been modified from a natural or semi-natural state. Values range from 0 to 100, with higher scores indicating more intensively-used ecosystems.
Sources: Statistics Canada, Environment and Energy Statistics Division, 2021, special tabulation based on Agriculture and Agri-Food Canada (AAFC), 2015, *Land Use, 2010;* Natural Resources Canada, 2017, Topographic Data of Canada - CanVec Series; Statistics Canada, 2017, *Road Network File, 2016;* AAFC, 2016, *Interpolated Census of Agriculture;* Guindon, L., et al., 2017, *Canada Landsat Disturbance (CanLaD): a Canada-wide Landsat-based 30-m resolution product of fire and harvest detection and attribution since 1984.*

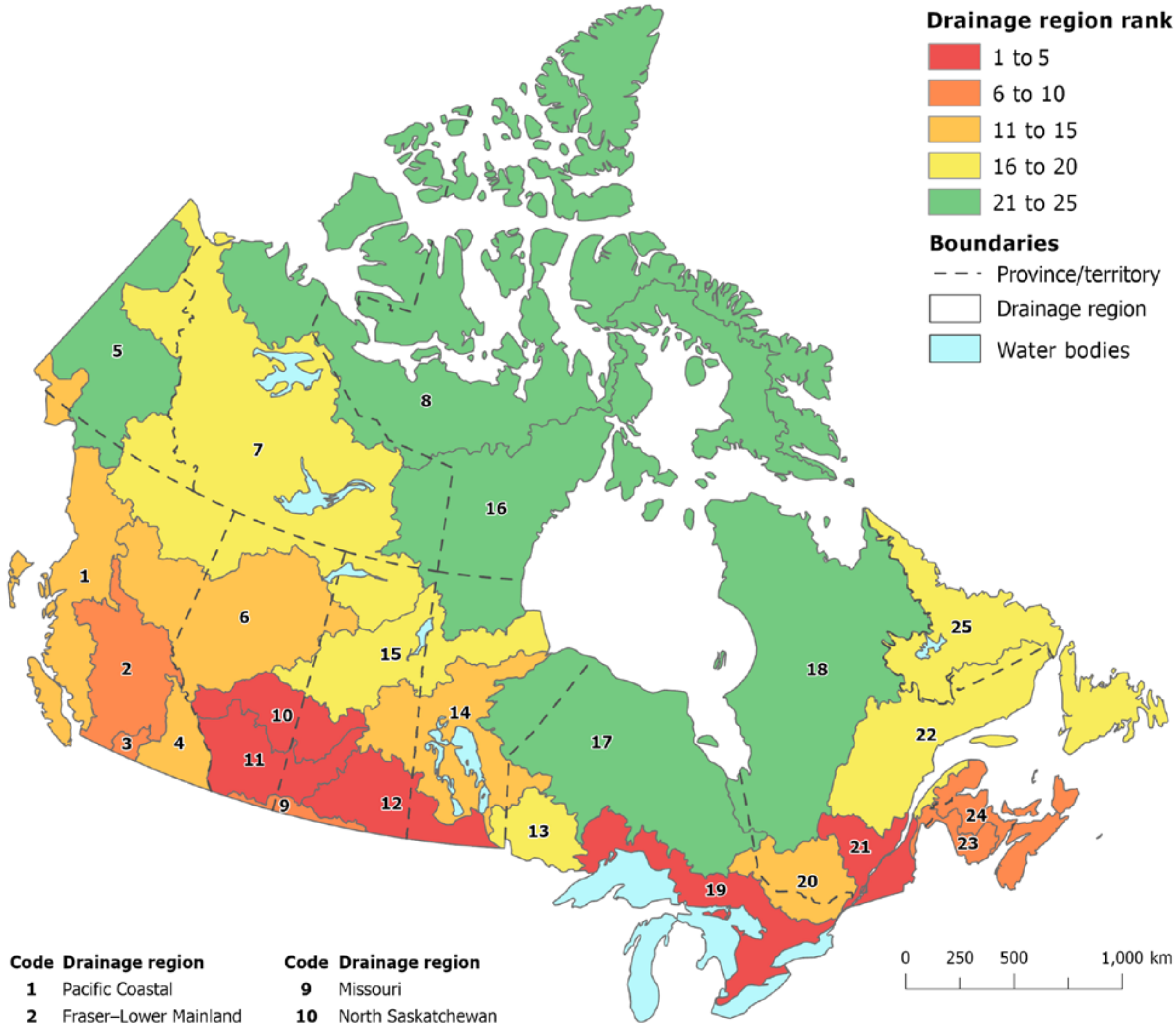
Map 3.5
Human landscape modification index, highly modified regions, 2011



Code	Ecoprovince	Code	Ecoprovince	Code	Ecoprovince	Code	Ecoprovince
1.1	Northern Arctic Cordillera	4.3	Hay–Slave Lowlands	8.1	Great Lakes–St. Lawrence	12.4	Western Boreal Cordillera
1.2	Southern Arctic Cordillera	5.1	Western Taiga Shield	8.2	Huron–Erie Plains	13.1	Georgia Depression
2.1	Sverdrup Islands	5.2	Eastern Taiga	9.1	Boreal Foothills	13.2	Southern Coastal Mountains
2.2	Ellesmere Basin	5.3	Labrador Uplands	9.2	Central Boreal Plains	13.3	Northern Coastal Mountains
2.3	Victoria Lowlands	5.4	Whale River Lowland	9.3	Eastern Boreal Plains	11.1	Northern Yukon Mountains
2.4	Parry Channel Plateau	6.1	Western Boreal Shield	10.1	Eastern Prairies	14.1	Northern Montane Cordillera
2.5	Boothia–Foxe Shield	6.2	Mid-Boreal Shield	10.2	Parkland Prairies	14.2	Central Montane Cordillera
2.6	Baffin Uplands	6.3	Eastern Boreal Shield	10.3	Central Grassland	14.3	Southern Montane Cordillera
2.7	Foxe–Boothia Lowlands	6.4	Newfoundland	11.2	Old Crow–Eagle Plains	14.4	Columbia Montane Cordillera
3.1	Amundsen Lowlands	6.5	Lake of the Woods	11.3	Ogilvie Mountains	15.1	Hudson Bay Coastal Plains
3.2	Keewatin Lowlands	6.6	Southern Boreal Shield	11.4	Mackenzie–Selwyn Mountains	15.2	Hudson–James Lowlands
3.3	Ungava–Belcher	7.1	Appalachian–Acadian Highlands	12.1	Wrangel Mountains		
4.1	Mackenzie Foothills	7.2	Northumberland Lowlands	12.2	Northern Boreal Cordillera		
4.2	Great Bear Lowlands	7.3	Fundy Uplands	12.3	Southern Boreal Cordillera		

Notes: The human landscape modification index (HLMI) is a composite index used to measure direct human modifications to the landscape based on the degree that an area has been modified from a natural or semi-natural state. Values range from 0 to 100, with higher scores indicating more intensively-used ecosystems.
Sources: Statistics Canada, Environment and Energy Statistics Division, 2021, special tabulation based on Agriculture and Agri-Food Canada (AAFC), 2015, *Land Use, 2010;* Natural Resources Canada, 2017, Topographic Data of Canada - CanVec Series; Statistics Canada, 2017, *Road Network File, 2016;* AAFC, 2016, *Interpolated Census of Agriculture;* Guindon, L., et al., 2017, *Canada Landsat Disturbance (CanLaD): a Canada-wide Landsat-based 30-m resolution product of fire and harvest detection and attribution since 1984.*

Map 3.6
Human freshwater influences index, by drainage region



Code	Drainage region
1	Pacific Coastal
2	Fraser–Lower Mainland
3	Okanagan–Similkameen
4	Columbia
5	Yukon
6	Peace–Athabasca
7	Lower Mackenzie
8	Arctic Coast–Islands
9	Missouri
10	North Saskatchewan
11	South Saskatchewan
12	Assiniboine–Red
13	Winnipeg
14	Lower Saskatchewan–Nelson
15	Churchill
16	Keewatin–Southern Baffin Island
17	Northern Ontario
18	Northern Quebec
19	Great Lakes
20	Ottawa
21	St. Lawrence
22	North Shore–Gaspé
23	Saint John–St. Croix
24	Maritime Coastal
25	Newfoundland–Labrador

Notes: The human freshwater influences index is an overall ranking of drainage regions based on individual rankings of selected anthropogenic variables that affect freshwater ecosystems. The overall rank is determined by ranking each variable individually from highest to lowest impact and then calculating the average of the rankings. Lower values indicate a higher degree of human influence.

Sources: Statistics Canada, Environment and Energy Statistics Division, 2021, special tabulation based on Environment and Climate Change Canada (ECCC), *Canadian Gridded Temperature and Precipitation Anomalies (CANGRD);* Statistics Canada, 2011, *Census of Population;* Agriculture and Agri-Food Canada (AAFC), 2015, *Land Use, 2010;* Natural Resources Canada (NRCan), 2017, *Topographic Data of Canada - CanVec Series;* Statistics Canada, 2017, *Road Network File, 2016;* Statistics Canada, 2013, *Table 16-403-X, Survey of Drinking Water Plants, 2011;* Statistics Canada, 2014, *Table 16-401-X Industrial Water Use, 2011;* AAFC, 2015, *Agri-environmental Indicator—Residual Soil Nitrogen (RSN);* AAFC, 2015, *Agri-environmental Indicator—Risk of P release in agricultural land (P-Source);* ECCC, 2015, *National Pollutant Release Inventory, Pollution Data and Reports;* Statistics Canada, 2020, *Table 38-10-0099-01 Wastewater volumes processed by municipal sewage systems (x 1,000,000);* NRCan, 2017, *CanVec Series;* Canadian Dam Association, 2019, *Inventory of Large Dams in Canada 2019.*

Textbox: Invasive species

Non-native species are plants, pathogens, insects, fish or other animals that have been introduced to Canada from other parts of the world. Some introduced species do not survive to reproduce and proliferate because environmental conditions may be unfavourable or native species may outcompete them. However other non-native species become invasive, establishing and spreading rapidly because of a lack of predators, changing environmental conditions and other reasons, which may cause considerable harm to existing ecosystems. These invasives can be found across the country on land and in fresh and marine waters.

In addition, some native species to Canada and the United States are expanding their ranges into new areas where they may become invasive. For example, the mountain pine beetle is native in certain parts of British Columbia,[78] but is causing devastation as it moves north in the province and eastward into Alberta. Not only does this cause mortality amongst pine species but may increase the risk of severe forest fires.[79] As sea ice melts in the Arctic Ocean, killer whales are becoming more common, potentially impacting populations of other whales such as narwhal.[80]

Over 80 destructive forest pests and pathogens have been introduced into Canada, including Dutch elm disease and more recent arrivals such as the Asian longhorned beetle and the emerald ash borer.[81] The emerald ash borer arrived in Canada in 2002 and has since killed millions of trees in five of Canada's provinces.[82] Purple loosestrife was introduced in the 1800s from Europe, but continues to be a problem in wetlands where it chokes out native plants.[83] Japanese knotweed establishes itself in dense patches with extensive root bases and aggressively chokes out native species and damages infrastructure.[84] Even moose, the well-known Canadian symbol, have become a problem since their 1878 introduction to Newfoundland,[85] with current numbers as high as one for every four people and moose density estimated at 3 to 20 times that of other boreal forest systems.[86] Moose affect the abundance and distribution of native vegetation throughout the province and are a traffic hazard along the province's highways.

Invasive species have spread into Canadian waters through the release of ballast water and hull fouling from global shipping, aquaculture importation of non-native species, as well as habitat, climate and oceanographic changes that have enabled invasive species to take hold. Zebra and quagga mussels, native to the Black Sea, are thought to have arrived in the Great Lakes in the late 1980s from ballast water in transoceanic vessels.[87] These

78 Forest Invasives Canada, n.d., *Mountain Pine Beetle*, https://forestinvasives.ca/Meet-the-Species/Insects/Mountain-Pine-Beetle (accessed May 9, 2020).

79 Ontario Federation of Anglers and Hunters/Ontario Ministry of Natural Resources and Forestry – Ontario Invading Species Awareness Program, 2012, *Mountain Pine Beetle*, www.invadingspecies.com/mountain-pine-beetle/ (accessed May 11, 2020); Stockdale, C., 2018, "Mountain pine beetle effects on wildfire rate of spread and landscape fire risk," QuickNotes the information note of FRI Research, https://friresearch.ca/sites/default/files/MPBEP_2018_06_MPB%20effects%20on%20wildfire%20quick%20note.pdf (accessed April 28, 2021).

80 Breed, G. A., et al., 2017, "Sustained disruption of narwhal habitat use and behaviour in the presence of Arctic killer whales," *Proceedings of the National Academy of Sciences of the United States of America*, https://doi.org/10.1073/pnas.1611707114 (accessed May 9, 2020).

81 Natural Resources Canada, 2015, *Forest Invasive Alien Species: Established species*, https://www.exoticpests.gc.ca/e-species (accessed May 2, 2020).

82 Natural Resources Canada, 2019, *Emerald Ash borer*, https://www.nrcan.gc.ca/our-natural-resources/forests-forestry/wildland-fires-insects-disturban/top-forest-insects-diseases-cana/emerald-ash-borer/13377 (accessed May 9, 2020).

83 Ontario Federation of Anglers and Hunters/Ontario Ministry of Natural Resources and Forestry – Ontario Invading Species Awareness Program, 2012, *Purple Loosestrife*, http://www.invadingspecies.com/purple-loosestrife/ (accessed May 9, 2020).

84 Ontario Federation of Anglers and Hunters/Ontario Ministry of Natural Resources and Forestry – Ontario Invading Species Awareness Program, 2012, *Japanese Knotweed*, http://www.invadingspecies.com/japanese-knotweed/ (accessed May 9, 2020).

85 McLaren, Brian, et al., 2004, "Effects of overabundant moose on the Newfoundland landscape," *ALCES*, Vol. 40, pp. 45-59, https://www.researchgate.net/publication/266214665_Effects_of_overabundant_moose_on_the_Newfoundland_landscape (accessed Nov 9, 2020).

86 Gosse, J., et al., n.d., *Impacts of Hyperabundant Moose on Forest Regeneration in Terra Nova and Gros Morne National Park*, Parks Canada, https://www.flr.gov.nl.ca/wildlife/biodiversity/invasive_alien_species/moose.pdf (accessed May 11, 2020).

87 Ontario Federation of Anglers and Hunters/Ontario Ministry of Natural Resources and Forestry – Ontario Invading Species Awareness Program, 2012, *Zebra and Quagga Mussels*, http://www.invadingspecies.com/zebra-quagga-mussels (accessed May 9, 2020).

aggressive species quickly colonized all available hard surfaces,[88] fouling boats and clogging water intakes on power stations and water treatment plants. The spread of Asian carp is another serious concern for the Great Lakes because of their voracious appetites, fast growth rates and ability to reproduce quickly, which may enable them to outcompete local species.[89] They were introduced in aquaculture facilities in the United States in the 1960s and 70s to use as a biological control, but escaped fish have moved north through the Mississippi River basin. Individual Asian carp have recently been found in the Great Lakes and in Canadian waterways.[90] Ongoing surveillance efforts are in place to prevent the establishment of these fish in Canadian waters.

Marine invasive species of concern include the European green crab and tunicates, which have been found on both the east and west coasts.[91] European green crabs outcompete native crabs, cause severe damage to mollusc beds and disrupt eelgrass beds, a productive habitat for many juvenile fish species. Tunicates or sea squirts are very hardy, tolerate a wide range of temperature and salinity conditions, have very few predators because of their noxious outer skin and can reproduce in vast numbers. They attach to firm surfaces such as fishing and aquaculture gear and also shellfish. Both species have had a substantial impact on the aquaculture industry, particularly on the East Coast.

3.2 Marine and coastal ecosystem condition

The health of Canada's oceans can be measured through a number of different abiotic, biotic and seascape characteristics. The complex interactions between these different characteristics can result in large-scale impacts on ocean currents, weather patterns[92] and productivity[93] to more local impacts affecting the level of biodiversity in marine regions.[94] This, in turn, can have serious impacts on ocean services and benefits, such as fishery landings and tourism as well as marine transportation routes and the accessibility of oil fields. Key abiotic characteristics include sea temperature, salinity, oxygen, stratification, acidity, nutrient and pollution levels; biotic characteristics may relate to the abundance of species and food webs; and seascape characteristics can include sea ice cover and the intactness or modification of ecosystems.

Sea surface temperature

Ocean temperatures are increasing with increasing atmospheric temperatures. Heat from the sun and atmosphere is absorbed at the ocean surface and spreads gradually into deeper waters and around the world by way of ocean currents and mixing of layers. Ocean warming can change the range distribution of species[95] and can impact fish spawning

88 Minnesota Sea Grant, n.d., *Zebra Mussels Threaten Inland Waters: An Overview*, http://www.seagrant.umn.edu/ais/zebramussels_threaten (accessed May 11, 2020).

89 Asian Carp Canada, n.d., *About Asian Carps*, https://asiancarp.ca/asian-carps/ (accessed May 9, 2020); Ontario Federation of Anglers and Hunters/Ontario Ministry of Natural Resources and Forestry – Ontario Invading Species Awareness Program, 2012, *Asian Carps*, http://www.invadingspecies.com/asian-carps (accessed May 9, 2020).

90 Duchaine, H., 2020, "Une carpe asiatique a été pêchée à Chambly," *Le Journal de Montréal*, July 28, 2020; Fisheries and Oceans Canada, 2020, Asian Carp, https://dfo-mpo.gc.ca/species-especes/profiles-profils/asiancarp-carpeasiatique-eng.html (accessed December 8, 2020).

91 Klassen, G., 2012, "Invasive species," *State of the Scotian Shelf Report*, Atlantic Coastal Zone Information Steering Committee, https://0fb5ebe8-ca92-4c3c-9170-ef778a77f76e.filesusr.com/ugd/cf2ff9_4899b39256974b1ea9da2bc791d2bd57.pdf (accessed May 11, 2020); Fisheries and Oceans Canada, 2018, *Invasive Tunicates*, https://www.dfo-mpo.gc.ca/species-especes/profiles-profils/invasivetunicates-tuniciersenvahissants-eng.html (accessed May 11, 2020); Fisheries and Oceans Canada, 2017, *Invasive tunicates and shellfish aquaculture: Assessing impacts and testing solutions*, https://www.dfo-mpo.gc.ca/aquaculture/rp-pr/acrdp-pcrda/projects-projets/P-09-03-011-eng.html (accessed May 11, 2020); Gillespie, G.E., et al., 2006, *Status of the European Green Crab, Carcinus maenas, in British Columbia- 2006*, Fisheries and Oceans Canada, http://www.aquaticnuisance.org/wordpress/wp-content/uploads/2009/01/Green%20Crab%20British%20Columbia%20Gillespie%20et%20al%202007.pdf (accessed September 30, 2020).

92 Jenkins, A., 2009, "With a pinch of salt," *NASA Global climate Change Vital Signs of the Planet*, April 19, 2009, https://climate.nasa.gov/news/58/with-a-pinch-of-salt/ (accessed May 15, 2020).

93 Greenan, B.J.W., et al., 2019.

94 McHenry, J., et al., 2019, "Projecting marine species range shifts from only temperature can mask climate vulnerability," *Global Change Biology*, Vol. 25, no. 12, https://doi.org/10.1111/gcb.14828 (accessed May 12, 2020).

95 Harball, E., 2013, "Climate Change Shifts Range and Behaviour of Ocean Species," *Scientific American*, https://www.scientificamerican.com/article/climate-change-shifts-range-and-behavior-of-ocean-species/ (accessed May 12, 2020); McHenry, J., et al, 2019.

areas and the survival of fish eggs.[96] Ocean temperature can also have a significant impact on coastal communities, not only through its impact on local fisheries and tourism, but also because of its effect on sea level through thermal expansion[97] and because warmer waters create more intense storms.[98]

Between 1901 and 2014, all Canadian marine ecoregions saw a rise in mean sea surface temperatures, with the highest temperature changes of 2°C or more occurring in the Arctic.[99] When the average annual temperature[100] from 2005 to 2017 is compared with the 1981 to 2010 climate normal average, most areas of the Canadian exclusive economic zone (EEZ) have warmed, though cooling is seen in parts of the Pacific and Hudson Bay (Map 3.7 and Table 3.6).

In summer, the Pacific waters had very different regions of warming than in winter, with a cold offshore region stretching from the Skeena River delta between two regions of warming, while in winter this region was warmer than the three-decade average (Maps 3.8 to 3.10). Temperature change in the Arctic was driven more by summer changes than by winter changes, while the Atlantic more consistently showed warming in both seasons, with the exception of the Gulf of St. Lawrence, which was colder in winter. The largest temperature differences were seen on the southern Scotian Shelf where they were larger than 3°C in some locations.

96 Pankhurst, N.W. and P.L. Munday, 2011, "Effects of climate change on fish reproduction and early life history stages," *Marine and Freshwater Research*, Vol. 62, no. 9, https://doi.org/10.1071/MF10269 (accessed May 16, 2020).

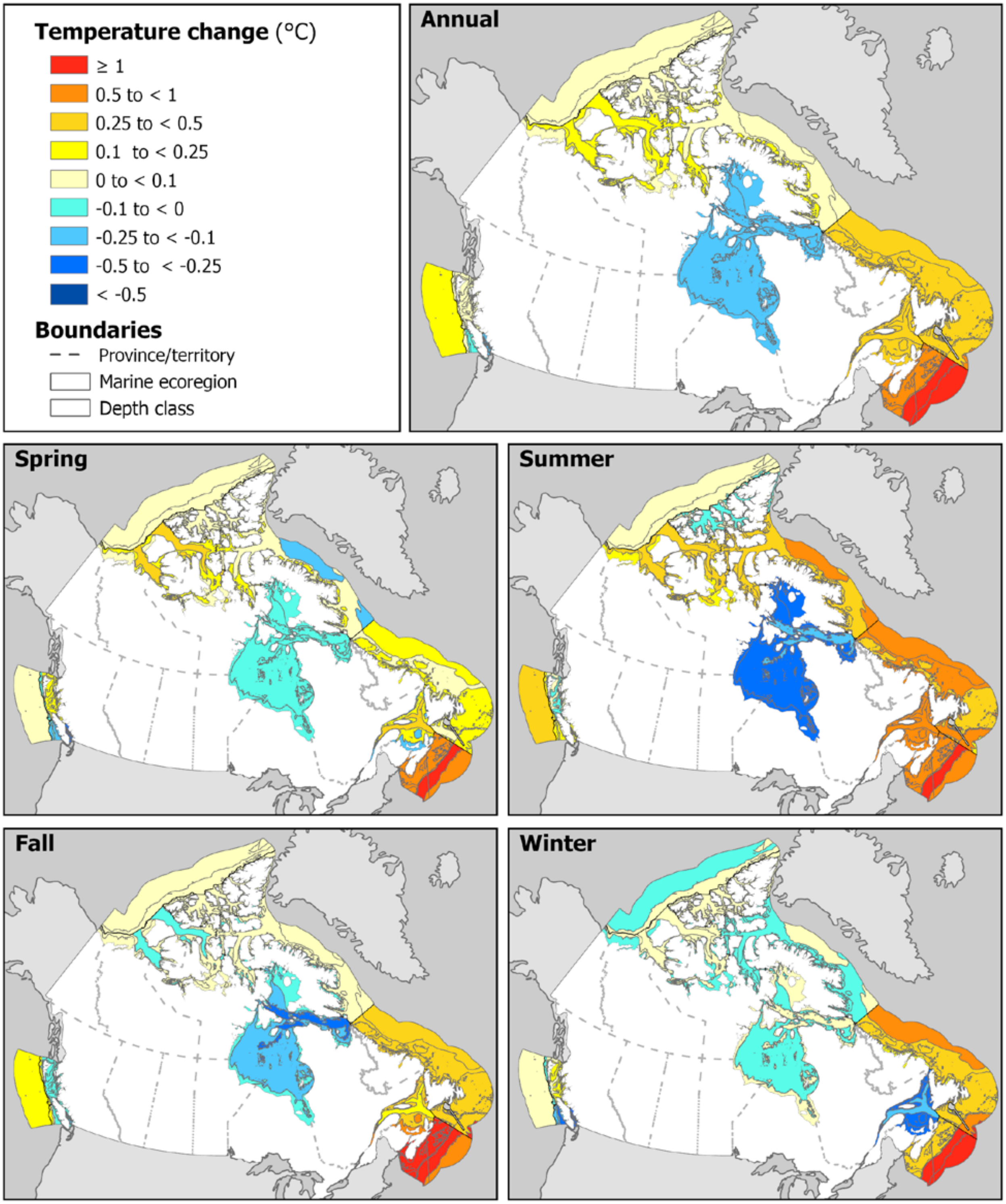
97 Frederikse, Thomas et al., 2020.

98 Office of Ocean Exploration and Research, National Oceanic and Atmospheric Administration, n.d., *How does the ocean affects hurricanes*?, https://oceanexplorer.noaa.gov/facts/hurricanes.html (accessed January 31, 2020).

99 Statistics Canada, 2017, "Freshwater in Canada," *Human Activity and the Environment*, Catalogue no. 16-201-X, https://www150.statcan.gc.ca/n1/pub/16-201-x/16-201-x2017000-eng.htm.

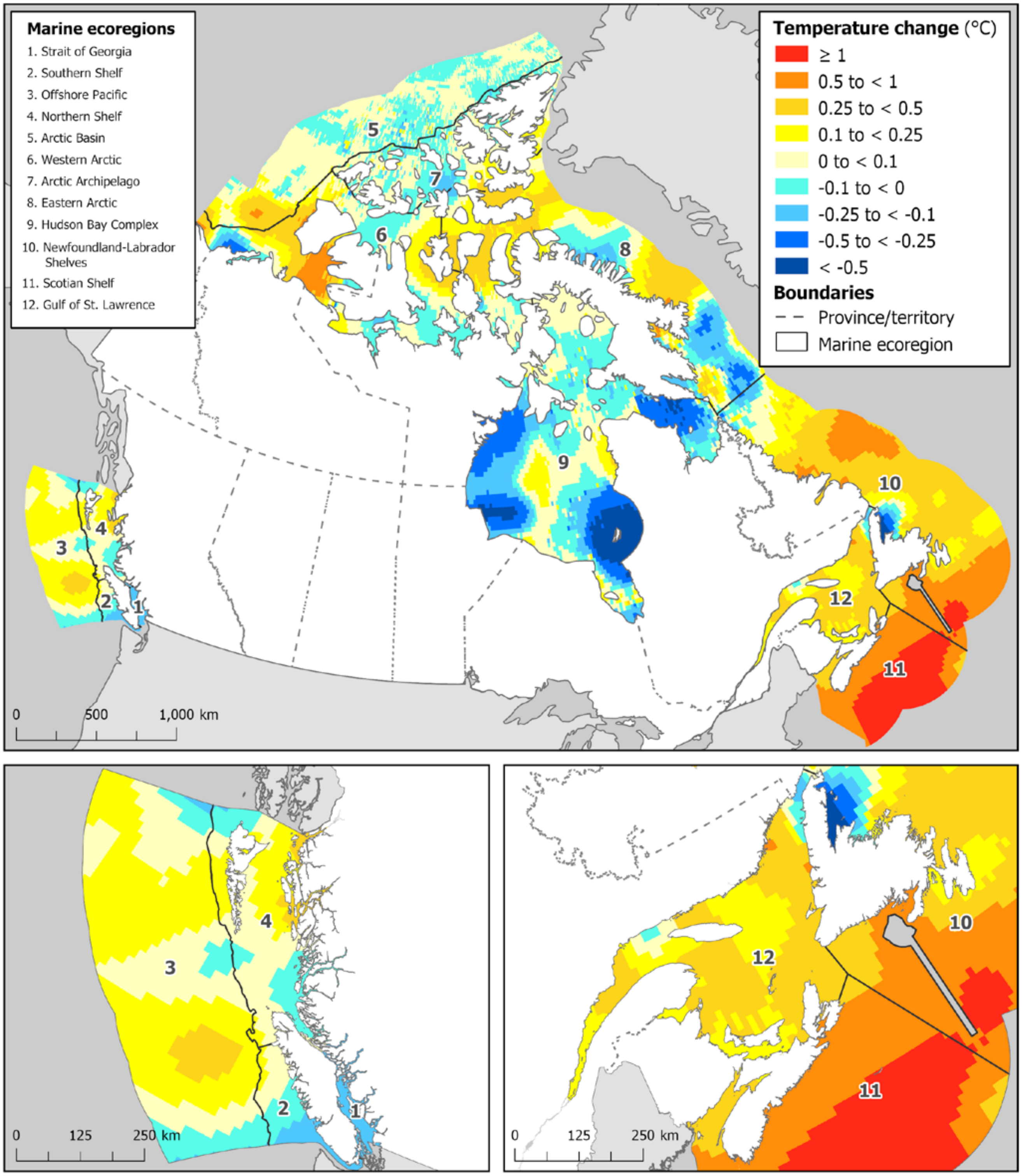
100 Locarnini, R. A., et al., 2018, *World Ocean Atlas 2018, Volume 1: Temperature*, National Oceanic and Atmospheric Administration, Mishonov, A. (ed.), https://www.nodc.noaa.gov/OC5/SELECT/woaselect/woaselect.html (accessed November 19, 2019). Note: the climatic mean data was used in this tabulation.

Map 3.7
Sea surface temperature departures (2005 to 2017) from the climate normal, by depth class, marine ecoregion and season



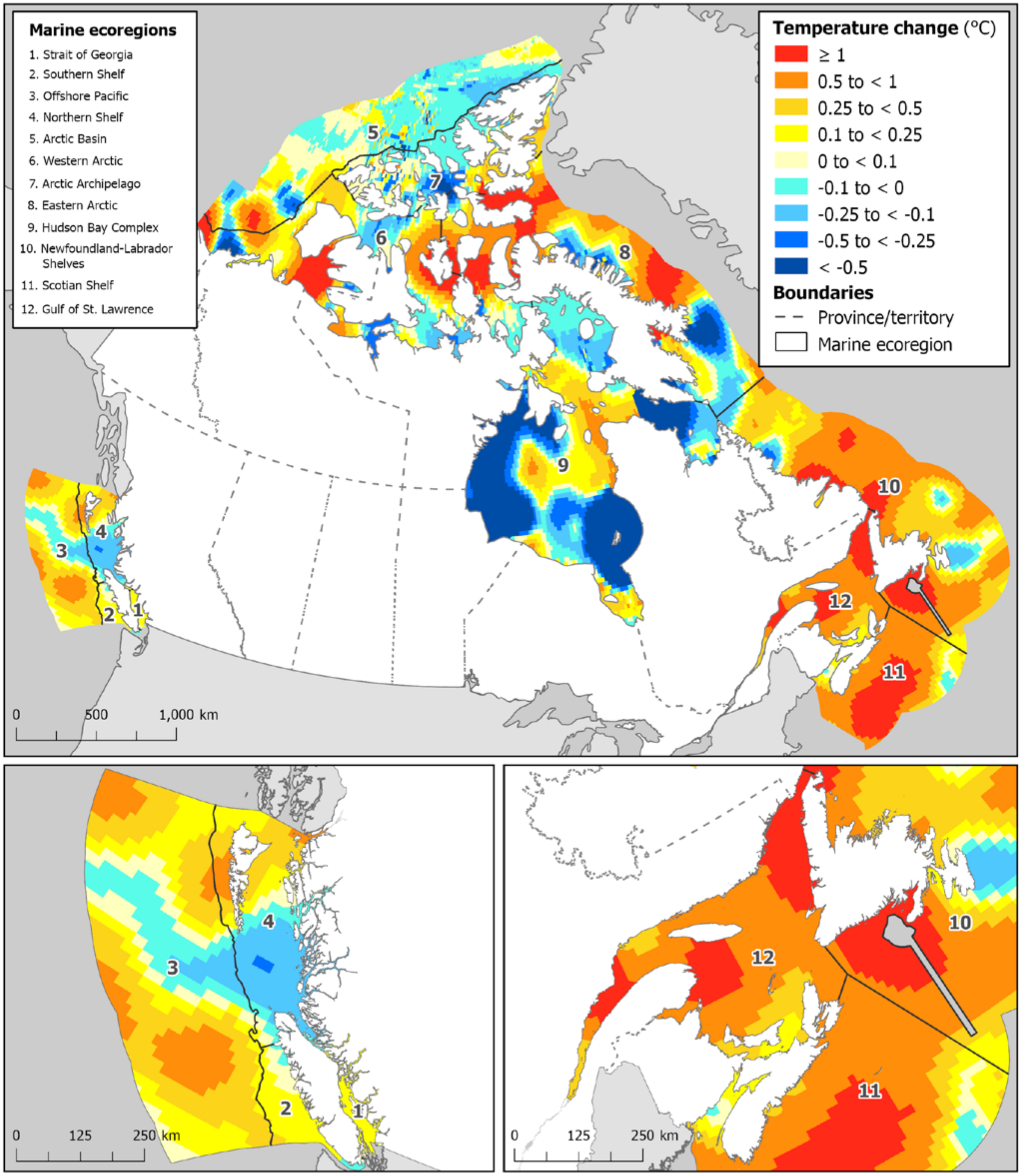
Note: The climate normal is the three decade average of climatological variables from 1981 to 2010. Winter data are from January to March with other seasons following sequentially.
Source: Locarnini, R. A., et al., 2018, *World Ocean Atlas 2018, Volume 1: Temperature*, A. Mishonov Technical Ed., NOAA Atlas NESDIS 81, 52 pp.

Map 3.8
Annual sea surface temperature departures (2005 to 2017) from the climate normal, at quarter degree grid



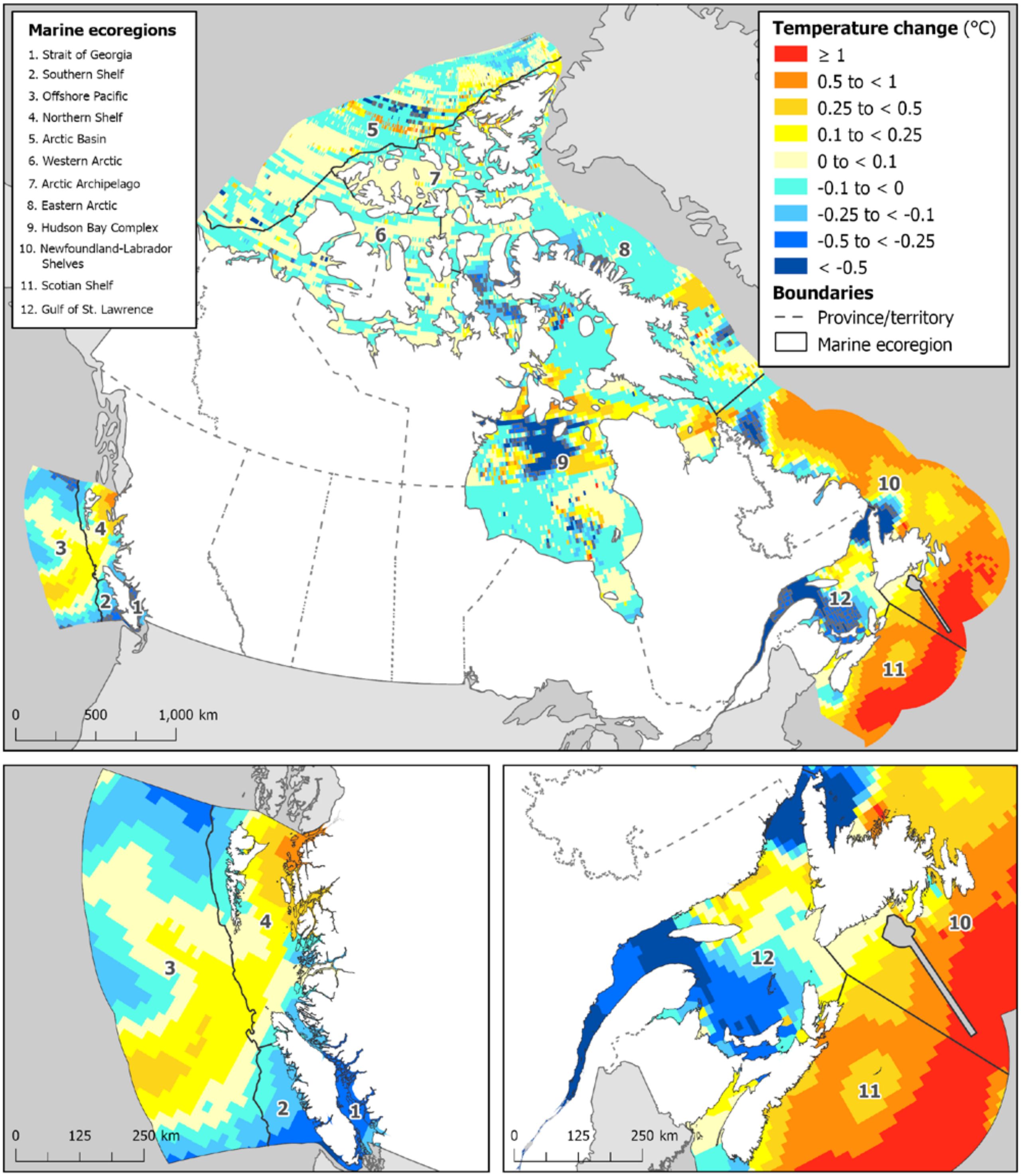
Note: The climate normal is the three decade average of climatological variables from 1981 to 2010.
Source: Locarnini, R. A., et al., 2018, *World Ocean Atlas 2018, Volume 1: Temperature*, A. Mishonov Technical Ed., NOAA Atlas NESDIS 81, 52 pp.

Map 3.9
Summer sea surface temperature departures (2005 to 2017) from the climate normal, at quarter degree grid



Note: The climate normal is the three-decade average of climatological variables from 1981 to 2010. Summer data are from July to September.
Source: Locarnini, R. A., et al., 2018, *World Ocean Atlas 2018, Volume 1: Temperature,* A. Mishonov Technical Ed., NOAA Atlas NESDIS 81, 52 pp.

Map 3.10
Winter sea surface temperature departures (2005 to 2017) from the climate normal, at quarter degree grid



Note: The climate normal is the three decade average of climatological variables from 1981 to 2010. Winter data are from January to March.
Source: Locarnini, R. A., et al., 2018, *World Ocean Atlas 2018, Volume 1: Temperature,* A. Mishonov Technical Ed., NOAA Atlas NESDIS 81, 52 pp.

Sea surface salinity

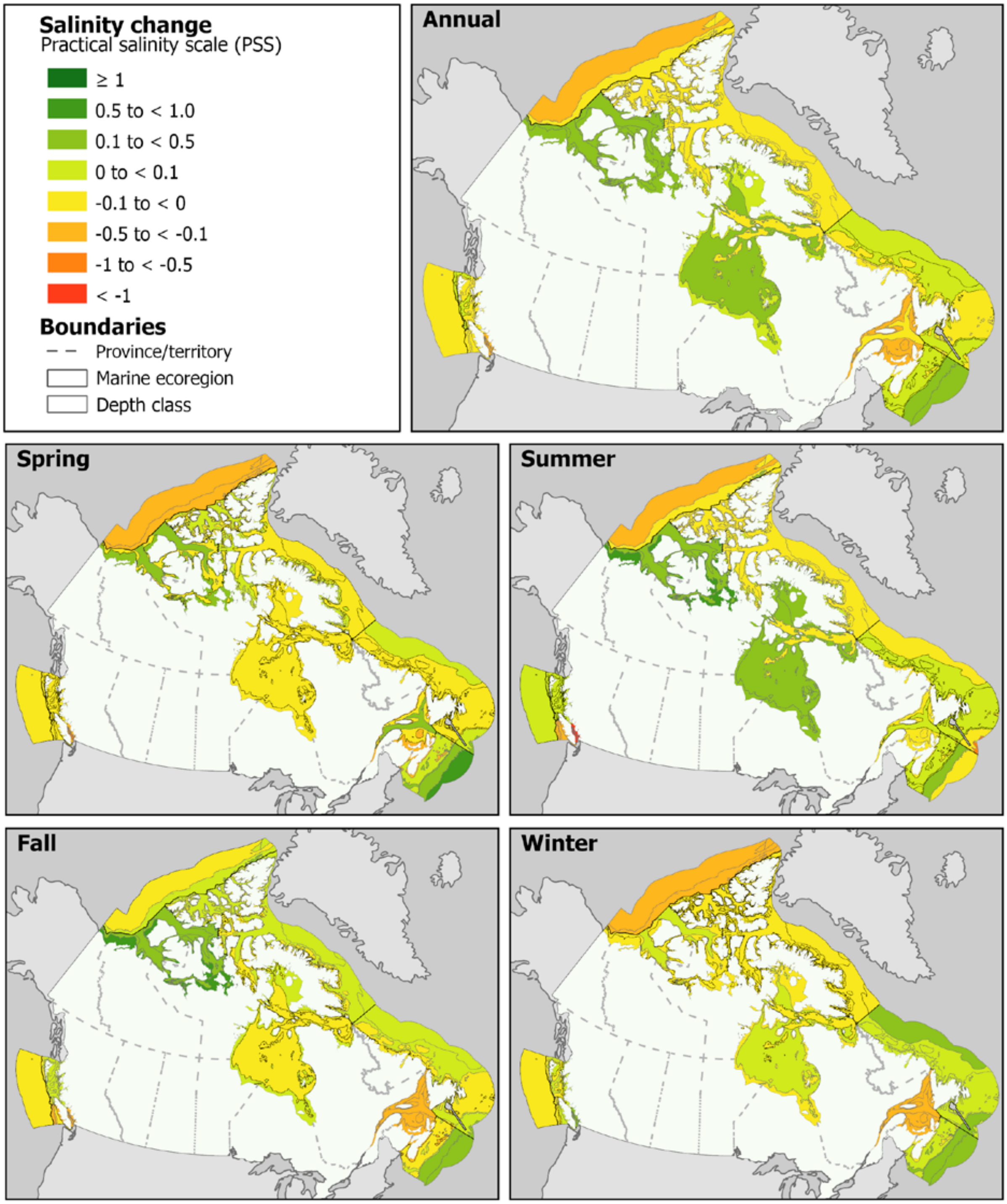
Salinity is another important abiotic component of marine ecosystems. Salinity, along with temperature and pressure, affects the mixing of different ocean layers. Freshwater flow from rivers and melting land and sea ice reduce salinity and increase stratification—the formation of distinct layers.[101] Significantly increased stratification can limit nutrient availability to surface phytoplankton at the base of the marine food web, affecting productivity and influencing the ocean's ability to capture carbon. A long-term decreasing trend in salinity has been found for most Canadian surface waters while deeper waters (200 m to 330 m) in the Gulf of St. Lawrence have experienced a statistically significant increase in salinity.[102] Comparing the average annual surface salinity from 2005 to 2017 to the climate normal average salinity shows that many regions have recently experienced reduced salinity levels (Map 3.11 and Table 3.7). The Strait of Georgia, Arctic Basin and Gulf of St. Lawrence have experienced the largest departures from the climate normal, with summer months experiencing the largest departure for the Strait of Georgia and autumn and winter months having the largest departures for the Gulf of St. Lawrence. Increases in salinity in Atlantic offshelf waters are consistent with northward shifts of subtropical waters.[103]

101 Greenan, B.J.W., et al., 2019.

102 Greenan, B.J.W., et al., 2019.

103 Greenan, B.J.W., et al., 2019.

Map 3.11
Sea surface salinity departures (2005 to 2017) from the climate normal reference period, by depth class, marine ecoregion and season



Notes: The climate normal is the three decade average of climatological variables from 1981 to 2010. Winter data are from January to March with other seasons following sequentially. Data are reported using the unitless Practical Salinity Scale (PSS), for more information please see http://salinometry.com/pss-78/ . Data for salinity in the Arctic Ocean are sparser than in other regions. In particular, winter salinity data are more scarce and the modelling methods used could result in artificially high salinities for this season in some regions of the Arctic Ocean.
Source: Zweng, M. M., et al., 2018, *World Ocean Atlas 2018, Volume 2: Salinity,* A. Mishonov Technical Ed., NOAA Atlas NESDIS 82, 50 pp.

Other abiotic condition characteristics

The level of dissolved oxygen in water is another important abiotic indicator of ocean water condition. Low oxygen levels are detrimental to marine life as they are associated with reduced growth rates, lower reproductive success and higher mortality.[104] Surface waters are normally oxygen rich, though intense algal blooms resulting from excess nutrients in the water can deplete oxygen levels and create dead zones where no marine life can survive.[105] Hypoxic—or low oxygen level—waters are a more normal occurrence in deeper water. There are several hypoxic areas in Canadian waters—some such as northern Pacific fjord inlets have had low levels for centuries. Others, such as deeper waters in the Gulf of St. Lawrence have shown a clear decline in oxygen levels over the past century. There are serious concerns that further oxygen depletion in some of these regions, particularly Queen Charlotte Sound, Hecate Strait and Dixon Entrance, could have serious impacts on biodiversity and on fisheries in the regions.[106]

Ocean acidification—the reduction of ocean pH levels—is well known for its damaging effects on tropical coral reefs; however, it is also an issue in Canadian waters. Increased acidity impacts cold water corals, shellfish and certain types of calcifying plankton by reducing their ability to build and maintain shells and calcium carbonate skeletal structures.[107] Arctic waters are expected to undergo rapid acidification in future years because of increasing carbon dioxide uptake from the atmosphere.[108]

Plastic pollution is also a concern for oceans globally, famously the marine debris circulating in the North Pacific Ocean, known as the Great Pacific Garbage Patch.[109] Coastlines and beaches worldwide are littered with washed up plastic from the sea, while lost or discarded fisheries nets, trawls, pots, traps and other derelict fishing gear continue to ghost fish at the ocean bottom. Beach litter surveys in Canada have found a high proportion of litter to be plastic, with one study on Fogo Beach in Newfoundland finding 67% of plastic litter was smaller than 1 cm^3.[110] Microplastic particles (i.e., those less than 5 mm long)[111] are also a pollution concern. These particles—a large proportion of which are polyester fibres from laundering clothing and other textiles—may be mistaken for food by animals low on the food chain and therefore concentrate in predator species. Studies of stomach contents of the Northern Fulmar, a type of seabird that feeds at the ocean surface, show that since 2000, between 28% and 63% of birds studied had at least 0.1 gram of plastic in their stomachs.[112]

Fish and marine mammal stocks

Biotic indicators such as species abundance, diversity and average size are also of high importance for measuring ocean condition. Phytoplankton, microscopic aquatic plants, are at the foundation of the marine food web. Phytoplankton are consumed by zooplankton—animal plankton—that are essential food for many fish and marine mammals.[113] The main phytoplankton blooms occur in spring and fall.[114] The abundance, composition, timing and duration of these blooms can have significant effects on marine food webs. Satellite measurements of chlorophyll in surface waters are often used to estimate phytoplankton production, but they will miss production at deeper levels. In the Atlantic Ocean the

104 Fisheries and Oceans Canada, 2012, "Hypoxia," *Canada's State of the Oceans Report, 2012*, https://www.dfo-mpo.gc.ca/oceans/publications/soto-rceo/2012/page03-eng.html (accessed February 25, 2020).

105 United States Environmental Protection Agency, 2017, "The effects: Dead zones and harmful algal blooms," *Nutrient Pollution*, https://www.epa.gov/nutrientpollution/effects-dead-zones-and-harmful-algal-blooms (accessed February 25, 2020).

106 Fisheries and Oceans Canada, 2012.

107 Fox. L., et al., 2020, "Quantifying the effect of anthropogenic climate change on calcifying plankton," *Scientific Reports*, Vol. 10, https://doi.org/10.1038/s41598-020-58501-w (accessed March 27, 2020).

108 Qi, D., et al., 2017, "Increase in acidifying water in the western Arctic Ocean," *Nature Climate Change*, Vol. 7, https://doi.org/10.1038/nclimate3228 (accessed May 12, 2020).

109 Lebreton, L., et al., 2018, "Evidence that the Great Pacific Garbage Patch is rapidly accumulating plastic," *Scientific Reports*, Vol. 8, article no. 4666, https://www.nature.com/articles/s41598-018-22939-w (accessed November 9, 2020)

110 Environment and Climate change Canada and Health Canada, 2020, *Draft science assessment of plastic pollution*, https://www.canada.ca/en/environment-climate-change/services/evaluating-existing-substances/draft-science-assessment-plastic-pollution.html (accessed February 20, 2020).

111 National Oceanic and Atmospheric Administration, 2020, "What are microplastics," *Ocean Facts*, https://oceanservice.noaa.gov/facts/microplastics.html (accessed March 30 2020).

112 Environment and Climate Change Canada, 2020, *Plastic Particles in the Northern Fulmar*, https://www.canada.ca/en/environment-climate-change/services/environmental-indicators/plastic-particles-northern-fulmar.html, (accessed April 15, 2021).

113 Fisheries and Oceans Canada, 2019, "Phytoplankton," *Canada's Oceans Now: Atlantic Ecosystems 2018*, https://www.dfo-mpo.gc.ca/oceans/publications/soto-rceo/2018/atlantic-ecosystems-ecosystemes-atlantiques/index-eng.html#phytoplankton (accessed June 8th, 2020).

114 Fisheries and Oceans Canada, 2019.

magnitude of the spring bloom increased from 1999 to 2011 while the duration decreased with both returning to an average state in 2016.[115] On the Pacific Coast, a recent study suggests there is no long-term trend in chlorophyll levels in the Strait of Georgia over the last 100 years, although other research has found significant increases in chlorophyll levels between 1997 and 2010.[116]

In 2019, only 52 of 176 fish and marine mammal stocks managed by Fisheries and Oceans Canada and deemed economically, culturally, or environmentally important were considered to be healthy (Table 3.8), while the status of 29 stocks was assessed as cautious and 25 critical.[117] Data were insufficient to assess the status of 70 stocks, with over a third of these uncertain stocks potentially facing conservation risks. The Arctic Ocean has the highest proportion (76%) of marine stocks with an uncertain status, while the Atlantic Ocean has the highest proportion (51%) of stocks with a status assessed as cautious, critical, or uncertain with risk of serious harm possible or likely (Table 3.9). Of the 25 stocks in the critical zone, 13 are groundfish stocks including 6 cod stocks. In December 2020, Canada committed to sustainably manage 100% of the oceans under its jurisdiction by 2025, as one of 14 members of the High Level panel for Sustainable Ocean Economy.[118]

Species listed under the *Species at Risk Act* (SARA) can be found in all areas of the Canadian Atlantic and Pacific.[119] In all, 225 aquatic species (both marine and freshwater) are listed as having at least one population at risk due to their status under SARA or the Committee on the Status of Endangered Wildlife in Canada (COSEWIC).[120]

Sea ice extent

Sea ice is a defining characteristic of marine and coastal ecosystems in the Arctic and also occurs in northern areas of the Atlantic in winter. The extent of sea ice varies by season and between years; however, a widespread, long-term decline in sea ice has been observed, driven by a warming arctic climate.[121] In particular, over the last 50 years, a decline in summer sea ice extent and an increase in seasonal ice free periods has occurred. As ice melts, the Arctic reflects less sunlight[122] allowing more solar energy to enter the ocean. Sea ice change can directly and indirectly affect all components of the marine ecosystem and surrounding environments. For example, sea ice loss and wave action can trigger erosion of coastlines and ice shelves. In 2020, large parts of the Milne ice shelf on Ellesmere Island broke off.[123] As multi-year ice disappears it is also easier for vessels to travel through the Arctic, resulting in increased human activity and shipping traffic.

Decreases in sea ice can have rippling effects throughout the entire food chain, for example, starting with changes affecting sea ice algae, which provide critical early energy for arctic marine food webs.[124] Changes in sea ice may also trigger changes in the territory and hunting methods of species such as polar bears.[125] As waters warm, southern species may migrate northwards potentially changing population interactions and impacting species with nowhere

115 Bernier, R.Y., R.E. Jamieson, and A.M. Moore, 2018, "State of the Atlantic Ocean Synthesis Report," *Canadian Technical Report of Fisheries and Aquatic Sciences*, Fisheries and Oceans Canada, no. 3167, https://waves-vagues.dfo-mpo.gc.ca/Library/40801755.pdf (accessed March 25, 2020).

116 Johannessen, S.C., R.W. Macdonald and J.E. Stivens, 2021, "Has primary production declined in the Salish Sea", *Canadian Journal of Fisheries and Aquatic Sciences*, Vol. 78, no. 3, https://cdnsciencepub.com/doi/full/10.1139/cjfas-2020-0115&af=R (accessed April 27, 2021); Jackson, J. M., et al., 2015, "Satellite chlorophyll off the British Columbia Coast, 1997-2010," *Journal of Geophysical Research*, Vol. 120, no. 7, https://doi.org/10.1002/2014JC010496 (accessed May 10, 2020).

117 The Canadian *Sustainability Survey for Fisheries* includes fish stocks, as well as stocks of a number of marine mammals, selected as a result of their importance for economic, cultural and environmental reasons. These stocks cover the majority of landings from managed fisheries. Fisheries and Oceans Canada, 2019, Sustainability Survey for Fisheries, https://www.dfo-mpo.gc.ca/reports-rapports/regs/sff-cpd/survey-sondage/index-en.html (accessed February 26, 2020).

118 Parker, L., 2020,"In rare show of solidarity, 14 key nations commit to protect oceans," *National Geographic*, https://www.nationalgeographic.com/environment/article/in-rare-show-of-solidarity-14-key-nations-commit-to-protect-oceans (accessed December 9, 2020).

119 Fisheries and Oceans Canada, 2019, *Aquatic Species at Risk Map*, https://www.dfo-mpo.gc.ca/species-especes/sara-lep/map-carte/index-eng.html (accessed May 15, 2020).

120 Fisheries and Oceans Canada, 2019, *Aquatic Species at Risk Found in Canadian Waters*, http://www.dfo-mpo.gc.ca/species-especes/sara-lep/identify-eng.html?sara=Endangered (accessed May 15, 2020).

121 Derksen, C., et al., 2019.

122 National Snow and Ice Data Center, 2020, *Thermodynamics: Albedo*, https://nsidc.org/cryosphere/seaice/processes/albedo.html (accessed February 12, 2020).

123 National Oceanic and Atmospheric Administration, 2020, *Canada's Milne Ice Shelf Collapses*, https://www.nesdis.noaa.gov/news/canadas-milne-ice-shelf-collapses (accessed September 30, 2020).

124 Heffernan, O., 2019, "Melting ice may be a boon for some Arctic whales—then a bust," *National Geographic*, June 2019, https://www.nationalgeographic.com/environment/article/melting-sea-ice-brings-boom-and-then-bust-for-arctic-iconic-whales (accessed February 12, 2020).

125 Regehr, E. V., et al., 2009, "Survival and breeding of polar bears in the southern Beaufort Sea in relation to sea ice," *Journal of Animal Ecology*, Vol. 79 , no. 1, https://doi.org/10.1111/j.1365-2656.2009.01603.x (accessed May 8, 2020).

left to migrate. Killer whales are already increasingly being found in arctic waters, resulting in impacts on narwhal and bowhead whale behaviour and distribution.[126] Inuit are experiencing impacts on harvesting activities as access to hunting areas becomes more difficult and the abundance and distribution of species change.[127]

Arctic sea ice reaches minimum levels in September and maximum levels in late February to early March. The record for minimum circumpolar arctic ice extent was set in the summer of 2012, followed by 2020 and 2019 with the second and third lowest summer sea ice area.[128] Canadian waters also experienced the smallest extent of sea ice in 2012, but 2011 and 1998 followed with the second and third smallest ice areas. Across the Canadian Arctic, all five marine ecoregions show significant drops in ice extent for September ice over the last four decades (Chart 3.5 and Table 3.10).

Multi-year ice is important in the Arctic,[129] as it reflects more light than first year ice and is also thicker, stabilizing the ice pack, providing more protection against coastal erosion and limiting the use of icebreakers. The rapid loss of multi-year ice in the central Arctic Ocean allows ice to move more freely, facilitating the loss of sea ice across other areas of the Arctic.[130] Northern Canadian waters have experienced summer season declines in multi-year sea ice area of 7.4% per decade from 1968 to 2018 and decadal decreases of 7.0% in total sea ice area; however, multi-year ice in the western Canadian Arctic Archipelago has remained stable.[131]

The maximum ice extent occurring in the three Atlantic marine ecoregions has also decreased (Chart 3.6 and Table 3.11). Sea ice begins forming starting in December on the coast of southern Labrador and by January in the northern Gulf of St. Lawrence. By the end of January, the western and northern parts of the Gulf of St. Lawrence are ice-covered. From January to March, pack ice spreads southwards from Labrador along the eastern coast of Newfoundland with distribution dependent on the severity of winter conditions and wind direction. Sea ice break up begins in mid–March, with ice retreating to the northern end of the Strait of Belle Isle by May, allowing icebergs to drift towards the Grand Banks on the East Coast, transported by the Labrador Current.[132]

126 Breed, G.A., et al., 2017, "Sustained disruption of narwhal habitat use and behaviour in the presence of Arctic killer whales," *Proceedings of the National Academy of Sciences of the United States of America*, https://www.pnas.org/content/114/10/2628 (accessed May 8, 2020); Dunmall, K., and C. Mathews, 2019, "Range Expansions and New Species Occurrences," *Canada's Ocean Now: Case Studies from State of Canada's Arctic Seas Report*, Niemi, A. (ed.), https://waves-vagues.dfo-mpo.gc.ca/Library/40833872.pdf (accessed May 19, 2020).

127 Kumar, M. et al., 2019, "Harvesting activities among First Nations people living off reserve, Métis and Inuit: Time trends, barriers and associated factors," *Aboriginal Peoples Survey*, https://www150.statcan.gc.ca/n1/pub/89-653-x/89-653-x2019001-eng.htm (accessed July 14, 2020).

128 Ramsayer, K., 2020, "2020 Arctic Sea Ice Minimum at Second Lowest on Record," *NASA global Climate Change Vital Signs of the Planet*, https://climate.nasa.gov/news/3023/2020-arctic-sea-ice-minimum-at-second-lowest-on-record/ (accessed September 30, 2020).

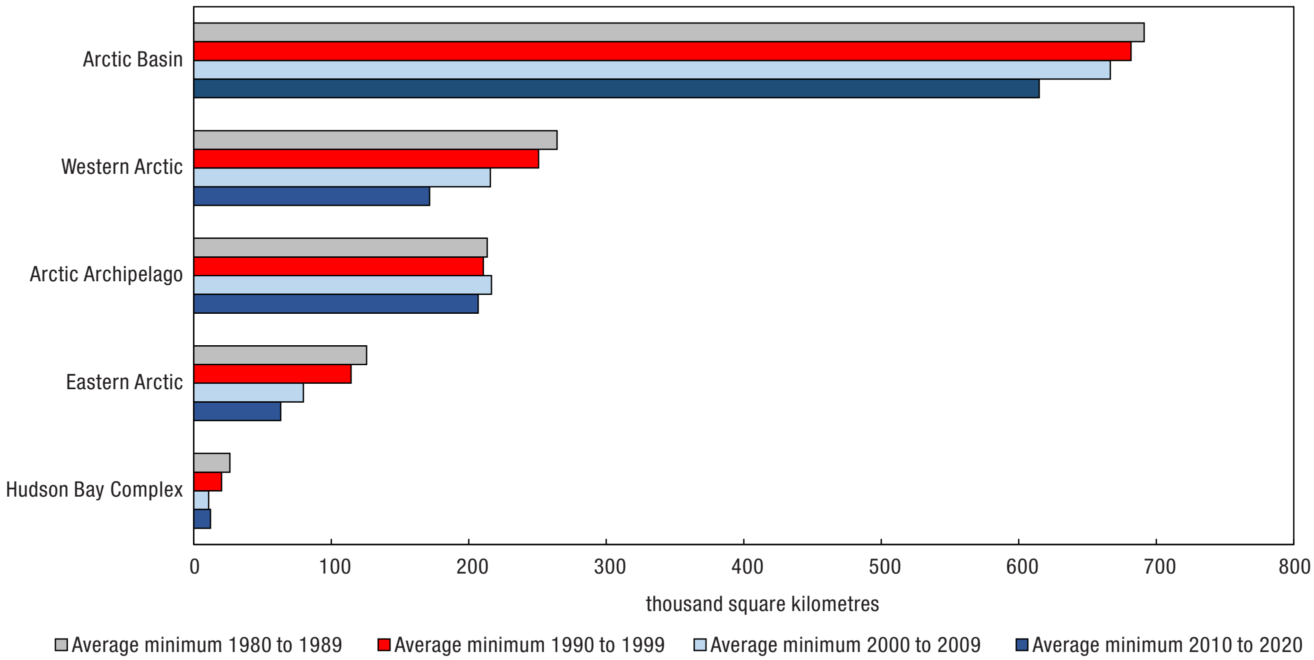
129 National Snow and Ice Data Center, 2020, *Multiyear ice*, https://nsidc.org/cryosphere/seaice/characteristics/multiyear.html (accessed July 14, 2020).

130 Babb, D.G., et al, 2015, "Physical processes contributing to an ice free Beaufort Sea during September 2012," *JGR Oceans*, Vol. 121, no. 1, https://doi.org/10.1002/2015JC010756 (accessed April 27, 2021)

131 Note: this estimate includes waters outside the Canadian marine ecoregions. Environment and Climate Change Canada, 2019, *Canadian Environmental Sustainability Indicators: Sea ice in Canada*, https://www.canada.ca/en/environment-climate-change/services/environmental-indicators/sea-ice.html (accessed July 14, 2020); Howell, Stephen, et al., 2008, "Multi-Year Sea-Ice Conditions in the Western Canadian arctic Archipelago Region of the Northwest Passage: 1968-2006", *Atmosphere-Ocean*, Vol. 46, no. 2, pp. 229-242, https://www.canada.ca/content/dam/eccc/migration/main/glaces-ice/0f9e03b9-1146-4ad4-a13b-ae9e07c9f72b/howell-20et-20al.-202008-20-20myi-20in-20the-20nwp.pdf (accessed April 26, 2021).

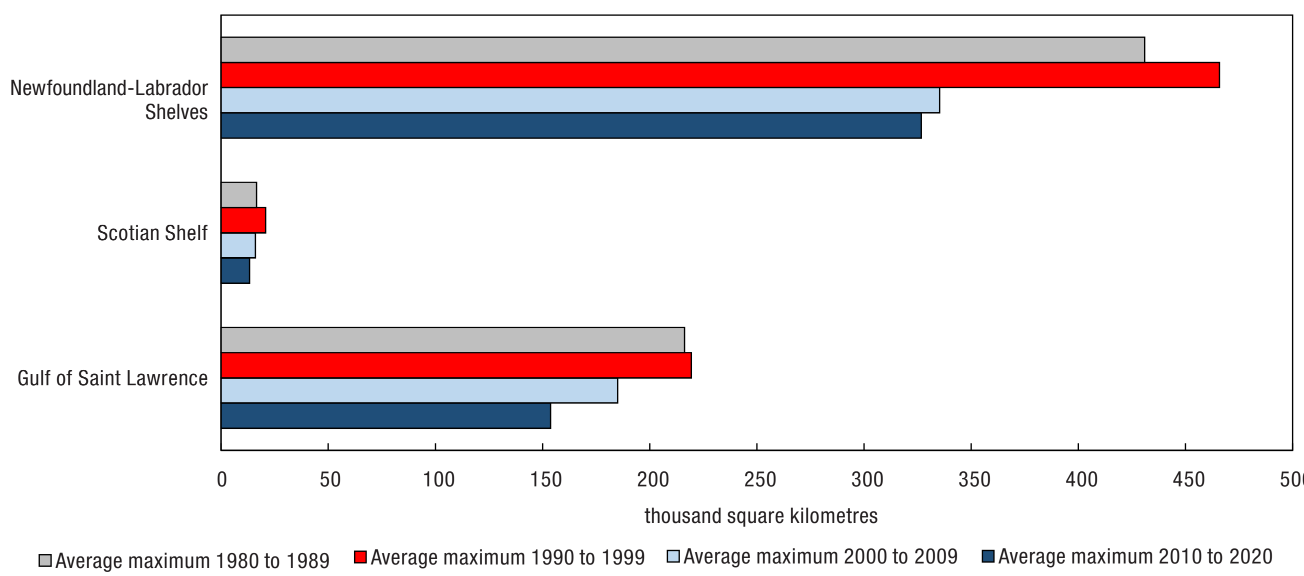
132 Environment and Climate Change Canada, 2015, *Where sea ice is found*, https://www.canada.ca/en/environment-climate-change/services/ice-forecasts-observations/latest-conditions/educational-resources/sea/where-sea-ice-is-found.html (accessed April 29, 2021)

Chart 3.5
Sea ice extent, average decadal minimums, by Arctic marine ecoregion, 1980 to 2020



Notes: Seasonal minimums occur in September. 2020 data are included in the latest decade.
Source: Fetterer, F., K. Knowles, W.N. Meier, M. Savoie and A.K. Windnagel, 2017, *Sea Ice Index*, Version 3, Northern Shapefiles, February, March and September, National Snow and Ice Data Center (NSIDC), Boulder, Colorado, USA, https://doi.org/10.7265/N5K072F8 (accessed July 13, 2020).

Chart 3.6
Sea ice extent, average decadal maximums, by Atlantic marine ecoregion, 1980 to 2020



Notes: Seasonal minimums occur in September. 2020 data are included in the latest decade.
Source: Fetterer, F., K. Knowles, W.N. Meier, M. Savoie and A.K. Windnagel, 2017, *Sea Ice Index*, Version 3, Northern Shapefiles, February, March and September, National Snow and Ice Data Center (NSIDC), Boulder, Colorado, USA, https://doi.org/10.7265/N5K072F8 (accessed July 13, 2020).

Human modifications

Although the ocean seafloor is a relatively unexplored region of Earth,[133] humans have had great impact in some areas, especially in shallower waters. Fisheries, especially with the use of bottom trawlers and ghost nets, can have a huge impact on the seafloor.[134] Bottom trawlers destroy coral beds and vegetative cover, while ghost nets and lost trawls can trap animals.[135] Aquaculture sites, which are located on approximately 400 km^2 of Canadian coastal area (Map 3.12 and Table 3.12), can potentially have a large impact on coastal areas and biodiversity.[136] Studies in Canada,[137] Norway[138] and Scotland[139] have investigated the spread of sea lice from fish farms to wild salmon. There is also concern that escaped Atlantic salmon populations could establish breeding populations, with some evidence of spawning in three streams in British Columbia.[140] Shellfish aquaculture creates additional habitat in the water column, which can have a positive impact on pelagic biomass and productivity. However, it can also be linked to reductions in local phytoplankton biomass and the establishment of non-native species.[141]

Areas licensed for offshore oil and gas production include 1,018 km^2, located in the Newfoundland and Labrador Shelves and Scotian Shelf. Discovery area licenses that indicate where production could be permitted in the future cover a total of 7,534 km^2 and licenses for exploration cover 51,491 km^2. Canada has had a moratorium on oil and gas activities on the West Coast since 1972 and on new activities in the Arctic Ocean since 2016. As of 2019, all oil and gas activity is prohibited in Canadian Arctic offshore waters.[142] Oil and gas exploration disrupts the ocean floor and creates pollution risks from oil leaks and spills, though old rigs can also provide shelter and habitat to species such as coral,[143] cod, flatfish and even porpoises.[144]

Harbours, manmade islands and infrastructure such as the Confederation Bridge joining Prince Edward Island and New Brunswick, disrupt the ocean floor and bring new sources of anthropogenic noise. The rise in ambient noise levels can have impacts on many species, such as whales, and may even impact fish egg and larvae development.[145] Marine shipping routes have large impacts on migratory species and recently slow-downs of traffic have been required to reduce noise impacting southern resident killer whales and reduce the chance of ship strikes to protect species such as the North Atlantic right whale.[146]

133 Copley, J., 2014, "Just How Little Do We Know about the Ocean Floor," *The Conversation UK*, October 9, 2014, https://theconversation.com/just-how-little-do-we-know-about-the-ocean-floor-32751 (accessed March 30, 2020).

134 Science Communication Unit – University of the West of England, 2013, "Seafloor damage," *Science for Environmental Policy*, no. 45, https://ec.europa.eu/environment/integration/research/newsalert/pdf/45si_en.pdf (accessed June 24, 2020).

135 Food and Agriculture Organisation of the United Nations, n. d., *Ghost nets hurting marine environment*, http://www.fao.org/news/story/en/item/19353/icode/ (accessed May 17, 2020).

136 Primavera, J.H., 2006,"Overcoming the impacts of aquaculture on the coastal zone," *Ocean and Coastal Management*, Vol. 49, no. 9-10, https://doi.org/10.1016/j.ocecoaman.2006.06.018 (accessed May 17,2020).

137 Krkošek, M., et al., 2011, "Effects of parasites from salmon farms on productivity of wild salmon," *Proceedings of the National Academy of Sciences of the United States of America*, Vol. 108, no. 35, https://doi.org/10.1073/pnas.1101845108 (accessed June 24, 2020).

138 Skarðhamer, J., et al., 2018, "Modelled salmon lice dispersion and infestation patterns in a sub-arctic fjord," *ICES Journal of Marine Science*, Vol. 75, no. 5, https://doi.org/10.1093/icesjms/fsy035 (accessed June 24, 2020).

139 Amundrud, T.L. and A.G. Murray, 2009, "Modelling sea lice dispersion under varying environmental forcing in a Scottish sea loch," *Journal of Fish Diseases*, Vol. 32, no. 1, https://doi.org/10.1111/j.1365-2761.2008.00980.x (accessed June 24, 2020).

140 Thorstad, E.B., et al., 2008, *Incidence and Impacts of Escaped Farmed Atlantic salmon Salmo salar in Nature.* NINA Special Report 36, http://www.fao.org/3/a-aj272e.pdf (accessed June 24, 2020).

141 Landry, T., et al., 2006, "A scientific review of bivalve aquaculture : interaction between wild and cultured species," *A Scientific Review of the Potential Environmental Effects of Aquaculture in Aquatic Ecosystems*, Fisheries and Oceans Canada, Vol.5, https://waves-vagues.dfo-mpo.gc.ca/Library/365656.pdf (accessed June 24, 2020).

142 The Canada Gazette, Part II, Vol. 153, no. 17 (21, August, 2019), Order Prohibiting Certain activities in Arctic Offshore Waters: SOR/2019-280, August 21, 2019, https://gazette.gc.ca/rp-pr/p2/2019/2019-08-21/html/sor-dors280-eng.html (accessed June 9, 2021).

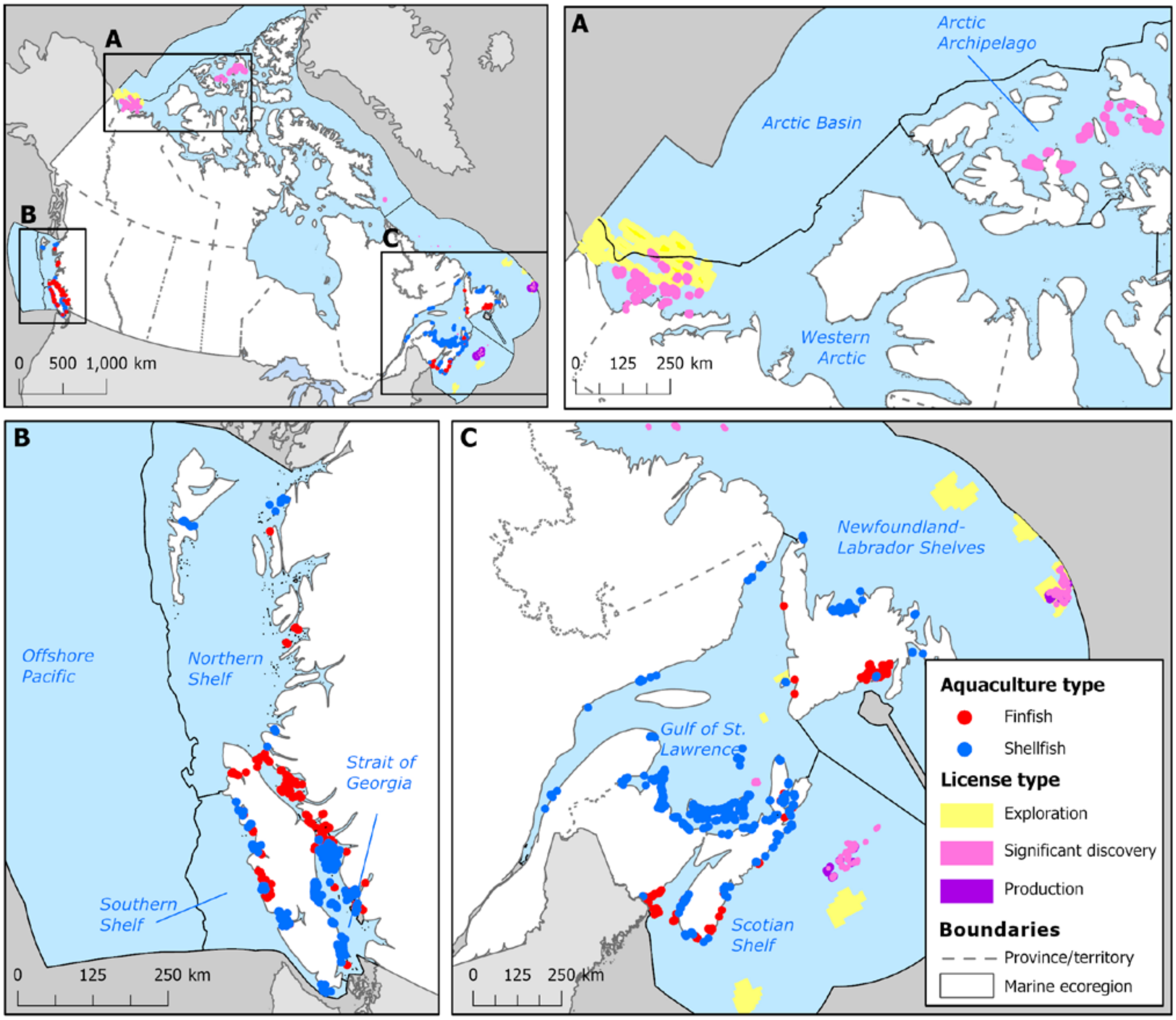
143 Bell, N., and J. Smith, 1999, "Coral growing on North Sea oil rigs," *Nature*, Vol. 402, https://doi.org/10.1038/45127 (accessed February 3, 2020).

144 Bull, A.S., and S.M. Love, 2019, "Worldwide oil and gas platform decommissioning: A review of practices and reefing options," *Ocean & Coastal Management*, Vol. 168, https://doi.org/10.1016/j.ocecoaman.2018.10.024 (accessed June 24, 2020); Zeldovich, L., 2018, "Can oil rigs grow into ocean reefs?," *JTSOR Daily*, https://daily.jstor.org/can-oil-rigs-grow-into-ocean-reefs/ (accessed June 24, 2020); Fowler, A., et al., 2018, "Environmental benefits of leaving offshore infrastructure in the ocean," *Frontiers in Ecology and the Environment*, Vol. 16, no. 10, https://doi.org/10.1002/fee.1827 (accessed June 20, 2020).

145 Fakan, E.P. and M.I. McCormick, 2019, "Boat noise affects the early life history of two damselfishes," *Marine Pollution Bulletin*, Volume 141, https://doi.org/10.1016/j.marpolbul.2019.02.054 (accessed August 10 2019). Nolet, V., 2017, *Understanding Anthropogenic Underwater Noise*, Prepared for Transport Canada, TP 15348 E, https://tc.canada.ca/en/initiatives/oceans-protection-plan/understanding-anthropogenic-underwater-noise (accessed August 10, 2019).

146 Vancouver Port Authority, 2015, *ECHO Program projects and initiatives*, https://www.portvancouver.com/environmental-protection-at-the-port-of-vancouver/maintaining-healthy-ecosystems-throughout-our-jurisdiction/echo-program/projects/ (accessed April 7, 2020); Transport Canada, 2020, *Protecting North Atlantic right whales from collisions with ships in the Gulf of St. Lawrence*, https://tc.canada.ca/en/marine-transportation/navigation-marine-conditions/protecting-north-atlantic-right-whales-collisions-ships-gulf-st-lawrence (accessed November 9, 2020).

Map 3.12
Marine and coastal modifications: aquaculture sites and oil licences, circa 2016 to 2020



Note: There has been a moratorium on oil exploration on the Pacific Coast of Canada since 1972 and on the Arctic Coast since 2016. As of 2019, all oil and gas activity is prohibited in Canadian Arctic offshore waters.

Sources: Newfoundland Aquaculture Industry Association, 2016, *Industry by the Numbers*; Newfoundland and Labrador Aquaculture, Fisheries and Land Resources, n.d., *Licensed aquaculture sites, 2015*; Nova Scotia Fisheries and Aquaculture, 2020, *Nova Scotia Marine Aquaculture Leases*; Mills, D., 2014, *PEI Aquaculture Licenses*; Ministère de l'Agriculture, des Pêcheries et de l'Alimentation du Québec, 2019, *Portrait-diagnostic sectoriel de l'industrie de la mariculture au Québec*; New Brunswick Department of Agriculture, Aquaculture and Fisheries, 2019, *Marine Aquaculture Site Mapping Program (MASMP)*; British Columbia Ministry of Forests, Lands, Natural Resource Operations and Rural Development, 2011, *Saltwater Finfish Tenures – Coastal Resource Information Management System (CRIMS), GeoBC*; Fisheries and Oceans Canada, 2017, *Shellfish Integrated Management of Aquaculture Plan, Version 2.1*; Fisheries and Oceans Canada, 2017, *Current valid British Columbia aquaculture licence holders*; Canada-Newfoundland and Labrador Offshore Petroleum Board, n.d., *Mapping Information and Shapefiles*; Canada-Nova Scotia Offshore Petroleum Board, *Oil 2019, Maps and Coordinates*, Canada-Nova Scotia Offshore Petroleum Board, 2019, *GIS Information*, Crown-Indigenous Relations and Northern Affairs Canada, 2015, *Oil and Gas Rights*.

Textbox: Biodiversity conservation

Protected areas play an important role in conserving nature and biodiversity. The first target of the 2020 Biodiversity Goals and Targets for Canada—related to the global Aichi Biodiversity Target 11—was to conserve 17% of terrestrial areas and inland water and 10% of coastal and marine areas by 2020 through protected areas and other effective area-based conservation measures.[147] The objectives of protected areas are to prevent the degradation of natural areas from increasing pressures and threats and to conserve biodiversity, natural conditions and related values and services. While the primary objective of areas conserved under other effective area-based conservation measures may be different, these measures also result in the protection of biodiversity.[148]

In Canada, federally protected[149] or conserved areas include National Parks, National Marine Conservation Areas, National Wildlife Areas, Migratory Bird Sanctuaries and Marine Protected Areas (MPA). Provincial and territorial designations for protected or conserved areas include, among others, Provincial Park, Territorial Park, Marine Park, Wilderness Park Wildlife Refuge, Nature Reserve, Biodiversity Reserve, Wilderness Area and Habitat Protected Area. Other areas are protected or conserved by Indigenous peoples, by collaborative governance and by non-profit organizations such as the Nature Conservancy of Canada, Ducks Unlimited or land trust organizations.

In December 2020, 12.5% of Canada's terrestrial and inland water area was conserved, mostly in parks or migratory bird sanctuaries (Map 3.13 and Table 3.13). These areas fall under different categories of protection and management and some face threats including climate change, fragmentation, invasive species and incompatible land uses or activities in areas adjacent to conserved areas, among others.[150] The Wrangel Mountains, almost entirely protected and conserved, is the ecoprovince with the greatest percentage of protected areas. In most ecoprovinces, however, the percentage of conserved terrestrial area is below the target.

In August 2019, Canada surpassed its target for the conservation of marine and coastal areas, with 13.8 % of the EEZ conserved, after the addition of Tuvaijuittuq Marine Protected Area in the Arctic Basin (Table 3.14).[151] Canada has recently committed to conserving 25% of its EEZ by 2025, working toward 30% by 2030.[152] Marine protected and conserved areas vary in their regulations and in the types of activities that are allowed. While a range of activities and management levels are permitted, new standards introduced in 2019 will prohibit oil and gas activities, mining, dumping and bottom trawling in federal marine protected areas.[153] The Laurentian Channel MPA, designated in 2019, was the first to follow these new protection standards.[154] These types of economic activities may occur in areas protected through other conservation measures, such as marine refuges; however, areas where oil and gas extraction occurs do not contribute towards the marine conservation target.

147 Federal, Provincial and Territorial Working Group on Biodiversity, n. d., *Canada Target 1*, https://biodivcanada.chm-cbd.net/canada-target-1 (accessed August 7, 2020).

148 Canadian Parks Council, 2019, *Decision Support Tool: For Assessing Areas Against Pan-Canadian Standards for Protected Areas and Other Effective Area-based Conservation Measures (OECMS) for Terrestrial and Inland Waters*, https://www.conservation2020canada.ca/accounting (accessed August 5, 2020).

149 A protected area is defined by the International Union for the Conservation of Nature (IUCN) as "a clearly geographical space, recognized, dedicated and managed, through legal or other effective means, to achieve the long-term conservation of nature with associated ecosystem services and cultural values." Protected areas can be classed into seven IUCN management categories that allow range of activities from Class 1a – Strict Nature Reserve to Class VI – Protected Area with Sustainable Use of Natural Resources.

150 Environment and Climate Change Canada, 2016.

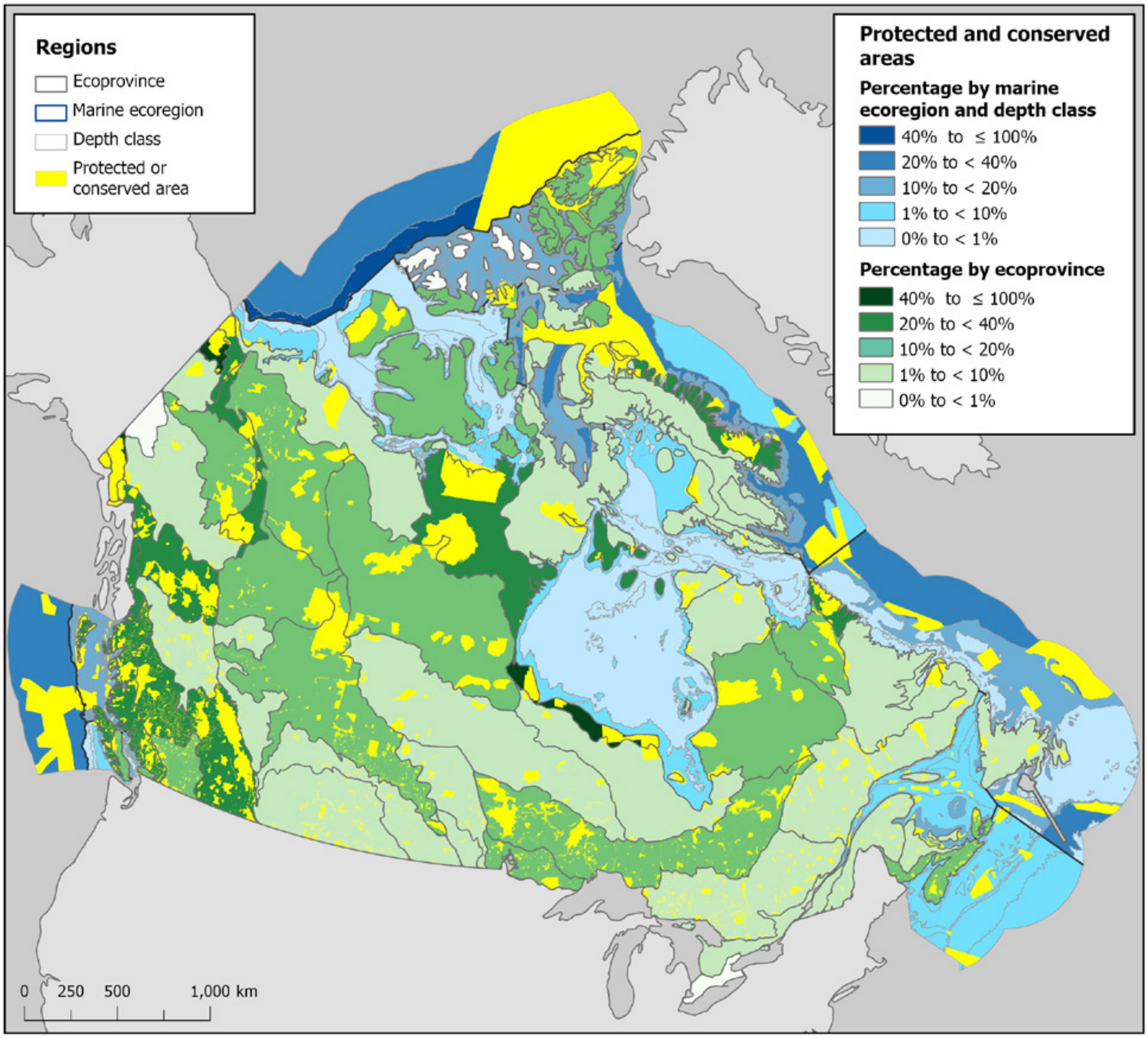
151 Fisheries and Oceans Canada, 2020, *Canada's marine protected and conserved areas*, https://www.dfo-mpo.gc.ca/oceans/conservation/areas-zones/index-eng.html (accessed July 15, 2020).

152 Fisheries and Oceans Canada, 2020, *Canada's Oceans Agenda: Protecting our oceans*, https://www.dfo-mpo.gc.ca/oceans/conservation/plan/MCT-OCM-eng.html (accessed April 15, 2021)

153 Fisheries and Oceans Canada, 2019, "Canada announces new standards for protecting our oceans," *News Release*, April 25, 2019, https://www.canada.ca/en/fisheries-oceans/news/2019/04/canada-announces-new-standards-for-protecting-our-oceans.html (accessed October 18, 2020)

154 Fisheries and Oceans Canada, 2019, *Backgrounder: Laurentian Channel marine protected area*, https://www.canada.ca/en/fisheries-oceans/news/2019/04/backgrounder-laurentian-channel-marine-protected-area.html (accessed February 26, 2019).

Map 3.13
Protected and conserved area extent, by ecoprovince and marine ecoregion depth class, 2020



Note: Protected and conserved areas have been divided into terrestrial and marine parts. Any overlap between protected and conserved areas has been removed to avoid double counting.
Source: Environment and Climate Change Canada, 2020, Canadian Protected and Conserved Areas Database, December 2020.

Table 3.1
Total water storage change and water yield, by ecoprovince

Ecoprovince	Code	Cumulative total water storage change, 2002 to 2016	Annual total water storage change, 2002 to 2016	Average annual water yield, 1971 to 2014	Average annual water yield per area, 1971 to 2014	Water yield variability
		km^3	mm/yr	km^3	mm	CV
Canada	**...**	**..**	**..**	**3,514**	**350**	**.**
Northern Arctic Cordillera	1.1	-170*	-105*	..	..	..
Southern Arctic Cordillera	1.2	-171*	-103*	..	..	..
Sverdrup Islands	2.1	..	..	..	..	..
Ellesmere Basin	2.2	-165*	-96*	..	..	..
Victoria Lowlands	2.3	33**	6**	..	..	..
Parry Channel Plateau	2.4	-66*	-41*	..	..	..
Boothia–Foxe Shield	2.5	-62*	-9*	..	..	..
Baffin Uplands	2.6	-91*	-50*	..	..	..
Foxe–Boothia Lowlands	2.7	..	..	..	..	..
Amundsen Lowlands	3.1	8[E]	2[E]	36	117	1.78
Keewatin Lowlands	3.2	0[E]	0[E]	66	171	1.79
Ungava–Belcher	3.3	-31*	-15*	66	417	1.71
Mackenzie Foothills	4.1	..	..	16	184	1.76
Great Bear Lowlands	4.2	-20*	-5*	41	120	1.76
Hay–Slave Lowlands	4.3	-17*	-5*	26	111	1.80
Western Taiga Shield	5.1	-36**	-4**	91	143	1.70
Eastern Taiga	5.2	23**	4**	231	585	1.67
Labrador Uplands	5.3	6[E]	2[E]	189	754	1.69
Whale River Lowland	5.4	-1[E]	-1[E]	66	580	1.71
Western Boreal Shield	6.1	-2[E]	0[E]	103	196	1.65
Mid-Boreal Shield	6.2	19[E]	3[E]	197	393	1.66
Eastern Boreal Shield	6.3	35*	7*	281	793	1.67
Newfoundland	6.4	11*	7*	128	1,147	1.62
Lake of the Woods	6.5	..	..	13	188	1.73
Southern Boreal Shield	6.6	27[E]	6[E]	165	517	1.65
Appalachian–Acadian Highlands	7.1	19*	15*	66	698	1.68
Northumberland Lowlands	7.2	..	..	26	735	1.66
Fundy Uplands	7.3	..	..	70	986	1.63
Great Lakes–St. Lawrence Lowlands	8.1	7*	6*	63	713	1.68
Huron–Erie Plains	8.2	..	..	15	595	1.74
Boreal Foothills	9.1	3[E]	2[E]	17	137	1.76
Central Boreal Plains	9.2	3[E]	0[E]	40	83	1.78
Eastern Boreal Plains	9.3	29*	19*	17	127	1.81
Eastern Prairies	10.1	..	..	2	68	2.29
Parkland Prairies	10.2	27*	11*	7	42	2.45
Central Grassland	10.3	45*	12*	5	20	2.35
Northern Yukon Mountains	11.1	..	..	4	153	1.78
Old Crow–Eagle Plains	11.2	..	..	3	165	1.79

Table 3.1
Total water storage change and water yield, by ecoprovince

Ecoprovince	Code	Cumulative total water storage change, 2002 to 2016	Annual total water storage change, 2002 to 2016	Average annual water yield, 1971 to 2014	Average annual water yield per area, 1971 to 2014	Water yield variability
		km³	mm/yr	km³	mm	CV
Ogilvie Mountains	11.3	..	..	12	200	1.75
Mackenzie–Selwyn Mountains	11.4	21*	10*	42	266	1.78
Wrangel Mountains	12.1	..	..	10	412	1.70
Northern Boreal Cordillera	12.2	-89*	-27*	69	289	1.69
Southern Boreal Cordillera	12.3	-97*	-41*	97	580	1.70
Western Boreal Cordillera	12.4	..	..	9	244	1.70
Georgia Depression	13.1	..	..	33	1,696	1.67
Southern Coastal Mountains	13.2	-43[E]	-22[E]	366	2,308	1.61
Northern Coastal Mountains	13.3	..	..	53	1,652	1.67
Northern Montane Cordillera	14.1	-37*	-19*	83	590	1.70
Central Montane Cordillera	14.2	-38**	-25**	29	274	1.70
Southern Montane Cordillera	14.3	..	..	20	342	1.74
Columbia Montane Cordillera	14.4	-13*	-5*	136	757	1.69
Hudson Bay Coastal Plains	15.1	..	..	17	272	1.69
Hudson–James Lowlands	15.2	26**	6**	105	337	1.68

. not available for any reference period
.. not available for a specific reference period
… not applicable
[E] use with caution
* significantly different from reference category ($p < 0.05$)
** significantly different from reference category ($p < 0.10$)

Notes: Total water storage change is an estimate of the change in water stored in the environment as groundwater, soil moisture, surface water, snow and ice. Caution must be used in interpreting total water storage change results because of the level of uncertainty in the models, the short length of the time series, and the coarse resolution of the data. Data were suppressed for smaller ecoprovinces using a threshold of approximately 90,000 km². Statistically significant linear trends are presented at the 90% confidence interval or above. Water yield is an estimate of freshwater runoff. Water yield data was suppressed at the ecoprovince level for the North, but these areas are included in the Canada estimate. Water yield variability is measured by using a coefficient of variation (CV) that allows the comparison of all months in all years of the 43-year time period. The CV of the data is a measure of the dispersion or variation in the monthly values over the period 1971 to 2014. It is defined as the ratio of the standard deviation of the monthly values to the mean. A higher CV indicates that the monthly data are more variable.

Sources: Statistics Canada, Environment and Energy Statistics Division, 2021, special tabulation based on Wang, S., et al., 2014, “Assessment of water budget for sixteen large drainage basins in Canada,” *Journal of Hydrology*, Vol. 512, pp. 1-15, https://doi.org/10.1016/j.jhydrol.2014.02.058 (accessed December 11, 2020); Wang, S. and J. Li, 2016, “Terrestrial water storage climatology for Canada from GRACE satellite observations in 2002-2014,” Canadian *Journal of Remote Sensing*, Vol. 42, no. 3, pp. 190-202, https://doi.org/10.1080/07038992.2016.1171132 (accessed December 17, 2020); Li, J., S. Wang and F. Zhou, 2016, "Time series analysis of long-term terrestrial water storage over Canada from GRACE satellites using principal component analysis," Canadian *Journal of Remote Sensing*, Vol. 42, no. 3, pp. 161-170, https://doi.org/10.1080/07038992.2016.1166042 (accessed March 23, 2021); Statistics Canada, Table 38-10-0091-01, https://www150.statcan.gc.ca/t1/tbl1/en/tv.action?pid=3810009101 (accessed December 17, 2020); Spence, C. and A. Burke, 2008, “Estimates of Canadian Arctic Archipelago runoff from observed hydrometric data,” *Journal of Hydrology*, Vol. 362, pp. 247-259.

Table 3.2
Average ambient air quality, by region and selected urban areas, 2002 and 2016

	$PM_{2.5}$		O_3		NO_2		SO_2		VOCs	
	2002	2016	2002	2016	2002	2016	2002	2016	2002	2016
	micrograms per cubic metre		parts per billion						parts per billion carbon	
National	**7.3**	**6.4**	**32.8**	**32.5**	**13.7**	**7.8**	**2.8**	**1.0**	**91.3**	**58.4**
Atlantic Canada	**4.8**	**5.6**	**33.7**	**31.9**	**6.9**	**3.1**	**5.7**	**0.6**	**103.6**	**65.5**
Fredericton, N.B.	..	5.8	33.8	30.2	3.9	2.4	.	.	.	.
St. John's, N.L.	4.8	5.1	34.0	33.0	..	3.5	.	.	.	.
Halifax, N.S.	4.1	5.0	31.0	29.0	..	5.0	.	.	.	.
Southern Quebec	**9.8**	**6.3**	**33.6**	**33.1**	**14.9**	**8.4**	**4.3**	**1.7**	**74.4**	**35.2**
Montréal, Que.	10.0	7.1	30.6	32.5	16.1	8.9	.	.	.	.
Gatineau, Que.	..	5.6	35.5	35.0	11.1	5.9	.	.	.	.
Sherbrooke, Que.	..	5.0	39.0	34.0	.	.	.	.	.	.
Québec, Que.	7.8	8.2	33.2	32.0	14.1	6.6	.	.	.	.
Southern Ontario	**8.5**	**6.6**	**37.8**	**37.5**	**18.5**	**8.7**	**6.0**	**1.5**	**68.3**	**37.1**
Windsor, Ont.	..	9.0	35.5	39.5	19.4	11.0	.	.	.	.
Hamilton, Ont.	11.2	7.8	36.7	37.3	19.4	10.5	.	.	.	.
Kitchener, Ont.	..	7.3	39.0	39.0	..	6.2	.	.	.	.
Toronto, Ont.	8.6	7.0	36.9	36.0	20.0	11.2	.	.	.	.
St. Catharines – Niagara, Ont.	..	6.9	36.0	40.0	..	6.6	.	.	.	.
London, Ont.	..	6.8	38.0	41.5	..	4.1	.	.	.	.
Oshawa, Ont.	9.1	5.9	35.0	36.0	17.2	6.3	.	.	.	.
Ottawa, Ont.	7.5	5.8	34.0	34.0	27.1	6.3	.	.	.	.
Prairies and northern Ontario	**5.8**	**7.7**	**31.8**	**31.5**	**10.6**	**6.8**	**1.7**	**0.8**	**150.6**	**93.8**
Regina, Sask.	7.3	8.1	18.0	34.0	13.9	7.3	.	.	.	.
Saskatoon, Sask.	..	6.8	28.0	29.0	11.7	8.9	.	.	.	.
Edmonton, Alta.	6.3	6.4	32.2	30.6	17.2	7.8	.	.	.	.
Winnipeg, Man.	6.0	5.8	28.0	24.5	12.1	8.0	.	.	.	.
British Columbia1	**6.6**	**5.3**	**25.7**	**26.6**	**14.3**	**9.2**	**2.0**	**1.0**	**114.9**	**85.4**
Vancouver, B.C.	5.5	4.5	23.5	25.8	16.2	10.6	.	.	.	.
Victoria, B.C.	6.1	4.3	25.0	30.0	10.4	6.7	.	.	.	.
Whitehorse, Y.T.	2.4	3.4	36.0	30.0	0.7	..	.	.	.	.
Yellowknife, N.W.T.	..	7.8	..	30.0	..	1.9	.	.	.	.
2020 annual CAAQS standard numerical value[2]	**8.8**	**8.8**	**..**	**..**	**17.0**	**17.0**	**5.0**	**5.0**	**..**	**..**

. not available for any reference period
.. not available for a specific reference period
1. Only stations from Metro Vancouver were available for VOCs.
2. The Canadian Ambient Air Quality Standards (CAAQS) consist of an averaging time, numerical value and a statistical form for each pollutant, including fine particulate matter ($PM_{2.5}$), ground-level ozone (O_3), nitrogen dioxide (NO_2) and sulphur dioxide (SO_2). The CAAQS standard for O_3 is for the peak value, not the annual average. The standards are reviewed periodically. The numerical values of the annual 2020 CAAQS are provided here for reference purposes only and not for assessing the achievement status of the standard.

Notes: National, regional and urban ambient air quality concentrations are averaged from monitoring station data. These stations are spread across the country, but are more concentrated in urban areas. Selected urban areas include 25 census metropolitan areas and census agglomerations, representing some of the most populated municpalities in Canada including provincial and territorial capitals, for which sufficient data was available for reporting. For more information about the methodology and included stations, see the CESI Air Quality Indicator.
Sources: Environment and Climate Change Canada, 2018, "Air Quality," *Canadian Environmental Sustainability Indicators*, https://www.canada.ca/en/environment-climate-change/services/environmental-indicators/air-quality.html (accessed May 11, 2020), based on data from the National Air Pollutant Surveillance Program, https://www.canada.ca/en/environment-climate-change/services/air-pollution/monitoring-networks-data/national-air-pollution-program.html; Canadian Council of Ministers of the Environment, 2017, Canada's Air, https://ccme.ca/en/air-quality-report (accessed February 14, 2020).

Table 3.3
Forest fire and harvesting area, by ecoprovince, 1986 to 2019

Ecoprovince	Code	1986 to 1995 Fire	1986 to 1995 Harvest	1996 to 2005 Fire	1996 to 2005 Harvest	2006 to 2015 Fire	2006 to 2015 Harvest	2016 to 2019 Fire	2016 to 2019 Harvest	Total[1] Fire	Total[1] Harvest
		km²									
Canada	...	**260,903**	**77,443**	**188,120**	**99,984**	**234,395**	**80,994**	**78,092**	..	**761,510**	**258,422**
Northern Arctic Cordillera	1.1	0	0	0	0	0	0	0	..	**0**	**0**
Southern Arctic Cordillera	1.2	0	0	0	0	0	0	0	..	**0**	**0**
Sverdrup Islands	2.1	0	0	0	0	0	0	0	..	**0**	**0**
Ellesmere Basin	2.2	0	0	0	0	0	0	0	..	**0**	**0**
Victoria Lowlands	2.3	0	0	0	0	0	0	0	..	**0**	**0**
Parry Channel Plateau	2.4	0	0	0	0	0	0	0	..	**0**	**0**
Boothia–Foxe Shield	2.5	0	0	0	0	0	0	0	..	**0**	**0**
Baffin Uplands	2.6	0	0	0	0	0	0	0	..	**0**	**0**
Foxe–Boothia Lowlands	2.7	0	0	0	0	0	0	0	..	**0**	**0**
Amundsen Lowlands	3.1	140	0	19	0	124	0	3	..	**286**	**0**
Keewatin Lowlands	3.2	0	0	0	0	27	0	0	..	**28**	**1**
Ungava–Belcher	3.3	0	0	0	0	0	0	0	..	**0**	**0**
Mackenzie Foothills	4.1	6,569	8	3,605	9	2,683	19	1,435	..	**14,292**	**37**
Great Bear Lowlands	4.2	42,506	24	10,851	28	15,919	103	2,864	..	**72,140**	**155**
Hay–Slave Lowlands	4.3	3,943	825	6,314	1,188	17,063	1,167	3,024	..	**30,344**	**3,180**
Western Taiga Shield	5.1	43,593	10	28,715	31	41,986	74	9,853	..	**124,147**	**114**
Eastern Taiga	5.2	23,723	16	14,890	4	3,413	30	722	..	**42,748**	**50**
Labrador Uplands	5.3	1,951	10	2,602	2	4,327	24	109	..	**8,990**	**36**
Whale River Lowland	5.4	72	1	3	0	262	0	31	..	**367**	**1**
Western Boreal Shield	6.1	62,596	649	29,849	1,915	62,716	922	9,216	..	**164,378**	**3,486**
Mid-Boreal Shield	6.2	16,478	16,162	17,329	19,399	13,631	10,724	6,277	..	**53,716**	**46,285**
Eastern Boreal Shield	6.3	6,043	5,989	10,584	9,724	11,603	6,252	361	..	**28,591**	**21,965**
Newfoundland	6.4	908	1,528	114	1,906	5	1,106	0	..	**1,026**	**4,540**
Lake of the Woods	6.5	901	2,287	498	3,021	620	2,516	147	..	**2,166**	**7,824**
Southern Boreal Shield	6.6	1,482	9,631	880	12,503	2,706	9,409	473	..	**5,542**	**31,543**
Appalachian–Acadian Highlands	7.1	414	6,448	33	6,759	4	5,232	2	..	**453**	**18,439**
Northumberland Lowlands	7.2	438	2,249	10	3,129	1	2,365	7	..	**457**	**7,743**
Fundy Uplands	7.3	32	3,701	18	5,376	39	4,426	17	..	**106**	**13,503**
Great Lakes–St. Lawrence Lowlands	8.1	1	320	34	373	5	342	3	..	**42**	**1,035**
Huron–Erie Plains	8.2	0	52	8	70	1	39	0	..	**8**	**161**
Boreal Foothills	9.1	618	3,533	2,614	5,421	1,431	6,059	1,571	..	**6,235**	**15,013**
Central Boreal Plains	9.2	15,158	4,039	16,974	8,215	26,194	7,440	13,150	..	**71,476**	**19,694**
Eastern Boreal Plains	9.3	7,147	681	810	718	1,192	734	625	..	**9,775**	**2,132**
Eastern Prairies	10.1	86	70	57	104	35	61	2	..	**179**	**235**
Parkland Prairies	10.2	76	157	92	488	32	376	15	..	**215**	**1,021**
Central Grassland	10.3	14	54	230	294	131	319	126	..	**502**	**668**
Northern Yukon Mountains	11.1	83	0	72	0	197	0	6	..	**358**	**0**
Old Crow–Eagle Plains	11.2	557	0	230	0	116	0	429	..	**1,332**	**0**

Table 3.3
Forest fire and harvesting area, by ecoprovince, 1986 to 2019

		1986 to 1995		1996 to 2005		2006 to 2015		2016 to 2019		Total[1]	
		Fire	Harvest	Fire	Harvest	Fire	Harvest	Fire	Harvest	Fire	Harvest
Ecoprovince	Code	km²									
Ogilvie Mountains	11.3	1,210	0	6,544	1	854	1	1,883	..	**10,492**	**2**
Mackenzie–Selwyn Mountains	11.4	1,150	6	1,671	5	460	3	236	..	**3,517**	**15**
Wrangel Mountains	12.1	0	0	23	0	0	0	0	..	**23**	**0**
Northern Boreal Cordillera	12.2	9,516	123	10,286	139	6,738	77	4,024	..	**30,564**	**339**
Southern Boreal Cordillera	12.3	772	161	1,123	155	1,549	43	1,742	..	**5,186**	**359**
Western Boreal Cordillera	12.4	1,986	18	4,976	16	1,918	5	1,006	..	**9,886**	**39**
Georgia Depression	13.1	5	846	1	1,218	20	1,406	9	..	**35**	**3,470**
Southern Coastal Mountains	13.2	179	3,695	78	2,476	378	2,382	370	..	**1,006**	**8,553**
Northern Coastal Mountains	13.3	9	17	37	9	0	9	1	..	**48**	**35**
Northern Montane Cordillera	14.1	238	4,089	20	4,121	1,459	4,705	1,069	..	**2,786**	**12,914**
Central Montane Cordillera	14.2	162	4,296	865	5,243	5,095	5,446	12,507	..	**18,628**	**14,985**
Southern Montane Cordillera	14.3	220	2,222	1,232	2,601	964	3,574	1,563	..	**3,979**	**8,397**
Columbia Montane Cordillera	14.4	255	3,436	2,065	3,254	1,079	3,508	2,226	..	**5,624**	**10,198**
Hudson Bay Coastal Plains	15.1	248	0	1,086	0	438	0	116	..	**1,888**	**1**
Hudson–James Lowlands	15.2	9,424	90	10,677	68	6,980	95	870	..	**27,951**	**253**

.. not available for a specific reference period
… not applicable
1. Spatial data on harvesting from the Canada Landsat Disturbance dataset are not yet available for the years subsequent to 2015. See the National Forestry Database (https://nfdp.ccfm.org/en/data/harvest.php) for annual data on forest area harvested by province and territory.
Notes: Harvest data are identified by 30 m Landsat remote sensing. Fire data are taken from the National Burned Area Composite, part of the Fire Monitoring, Accounting and Reporting System, based on the integration of data from fine and coarse resolution satellite data from Natural Resources Canada and Provincial, Territorial and Parks Canada Agencies. These data differ from the harvesting and burned area totals reported in the National Forestry Database, which are based on different methodologies.
Sources: Natural Resources Canada, Canadian Forest Service, 2020, National Burned Area Composite (NBAC), http://cwfis.cfs.nrcan.gc.ca/datamart (accessed October 26, 2020); Guindon, L., et al., 2017, Canada Landsat Disturbance (CanLaD): a Canada-wide Landsat-based 30-m resolution product of fire and harvest detection and attribution since 1984, https://doi.org/10.23687/add1346b-f632-4eb9-a83d-a662b38655ad (accessed July 20, 2020); Data file downloaded from https://opendata.nfis.org/mapserver/nfis-change_eng.html (accessed July 20, 2020).

Table 3.4
Average urban greenness, by population centre size class and region, 2001, 2011 and 2019

		Average urban greenness			Type of greenness change					
					2001 to 2011			2001 to 2019		
	Population centres	2001	2011	2019	Decrease	Stable	Increase	Decrease	Stable	Increase
	number	percentage of area			percentage of population centres					
Total population centres	**996**	**80.3**	**80.3**	**75.7**	**27.0**	**35.2**	**37.8**	**38.8**	**30.1**	**31.1**
Size classes										
Large urban	31	75.8	75.4	69.6	29.0	16.1	54.8	77.4	0.0	22.6
Medium	58	82.0	81.6	77.7	46.6	12.1	41.4	70.7	8.6	20.7
Small	907	88.3	89.1	87.0	25.7	37.4	36.9	35.4	32.5	32.1
Regions										
Atlantic	101	94.3	95.6	93.9	6.9	55.4	37.6	20.8	50.5	28.7
Québec	268	86.0	87.2	82.8	13.1	51.1	35.8	30.6	43.7	25.7
Ontario	286	81.8	81.4	78.7	26.6	37.1	36.4	38.1	33.6	28.3
Prairies	234	61.5	62.6	55.5	41.9	9.8	48.3	43.6	8.1	48.3
British Columbia	107	84.0	80.6	72.9	49.5	27.1	23.4	67.3	15.9	16.8

Notes: Estimates of population centre greenness are based on the normalized difference vegetation index (NDVI) from MODIS. Water areas have been excluded. Includes population centres south of 60° latitude based on the 2016 population centre boundaries for all years to ensure consistency. Change in greenness compares the point in time to 2001 and does not represent a trend over time. For more information, see Appendix A.
Source: Statistics Canada, 2020, *Corrected representation of the NDVI using historical MODIS satellite images (250 m resolution) from 2000 to 2019*, https://open.canada.ca/data/en/dataset/dc700f75-19d8-4913-9846-78615ca93784 (accessed April 29 2020).

Table 3.5
Landscape condition indicators, by ecoprovince

Ecoprovince	Code	Average patch size of natural and semi-natural land, 2016	Average distance to patch of natural and semi-natural land, 2016	Linear feature density, 2016	Water crossing density, 2011	Human landscape modification index, 2011
		km²	m	m/km²	crossings/km²	Score (0 to 100)
Canada	...	**436.0**	**24.8**	**194.5**	**0.09**	**7.9**
Northern Arctic Cordillera	1.1	1,457.3	0.0	0.0	0.00	0.0
Southern Arctic Cordillera	1.2	186.7	0.0	0.4	0.00	0.2
Sverdrup Islands	2.1	155.6	0.0	0.0	0.00	0.5
Ellesmere Basin	2.2	514.4	0.0	0.1	0.00	0.3
Victoria Lowlands	2.3	210.0	0.0	0.4	0.00	0.2
Parry Channel Plateau	2.4	1,018.3	0.0	0.7	0.00	0.2
Boothia–Foxe Shield	2.5	69.8	0.0	0.5	0.00	0.2
Baffin Uplands	2.6	6,913.2	0.0	0.0	0.00	0.2
Foxe–Boothia Lowlands	2.7	179.0	0.0	1.4	0.00	0.3
Amundsen Lowlands	3.1	317.9	0.0	7.4	0.01	1.1
Keewatin Lowlands	3.2	140.4	0.0	0.5	0.00	0.1
Ungava–Belcher	3.3	94.6	0.0	1.2	0.00	0.1
Mackenzie Foothills	4.1	187.8	0.0	82.8	0.06	4.0
Great Bear Lowlands	4.2	136.2	0.0	116.0	0.05	5.1
Hay–Slave Lowlands	4.3	4.4	0.4	606.3	0.23	6.2
Western Taiga Shield	5.1	1,267.8	0.0	2.8	0.00	0.7
Eastern Taiga	5.2	1,210.4	0.0	7.5	0.00	0.9
Labrador Uplands	5.3	359.1	0.0	12.6	0.01	1.3
Whale River Lowland	5.4	1,662.1	0.0	2.0	0.00	0.2
Western Boreal Shield	6.1	85.4	0.2	29.2	0.01	3.5
Mid-Boreal Shield	6.2	9.0	2.8	111.9	0.05	8.1
Eastern Boreal Shield	6.3	8.6	3.0	59.1	0.04	4.8
Newfoundland	6.4	5.1	1.9	309.5	0.16	11.6
Lake of the Woods	6.5	3.9	12.7	339.1	0.12	14.9
Southern Boreal Shield	6.6	4.7	5.2	372.7	0.27	15.5
Appalachian–Acadian Highlands	7.1	2.4	12.9	555.9	0.39	20.5
Northumberland Lowlands	7.2	1.7	20.7	849.0	0.34	23.8
Fundy Uplands	7.3	1.8	13.0	825.8	0.36	21.1
Great Lakes–St. Lawrence Lowlands	8.1	1.3	154.1	1,815.4	0.85	43.8
Huron–Erie Plains	8.2	1.1	330.7	2,769.4	1.24	57.2
Boreal Foothills	9.1	2.1	8.3	1,132.0	0.47	15.0
Central Boreal Plains	9.2	2.4	47.6	588.4	0.15	19.2
Eastern Boreal Plains	9.3	6.8	18.2	285.0	0.03	12.0
Eastern Prairies	10.1	1.8	508.0	1,249.9	0.23	43.5
Parkland Prairies	10.2	1.1	203.6	1,032.8	0.41	50.5
Central Grassland	10.3	1.0	515.4	833.5	0.33	53.3
Northern Yukon Mountains	11.1	506.5	0.0	4.4	0.01	1.9
Old Crow–Eagle Plains	11.2	1,869.3	0.0	16.7	0.02	5.0

Table 3.5
Landscape condition indicators, by ecoprovince

Ecoprovince	Code	Average patch size of natural and semi-natural land, 2016	Average distance to patch of natural and semi-natural land, 2016	Linear feature density, 2016	Water crossing density, 2011	Human landscape modification index, 2011
		km²	m	m/km²	crossings/km²	Score (0 to 100)
Ogilvie Mountains	11.3	78.4	0.0	97.2	0.09	6.1
Mackenzie–Selwyn Mountains	11.4	454.0	0.0	4.5	0.01	2.2
Wrangel Mountains	12.1	24,469.5	0.0	2.7	0.00	1.3
Northern Boreal Cordillera	12.2	57.7	0.1	37.8	0.04	5.6
Southern Boreal Cordillera	12.3	366.9	0.0	14.5	0.02	3.2
Western Boreal Cordillera	12.4	50.4	0.0	44.7	0.04	6.7
Georgia Depression	13.1	1.8	56.0	1,692.3	0.79	26.4
Southern Coastal Mountains	13.2	15.0	1.1	88.7	0.17	8.9
Northern Coastal Mountains	13.3	304.6	0.0	8.4	0.01	1.9
Northern Montane Cordillera	14.1	5.0	3.4	118.2	0.11	8.8
Central Montane Cordillera	14.2	2.8	8.2	193.7	0.17	14.2
Southern Montane Cordillera	14.3	1.9	17.7	551.4	0.57	18.7
Columbia Montane Cordillera	14.4	7.5	2.6	219.3	0.21	11.7
Hudson Bay Coastal Plains	15.1	455.3	0.0	14.1	0.01	0.7
Hudson–James Lowlands	15.2	486.8	0.0	8.5	0.00	0.8

… not applicable

Notes: Linear features include roads, rail lines, cutlines and electrical transmission lines that fragment landscapes. Water crossings include, for example, road crossings of bridges and culverts. The human landscape modification index is a measure of direct human modifications to the landscape. For more information, see Appendix A.

Sources: Statistics Canada, Environment and Energy Statistics Division, 2021, special tabulation based on Agriculture and Agri-Food Canada (AAFC), 2015, *Land Use, 2010*, https://open.canada.ca/data/en/dataset/18e3ef1a-497c-40c6-8326-aac1a34a0dec (accessed June 1, 2020); AAFC, 2020, *Land Use, 2015* (beta version); Natural Resources Canada, 2017, *Topographic Data of Canada* - CanVec Series, https://open.canada.ca/data/en/dataset/8ba2aa2a-7bb9-4448-b4d7-f164409fe056 (accessed December 21, 2020); Statistics Canada, 2017, *Road Network File, 2016*, https://www150.statcan.gc.ca/n1/en/catalogue/92-500-X (accessed December 21, 2020); AAFC, 2016, *Interpolated Census of Agriculture*, https://open.canada.ca/data/en/dataset/1dee8513-5c73-43b6-9446-25f7b985cd00 (accessed December 3, 2020); Guindon, L., et al., 2017, *Canada Landsat Disturbance (CanLaD): a Canada-wide Landsat-based 30-m resolution product of fire and harvest detection and attribution since 1984*, https://doi.org/10.23687/add1346b-f632-4eb9-a83d-a662b38655ad (accessed July 20, 2020); data file downloaded from https://opendata.nfis.org/mapserver/nfis-change_eng.html (accessed July 20, 2020).

Table 3.6
Sea surface temperature departures (2005 to 2017) from the climate normal, by depth class, marine ecoregion and season

Marine ecoregion and depth class	Annual		Spring		Summer		Autumn		Winter	
	Average temperature, 1981 to 2010 climate normal	Temperature departure of the 2005 to 2017 average from the climate normal	Average temperature, 1981 to 2010 climate normal	Temperature departure of the 2005 to 2017 average from the climate normal	Average temperature, 1981 to 2010 climate normal	Temperature departure of the 2005 to 2017 average from the climate normal	Average temperature, 1981 to 2010 climate normal	Temperature departure of the 2005 to 2017 average from the climate normal	Average temperature, 1981 to 2010 climate normal	Temperature departure of the 2005 to 2017 average from the climate normal
	˚C									
Strait of Georgia										
Coastal	10.75	-0.18	11.67	-0.44	14.44	0.15	9.28	-0.09	7.60	-0.32
Epipelagic	10.77	-0.17	11.72	-0.44	14.51	0.16	9.27	-0.10	7.57	-0.32
Mesopelagic	10.86	-0.17	11.73	-0.46	14.80	0.19	9.38	-0.11	7.51	-0.31
Bathypelagic	10.72	-0.16	11.94	-0.32	14.14	0.17	9.13	-0.10	7.7	-0.40
Southern Shelf										
Coastal	10.75	-0.06	10.89	-0.10	13.21	0.08	10.46	0.00	8.44	-0.24
Epipelagic	10.86	-0.08	10.96	-0.11	13.36	0.12	10.58	-0.07	8.53	-0.26
Mesopelagic	11.02	-0.01	10.86	-0.10	13.79	0.14	10.92	0.08	8.51	-0.17
Bathypelagic	11.16	0.02	10.84	-0.13	14.17	0.19	11.14	0.15	8.48	-0.12
Offshore Pacific										
Coastal	9.85	0.06	8.74	0.09	13.83	0.29	9.99	0.03	6.84	-0.18
Epipelagic	9.85	0.06	8.74	0.09	13.83	0.29	9.99	0.03	6.84	-0.18
Mesopelagic	10.09	0.06	8.92	0.08	14.10	0.25	10.28	0.05	7.06	-0.13
Bathypelagic	10.61	0.11	9.39	0.03	14.58	0.25	10.88	0.14	7.60	0.02

Table 3.6
Sea surface temperature departures (2005 to 2017) from the climate normal, by depth class, marine ecoregion and season

Marine ecoregion and depth class	Annual		Spring		Summer		Autumn		Winter	
	Average temperature, 1981 to 2010 climate normal	Temperature departure of the 2005 to 2017 average from the climate normal	Average temperature, 1981 to 2010 climate normal	Temperature departure of the 2005 to 2017 average from the climate normal	Average temperature, 1981 to 2010 climate normal	Temperature departure of the 2005 to 2017 average from the climate normal	Average temperature, 1981 to 2010 climate normal	Temperature departure of the 2005 to 2017 average from the climate normal	Average temperature, 1981 to 2010 climate normal	Temperature departure of the 2005 to 2017 average from the climate normal
	°C									
Northern Shelf										
Coastal	10.07	0.09	9.77	0.15	13.13	0.09	9.89	0.00	7.47	0.13
Epipelagic	10.17	0.08	9.82	0.21	13.29	-0.02	9.95	-0.02	7.61	0.13
Mesopelagic	10.12	0.05	9.67	0.13	13.41	0.01	9.92	-0.02	7.48	0.09
Bathypelagic	10.25	0.07	9.53	-0.02	13.67	0.22	10.20	0.11	7.61	-0.03
Arctic Basin										
Coastal	-0.91	-0.02	-1.34	-0.01	-0.41	-0.12	-0.72	0.00	-1.65	0.02
Epipelagic	-0.86	0.04	-1.34	0.09	0.17	-0.03	-0.94	0.04	-1.54	0.04
Mesopelagic	-1.07	0.04	-1.44	0.09	0.00	0.05	-1.33	0.01	-1.52	0.03
Bathypelagic	-1.29	0.04	-1.47	0.05	-0.76	0.06	-1.42	0.05	-1.48	-0.01
Western Arctic										
Coastal	-0.22	0.06	-0.55	0.08	2.15	0.18	-1.12	0.01	-1.39	-0.01
Epipelagic	-0.50	0.15	-0.80	0.19	1.38	0.40	-1.22	0.02	-1.42	0.00
Mesopelagic	-0.60	0.21	-1.23	0.37	1.47	0.48	-1.22	-0.01	-1.44	0.00
Arctic Archipelago										
Coastal	-1.07	0.02	-1.36	0.02	-0.13	0.04	-1.45	0.01	-1.28	0.04
Epipelagic	-1.09	0.01	-1.40	0.01	-0.19	0.01	-1.39	0.01	-1.38	0.03
Mesopelagic	-1.13	0.00	-1.47	0.01	-0.16	-0.01	-1.50	0.00	-1.39	0.03
Eastern Arctic										
Coastal	-0.48	0.12	-0.58	0.06	1.15	0.42	-0.92	-0.01	-1.30	-0.03
Epipelagic	-0.57	0.12	-0.51	0.10	0.93	0.38	-1.14	0.01	-1.36	-0.04
Mesopelagic	0.04	0.08	-0.32	0.05	2.34	0.31	-0.66	0.05	-1.43	0.00
Bathypelagic	0.63	0.10	0.42	-0.11	3.05	0.54	-0.05	0.06	-1.51	0.03
Hudson Bay Complex										
Coastal	0.98	-0.11	-0.34	-0.08	4.21	-0.35	1.32	-0.01	-1.03	0.01
Epipelagic	1.30	-0.16	-0.08	-0.05	5.61	-0.45	1.19	-0.13	-0.72	-0.03
Mesopelagic	0.30	-0.12	-0.54	-0.05	2.96	-0.13	0.14	-0.31	-0.11	0.05
Newfoundland-Labrador Shelves										
Coastal	3.46	0.40	1.38	0.14	9.36	0.74	3.45	0.50	-0.29	0.22
Epipelagic	4.76	0.40	2.43	0.19	11.01	0.49	5.28	0.40	0.25	0.49
Mesopelagic	3.54	0.33	1.79	0.04	9.30	0.63	3.32	0.37	-0.24	0.28
Bathypelagic	4.96	0.44	3.76	0.15	9.15	0.56	5.05	0.46	2.04	0.66
Abyssalpelagic	12.99	0.89	10.28	0.24	19.49	0.25	14.47	1.34	7.72	1.72
Scotian Shelf										
Coastal	8.02	0.62	5.54	0.56	14.79	0.60	9.63	1.01	2.14	0.28
Epipelagic	8.27	0.76	5.53	0.64	15.54	0.79	9.79	1.17	2.23	0.44
Mesopelagic	8.90	0.84	6.25	0.79	15.95	0.85	10.37	1.22	3.11	0.49
Bathypelagic	11.28	1.31	9.00	1.33	18.79	1.14	13.10	1.53	6.03	1.11
Abyssalpelagic	15.06	1.22	14.18	0.90	22.09	0.53	17.56	0.72	11.14	1.92
Gulf of St. Lawrence										
Coastal	6.30	0.26	5.09	-0.14	14.71	0.68	6.02	0.77	-0.61	-0.28
Epipelagic	5.69	0.27	4.18	0.11	13.88	0.88	5.37	0.36	-0.68	-0.25
Mesopelagic	5.55	0.27	4.04	0.26	13.54	0.84	5.15	0.13	-0.54	-0.15

Notes: The climate normal is the three-decade average of climatological variables from 1981 to 2010. Winter data are from January to March with other seasons following sequentially. Areas classed as coastal have a maximum depth of 50 m, the epipelagic class has depths from 50 m to 200 m, the mesopelagic class has depths from 200 m to 1,000 m, the bathypelagic class has depths of 1 km to 4 km and the abyssalpelagic class includes all areas with depths of more than 4 km.
Source: Locarnini, R. A., et al., 2018, *World Ocean Atlas 2018: Volume 1: Temperature*, A. Mishonov (Technical Ed.), NOAA Atlas NESDIS 81, https://www.nodc.noaa.gov/OC5/SELECT/woaselect/woaselect.html (accessed November 15, 2019).

Table 3.7
Sea surface salinity departures (2005 to 2017) from the climate normal reference period, by depth class, marine ecoregion and season

Marine ecoregion and depth class	Annual		Spring		Summer		Autumn		Winter	
	Average salinity, 1981 to 2010 climate normal	Salinity departure of the 2005 to 2017 average from the 1981 to 2010 climate normal	Average salinity, 1981 to 2010 climate normal	Salinity departure of the 2005 to 2017 average from the 1981 to 2010 climate normal	Average salinity, 1981 to 2010 climate normal	Salinity departure of the 2005 to 2017 average from the 1981 to 2010 climate normal	Average salinity, 1981 to 2010 climate normal	Salinity departure of the 2005 to 2017 average from the 1981 to 2010 climate normal	Average salinity, 1981 to 2010 climate normal	Salinity departure of the 2005 to 2017 average from the climate normal
	practical salinity scale (PSS)									
Strait of Georgia										
Coastal	26.7	-0.44	26.0	-0.41	26.1	-1.56	28.1	-0.21	28.0	0.39
Epipelagic	26.6	-0.46	26.0	-0.45	26.1	-1.57	28.1	-0.24	28.0	0.38
Mesopelagic	26.3	-0.48	25.7	-0.52	25.7	-1.60	27.9	-0.24	27.9	0.43
Bathypelagic	27.3	-0.56	27.0	-0.54	27.2	-1.52	28.7	-0.39	28.4	0.22
Southern Shelf										
Coastal	31.2	-0.09	30.8	-0.07	31.3	-0.34	31.5	-0.12	31.0	0.07
Epipelagic	31.3	-0.07	30.8	-0.08	31.3	-0.30	31.5	-0.09	31.1	0.07
Mesopelagic	31.7	-0.08	31.6	-0.05	32.0	-0.16	32.0	-0.12	31.7	0.00
Bathypelagic	31.9	-0.07	31.9	-0.04	32.0	-0.12	32.1	-0.11	31.9	-0.01
Offshore Pacific										
Coastal	32.3	0.02	32.3	0.07	32.1	0.08	32.3	-0.04	32.5	-0.02
Epipelagic	32.3	0.02	32.3	0.07	32.1	0.08	32.3	-0.04	32.5	-0.02
Mesopelagic	32.3	0.00	32.3	0.03	32.1	0.03	32.3	-0.05	32.5	-0.02
Bathypelagic	32.3	-0.02	32.3	-0.03	32.1	0.00	32.3	-0.05	32.4	-0.02
Northern Shelf										
Coastal	31.4	-0.01	31.4	-0.09	31.1	0.03	31.5	0.02	31.7	0.01
Epipelagic	31.5	-0.01	31.4	-0.06	31.2	0.05	31.5	0.02	31.7	-0.03
Mesopelagic	31.6	0.02	31.6	-0.02	31.3	0.05	31.7	0.02	31.9	0.02
Bathypelagic	32.0	0.00	32.0	-0.01	31.8	0.05	32.1	-0.03	32.1	0.00
Arctic Basin[1]										
Coastal	26.6	0.09	31.3	-0.01	27.1	0.30	16.2	0.05	31.7	0.00
Epipelagic	27.5	-0.01	30.1	-0.32	27.1	0.25	22.4	0.16	30.5	-0.14
Mesopelagic	29.1	-0.06	29.9	-0.22	28.2	-0.01	28.5	0.07	29.8	-0.10
Bathypelagic	28.2	-0.14	28.5	-0.25	27.8	-0.11	28.2	-0.04	28.4	-0.16
Western Arctic[1]										
Coastal	26.5	0.35	26.6	0.19	23.3	0.67	27.2	0.53	28.8	0.00
Epipelagic	27.5	0.13	28.8	0.00	24.4	0.35	27.5	0.25	29.4	-0.05
Mesopelagic	28.3	0.25	30.4	0.20	25.3	0.41	27.4	0.34	30.0	0.07
Arctic Archipelago[1]										
Coastal	29.7	-0.03	31.4	-0.01	28.3	-0.08	28.4	0.00	30.7	-0.02
Epipelagic	30.0	-0.02	31.5	0.00	28.8	-0.08	28.8	0.01	30.8	0.00
Mesopelagic	30.3	-0.01	31.6	0.01	29.2	-0.06	29.5	0.00	30.7	-0.01
Eastern Arctic[1]										
Coastal	31.2	0.01	32.0	0.00	29.7	0.05	31.1	-0.01	32.1	-0.02
Epipelagic	31.2	-0.02	31.9	0.01	29.7	-0.03	31.1	-0.01	31.9	-0.04
Mesopelagic	32.1	-0.03	32.7	-0.05	31.3	-0.03	31.7	0.03	32.7	-0.07
Bathypelagic	32.5	-0.03	32.9	-0.04	31.4	-0.07	32.3	0.00	33.3	-0.03
Hudson Bay Complex[1]										
Coastal	29.3	0.09	28.8	0.00	28.2	0.36	29.7	0.01	30.4	0.00
Epipelagic	29.2	0.10	28.9	0.00	27.8	0.41	29.3	-0.01	30.8	0.00
Mesopelagic	31.6	-0.02	32.0	-0.01	30.8	-0.03	31.4	-0.03	32.2	-0.01

Table 3.7
Sea surface salinity departures (2005 to 2017) from the climate normal reference period, by depth class, marine ecoregion and season

Marine ecoregion and depth class	Annual		Spring		Summer		Autumn		Winter	
	Average salinity, 1981 to 2010 climate normal	Salinity departure of the 2005 to 2017 average from the 1981 climate normal	Average salinity, 1981 to 2010 climate normal	Salinity departure of the 2005 to 2017 average from the 1981 climate normal	Average salinity, 1981 to 2010 climate normal	Salinity departure of the 2005 to 2017 average from the 1981 climate normal	Average salinity, 1981 to 2010 climate normal	Salinity departure of the 2005 to 2017 average from the 1981 climate normal	Average salinity, 1981 to 2010 climate normal	Salinity departure of the 2005 to 2017 average from the climate normal
	practical salinity scale (PSS)									
Newfoundland-Labrador Shelves										
Coastal	32.0	-0.04	32.5	-0.09	31.2	-0.04	31.9	-0.07	32.6	0.03
Epipelagic	32.3	-0.01	32.6	-0.09	31.7	0.02	32.1	-0.02	32.7	0.04
Mesopelagic	32.6	0.01	32.8	-0.05	31.9	0.02	32.5	0.01	33.1	0.05
Bathypelagic	33.9	0.04	34.0	0.03	33.6	-0.04	33.8	0.07	34.2	0.11
Abyssalpelagic	33.8	-0.01	33.7	0.10	33.6	-0.51	33.8	0.28	34.1	0.08
Scotian Shelf										
Coastal	31.3	-0.08	31.4	-0.12	31.1	-0.03	31.3	-0.16	31.6	-0.01
Epipelagic	31.5	0.03	31.6	0.04	31.1	0.04	31.4	-0.06	31.7	0.08
Mesopelagic	31.9	0.08	32.0	0.12	31.6	0.08	31.9	0.01	32.0	0.10
Bathypelagic	32.9	0.35	33.0	0.46	32.6	0.21	33.0	0.47	33.1	0.25
Abyssalpelagic	34.4	0.30	34.5	0.52	34.0	-0.05	34.3	0.47	34.7	0.26
Gulf of St. Lawrence										
Coastal	29.7	-0.23	29.6	-0.23	28.7	-0.08	30.0	-0.30	30.6	-0.29
Epipelagic	30.5	-0.13	30.4	-0.02	29.5	-0.05	30.7	-0.25	31.2	-0.20
Mesopelagic	30.6	-0.05	30.5	0.12	29.7	0.09	31.0	-0.26	31.3	-0.12

1. Data for salinity in the Arctic Ocean are sparser than in other regions. In particular, winter salinity data are more scarce and thus modelled winter salinity values in some regions of the Arctic Ocean may be artificially high, resulting in less robust change values.

Notes: The climate normal is the three-decade average of climatological variables from 1981 to 2010. Winter data are from January to March with other seasons following sequentially. Areas classed as coastal have a maximum depth of 50 m, the epipelagic class has depths from 50 m to 200 m, the mesopelagic class has depths from 200 m to 1,000 m, the bathypelagic class has depths of 1 km to 4 km and the abyssalpelagic class includes all areas with depths of more than 4 km. Salinity is a unitless measure related to a ratio of electrical conductivity between a seawater sample at temperature 15˚C and pressure of one standard atmosphere to that of a potassium chloride solution in which the mass fraction of KCl is 32.4356E-3 at the same temperature and pressure. For more information, see http://salinometry.com/pss-78/.

Source: Zweng, M. M., et al., 2018, *World Ocean Atlas 2018: Volume 2: Salinity*, A. Mishonov (Technical Ed.), NOAA Atlas NESDIS 82, https://www.nodc.noaa.gov/OC5/SELECT/woaselect/woaselect.html (accessed May 31, 2020).

Table 3.8
Status of major stocks of fish and marine mammals, 2011 to 2019

	Stock status					
				Uncertain		
	Healthy	Cautious	Critical	Conservation risk likely or possible	Total	Total stocks
	number of stocks					
2011	72	31	17	..	35	155
2012	75	37	15	..	28	155
2013	74	41	16	..	24	155
2014	75	40	15	..	24	154
2015	78	28	19	10	34	159
2016	76	31	21	14	42	170
2017	63	25	18	22	73	179
2018	58	27	19	25	73	177
2019	52	29	25	26	70	176

.. not available for a specific reference period

Notes: The *Canadian Sustainability Survey for Fisheries* includes fish stocks, as well as stocks of a number of marine mammals, selected as a result of their importance for cultural, economic and environmental reasons. These stocks cover the majority of landings from managed fisheries. Two Great Slave Lake fish stocks are included in the survey. For more information on the stocks covered in this survey, see Fisheries and Oceans Canada, 2019.

Source: Fisheries and Oceans Canada, 2019, *Sustainability Survey for Fisheries*, https://www.dfo-mpo.gc.ca/reports-rapports/regs/sff-cpd/survey-sondage/comparison-comparaison-en.html (accessed April 1, 2021).

Table 3.9
Status of major stocks of fish and marine mammals, by region and species group, 2019

	Stock status							
				Uncertain				
Region and species group	Healthy	Cautious	Critical	Serious harm unlikely	Serious harm possible	Serious harm likely	Total	Total stocks
	number of stocks							
Arctic	**4**	**2**	**0**	**14**	**4**	**1**	**19**	**25**
Crustaceans	2	1	0	0	2	0	2	**5**
Groundfish	1	0	0	1	0	0	1	**2**
Marine mammals	0	0	0	12	2	1	15	**15**
Salmonids	1	1	0	1	0	0	1	**3**
Atlantic	**28**	**16**	**16**	**18**	**15**	**1**	**34**	**94**
Crustaceans	13	4	2	6	6	0	12	**31**
Groundfish	7	9	10	4	0	0	4	**30**
Large pelagics	1	0	0	1	0	0	1	**2**
Marine mammals	2	0	0	0	0	0	0	**2**
Molluscs	5	1	0	2	4	0	6	**12**
Other	0	0	0	0	3	0	3	**3**
Salmonids	0	0	0	0	1	1	2	**2**
Small pelagics	0	2	4	5	1	0	6	**12**
Pacific	**20**	**11**	**9**	**11**	**3**	**1**	**15**	**55**
Crustaceans	3	1	0	1	0	0	1	**5**
Groundfish	8	2	3	4	0	0	4	**17**
Molluscs	1	0	1	4	0	0	4	**6**
Other	3	0	0	0	0	0	0	**3**
Salmonids	3	5	4	2	2	0	4	**16**
Small pelagics	2	3	1	0	1	1	2	**8**
Great Slave Lake[1]	**0**	**0**	**0**	**1**	**1**	**0**	**2**	**2**
Groundfish	0	0	0	1	0	0	1	**1**
Salmonids	0	0	0	0	1	0	1	**1**
Total	**52**	**29**	**25**	**44**	**23**	**3**	**70**	**176**

1. The survey includes stocks of Lake Trout and Lake Whitefish in Great Slave Lake.

Notes: The C*anadian Sustainability Survey for Fisheries* includes fish stocks, as well as stocks of a number of marine mammals, selected as a result of their importance for cultural, economic and environmental reasons. These stocks cover the majority of landings from managed fisheries. For more information on the stocks covered in this survey, see Fisheries and Oceans Canada, 2019.

Source: Fisheries and Ocean Canadas, 2019, *Sustainability Survey for Fisheries*, https://www.dfo-mpo.gc.ca/reports-rapports/regs/sff-cpd/survey-sondage/comparison-comparaison-en.html (accessed April 1, 2021).

Table 3.10
Sea ice extent, average decadal minimums, by Arctic marine ecoregion, 1980 to 2020

	Decadal average sea ice extent				Decrease from 1980 to 1989 decade to 2010 to 2020 decade
Marine ecoregion	1980 to 1989	1990 to 1999	2000 to 2009	2010 to 20202	
	thousand km²				percentage
Arctic Basin	728.8	712.6	696.0	639.4	12.3
Western Arctic	267.8	265.7	219.1	173.5	35.2
Arctic Archipelago	222.1	219.3	225.4	214.4	3.5
Eastern Arctic	116.4	119.1	80.8	63.9	45.1
Hudson Bay Complex	25.9	19.5	10.5	11.8	54.3

Notes: Seasonal minimums occur in September. 2020 data are included in the latest decade.

Source: Fetterer, F., K. Knowles, W. N. Meier, M. Savoie and A. K. Windnagel, 2017, *Sea Ice Index, Version 3*, Northern Shapefiles, updated daily, February, March and September, Boulder, Colorado USA, NSIDC: National Snow and Ice Data Center, https://doi.org/10.7265/N5K072F8 (accessed July 13, 2020).

Table 3.11
Sea ice extent, average decadal maximum, by Atlantic marine ecoregion, 1980 to 2020

	Decadal average sea ice extent				Decrease from 1980 to 1989 decade to 2010 to 2020 decade
	1980 to 1989	1990 to 1999	2000 to 2009	2010 to 2020	
Marine ecoregion	thousand km²				percentage
Newfoundland-Labrador Shelves	430.9	465.9	335.3	326.7	24.2
Scotian Shelf	16.5	20.8	16.0	13.2	19.8
Gulf of Saint Lawrence	216.2	219.5	185.1	153.8	28.9

Notes: Seasonal maximums occur in February-March. 2020 data are included in the latest decade.
Source: Fetterer, F., K. Knowles, W. N. Meier, M. Savoie and A. K. Windnagel, 2017, *Sea Ice Index, Version 3*, Northern Shapefiles, updated daily, February, March and September, Boulder, Colorado USA, NSIDC: National Snow and Ice Data Center, https://doi.org/10.7265/N5K072F8 (accessed July 13, 2020).

Table 3.12
Selected human modifications of marine and coastal areas, by marine ecoregion, circa 2016 to 2020

	Human modification					
	Aquaculture sites			Oil licenses[1]		
	Shellfish	Finfish	Combined	Production	Discovery	Exploration
Marine ecoregion	km²					
Canada EEZ	**320.41**	**92.84**	**0.15**	**1,018**	**7,534**	**51,491**
Strait of Georgia	33.28	8.62	0.00	0	0	0
Southern Shelf	5.89	17.63	0.00	0	0	0
Offshore Pacific	0.00	0.00	0.00	0	0	0
Northern Shelf	1.41	18.49	0.00	0	0	0
Arctic Basin	0.00	0.00	0.00	0	90	8,009
Western Arctic	0.00	0.00	0.00	0	2,154	10,677
Arctic Archipelago	0.00	0.00	0.00	0	2,825	0
Eastern Arctic	0.00	0.00	0.00	0	112	0
Hudson Bay Complex	0.00	0.00	0.00	0	0	0
Newfoundland-Labrador Shelves	41.54	24.15	0.00	638	1,442	17,794
Scotian Shelf	43.42	22.65	0.08	380	762	13,515
Gulf of St. Lawrence	194.86	1.30	0.07	0	149	1,496

1.There has been a moratorium on oil exploration on the Pacific Coast of Canada since 1972 and on the Arctic Coast since 2016. As of 2019, all oil and gas activity is prohibited in Canadian Arctic offshore waters.

Sources: Newfoundland Aquaculture Industry Association, 2016, *Industry by the Numbers*, https://naia.ca/index.php/aquaculture-nl/production-stats (accessed July 20, 2020); Newfoundland and Labrador Aquaculture, Fisheries and Land Resources, n.d., *Licensed aquaculture sites, 2015*, https://www.fishaq.gov.nl.ca/pdf/aquaculture_2015_year.pdf (accessed February 14, 2019); Nova Scotia Fisheries and Aquaculture, 2020, *Nova Scotia Marine Aquaculture Leases*, https://data.novascotia.ca/Fishing-and-Aquaculture/Aquaculture-License-and-Lease-GIS-Database/h57h-p9mm (accessed December 16, 2020); Mills, D., 2014, *PEI Aquaculture Licenses*, http://www.arcgis.com/home/webmap/viewer.html?webmap=16aa8830c7084a8a92ce066b525978b4 (accessed December 16, 2020); Ministère de l'Agriculture, des Pêcheries et de l'Alimentation du Québec, 2019, *Portrait-diagnostic sectoriel de l'industrie de la mariculture au Québec*, https://www.mapaq.gouv.qc.ca/fr/Publications/Portrait-diagnostic_mariculture.pdf (accessed October 20, 2019) and https://catalogue.ogsl.ca/data/mapaq/f9558184-92d8-4925-b280-bcfbd75ea20f/mariculture_mapaq_2017.xlsx (accessed July 20, 2020); New Brunswick Department of Agriculture, Aquaculture and Fisheries, 2019, *Marine Aquaculture Site Mapping Program (MASMP),* https://nbdnr.maps.arcgis.com/apps/webappviewer/index.html?id=24c65e8718724c5db1de77899172630d (accessed October 20, 2019); British Columbia Ministry of Forests, Lands, Natural Resource Operations and Rural Development, 2011, *Saltwater Finfish Tenures – Coastal Resource Information Management System (CRIMS)*, GeoBC, https://catalogue.data.gov.bc.ca/dataset/saltwater-finfish-tenures-coastal-resource-information-management-system (accessed November 10, 2019); Fisheries and Oceans Canada, 2017, *Shellfish Integrated Management of Aquaculture Plan, Version 2.1*, https://www.pac.dfo-mpo.gc.ca/aquaculture/management-gestion/shellfish-mollusques/background-contexte-eng.html (accessed April 25, 2019); Fisheries and Oceans Canada, 2017, *Current Valid British Columbia Aquaculture Licence Holders*, https://open.canada.ca/data/en/dataset/522d1b67-30d8-4a34-9b62-5da99b1035e6 (accessed July 20, 2020); Canada-Newfoundland and Labrador Offshore Petroleum Board, n.d., *Mapping Information and Shapefiles*, https://www.cnlopb.ca/information/shapefiles/ (accessed February 26, 2019); Canada-Nova Scotia Offshore Petroleum Board, 2019, *Maps and Coordinates*, https://www.cnsopb.ns.ca/what-we-do/lands-management/maps-and-coordinates (accessed November 30, 2020), Canada-Nova Scotia Offshore Petroleum Board, 2019, *GIS Information*, https://callforbids.cnsopb.ns.ca/2011/01/gis_information.html (accessed November 30, 2020); Crown-Indigenous Relations and Northern Affairs Canada, 2015, *Oil and Gas Rights*, https://open.canada.ca/data/en/dataset/208ddd6d-dea8-4d1c-bf62-5b49e8983a51#wb-auto-6 (accessed May 20, 2020).

Table 3.13
Protected and conserved area, by ecoprovince, 2020

	Total area	Protected and conserved area	Share of ecoprovince protected and conserved	Share of protected and conserved area
	km²		percentage	
Canada total	**9,978,923**	**1,249,497**	**12.5**	**100.0**
Ecoprovince				
Northern Arctic Cordillera	113,667	14,119	12.4	1.1
Southern Arctic Cordillera	129,758	41,849	32.3	3.3
Sverdrup Islands	65,520	0	0.0	0.0
Ellesmere Basin	129,117	21,690	16.8	1.7
Victoria Lowlands	429,668	43,780	10.2	3.5
Parry Channel Plateau	134,422	11,893	8.8	1.0
Boothia–Foxe Shield	546,492	30,032	5.5	2.4
Baffin Uplands	131,350	1,898	1.4	0.2
Foxe–Boothia Lowlands	80,387	6,587	8.2	0.5
Amundsen Lowlands	308,466	24,263	7.9	1.9
Keewatin Lowlands	383,489	107,852	28.1	8.6
Ungava–Belcher	158,527	25,029	15.8	2.0
Mackenzie Foothills	86,572	28,729	33.2	2.3
Great Bear Lowlands	340,206	43,864	12.9	3.5
Hay–Slave Lowlands	235,507	26,757	11.4	2.1
Western Taiga Shield	635,379	73,462	11.6	5.9
Eastern Taiga	394,475	55,101	14.0	4.4
Labrador Uplands	250,152	13,051	5.2	1.0
Whale River Lowland	114,641	20,522	17.9	1.6
Western Boreal Shield	524,821	23,959	4.6	1.9
Mid-Boreal Shield	500,600	83,776	16.7	6.7
Eastern Boreal Shield	354,666	33,848	9.5	2.7
Newfoundland	111,239	7,443	6.7	0.6
Lake of the Woods	71,646	9,691	13.5	0.8
Southern Boreal Shield	319,993	29,237	9.1	2.3
Appalachian–Acadian Highlands	94,951	4,088	4.3	0.3
Northumberland Lowlands	35,629	1,339	3.8	0.1
Fundy Uplands	71,086	7,992	11.2	0.6
Great Lakes–St. Lawrence Lowlands	88,174	1,905	2.2	0.2
Huron–Erie Plains	24,724	190	0.8	0.0
Boreal Foothills	124,690	2,838	2.3	0.2
Central Boreal Plains	483,992	68,846	14.2	5.5
Eastern Boreal Plains	130,770	8,232	6.3	0.7
Eastern Prairies	32,872	369	1.1	0.0
Parkland Prairies	177,448	7,416	4.2	0.6
Central Grassland	254,376	20,380	8.0	1.6
Northern Yukon Mountains	26,893	9,184	34.2	0.7
Old Crow–Eagle Plains	20,760	9,210	44.4	0.7
Ogilvie Mountains	60,089	5,901	9.8	0.5
Mackenzie–Selwyn Mountains	159,487	22,066	13.8	1.8
Wrangel Mountains	24,471	21,967	89.8	1.8
Northern Boreal Cordillera	239,038	10,728	4.5	0.9
Southern Boreal Cordillera	168,162	53,700	31.9	4.3
Western Boreal Cordillera	38,797	0	0.0	0.0
Georgia Depression	19,470	2,501	12.8	0.2

Table 3.13
Protected and conserved area, by ecoprovince, 2020

	Total area	Protected and conserved area	Share of ecoprovince protected and conserved	Share of protected and conserved area
	km²		percentage	
Southern Coastal Mountains	158,751	41,609	26.2	3.3
Northern Coastal Mountains	31,881	7,604	23.8	0.6
Northern Montane Cordillera	141,283	13,570	9.6	1.1
Central Montane Cordillera	106,009	24,163	22.8	1.9
Southern Montane Cordillera	59,034	7,451	12.6	0.6
Columbia Montane Cordillera	180,331	60,653	33.6	4.9
Hudson Bay Coastal Plains	64,090	27,729	43.3	2.2
Hudson–James Lowlands	311,730	17,916	5.7	1.4
Great Lakes	88,379	11,516	13.0	0.9

Notes: This table includes only the terrestrial portion of protected and conserved areas with both terrestrial and marine regions. Any overlap between areas has been removed to avoid double counting. The total area for Canada includes the Canadian portion of the Great Lakes and residual areas along shorelines not included in the ecoprovince areas. These data may differ from other published tabulations. Only public data were used in this compilation.
Source: Environment and Climate Change Canada, 2020, *Canadian Protected and Conserved Areas Database*, December 2020, https://www.canada.ca/en/environment-climate-change/services/national-wildlife-areas/protected-conserved-areas-database.html (accessed September 22, 2021).

Table 3.14
Protected and conserved area, by marine ecoregion and depth class, 2020

Marine ecoregion and depth class	Total area	Protected and conserved area	Share of marine ecoregion protected or conserved by depth class	Share of protected and conserved area
	km²		percentage	
Total exclusive economic zone	**5,746,894**	**794,594**	**13.8**	**100.0**
Strait of Georgia	**8,970**	**458**	**5.1**	**0.1**
Coastal	3,273	392	12.1	0.0
Epipelagic	3,173	62	1.9	0.0
Mesopelagic	2,522	3	0.1	0.0
Bathypelagic	2	0	0.0	0.0
Southern Shelf	**28,158**	**786**	**2.8**	**0.1**
Coastal	4,132	642	16.0	0.1
Epipelagic	11,176	141	1.3	0.0
Mesopelagic	4,583	3	0.1	0.0
Bathypelagic	8,267	0	0.0	0.0
Offshore Pacific	**315,724**	**92,977**	**29.4**	**11.7**
Coastal	3	3	100.0	0.0
Epipelagic	15	15	100.0	0.0
Mesopelagic	211	205	97.2	0.0
Bathypelagic	315,495	92,754	29.4	11.7
Northern Shelf	**101,328**	**16,668**	**16.4**	**2.1**
Coastal	23,423	3,993	17.1	0.5
Epipelagic	39,737	7,644	19.2	1.0
Mesopelagic	25,109	3,427	13.6	0.4
Bathypelagic	13,060	1,603	12.3	0.2
Arctic Basin	**752,053**	**284,091**	**37.8**	**35.8**
Coastal	142	101	72.0	0.0
Epipelagic	13,117	9,853	75.1	1.2
Mesopelagic	224,802	115,044	51.2	14.5
Bathypelagic	513,992	159,094	31.0	20.0
Western Arctic	**539,793**	**12,085**	**2.2**	**1.5**
Coastal	177,824	10,877	6.1	1.4
Epipelagic	189,473	1,148	0.6	0.1
Mesopelagic	172,497	60	0.0	0.0
Arctic Archipelago	**268,797**	**38,923**	**14.5**	**4.9**
Coastal	43,739	7,347	16.8	0.9
Epipelagic	91,959	15,723	17.1	2.0
Mesopelagic	133,099	15,853	11.9	2.0

Table 3.14
Protected and conserved area, by marine ecoregion and depth class, 2020

Marine ecoregion and depth class	Total area	Protected and conserved area	Share of marine ecoregion protected or conserved by depth class	Share of protected and conserved area
	km²		percentage	
Eastern Arctic	**782,639**	**174,061**	**22.2**	**21.9**
Coastal	77,149	12,112	15.8	1.5
Epipelagic	154,899	25,731	16.6	3.2
Mesopelagic	362,773	119,538	32.9	15.0
Bathypelagic	187,819	16,680	8.9	2.1
Hudson Bay Complex	**1,244,644**	**8,684**	**0.7**	**1.1**
Coastal	343,386	8,507	2.5	1.1
Epipelagic	759,653	177	0.0	0.0
Mesopelagic	141,606	0	0.0	0.0
Newfoundland-Labrador Shelves	**1,041,656**	**118,425**	**11.4**	**14.9**
Coastal	49,994	364	0.8	0.0
Epipelagic	350,532	1,783	0.5	0.2
Mesopelagic	287,743	39,662	13.8	5.0
Bathypelagic	344,977	76,616	22.2	9.6
Abyssalpelagic	8,410	0	0.0	0.0
Scotian Shelf	**416,485**	**25,736**	**6.2**	**3.2**
Coastal	25,964	741	2.9	0.1
Epipelagic	145,984	13,368	9.2	1.7
Mesopelagic	28,277	1,763	6.2	0.2
Bathypelagic	102,137	6,301	6.2	0.8
Abyssalpelagic	114,123	3,563	3.1	0.4
Gulf of St. Lawrence	**246,646**	**21,700**	**8.8**	**2.7**
Coastal	63,504	11,373	18.5	1.4
Epipelagic	107,183	3,633	3.4	0.5
Mesopelagic	75,959	6,695	8.8	0.8

Notes: This table includes only the marine portion of protected and conserved areas with both terrestrial and marine regions. Any overlap between areas has been removed to avoid double counting. Areas classed as coastal have a maximum depth of 50 m, the epipelagic class has depths from 50 m to 200 m, the mesopelagic class has depths from 200 m to 1,000 m, the bathypelagic class has depths of 1 km to 4 km and the abyssalpelagic class includes all areas with depths of more than 4 km. These data may differ from other published tabulations. Only public data were used in this compilation.
Source: Environment and Climate Change Canada, 2020, *Canadian Protected and Conserved Areas Database*, December 2020, https://www.canada.ca/en/environment-climate-change/services/national-wildlife-areas/protected-conserved-areas-database.html (accessed September 22, 2021).

4.0 Supply and use of ecosystem services

People benefit from ecosystem contributions such as food, clean air and water, as well as the physical space for recreational activities and enjoyment of nature. These ecosystem services can be classified as provisioning services, regulating services and cultural services.[155]

Some ecosystem services provide benefits locally, while others contribute to services enjoyed globally. For example, trees and vegetation in urban areas can help regulate local temperature and reduce local heat island effects, while carbon sequestration and storage provide global climate regulation benefits that are enjoyed by people around the world.

The development of preliminary ecosystem service accounts, which compile information on the services provided by ecosystems and their use by people, is largely experimental and methods are still being developed. A better understanding of the various services provided and how they are used may lead to decision making that reflects a more comprehensive assessment of tradeoffs and impacts on human well-being.

4.1 Provisioning services

Provisioning services include flows of biomass including food, fuel, fibre and timber, as well as environmental flows, such as water, from ecosystems to people. Many of these goods are the product of ecosystems and economic activities. For example, crop production relies on water, energy from the sun, nutrients from soil, genetic material from seeds and pollination from wind and insects, but is also the result of labour, fuel use, fertilizer and pesticide inputs. Data are available for many of these products because they are valued by markets. However, it is difficult to disentangle the contribution that ecosystems make towards the service from the economic contribution.[156]

Over 141 million tonnes of timber were harvested from forest ecosystems in 2019, down from 196 million tonnes in 2002 (Table 4.1). In 2019, the largest proportion of the timber harvest occurred in British Columbia (39%), followed by Quebec (20%) and Alberta (17%).[157] The most commonly harvested species included spruce, pine and fir, while other harvested species used for lumber production included Douglas-fir, western larch, hemlock and western red cedar.[158] The forest sector, including pulp and paper and wood product manufacturing, contributed $29.2 billion (1.4%) towards Canada's GDP and provided 210,600 jobs in 2018.[159] The number and population of communities that are heavily based on the forest sector for employment income has decreased in recent decades.[160]

In 2020, Canada's agricultural ecosystems produced an estimated 137 million tonnes of crops, honey and maple products used for food, animal feed and industrial use, as well as an estimated 12 million tonnes of forage for grazing livestock.[161] Field crops, such as wheat, tame hay, corn, canola, barley and soybean, accounted for the majority of this total estimated production (87%) (Table 4.2). Most (71%) of this production occurred in the Prairie provinces, followed by Ontario (17%) and Quebec (8%). Crop production—particularly of field crops—has increased since 2002 while estimates of forage production for grazing livestock on pasture have decreased since 2001 (Chart 4.1). In 2018, the primary agriculture sector, excluding aquaculture, contributed $28.1 billion (1.4%) towards Canada's GDP and 314,700 jobs.[162]

155 European Environment Agency, 2020, *CICES: Towards a common classification of ecosystem services*, https://cices.eu (accessed January 6, 2020).

156 The provisioning services table reports production as a proxy for the ecosystem service since it is difficult to disentangle the contribution of ecosystems from economic contributions (Table 4.1).

157 National Forestry Database, 2021, *Table 5.1 Net merchantable volume of roundwood harvested by jurisdiction, tenure, category and species group*, http://nfdp.ccfm.org/en/index.php (accessed July 14, 2021); FAO, ITTO and United Nations, 2020, *Forest Product Conversion Factors*, Rome, Italy, https://doi.org/10.4060/ca7952en (accessed June 3, 2021).

158 Statistics Canada, Table 16-10-0017-01, https://doi.org/10.25318/1610001701-eng (accessed January 6, 2020).

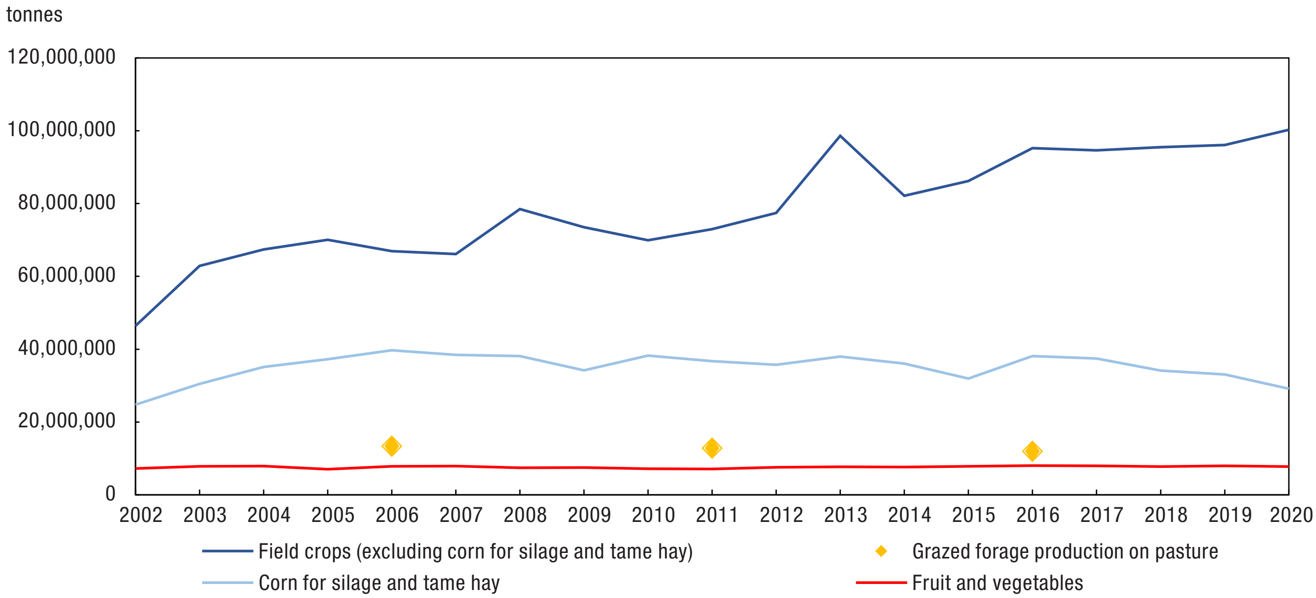
159 Statistics Canada, Table 36-10-0401-01, https://doi.org/10.25318/3610040101-eng (accessed January 7, 2022); Statistics Canada, Table 36-10-0489-01, https://doi.org/10.25318/3610048901-eng (accessed January 7, 2022).

160 Statistics Canada, 2018, "Forests in Canada," *Human Activity and the Environment*, Catalogue no. 16-201-X, https://www150.statcan.gc.ca/n1/pub/16-201-x/16-201-x2018001-eng.htm (accessed July 15, 2021).

161 Feed and forage crop production and an estimate of grazing based on pasture areas reported on the 2016 Census of Agriculture are included. Estimates of the ecosystem service exclude production of meat, dairy, eggs, wool, pelts and other products from animal agriculture other than honey.

162 Statistics Canada, Table 36-10-0401-01, https://doi.org/10.25318/3610040101-eng (accessed January 7, 2022); Statistics Canada, Table 36-10-0489-01, https://doi.org/10.25318/3610048901-eng (accessed January 7, 2022).

Chart 4.1
Provisioning services, agricultural ecosystems, by type of product, Canada, 2002 to 2020



Notes: Agricultural production is reported as a proxy of the provisioning service provided by agricultural ecosystems. Provincial data that are unavailable or data that are suppressed to meet confidentiality or data quality standards are not included in total. For more information on definitions, sources and methods, see Appendix A.
Sources: Statistics Canada, *Tables 32-10-0359-01, 32-10-0364-01, 32-10-0365-01, 32-10-0358-01 and 32-10-0406-01* (accessed March 16, 2021); Statistics Canada, 2007, *Census of Agriculture, 2006: Farm data and farm operator data tables*, https://www150.statcan.gc.ca/n1/pub/95-629-x/2007000/4123856-eng.htm (accessed January 14, 2020); Yungblut, D., 2012, *National Forage and Grassland Assessment*, http://www.canadianfga.ca/wp-content/uploads/2011/04/V1-Final-June-2012-Report-National-Forage-and-Grassland-Assessment-formatted.pdf (accessed December 3, 2019).

Freshwater, coastal and marine ecosystems produced the 808 thousand tonnes of shellfish, wild fish and marine plants harvested in 2019 by commercial fisheries or produced through aquaculture activities, down 30% from 1.1 million tonnes in 2002 (Table 4.1).[163] In 2019, 68% of this biomass was landed or farmed in the Atlantic provinces, followed by 24% in British Columbia and 6% in Quebec.[164]

In addition to commercial harvests of timber, crops and fish, Canada's terrestrial and aquatic ecosystems support other harvests of flora and fauna, including firewood, mushrooms, berries, foliage, fish and game for commercial, recreational, cultural and subsistence use. Comprehensive harvest statistics are not available for all foraging, trapping and recreational fishing and hunting activities. In 2018, hunters harvested an estimated 1.9 million migratory game birds including ducks, geese, woodcocks and other hunted species.[165] Canadian commercial harp seal landings in Atlantic Canada and Quebec totalled 32,223, while grey seal landings totalled 1,234 in 2019.[166] Recreational anglers caught over 194 million fish in 2015, of which 30% were kept and the remainder released.[167] The most commonly caught species include walleye, trout, pike, perch and bass. Many provinces track statistics on hunting and trapping activities, including harvests of caribou, deer, moose, elk, pronghorn antelope, big horn sheep, bear, turkey, grouse, pheasant,

163 Estimates of the ecosystem service exclude finfish production from aquaculture. For data on fish aquaculture production see Statistics Canada, Table 32-10-0107-01, https://doi.org/10.25318/3210010701-eng (accessed January 31, 2019).

164 Fisheries and Oceans Canada, 2021, *Commercial fisheries: Landings*, http://www.dfo-mpo.gc.ca/stats/commercial/land-debarq-eng.htm (accessed March 18, 2021).

165 Gendron, M.H., and A.C. Smith, 2019, *National Harvest Survey*, Canadian Wildlife Service, Environment and Climate Change Canada, https://wildlife-species.canada.ca/harvest-survey (accessed December 11, 2019).

166 Fisheries and Oceans Canada, Fisheries and Harbour Management Directorate, Commercial Sealing Statistics, Ottawa.

167 Fisheries and Oceans Canada, 2019, *Survey of Recreational Fishing in Canada, 2015*, https://www.dfo-mpo.gc.ca/stats/rec/can/2015/index-eng.html#4-3 (accessed February 24, 2020).

partridge, hare, beaver, muskrat, wolf and other species.[168] In 2009, the latest year for which provincial data were compiled, a total of 730,915 wildlife pelts were produced by fur trappers including muskrat (36%), beaver (19%), marten (13%), coyote (6%) and squirrel (5%), among others.[169]

The fishing, hunting and trapping, aquaculture and fish processing industries—which exclude recreational services industries—contributed $4.5 billion (0.2%) to Canada's GDP and 34,800 jobs in 2018.[170] Despite the smaller size of these industries on a national scale, they can be of significant importance to regional economies, particularly in smaller coastal or remote communities. For example, the fishing and seafood sector provides a significant source of income for many coastal communities on the Atlantic and Pacific coasts. In 2015, these industries were an important economic driver for 150 coastal communities, the majority of which were located on the East Coast in proximity to current and historically abundant fishing grounds.[171] These communities tend to be smaller, many with populations of 1,000 or less, with most experiencing a decline in population since 2001 (Map 4.1). Communities that experienced population increases tended to be in regions with aquaculture industry.

In 2017, Canadian households and industries used 36.8 billion m^3 of water (Chart 4.2), excluding water used in hydro-electric generation.[172] The electric power generation industry uses water for cooling in thermal power plants and is responsible for close to two-thirds of water use. Other large users include agriculture (10% of total water use), households (8%), pulp and paper manufacturing (4%) and petroleum and coal product, chemical and primary metal manufacturing (5%).

168 For example, Prince Edward Island, n.d., 2019 *Hunting and Trapping Summary*, https://www.princeedwardisland.ca/sites/default/files/publications/2019-20_hunting_summary_updated_for_web.pdf (accessed December 11, 2019); New Brunswick Fish and Wildlife Branch, 2014, *New Brunswick Furbearer Harvest Report 2013-2014,* https://www2.gnb.ca/content/dam/gnb/Departments/nr-rn/pdf/en/Wildlife/FurbearerHarvestReport.pdf (accessed December 19, 2019); New Brunswick Fish and Wildlife Branch, 2019, *Big Game Harvest Reports, 2018, In progress,* https://www2.gnb.ca/content/dam/gnb/Departments/nr-rn/pdf/en/Wildlife/2018_big_game_report.pdf (accessed December 19, 2019); Nova Scotia, 2018, *Hunter and Trapper Harvest Statistics Index*, https://www2.gnb.ca/content/dam/gnb/Departments/nr-rn/pdf/en/Wildlife/2018_big_game_report.pdf (accessed December 19, 2019); Forêts, Faune et Parcs Québec, 2020, *Statistics on hunting and trapping in Québec*, https://mffp.gouv.qc.ca/the-wildlife/hunting-fishing-trapping/statistics-on-hunting-and-trapping-in-quebec/?lang=en (accessed December 19, 2019); Saskatchewan, n.d., 2018 *Hunter Harvest Survey Results,* https://pubsaskdev.blob.core.windows.net/pubsask-prod/112335/2018%252BHunter%252BHarvest%252BSurvey%252BResults.pdf (accessed December 19, 2019); Alberta, 2019, *Hunter Harvest,* https://mywildalberta.ca/hunting/hunters-harvest.aspx (accessed December 19, 2019).

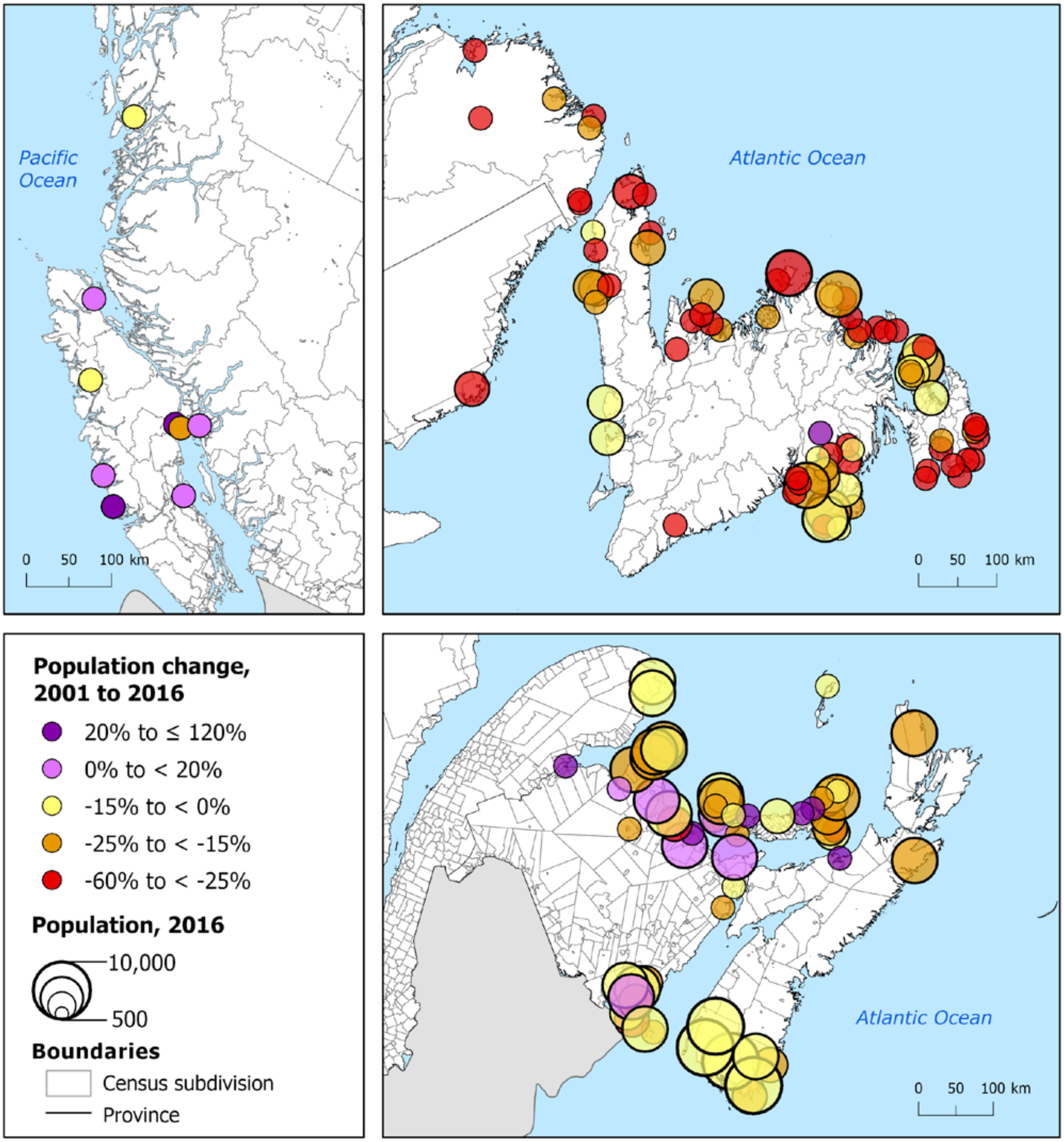
169 Statistics Canada, Table 32-10-0293-01, https://doi.org/10.25318/3210029301-eng (accessed December 11, 2019). Excludes seal pelts from the Atlantic provinces and Quebec, which are regulated under federal Marine Mammal Regulations.

170 Statistics Canada, Table 36-10-0401-01, https://doi.org/10.25318/3610040101-eng (accessed January 7, 2022); Statistics Canada, Table 36-10-0489-01, https://doi.org/10.25318/3610048901-eng (accessed January 7, 2022).

171 Communities were considered to be fishing and seafood sector-based if the employment income earned by individuals working in the fishing, aquaculture or seafood processing industries represented at least 20% of the employment income of the CSD in 2015, according to the 2016 Census.

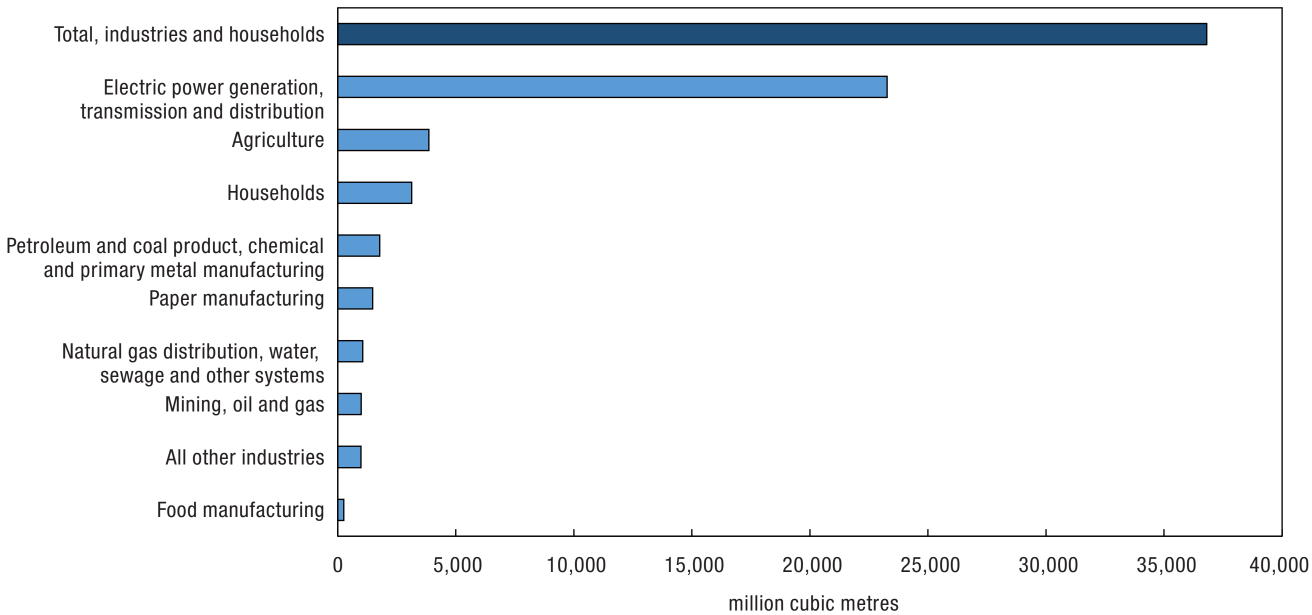
172 Statistics Canada, Table 38-10-0250-01, https://doi.org/10.25318/3810025001-eng (accessed January 24, 2020).

Map 4.1
Population size and variation of 2016 fishing and seafood sector-based communities, Pacific and Atlantic coasts, 2001 to 2016



Notes: This map displays population size and variation for census subdivisions (CSDs) for which the fishing and seafood sector is a major source of employment income—defined here as individuals working in these sectors earning 20% or more of total CSD employment income. Data from the 2016 Census of Population were used to identify the 150 coastal CSDs represented on this map. The reference period for income data is the calendar year prior to the census. The fishing and seafood sector, as defined for this map, includes North American Industry Classification Codes: 1141 – Fishing, 1125 – Aquaculture and 3117 Seafood product preparation and packaging.
Source: Statistics Canada, Environment and Energy Statistics Division, 2020, special tabulation from the 2001 and 2016 Census of Population.

Chart 4.2
Water use, by industry and households, 2017



Note: Electric power generation does not include water used in hydropower production.
Source: Statistics Canada, *Table 38-10-0250-01*, https://www150.statcan.gc.ca/t1/tbl1/en/tv.action?pid=3810025001 (accessed November 28, 2020).

4.2 Regulating services

Regulating services include filtration, sequestration, remediation, regulation and maintenance services provided by ecosystems. For example, they include services such as air filtration by urban trees, carbon retention in ecosystems, carbon sequestration by vegetation, and water flow regulation and flood control by vegetation, among many others.

The value of these types of services is often difficult to quantify even though they provide vital benefits to people. Models are often used to estimate the amount of pollutants filtered, waste material remediated, carbon sequestered, noise levels reduced, cooling provided, pest damage mitigated, or the frequency or magnitude of flood or fire events avoided. Estimates are subject to uncertainty and data and information from one area or time period cannot always be used elsewhere. Still, where estimates are available, they can provide useful information to support decision making.

Carbon retention or storage refers to the total stock of carbon held in living and dead biomass in ecosystems including forests, peatlands and agricultural and coastal areas. Carbon sequestration represents a flow of carbon and occurs when carbon is removed by plants through photosynthesis and stored in woody biomass or transferred to soils and sediment at a greater rate than it is released back to the atmosphere. Estimating carbon retention and sequestration services across the wide range of terrestrial, marine and coastal ecosystems relies on information from many different sources.

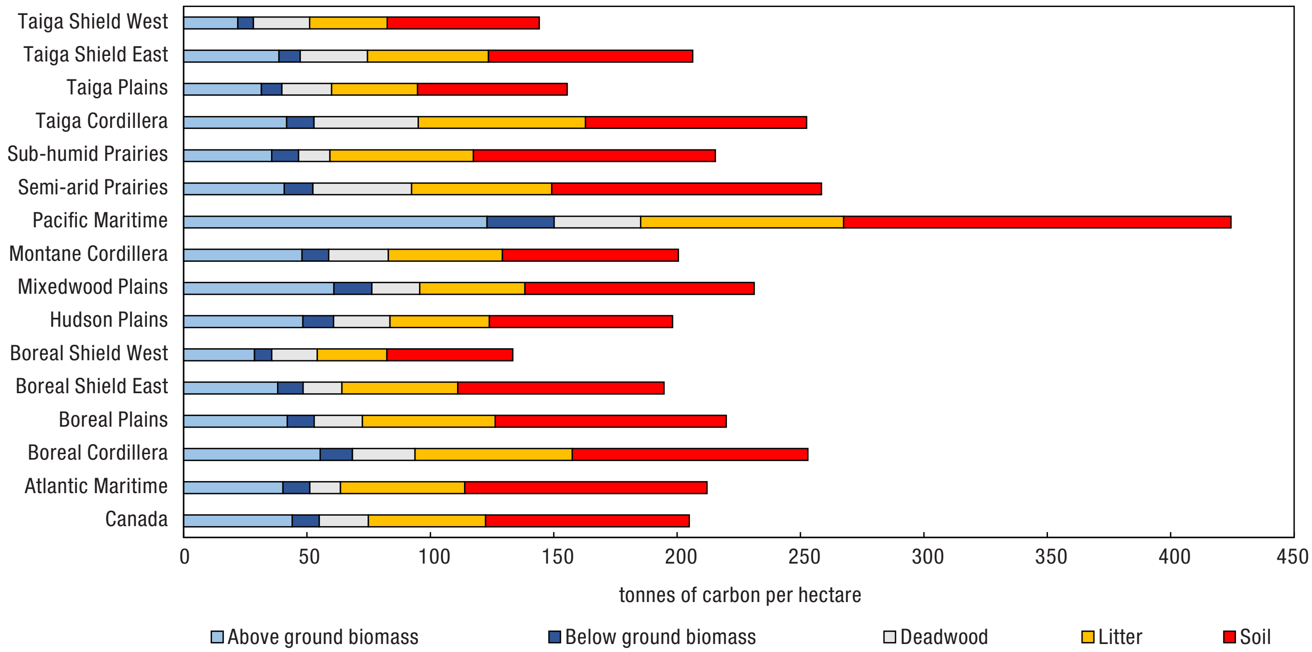
According to Natural Resources Canada's National Forest Carbon Monitoring, Accounting and Reporting System (NFCMARS), in 2018, an estimated 46 gigatonnes (Gt) of carbon was stored in Canada's managed forests[173]—which represent about two-thirds of Canada's forest area.[174] Of this total stock, 40% of carbon was stored in soils, 27%

173 Natural Resources Canada, 2020, *Carbon Accounting*, https://www.nrcan.gc.ca/climate-change/impacts-adaptations/climate-change-impacts-forests/carbon-accounting/13087 (accessed April 9, 2021); Stinson, G., et al., 2011, "An inventory–based analysis of Canada's managed forest carbon dynamics, 1990 to 2008," *Global Change Biology*, Vol. 17, pp. 2227–2244, https://doi.org/10.1111/j.1365-2486.2010.02369.x (accessed April 4, 2020); Kurz, W.A., et al., 2013, "Carbon in Canada's boreal forest — A synthesis," *Environmental Reviews*, Vol. 21, pp. 260-292, https://doi.org/10.1139/er-2013-0041 (February 2, 2020).

174 Managed forests are those managed for timber and non-timber resources (including parks) or that are subject to fire protection. They represent approximately 65.7% of Canada's forest area. For more information, see: Ogle, S.M., et al., 2018, "Delineating managed land for reporting national greenhouse gas emissions and removals to the United Nations framework convention on climate change," *Carbon Balance and Management*, Vol. 13, no. 9, https://doi.org/10.1186/s13021-018-0095-3 (accessed April 9, 2021).

in tree trunks, branches, leaves and roots (above ground and below ground biomass), 23% in litter and 10% in deadwood (Table 4.3). Managed forests stored on average 205 tonnes of carbon per hectare in 2018, though this varied widely from 424 tonnes per hectare in the Pacific Maritime ecozone to 133 tonnes per hectare for forests in the Boreal Shield West (Chart 4.3).

Chart 4.3
Managed forest carbon stock, by Intergovernmental Panel on Climate Change (IPCC) carbon pool and by reporting zone, 2018



Notes: The National Forest Carbon Monitoring, Accounting and Reporting System (NFCMARS) used by the Canadian Forest Service (CFS) to estimate greenhouse gas (GHG) sources and sinks for Canada's *National Inventory Report 1990-2018* submission to the United Nations Convention on Climate Change covers managed forest land only (excludes unmanaged forests). Data are reported by reporting zone, which are based on Canada's terrestrial ecozones with three exceptions: the Boreal Shield and the Taiga Shield ecozones are split into east and west components, the Prairie ecozone is split into sub-humid and semi-arid components and the Arctic Cordillera is excluded. For some regions, notably the Hudson Plains and Taiga Shield, only a very small proportion of forest area is considered managed. Managed boreal forest represents about half of Canada's boreal forest area. The Carbon Budget Model of the CFS (CBM-CFS3) at the core of NFCMARS is designed for use on non-frozen upland mineral soils (0 to 100 cm) and therefore excludes organic soils (peatland) and permafrost.
Source: Natural Resources Canada, Canadian Forest Service, Carbon Accounting.

Trees in Canada's managed forests take up large amounts of carbon. In 2018, modeled net primary productivity (NPP) from these forests was 710,000 kilotonnes (kt) of carbon and net ecosystem productivity was 41,000 kt of carbon (Table 4.4). However, taking into account the emissions associated with harvested wood[175] and natural disturbances, such as forest fires and insect damage, these forests were a net emitter of carbon in 2018. Net biome productivity was estimated at -68,000 kt of carbon in 2018, a net loss of carbon from managed forest ecosystems. Estimates are not available for unmanaged forest areas in Canada's North.

The amount of carbon stored in soil varies considerably by region and soil type. Organic soils, which are composed of large amounts of organic matter in the form of peat or leaf litter, store large amounts of soil organic carbon.[176] Peatlands in boreal and subarctic regions contain an estimated 147 Gt of soil organic carbon, over half of the organic carbon stored in all Canadian soils.[177] Carbon dynamics are likely changing as a result of rising temperatures and

175 Carbon transferred to harvested wood products is not emitted immediately—carbon can remain stored in lumber and other wood products used in construction and manufacturing for some time, while carbon in wood used for firewood or newsprint will more quickly become oxidized.

176 Organic soils store at least 17% organic carbon (30% or more organic matter) by weight. Soil Classification Working Group, 1998, *The Canadian System of Soil Classification*, 3rd Ed., Agriculture and Agri-Food Canada, Publication 1646, http://sis.agr.gc.ca/cansis/publications/manuals/1998-cssc-ed3/index.html (accessed June 25, 2020).

177 Tarnocai, C., 2009, "The impact of climate change on Canadian peatlands," *Canadian Water Resources Journal*, Vol. 34, no. 4, https://doi.org/10.4296/cwrj3404453 (accessed June 25, 2020).

changing water regimes.[178] For example, carbon sequestration will be affected by an increase in growing season length impacting vegetation productivity. Much of the carbon stock in these soils is frozen and will be affected by permafrost thaw, through increased emissions from respiration. Peatlands can also be vulnerable to fire, releasing large amounts of stored carbon into the atmosphere when burned. Past studies have estimated long-term rates of organic carbon accumulation of 9,800 kt per year for boreal peatlands and 30,000 kt per year for all Canadian peatlands; however, a more recent study indicates that Canadian peatlands may now be a source of carbon emissions to the atmosphere with estimated emissions of 151.8 Mt CO_2 equivalent (10,400 kt of C) per year for peatlands in Canada including carbon dioxide and methane.[179]

An estimated 5.5 Gt of carbon are stored in soils used for agriculture.[180] Most of this carbon storage occurs in the Prairies, since soils that developed under prairie grassland—for example, the black chernozemic soils in the Aspen Parkland ecoregion—contain a relatively high percentage of soil organic matter.[181] The amount of carbon stored in agricultural soils depends on many factors including climate, soil texture, vegetation type and land management practices such as tillage, cover cropping, crop rotation and inputs from fertilizers, manure and crop residues.[182] Most agricultural crops are annual plants that do not provide long-term carbon storage in above ground biomass, though orchards, for example, which represent a small fraction of Canada's agricultural land, have above ground biomass in the range of 36 to 40 kilotonnes per hectare.[183] Environment and Climate Change Canada reports annual estimates of carbon emissions and removals to the United Nations Framework Convention on Climate Change (UNFCCC) in the *National Inventory Report,* Canada's official greenhouse gas inventory. In 2018, an estimated 2,400 kt of carbon was removed by cropland.[184]

While urban areas occupy a small percentage of Canada's terrestrial extent, an estimated 27,000 kt of carbon are stored in trees in large urban and medium population centres.[185] On average, urban forests stored 62 tonnes per hectare of canopy cover, but this varies by ecozone from a low of 23 tonnes per hectare in the Montane Cordillera ecozone to 97 tonnes per hectare in the Pacific Maritime ecozone. In 2018, an estimated 1,100 kt of carbon was removed by trees in urban areas.

Ocean and coastal ecosystems also provide important carbon sequestration and carbon retention services. In fact, marine plants are responsible for about half of global NPP[186] and the world's oceans store more carbon overall than either soils or the atmosphere. Phytoplankton, which absorb CO_2 through photosynthesis, are the primary contributor to NPP in oceans (94%). Macroalgae, such as kelp or seaweed, as well as seagrasses, salt marsh plants, mangroves and other macrophytes are responsible for the remainder of marine NPP.[187] Much of the carbon absorbed by phytoplankton is recycled through the food web by zooplankton, fish and other marine species. However, a small proportion of this carbon sinks into the deep ocean for long-term storage. Another source of carbon in the deep sea includes deadfall carbon from the carcasses of whales and other large vertebrates as they sink to the ocean floor.[188]

178 Kurz, W.A. et al., 2013; Tarnocai, C., 2009; Webster, K.L., et al., 2018, "Spatially-integrated estimates of net ecosystem exchange and methane fluxes from Canadian peatlands," *Carbon Balance and Management,* https://doi.org/10.1186/s13021-018-0105-5 (accessed August 18, 2019); De Groot, W., 2012, "Peatland fires and carbon emissions," *Front Line Express,* Natural Resources Canada, Canadian Forest Service, Great Lakes Forestry Centre, https://cfs.nrcan.gc.ca/publications?id=33351 (accessed June 25, 2020); Ogle, S.M., et al., 2018.

179 Zoltai et al., 1998 and Gorham, 1988, as cited in Tarnocai, C., 2009, "The impact of climate change on Canadian peatlands," Canadian Water Resources Journal, Vol. 34, no. 4, https://doi.org/10.4296/cwrj3404453 (accessed October 10, 2017); Webster, K.L., et al, 2018.

180 Minasny, B., at al., 2017, "Soil carbon 4 per mille," *Geoderma*, Vol. 292, pp. 59-86, https://doi.org/10.1016/j.geoderma.2017.01.002 (accessed May 31, 2021).

181 Canadian Society of Soil Science, 2020, "Chernozemic," *Soils of Canada*, https://soilsofcanada.ca/orders/chernozemic-soils.php (accessed June 8, 2020).

182 Ontl, T.A. and L. A. Schulte, 2012, "Soil carbon storage," *Nature Education Knowledge, Vol. 3, no. 10,* https://www.nature.com/scitable/knowledge/library/soil-carbon-storage-84223790/ (accessed March 30, 2020); Environment and Climate Change Canada, 2020, *National Inventory Report 1990 – 2018: Greenhouse gas sources and sinks in Canada, Part 2*, Catalogue no. EN81-4E-PDF, https://publications.gc.ca/site/eng/9.506002/publication.html (accessed July 20, 2020).

183 McConkey, B., et al., 2007, cited in Environment and Climate Change Canada, 2020, *National Inventory Report 1990 – 2018: Greenhouse gas sources and sinks in Canada, Part 2,* Catalogue no. EN81-4E-PDF, https://publications.gc.ca/site/eng/9.506002/publication.html (accessed July 20, 2020);

184 Excludes losses of carbon associated with the conversion of forest and grassland to settlements and cropland.

185 Ristow, M., J. W. Steenberg and P. N. Duinker, 2019, "An updated approach for assessing Canada's urban forest carbon storage and sequestration," Report submitted to Environment and Climate Change Canada.

186 Malone, T., et al., 2016, "Chapter 6. Primary production, cycling of nutrients, surface layer and plankton," *The First Global Integrated Marine Assessment: World Ocean Assessment 1*, United Nations, https://www.un.org/Depts/los/global_reporting/WOA_RPROC\Chapter_06.pdf (accessed April 4, 2020).

187 Malone, T., et al., 2016.

188 Hodson, H., 2018, "The mesopelagic: Cinderella of the ocean," *The Economist*, https://www.economist.com/science-and-technology/2017/04/15/the-mesopelagic-cinderella-of-the-oceans (accessed February 21, 2020).

Kelp forests, seagrass meadows and salt marshes in coastal areas have an important role in carbon cycling.[189] Carbon from this biomass can be stored in plant roots and in coastal and marine sediment once the seaweeds and plants decompose. Carbon from plankton, as well as carbon from wetlands, rivers and streams that discharge into the ocean also contribute to the carbon buried in these coastal ecosystems.[190] Studies in British Columbia and across the Pacific Northwest have found significant variability in organic carbon stocks in coastal sediment within eelgrass (a type of seagrass) meadows.[191] One synthesis of studies on the Pacific Coast found average carbon accumulation rates of 25 g of organic carbon per m^2 of sediment per year. Carbon stocks in the top 1 m of sediment averaged 7,168 g of organic carbon per m^2.[192] On a per hectare basis, these estimates suggest that seagrass meadows in British Columbia could store an estimated 72 tonnes of carbon.

Another important regulating service provided by ecosystems is air filtration. Exposure to air pollution has an important impact on human health.[193] In 2006, mean national residential exposure to ambient air concentrations of fine particulate matter ($PM_{2.5}$)—made up of aerosols, smoke and dust—was 7.05 $\mu g/m^3$.[194] However, exposure estimates were higher in parts of southern Ontario and in major cities, particularly within the urban cores. People living in rural areas had lower mean exposures to $PM_{2.5}$. Ambient nitrogen dioxide concentrations depend heavily on vehicular traffic and exposure to this pollutant has been shown to vary within cities, including by neighbourhood socio-economic status.[195] Exposure to ozone—a secondary air pollutant created by reactions between nitrogen oxides and volatile organic compounds —can differ geographically over larger regions.[196]

Some research has focused on the extent to which urban trees provide an ecosystem service by removing air pollutants and supplying associated benefits for human health.[197] Trees can remove air pollution by taking up gaseous pollutants and by intercepting particulate matter on leaf surfaces. The average air pollutant removal per square metre of tree cover in 86 Canadian cities in 2010 was estimated to be 3.72 g/m^2/year.[198] This removal resulted in small improvements in air quality. Total pollution removal for these cities was estimated at 16,500 tonnes of air pollutants (Table 4.5), with human health benefits valued at $227.2 million, equivalent to $511 per hectare of urban tree cover.

4.3 Cultural services

Cultural services can involve interaction with and appreciation of nature, including direct experiences in the outdoors through recreation, tourism and education. They can also involve the contribution of ecosystems and their biodiversity to social interaction and spiritual and mental well-being.

189 Krause-Jensen, D., Duerte, C. M., 2016, "Substantial role of macroalgae in marine carbon sequestration," *Nature Geoscience*, Vol. 9, https://doi.org/10.1038/ngeo2790 (accessed March 30, 2020); Duarte, C. M., et al., 2013, "The role of coastal plant communities for climate change mitigation and adaptation," *Nature Climate Change,* Vol. 3, https://doi.org/10.1038/nclimate1970 (accessed April 4, 2020); Commission for Environmental Cooperation, 2016, *North America's Blue Carbon: Assessing Seagrass, Salt Marsh and Mangrove Distribution and Carbon Sinks*, Montréal, Canada, http://www3.cec.org/islandora/en/item/11664-north-america-s-blue-carbon-assessing-seagrass-salt-marsh-and-mangrove (accessed April 4, 2020).

190 Bauer, J., et al., 2013, "The changing carbon cycle of the coastal ocean," *Nature*, Vol. 504, https://doi.org/10.1038/nature12857 (accessed March 30, 2020); Kennedy, H., et al., 2010, "Seagrass sediments as a global carbon sink: Isotopic constraints," *Global Biogeochemical Cycles*, https://doi.org/10.1029/2010GB003848 (accessed April 4, 2020).

191 Prentice, C., et al., 2019, "Reduced water motion enhances organic carbon stocks in temperate eelgrass meadows," *Limnology and Oceanography,* Vol. 64, no. 6, https://doi.org/10.1002/lno.11191 (accessed April 4, 2020); Prentice, C., et al., 2020, "A synthesis of blue carbon stocks, sources and accumulation rates in eelgrass (*Zostera marina*) meadows in the Northeast Pacific," *Global Biogeochemical Cycles,* Vol. 34, no. 2, https://doi.org/10.1029/2019GB006345 (accessed April 4, 2020); Postlethwaite, V. R., 2018, "Low blue carbon storage in eelgrass (*Zostera marina*) meadows on the Pacific Coast of Canada," *Plos One*, Vol. 13, no. 6, https://doi.org/10.1371/journal.pone.0198348 (accessed April 10, 2020).

192 Prentice, C., et al., 2020.

193 Pappin, A., et al., 2019, "Nonlinear associations between low levels of fine particulate matter and mortality across three cycles of the Canadian Census Health and Environment Cohort," *Environmental Epidemiology*, Vol. 3, https://doi.org/10.1097/01.EE9.0000606600.36083.92 (accessed February 13, 2020).

194 Pinault, L., A. van Donkelaar and R. Martin, 2017, "Exposure to fine particulate matter air pollution in Canada," Health Reports, Statistics Canada, Catalogue no. 82-003-X, https://www150.statcan.gc.ca/n1/pub/82-003-x/2017003/article/14781-eng.htm (accessed February 13, 2020).

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198 Nowak, D., 2018; Included estimates for carbon monoxide (CO), nitrogen dioxide (NO_2), ozone (O_3), fine particulate matter ($PM_{2.5}$) and sulphur dioxide (SO_2).

Natural areas such as forests, grasslands, lakes and other 'green' and 'blue' spaces, can play a positive role in human well-being.[199] One recent study of urban Canadians found increased amounts of residential greenness to be associated with reduced risk of dying from several common causes.[200] Exposure to greenness varies spatially within cities and also by socio-economic characteristics such as income, immigrant status, ethnocultural identity and housing tenure.[201]

Natural areas in both public and private areas can provide benefits, though public areas such as parks provide wider opportunities for recreation and enjoyment of nature. Urban areas are heavily modified, but can nevertheless include large and small areas of green and blue space such as parks, gardens, beaches and yards. They can also include green features like street trees, green walls or green roofs that provide aesthetic enjoyment for many people.

There are many different types of parks in Canada, ranging from pristine wilderness areas to heavily used urban parks. While comparable visitation statistics for urban, regional and provincial or territorial parks are not available across the country, Parks Canada reported 16.1 million person-visits at National Parks and 8.7 million person-visits at National Historic Sites in 2019 (Table 4.6). In 2019, 90% of households reported that they lived close to a park or public green space. Of these households, 85% indicated that they had visited a nearby park or green space. In addition, 73% of households indicated they had visited sites that were more distantly located. Reported proximity to public parks and green spaces was highest for households living in census metropolitan areas (CMAs) (93%) and lowest for households living in small towns and rural areas (78%).[202]

While public parks play a particularly important role in providing green space in cities, private green space, including lawns and gardens, also provide benefits. In 2019, 71% of households reported having a lawn and 62% reported having a garden.[203] Households living in CMAs were less likely to have a lawn (65%) or garden (58%) compared to those in small towns and rural areas.

In 2019, over three-quarters of Canadian households participated in activities near their home that brought them outside and into nature (Table 4.7). The most popular activities include walking, going to the park and bicycling, but others include picnicking, swimming, hiking and other sports activities. Household proximity to parks, access to private green space such as lawns and gardens and participation in outdoor activities increased with income. Participation in some activities, including hiking, wildlife viewing, camping, fishing, canoeing, snowshoeing and others are likely higher than indicated in Table 4.7 since these activities frequently occur further away from home.[204]

In 2016, an estimated 22% of Canadians 15 years or older spent time fishing, 16% reported foraging and 6% hunting or trapping for employment or recreational purposes.[205] These harvesting activities including fishing, hunting, trapping and gathering wild plants have been a foundational part of Indigenous peoples' lives for millennia and they still play an important role in providing food security and fostering cultural identity. In 2017, 33% of First Nations peoples living off reserve, 35% of Métis, and 65% of Inuit living in the Inuit Homeland of Inuit Nunangat, participated in fishing, hunting or trapping.[206] Indigenous peoples also frequently participated in wild berry or plant gathering, with among 30% of First Nations living off reserve and 47% of Inuit engaging in this activity. The most common reasons for participating in these harvesting activities included subsistence use (own use / family's use), pleasure or leisure, sharing with others in the community and cultural reasons.

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203 Statistics Canada, Table 38-10-0282-01, https://www150.statcan.gc.ca/t1/tbl1/en/cv.action?pid=3810028201 (accessed October 21, 2021).

204 Statistics Canada, Table 45-10-0030-01, https://doi.org/10.25318/4510003001-eng (accessed January 22, 2020); Fisheries and Oceans Canada, 2019, *Survey of Recreational Fishing in Canada, 2015*, https://www.dfo-mpo.gc.ca/stats/rec/can/2015/index-eng.html#4-3 (accessed February 24, 2020).

205 Statistics Canada, Table 45-10-0030-01, https://doi.org/10.25318/4510003001-eng (accessed January 22, 2020). Note this includes participation for employment, self-employment and recreational purposes.

206 Kumar, M.B., et al., 2019, "Harvesting activities among First Nations people living off reserve, Métis and Inuit: Time trends, barriers and associated factors," *Aboriginal Peoples Survey,* Catalogue no. 89-653-X, https://www150.statcan.gc.ca/n1/en/catalogue/89-653-X2019001 (June 15, 2021).

Table 4.1
Biomass provisioning services supply, by ecosystem type, Canada, 2002 to 2020

		Agricultural ecosystems		Forest	Other natural and semi-natural land and freshwater	Coastal and marine ecosystems			Total supply
	Built-up and artificial surfaces	Crop (includes hay), honey and maple production	Grazed forage production on pasture	Roundwood harvested	Freshwater fishery landings	Seafisheries landings	Shellfish aquaculture production	Marine plants harvested	Biomass extraction
	kilotonnes								
2002	.	78,476	..	196,360	41	1,030	34	42	.
2003	.	101,303	..	182,101	37	1,071	36	46	.
2004	.	110,516	..	208,884	36	1,130	38	41	.
2005	.	114,382	..	204,109	32	1,077	38	42	.
2006	.	114,523	13,346	183,758	31	1,043	40	43	.
2007	.	112,508	..	163,670	32	990	37	19	.
2008	.	124,114	..	139,006	30	917	34	18	.
2009	.	115,275	..	116,666	30	914	35	43	.
2010	.	115,466	..	141,996	27	905	40	43	.
2011	.	116,897	12,796	147,982	26	836	38	19	.
2012	.	120,762	..	151,167	29	787	43	14	.
2013	.	144,338	..	153,951	28	820	39	15	.
2014	.	125,911	..	153,195	27	832	38	14	.
2015	.	126,030	..	158,820	28	823	39	12	.
2016	.	141,496	11,965	156,547	30	832	40	13	.
2017	.	140,135	..	153,279	29	806	40	13	.
2018	.	137,489	..	155,953	39	784	41	11	.
2019	.	137,229	..	141,116	24	728	43	13	.
2020	.	137,281	..	..	..	..	..	..	.

. not available for any reference period
.. not available for a specific reference period

Notes: Production data are reported as a proxy value of provisioning ecosystem services provided by ecosystems and will include different moisture contents. Timber is reported in green weight. Provincial data that are unavailable or data that are suppressed to meet confidentiality or data quality standards are not included in total. Data exclude non-commercial harvests. For more information about definitions, sources and methods, see Appendix A.

Sources: Statistics Canada, *Tables 32-10-0359-01, 32-10-0365-01, 32-10-0364-01, 32-10-0358-01, 32-10-0353-01, 32-10-0354-01, 32-10-0406-01 and 32-10-0107-01* (accessed March 16, 2021); Statistics Canada, 2007, Census of Agriculture, 2006, Farm data and farm operator data tables, https://www150.statcan.gc.ca/n1/pub/95-629-x/2007000/4123856-eng.htm (accessed January 14, 2020); Yungblut, D., 2012, *National Forage and Grassland Assessment*, http://www.canadianfga.ca/wp-content/uploads/2011/04/V1-Final-June-2012-Report-National-Forage-and-Grassland-Assessment-formatted.pdf (accessed December 3, 2019); National Forestry Database, 2021, *Table 5.1 Net merchantable volume of roundwood harvested by jurisdiction, tenure, category and species group,* http://nfdp.ccfm.org/en/index.php (accessed July 14, 2021); FAO, ITTO and United Nations, 2020, *Forest Product Conversion Factors*, Rome, https://doi.org/10.4060/ca7952en (accessed June 3, 2021); Fisheries and Oceans Canada, 2021, *Commercial Fisheries: Landings*, http://www.dfo-mpo.gc.ca/stats/commercial/land-debarq-eng.htm (accessed March 18, 2021).

Table 4.2
Biomass provisioning services, agricultural ecosystems, by type of product and province

	2020				2016	
	Field crops (excluding corn for silage and tame hay)	Corn for silage and tame hay	Fruit and vegetables	Honey and maple products	Grazed forage production on pasture	Total estimated production
	tonnes					
Total	**100,236,400**	**29,130,800**	**7,790,717**	**123,529**	**11,965,330**	**149,246,776**
Newfoundland and Labrador	0	14,500	5,794	.	11,242	31,536
Prince Edward Island	238,900	345,300	975,383	72	31,654	1,591,309
Nova Scotia	80,900	419,200	130,737	513	61,482	692,832
New Brunswick	75,600	260,700	553,898	3,452	45,985	939,635
Quebec	5,062,300	4,691,700	1,479,409	81,001	341,846	11,656,257
Ontario	16,158,300	6,510,700	1,883,164	6,676	734,490	25,293,330
Manitoba	13,333,600	3,353,600	1,113,513	9,369	908,535	18,718,618
Saskatchewan	39,064,300	3,394,900	67,517	7,123	3,888,253	46,422,094
Alberta	25,928,200	8,397,500	1,115,719	13,578	5,132,279	40,587,276
British Columbia	277,900	1,742,700	445,065	1,744	809,562	3,276,971

. not available for any reference period

Notes: Agricultural production is reported as a proxy of the provisioning ecosystem service provided by agricultural ecosystems. Provincial data that are unavailable or data that are suppressed to meet confidentiality or data quality standards are not included in total. For more information about definitions, sources and methods, see Appendix A.
Sources: Statistics Canada, *Tables 32-10-0359-01, 32-10-0365-01, 32-10-0364-01, 32-10-0358-01, 32-10-0353-01, 32-10-0354-01 and 32-10-0406-01* (accessed March 16, 2021); Yungblut, D. 2012, *National Forage and Grassland Assessment*, http://www.canadianfga.ca/wp-content/uploads/2011/04/V1-Final-June-2012-Report-National-Forage-and-Grassland-Assessment-formatted.pdf (accessed December 3, 2019).

Table 4.3
Managed forest carbon stocks, by Intergovernmental Panel on Climate Change (IPCC) carbon pool and reporting zone, 2018

	Forest carbon stock by IPCC pool							
	Above ground biomass	Below ground biomass	Deadwood	Litter	Soil	Total	Managed forest	Forest carbon stock
	kilotonnes C						kilohectares	tonnes/hectare
Total	**9,940,000**	**2,470,000**	**4,500,000**	**10,700,000**	**18,600,000**	**46,200,000**	**225,706**	**205**
Atlantic Maritime	622,000	168,000	192,000	776,000	1,510,000	3,270,000	15,424	212
Boreal Cordillera	817,000	193,000	375,000	942,000	1,410,000	3,740,000	14,774	253
Boreal Plains	1,560,000	406,000	728,000	2,000,000	3,490,000	8,190,000	37,231	220
Boreal Shield East	2,120,000	571,000	873,000	2,610,000	4,650,000	10,800,000	55,622	195
Boreal Shield West	826,000	202,000	529,000	811,000	1,470,000	3,840,000	28,767	133
Hudson Plains	14,600	3,750	6,900	12,200	22,400	59,900	302	198
Mixedwood Plains	162,000	41,100	51,600	113,000	247,000	616,000	2,663	231
Montane Cordillera	1,660,000	373,000	838,000	1,600,000	2,470,000	6,950,000	34,647	200
Pacific Maritime	1,340,000	296,000	383,000	898,000	1,710,000	4,630,000	10,912	424
Semi-arid Prairies	1,610	459	1,580	2,250	4,320	10,200	40	258
Sub-humid Prairies	63,600	19,300	22,700	103,000	175,000	384,000	1,781	215
Taiga Cordillera	17,200	4,580	17,400	27,900	36,900	104,000	412	252
Taiga Plains	637,000	168,000	407,000	704,000	1,230,000	3,140,000	20,203	155
Taiga Shield East	42,600	9,470	30,100	54,000	91,200	227,000	1,102	206
Taiga Shield West	40,100	11,600	41,700	57,400	112,600	263,000	1,827	144

Notes: The National Forest Carbon Monitoring, Accounting and Reporting System (NFCMARS) used by the Canadian Forest Service (CFS) to estimate greenhouse gas (GHG) sources and sinks for Canada's *National Inventory Report 1990 to 2018* submission to the United Nations Framework Convention on Climate Change covers managed forest land only (excludes unmanaged forests). Data are reported by reporting zone, which are based on Canada's terrestrial ecozones with three exceptions: the Boreal Shield and the Taiga Shield ecozones are split into east and west components, the Prairie ecozone is split into sub-humid and semi-arid components and the Arctic Cordillera is excluded. For some regions, notably the Hudson Plains and Taiga Shield, only a very small proportion of forest area is considered managed. Managed boreal forest represents about half of Canada's boreal forest area. The Carbon Budget Model of the CFS (CBM-CFS3) at the core of NFCMARS is designed for use on non-frozen upland mineral soils (0 to 100 cm) and therefore excludes organic soils (peatland) and permafrost.
Source: Natural Resources Canada, Canadian Forest Service, Carbon Accounting.

Table 4.4
Carbon sequestration services, by ecosystem type, 2005 to 2018

	Built-up and artificial surfaces	Arable	Grassland and natural pasture	Managed forest: Net primary productivity	Managed forest: Net ecosystem productivity	Managed forest: Disturbance emissions	Managed forest: Harvest transfers	Managed forest: Net biome productivity	Other natural and semi-natural land and freshwater	Coastal and marine ecosystems	Total
	kilotonnes C										
2005	1,100	4,100	..	730,000	47,000	18,000	56,000	-27,000	..	..	..
2006	1,100	4,300	..	730,000	44,000	22,000	51,000	-29,000	..	..	..
2007	1,100	4,300	..	730,000	42,000	23,000	46,000	-27,000	..	..	..
2008	1,100	4,200	..	730,000	44,000	10,000	40,000	-6,600	..	..	..
2009	1,100	4,200	..	730,000	47,000	16,000	34,000	-3,500	..	..	..
2010	1,100	4,100	..	730,000	45,000	32,000	41,000	-29,000	..	..	..
2011	1,100	4,100	..	725,000	46,000	38,000	43,000	-35,000	..	..	..
2012	1,100	3,800	..	720,000	46,000	32,000	44,000	-29,000	..	..	..
2013	1,100	3,600	..	720,000	47,000	16,000	44,000	-12,000	..	..	..
2014	1,100	3,300	..	720,000	46,000	44,000	43,000	-41,000	..	..	..
2015	1,100	3,100	..	720,000	43,000	61,000	45,000	-63,000	..	..	..
2016	1,100	2,900	..	720,000	44,000	33,000	45,000	-34,000	..	..	..
2017	1,100	2,600	..	710,000	43,000	56,000	45,000	-59,000	..	..	..
2018	1,100	2,400	..	710,000	41,000	63,000	45,000	-68,000	..	..	..

.. not available for a specific reference period

Notes: Modeling of carbon fluxes draws upon collaboration among scientists and experts in several disciplines and is used for reporting in Canada's *National Inventory Report 1990-2018* submission to the United Nations Framework Convention on Climate Change. For more information, see Appendix A.

Sources: Environment and Climate Change Canada, 2020, *CRF Tables, Canada's National Inventory Submissions 2018 to the UNFCCC*, https://unfccc.int/process-and-meetings/transparency-and-reporting/reporting-and-review-under-the-convention/greenhouse-gas-inventories-annex-i-parties/submissions/national-inventory-submissions-2018#fn1 (accessed April 30, 2020); Natural Resources Canada, Canadian Forest Service, Carbon Accounting.

Table 4.5
Air pollutant removal services by urban trees in selected population centres, 2010

Population centre	Area	Tree cover	Estimated removal of pollution	Average pollution removal per unit of tree cover	Population, 2011	Estimated monetary value associated with various health effects due to pollutant reduction from trees
	km^2	percentage	tonnes	g/m^2	number	dollars/hectare
Calgary	722.8	9.3	203.3	3.0	1,095,404	1,074
Edmonton	872.6	13.0	304.6	2.7	960,015	1,206
Ottawa-Gatineau (Que.)	172.3	30.6	183.5	3.5	236,329	547
Halifax	291.4	51.8	547.0	3.6	297,943	547
Hamilton	394.8	21.6	458.7	5.4	670,580	1,016
Kitchener	319.4	20.5	300.7	4.6	444,681	1,564
London	225.7	20.3	199.0	4.3	366,191	804
Montréal	1,557.6	22.7	1,400.3	4.0	3,407,963	886
Ottawa-Gatineau (Ont.)	389.4	26.5	366.1	3.6	697,267	484
Québec	682.9	47.0	686.1	2.1	696,946	275
St. Catharines – Niagara	394.4	23.9	491.9	5.2	309,319	471
Toronto	1,763.4	18.2	1,472.2	4.6	5,132,794	792
Vancouver	1,206.6	40.0	1,744.6	3.6	2,135,201	336
Victoria	281.6	45.5	450.1	3.5	316,327	334
Winnipeg	460.1	16.5	244.6	3.2	671,551	938
Other population centres	6,578.8	30.2	7,467.6	3.8	5,564,040	371

Notes: This study covers 85 medium and large urban population centres (i.e. those with a population greater than 30,000). Population and area are reported for population centres as reported in the 2011 Census of Population. Ottawa-Gatineau has been split at the provincial boundary. The estimated monetary values associated with health effects due to pollutant reduction in Ottawa and Gatineau have been revised from the original article to adjust for the actual population in 2011.

Sources: Nowak, D., et al., 2018, "Air pollution removal by urban forests in Canada and its effect on air quality and human health," *Urban Forestry and Urban Greening*, Vol. 29, pp. 40-48, https://doi.org/10.1016/j.ufug.2017.10.019 (accessed March 4, 2020); Statistics Canada, 2012, 2011 *Census Profiles,* Catalogue no. 98-316-XWE, http://www12.statcan.gc.ca/census-recensement/2011/dp-pd/prof/index.cfm?Lang=E (accessed July 6, 2020); Statistics Canada, *Boundary Files, 2011 Census*, https://www12.statcan.gc.ca/census-recensement/2011/geo/bound-limit/bound-limit-2011-eng.cfm (accessed July 6, 2020); Pasher, J., et al., 2014, "Assessing carbon storage and sequestration by Canada's urban forests using high resolution earth observation data," *Urban Forestry and Urban Greening*, Vol. 13, no. 3, p. 484-494, https://doi.org/10.1016/j.ufug.2014.05.001 (accessed June 15, 2015).

Table 4.6
Use of recreational services, Canada, 2011 to 2019

	National parks	National historic sites	Households that had a park or green space close to home[2]		Households that visited a park or green space not close to home[3]
			Total	Households that visited a park or greenspace close to home[2]	
	person-visits[1]		percentage		
2011	..	..	86	84	70
2012	..	..	..	..	..
2013	..	..	85	85	69
2014	13,520,886	8,255,118	..	..	..
2015	14,469,008	8,853,089	87	87	72
2016	15,449,249	9,288,024	..	..	..
2017	16,833,896	10,419,484	87	85	71
2018	15,898,110	9,198,126	..	..	..
2019	16,146,557	8,741,684	90	85	73

.. not available for a specific reference period

1. Person visits represent each time a person enters the land or marine part of a reporting unit for recreational, educational or cultural purposes during business hours. Through, local and commercial traffic are excluded. Same day re-entries and re-entries by visitors staying overnight in the reporting unit do not constitute new person-visits. Reporting is per fiscal year starting April 1. In 2017, admission was free to all Parks Canada places to mark Canada's 150th birthday.
2. Survey-based reporting of whether households had a park or green space located close to home and whether or not they visited a park or green space close to or not close to home. The denominator of those visiting a park or green space close to home is households reporting having a park or green space close to home. Close to home is defined as within a 10-minute journey of home.
3. As a percentage of all households.

Sources: Parks Canada, 2021, *Parks Canada Attendance 2019-20,* https://www.pc.gc.ca/en/docs/pc/attend (accessed February 10, 2021); Parks Canada, personal communication with Brenda Jones, September 6, 2019; Statistics Canada, *Table 38-10-0020-01, Parks and green spaces*, https://www150.statcan.gc.ca/t1/tbl1/en/tv.action?pid=3810002001 (accessed October 19, 2021).

Table 4.7
Participation in outdoor activities close to home, by household income, 2019

	Household income							
	Under $20,000 (includes income loss)	$20,000 to $39,999	$40,000 to $59,999	$60,000 to $79,999	$80,000 to $99,999	$100,000 to $149,999	$150,000 and more	All households
	percentage							
Participated in outdoor activities close to home	**59**	**61**	**72**	**76**	**83**	**87**	**88**	**77**
Walking	56	56	67	71	78	82	83	72
Jogging, running, rollerblading, cross-country running	10	8	14	17	26	34	39	22
Hiking	14	12	21	25	32	32	38	26
Football, soccer, field hockey, basketball, volleyball, baseball, rugby, lacrosse, ultimate (frisbee), ball/road hockey	6E	8	10	16	19	25	31	17
Golfing, croquet, lawn darts, lawn bowling, bocci	4E	5	8	12	13	18	23	13
Boating, sailing, canoeing, kayaking, rafting, rowing, dragonboating, seadooing	5	6	8	11	16	17	20	12
Swimming, going to the beach, surfing, scuba diving, snorkeling	12	15	20	25	32	34	36	26
Bicycling	16	17	25	31	40	46	53	34
All-terrain vehicle (ATV)	2E	2	4	4	7	7	8	5
Skiing, snowboarding, telemark	1E	2E	3	5	8	9	14	6
Snowmobiling	1E	1E	3E	3	4	5	6	3
Cross-country skiing, snowshoeing	3E	4	6	8	10	11	14	8
Hunting								
Fishing	5E	6	9	11	13	15	16	11
Camping	6	6	10	12	14	17	16	12
Picnicking, barbecue	15	16	24	27	32	39	37	29
Skating	4E	5	8	12	15	20	25	14
Ice hockey, broomball, curling	F	2E	4	6	8	11	16	8
Bird watching, photography	7	8	11	11	15	17	13	12
Exercise, tai chi, aerobics, yoga	8	9	13	16	16	22	23	16
Go to the park/playground	18	23	29	36	41	46	50	36
Mountain climbing	F	1E	2E	2E	4	4	4	3
Tobogganing, sliding	4E	3	8	8	13	16	20	11
Geocaching	F	F	1E	1E	2E	3	3	2
Badminton, tennis	3E	2E	7E	6	7	11	14	8
Other outdoor activities	2E	2E	3E	3	3E	3	3	3
Did not participate in outdoor activities close to home	41	39	28	24	17	13	12	23

E use with caution
F too unreliable to be published
Note: "Close to home" is defined as being within a 10-minute journey of home. Figures may not add up to 100% as a result of rounding or due to the exclusion of respondents that did not answer the question.
Source: Statistics Canada, *Tables 38-10-0123-01 and 38-10-0121-01*, https://doi.org/10.25318/3810012301-eng and https://doi.org/10.25318/3810012101-eng (accessed October 21, 2021).

5.0 Appendices

A. Methodology and data limitations

Human Activity and the Environment 2021: Accounting for ecosystem change in Canada brings together data from many sources to provide accessible information on the state of Canada's environment. It is a first effort to organize available data according to the new integrated and comprehensive statistical framework for ecosystem accounting described in the System of Environmental-Economic Accounting–Ecosystem Accounting (SEEA – EA)[207] that has been adopted by the United Nations Statistical Commission. While there are multiple components of these accounts, this report focuses on developing data for the core extent, condition and supply and use of ecosystem services accounts. The main data sources, methods and key data limitations are summarized below.

Extent and drivers of change

Terrestrial and freshwater ecosystems

The extent section compiles comprehensive terrestrial and freshwater area estimates that are comparable across the country at the ecoprovince level. Sources include data gathered through satellite imagery, ground plots and photo plots, soil surveys and respondent surveys. In some cases, multiple data sources have been combined to provide a more robust estimate. However, there are difficulties both in consistently delineating ecosystem types across the country and in accurately tracking change in ecosystem areas over time. Data are frequently inconsistent or unavailable across time and space, making time series comparisons difficult. Most land cover and land use maps currently available do not explicitly address changes over time. As a result, estimates of ecosystem extents may change in the future, reflecting not only actual changes on the ground over time, but also changes in data. For similar reasons, caution should be used when interpreting the changes in ecosystem extents over time that are presented in this report.

Table 2.1 (Part 1)

The total area for Canada includes land and water including the Canadian portion of the Great Lakes system. Ecoprovince boundaries are based on the *Terrestrial Ecoprovinces of Canada,* which exclude the Great Lakes.[208]

Freshwater areas are derived from the *Canvec Series – Hydrographic Features* at a scale of 1:50,000 using the layers for waterbodies and watercourses.[209] A 5 m buffer was applied to watercourses to estimate the area.[210] Land areas are calculated as the difference between the total ecoprovince area and the water area.

Mapping wetlands and measuring change in extent are difficult on a national and regional scale. Peatlands are organic wetland ecosystems with peat deposits that are at least 40 cm thick, including bogs and fens. Peatland areas can underlie various land covers—these areas overlap with the land and freshwater areas and with other ecosystem types (e.g., forest, tundra, other natural and semi-natural area). Peatland data are taken from the *Peatlands of Canada Database* (2011), which is based on Soil Landscapes of Canada (SLC) polygons.[211] Area is calculated by multiplying the percent of peatland by the area of the SLC and aggregating by ecoprovince. Map 2.1 displays soil landscape polygons where 50% or more of the area is classed as peatland. The development of updated spatial data on peatland areas is ongoing,[212] but these newer results have not been assessed fully for the purposes of this study.

207 United Nations, 2021, *System of Environmental-Economic Accounting — Ecosystem Accounting*, https://seea.un.org/ecosystem-accounting (accessed March 15, 2021).

208 Agriculture and Agri-Food Canada, 2013, *Terrestrial Ecoprovinces of Canada*, https://open.canada.ca/data/en/dataset/98fa7335-fbfe-4289-9a0e-d6bf3874b424 (accessed December 2, 2020).

209 Natural Resources Canada, Canada Centre for Mapping and Earth Observation, 2018, *Lakes, Rivers and Glaciers in Canada – CanVec Series – Hydrographic Features, 50K*, https://open.canada.ca/data/en/dataset/9d96e8c9-22fe-4ad2-b5e8-94a6991b744b (accessed December 2, 2020). Note that the extent of freshwater area differs from areas previously published for Canada in Statistics Canada, 2017, "Freshwater in Canada," *Human Activity and the Environment,* Catalogue no. 16-201-X, https://www150.statcan.gc.ca/n1/pub/16-201-x/16-201-x2017000-eng.htm.

210 The 5 m buffer was selected based on consultation with data providers and was based on an average watercourse width estimate of 10 m.

211 Tarnocai, C., I.M. Kettles and B. Lacelle, 2011, *Peatlands of Canada*, Geological Survey of Canada, https://geoscan.nrcan.gc.ca/starweb/geoscan/servlet.starweb?path=geoscan/fulle.web&search1=R=288786 (accessed March 16, 2020).

212 For example, Webster, K.L., et al., 2018, "Spatially-integrated estimates of net ecosystem exchange and methane fluxes from Canadian peatlands," *Carbon Balance and Management,* https://doi.org/10.1186/s13021-018-0105-5 (accessed August 18, 2019).

Table 2.1 (Part 2)

Canada's official *National Forest Inventory* (NFI) is produced by Natural Resources Canada's Canadian Forest Service (CFS) on a 10-year cycle and is based on a stratified sample of ground and photo plots to support reporting at the national and ecozone level.[213] The NFI uses the Food and Agriculture Organization of the United Nations (FAO) definition of forest land as "land spanning more than 0.5 hectares with trees higher than 5 metres and a canopy cover of more than 10% or trees able to reach these thresholds in situ," including areas that are temporarily unstocked (areas harvested or burned).[214] The National Deforestation Monitoring System tracks forest area lost to other land uses and, in conjunction with afforestation data, is used to estimate forest area between cycles of the NFI.[215] The extent of boreal and non-boreal forests was estimated with boundaries from Brandt (2009).[216]

Statistics Canada has produced an estimate of forest extent at the ecoprovince level for the purposes of ecosystem accounting. Estimates provided here were downscaled by benchmarking treed area data derived from medium resolution satellite imagery to the latest NFI estimates[217] This method increases uncertainty and error in the ecoprovince-level estimate. In addition, the use of treed area data excludes temporarily unstocked areas, which can be a significant component of forests in some regions, with estimates of about 10% of forest area temporarily unstocked a result of fire or harvest.[218] For these reasons, these estimates are not intended as official estimates of forest land, which are reported in the NFI and in *The State of Canada's Forests*.

There is considerable difficulty in accurately classifying grassland areas using satellite imagery data because of the similarities between natural grasslands and tame or seeded pasture, both of which can be used for grazing livestock. [219]ssessed data sets showed considerable interannual fluctuations between these classes and between pasture and cropland classes (e.g., hay land, from which a hay crop may be harvested.) In order to minimize fluctuations and provide a more robust estimate, the grassland data are estimated using multiple data sets, with satellite imagery data averaged over several years. As a result, change over time is difficult to assess.

First, Agriculture and Agri-Food Canada's (AAFC) space-based 30 m resolution *Annual Crop Inventory*[220] classes for grassland and pasture were averaged for 2014, 2015 and 2016. For areas located outside Canada's agricultural ecumene, grassland was estimated with averaged 2010 and 2015 data from the temperate or subpolar grassland class from the Commission for Environmental Cooperation's (CEC) *Land Cover of North America at 30 m*.[221] In mountainous ecoprovinces, where there was a high degree of variability in grassland results between the datasets, results were further adjusted using derived coefficients. Treed pasture was removed by overlaying the 2015 *Land Cover of North America* temperate or sub-polar needleleaf forest, temperate or sub-polar shrubland, temperate or sub-polar broadleaf deciduous forest and mixed forest classes over the area and results were aggregated by ecoprovince. Tame or

213 National Forest Inventory, 2021, *Standard Reports*, https://nfi.nfis.org/en/standardreports, (accessed August 13, 2021); Natural Resources Canada, 2020, *The State of Canada's Forests 2020*, https://www.nrcan.gc.ca/our-natural-resources/forests-forestry/state-canadas-forests-report/16496 (accessed December 8, 2020).

214 Food and Agriculture Organization of the United Nations, 2020, *Global Forest Resources Assessment 2020 Main Report*, Rome, Italy, https://doi.org/10.4060/ca9825en (accessed December 8, 2020).

215 Dyk, A., D. Leckie, S. Tinis and S. Ortlepp, 2015, *Canada's National Deforestation Monitoring System: System Description*, Information Report—Pacific Forestry Centre, Canadian Forest Service, https://cfs.nrcan.gc.ca/publications?id=36042 (accessed April 20, 2021).

216 Brandt, J.P., 2009, "The extent of the North American boreal zone," *Environmental Reviews*, Vol. 27, no. 1, pp. 101-161, http://cfs.nrcan.gc.ca/publications/?id=29569 (accessed June 15, 2017)

217 National Forest Inventory, 2021, First remeasurement standard reports (2007-2017), Table 4.1. Area (1000 ha) of forest and non-forest land by terrestrial ecozone in Canada, https://nfi.nfis.org/resources/general/summaries/en/html/NFI3_T4_FOR_AREA_en.html (accessed August 13, 2021); Beaudoin, A., et al., 2017, *Species composition, forest properties and land cover types across Canada's forests at 250 m resolution for 2001 and 2011*, Natural Resources Canada (NRCan), Canadian Forest Service, Laurentian Forestry Centre, https://doi.org/10.23687/ec9e2659-1c29-4ddb-87a2-6aced147a990 (accessed March 31, 2019).

218 Wulder, M.A., et al., 2020, "Satellite-based time series land cover and change information to map forest area consistent with national and international reporting requirements," *Forestry: An International Journal of Forest Research*, Vol. 93, no. 3, pp. 331-343, https://doi.org/10.1093/forestry/cpaa006 (accessed April 8, 2021).

219 Ogle, S.M., et al., 2018, "Delineating managed land for reporting national greenhouse gas emissions and removals to the United Nations framework convention on climate change," *Carbon Balance and Management*, Vol. 13, no. 9, https://doi.org/10.1186/s13021-018-0095-3 (accessed April 9, 2021).

220 Agriculture and Agri-Food Canada, 2020, *Annual Crop Inventory, 2014-2016*, https://open.canada.ca/data/en/dataset/ba2645d5-4458-414d-b196-6303ac06c1c9 (accessed December 3, 2020).

221 Natural Resources Canada, Canada Centre for Mapping and Earth Observation, Comisión Nacional para el Conocimiento y Uso de la Biodiversidad, Comisión Nacional Forestal, Instituto National de Estadística y Geografía and U.S. Geological Survey, 2020, *2010 and 2015 Land Cover of North America at 30 metres*, Ed. 2.0, Commission for Environmental Cooperation (CEC), North American Land Change Monitoring System, http://www.cec.org/north-american-land-change-monitoring-system/ (accessed December 9, 2020).

seeded pasture areas from the *Interpolated Census of Agriculture*[222] were subtracted to avoid double counting, as these are reported as arable land in the intensive use area in Table 2.1 (Part 3). Final adjustments were made to ensure consistency with other classes.

Areas of arctic tundra were estimated using the tundra areas from Baldwin, et al. (2018)[223] and subtracting areas of permanent snow and ice from the 2015 *Land Cover of North America* snow and ice class. Note that this estimate of area north of the boreal zone includes freshwater areas and barrenland.

The other natural and semi-natural area category is calculated by subtracting all other ecosystem types from the total area. It may include, for example, woodland, shrubland, barrenland, wetland and lakes and rivers.

Table 2.1 (Part 3)

Arable land is reported as the sum of cropland, tame or seeded pasture and summerfallow from the *Interpolated Census of Agriculture*, which aggregates *Census of Agriculture* data by ecological and drainage units. Other land on farms (e.g., idle land, land occupied by farm buildings, wetlands and woodlands) and natural pasture are not included. Data for arable land do not indicate the amount of land that is potentially cultivable. There are differences between tabulations of Statistics Canada's Census of Agriculture data by standard geographies and the interpolated data provided to AAFC. Specifically, confidentiality procedures are applied to the data in order to avoid the possibility of identifying any specific agricultural operation. This involves the suppression of selected data. As well, the interpolated data are based on the Census Geographic Component Database, in which splits of selected key farms have been reallocated to specific geolocations, rather than to the location of the farm headquarters.

Settlements and human infrastructure are represented with land cover data on built-up and artificial surfaces (BUAS), defined as areas that are predominantly built-up or developed including road surfaces, railway surfaces, buildings and paved surfaces, urban areas, industrial sites, mine structures and golf courses, as well the vegetated areas associated with these land covers. These estimates are based on the settlement (built-up and urban) and roads classes from AAFC's *Land Use, 2000 and 2010*[224] at 30 m resolution for areas of Canada south of 60° N. For areas north of 60° N, where no AAFC land use data was available, estimates were generated for 2000 based on road lengths from Statistics Canada's *Road Network File*.[225] For 2010, the *Land Cover of North America* urban and built-up class was used to estimate the BUAS for northern areas.

The 2015 national BUAS extent was estimated by adding the area converted to settlement from Environment and Climate Change Canada's *National Inventory Report* (NIR) for the years from 2011 to 2015 to the 2010 national BUAS estimate. The NIR reports supplementary data in the common reporting format (CRF) tables, with Table 4.1 providing data on the area of land converted from forest, cropland and grassland to settlements. Settlements as defined in the NIR include all roads and transportation infrastructure; rights-of-way for power transmission and pipeline corridors; residential, recreational, commercial and industrial lands in urban and rural settings; and land used for resource extraction other than forestry. Land converted from wetlands and 'other land' are not included in the conversion. A detailed methodology of data development is available in Part 2 of the NIR.

A quality assessment of the change in BUAS areas in a buffer area surrounding 20 population centres was conducted for the 2000 to 2010 time period. These population centres were selected in different regions of the country. It found that the change accuracy was greater than 90% for large polygons greater than 10 ha, which contributed 90% of the change, and above 80% for medium sized polygons between 5 to 10 ha, which contributed 7% of change. Accuracy was lower for smaller polygons, but these polygons contributed less than 5% of the change. Additional but more general assessments were also done using satellite imagery.

222 Agriculture and Agri-Food Canada, 2016, *Interpolated Census of Agriculture,* https://open.canada.ca/data/en/dataset/1dee8513-5c73-43b6-9446-25f7b985cd00 (accessed December 3, 2020).

223 Baldwin, K., et al., 2018, *Vegetation Zones of Canada: a Biogeoclimatic Perspective* [Map], Scale 1:5,000,000, NRCAN, CFS, https://open.canada.ca/data/en/dataset/22b0166b-9db3-46b7-9baf-6584a3acc7b1 (accessed October 26, 2020).

224 Agriculture and Agri-Food Canada, 2015, *Land Use, 2000 & 2010*, https://open.canada.ca/data/en/dataset/18e3ef1a-497c-40c6-8326-aac1a34a0dec (accessed June 1, 2020).

225 Statistics Canada, 2017, *Road Network File, 2016*, https://www150.statcan.gc.ca/n1/en/catalogue/92-500-X (accessed December 21, 2020).

Marine and coastal ecosystems

As a first step a hexagon grid was built for the entire area of Canada's exclusive economic zone. These 1 km^2 hexagons are used as the basic spatial unit for all of the marine data in this report.

Data for bathymetry, slope and the terrain ruggedness index were calculated from the General Bathymetric Chart of the Oceans (GEBCO) data (version 20150318). Depth classes were assigned by averaging bathymetry data over each hexagon.

Slope was calculated using the tool in ArcGIS, resampled at 25 m, and then the mean for each hexagon was calculated using zonal statistics.

Terrain ruggedness was calculated as a raster layer using the method described in Riley et al. (1999).[226] It was then resampled at 25 m and the mean for each hexagon of the grid was calculated using zonal statistics.

Data for seagrass meadows, kelp forest and cold water coral were taken from a mix of polygon and point sources. For seagrass meadows, both polygon and point data were used. Polygon data that overlapped were treated as a single patch. Where point data did not overlap existing polygon data, the patch size was assumed to be equivalent to the ecoregion's average seagrass patch size. These derived polygons were then merged with the initial polygon data.

A similar methodology was used for cold water coral; however, the applied mean patch size was calculated using only coral areas less than 100 km^2, since the inclusion of larger patches would have skewed the mean and overestimated coral areas. Many of these larger patches were estimated using kernel density methods and may also overestimate coral area.

For kelp forests, only polygon data was used, as point data on the East Coast was scarce and clearly underestimated kelp area.

Salt marsh estimates were based on United Nations Environment Programme (UNEP)[227] polygon data. Although there are other known areas of salt marsh in Canada, it was not possible to obtain area estimates for this analysis.

Seagrass, kelp and salt marsh ecosystems all occur in coastal areas, including in a number of small bays and inlets on the borders between land and sea—they were included in the extent even if in areas that were assigned to land. Furthermore there were some areas of overlap between ecosystem types. These areas have been assigned to both ecosystems rather than creating joint ecosystem types. As such, totals in this table will not match totals in other marine tables in the publication. As detailed marine data is costly to acquire, there are many gaps in the extent accounts, some of which could be filled by modelling exercises or potentially satellite data. Accounting for change over time of marine ecosystems is likely to prove particularly difficult.

Climate

Average annual and seasonal air temperature changes from 1948 to 2016 are produced by Environment and Climate Change Canada (ECCC) based on gridded temperature data interpolated from weather stations.[228] The long-term temperature trend (1948 to 2016) refers to the linear trend of temperature departures from the 1961 to 1990 climate normal. The data are tabulated by ecoprovince and for different ecosystem types and areas by ecoprovince. Caution should be exercised when analyzing change results in the North because of lower climate station densities. Significance levels are not available.

To calculate the temperature change occurring in forest, freshwater, peatland, agricultural and built-up and artificial surface areas (Table 2.9), the temperature change data were overlayed on each class layer and an average was generated by ecoprovince. Each class is treated independently from the others and overlap exists between classes.

226 Riley, S.J., et al., 1999, "A terrain ruggedness index that quantifies topographic heterogeneity," *Intermountain Journal of Sciences*, Vol. 5, no. 1-4.

227 McOwen, C., et al., 2017, "A global map of saltmarshes," *Biodiversity Data Journal,* Vol. 5: e11764, https://doi.org/10.3897/BDJ.5.e11764 and http://data.unepwcmc.org/datasets/43 (v.6) (accessed September 20, 2019).

228 Environment and Climate Change Canada (ECCC), *Canadian Gridded Temperature and Precipitation Anomalies (CANGRD)*, https://open.canada.ca/data/en/dataset/3d4b68a5-13bc-48bb-ad10-801128aa6604#wb-auto-6 (accessed May 15, 2020); ECCC, Climate Trends and Variations Bulletin, https://www.canada.ca/en/environment-climate-change/services/climate-change/science-research-data/climate-trends-variability/trends-variations.html (accessed May 15, 2020).

Some classes differ from the areas reported in Table 2.1. Specifically, the forest area layer uses treed area from Beaudoin (2017), while agricultural area is based on the total farm area (TFAREA) variable by soil landscape polygon from the *Interpolated Census of Agriculture* (2011).[229] This variable represents all areas operated by farms including cropland, summerfallow, tame or seeded pasture, improved pasture and other areas on farms (woodlands, wetlands, idle land and farm buildings including barns, greenhouses, mushroom houses and dwellings).

Average annual, maximum and minimum monthly temperature, precipitation, evapotranspiration and potential evapotranspiration, as well as average annual and seasonal change in precipitation, evapotranspiration and potential evapotranspiration from 1979 to 2016 are based on the Ecological Assimilation of Land and Climate Observations (EALCO) model used by the Canada Centre for Mapping and Earth Observation, Natural Resources Canada.[230]

These variables were estimated from models that used a combination of climate and satellite data. Caution should be used when interpreting these results and in particular trend results. There can be higher levels of uncertainty in some areas because of a scarcity of data, for example, in northern and mountainous regions.[231] These variables are useful indicators for identifying where ecosystem changes might be occurring or may have occurred. For other types of research, such as water budget or climate change analysis, broader considerations and more validation are recommended. The time series data from the EALCO model were tested for the presence of serial correlation and for anomalous observations (outliers). The ARIMA function in the R statistical program was used to compute the overall trend. The ARIMA function produces a linear trend and the associated significance level is adjusted for any existing serial correlation and anomalous observations. Statistically significant linear trends at the 90% confidence level or above are indicated.

The average climate variables are defined as the mean of the reference period. The months used to calculate each season are as follows: spring (March, April, May); summer (June, July, August); fall (September, October, November); and winter (December, January, February).

Condition characteristics

Total water storage change and water yield

Total water storage change is a coarse resolution estimate of changes in the amount of water stored in the environment above and below the Earth's surface including groundwater, soil moisture, snow, ice and surface water. Change in total water storage is indicative of changing climate conditions and is useful for understanding potential influences on ecosystems. Results should be interpreted with caution, in context with supporting data.

Total water storage change data are based on Wang and Li (2016)[232] who used monthly data from the Gravity Recovery and Climate Experiment (GRACE) satellite mission to assess terrestrial water storage climatology for 2002 to 2016. This data has been resampled from the GRACE data to a resolution of 5 km using the EALCO model.[233]

229 Beaudoin, A., et al., 2017, *Species composition, forest properties and land cover types across Canada's forests at 250 m resolution for 2001 and 2011*, Natural Resources Canada (NRCan), Canadian Forest Service, Laurentian Forestry Centre, https://doi.org/10.23687/ec9e2659-1c29-4ddb-87a2-6aced147a990 (accessed March 31, 2019); Agriculture and Agri-Food Canada, 2016, *Interpolated Census of Agriculture*, https://open.canada.ca/data/en/dataset/1dee8513-5c73-43b6-9446-25f7b985cd00 (accessed December 3, 2020).

230 Statistics Canada, Environment and Energy Statistics Division, 2021, special tabulation based on Wang, S., Y. Yang, Y. Luo and A. Rivera, 2013, "Spatial and seasonal variations in evapotranspiration over Canada's landmass," *Hydrology and Earth System Sciences*, Vol. 17, no. 9, pp. 3561-3575, https://doi.org/10.5194/hess-17-3561-2013 (accessed December 1, 2020); Wang, S., et al., 2014, "A national-scale assessment of long-term water budget closures for Canada's watersheds," *Journal of Geophysical Research: Atmospheres*, Vol. 119, pp. 8712–8725, https://doi.org/10.1002/2014JD021951 (accessed February 1, 2021); Li, Z., S. Wang and J. Li, 2020, "Spatial variations and long-term trends of potential evapotranspiration in Canada," *Scientific Reports*, Vol. 10, no. 22089, https://doi.org/10.1038/s41598-020-78994-9 (accessed February 3, 2021).

231 Wang, S., et al., 2014, "A national-scale assessment of long-term water budget closures for Canada's watersheds," *Journal of Geophysical Research: Atmospheres*, Vol. 119, pp. 8712–8725, https://doi.org/10.1002/2014JD021951 (accessed February 1, 2021).

232 Wang, S. and J. Li, 2016, "Terrestrial water storage climatology for Canada from GRACE satellite observations in 2002-2014," *Canadian Journal of Remote Sensing*, Vol. 42, no. 3, pp. 190-202, https://doi.org/10.1080/07038992.2016.1171132 (accessed December 17, 2020).

233 Zhong, D., S. Wang and J. Li, 2020, "A self-calibration variance-component model for spatial downscaling of GRACE observations using land surface model outputs," *Water Resources Research*, Vol. 57, no. 1, https://doi.org/10.1029/2020WR028944 (accessed February 11, 2021).

Time series results were generated monthly at the ecoprovince level. Data were suppressed for smaller ecoprovinces using a threshold of approximately 90,000 km^2 based on recommendations from Wang et al. (2014).[234] The time series data were tested for the presence of serial correlation and for anomalous observations (outliers). The ARIMA function in the R statistical program was used to compute the overall trend. The ARIMA function produces a linear trend and the associated significance level is adjusted for any existing serial correlation and anomalous observations. Statistically significant linear trends at the 90% confidence level or above are indicated.

Water yield is an estimate of freshwater runoff, derived from data on the unregulated flow of water in rivers and streams in Canada. Data were suppressed at the ecoprovince level for the North, but are included in the Canada-level estimate. The national average annual water yield is area-weighted based on ecoprovince areas. The methodology for water yield is described in Statistics Canada, 2017, "Freshwater in Canada," *Human Activity and the Environment*, Catalogue no. 16-201-X and Statistics Canada, 2009, "The Water Yield for Canada as a Thirty-year Average (1971 to 2000): Concepts, Methodology and Initial Results," Environment Accounts and Statistics Analytical and Technical Paper Series, Catalogue no. 16-001-M, no. 7.

Forest condition

The *National Forestry Database* is Canada's main source of provincial and territorial data on forest management and impacts on forest resources.[235] These data differ from the spatial data on timber harvesting and burned areas mapped and reported by ecoprovince in this report in Table 3.3 and Map 3.3. Fire data were taken from the National Burned Area Composite (NBAC), which calculates the area of forest burned on a national scale for each year since 1986. The NBAC is part of the Fire Monitoring, Accounting and Reporting System and is based on the integration of data from fine and coarse resolution satellite data from Natural Resources Canada and Provincial, Territorial and Parks Canada Agencies. Time series harvest data (1985 to 2015) were identified by 30 m Landsat remote sensing, as part of the *Canada Landsat Disturbance* (CanLaD), by Guindon, et al. (2017).[236]

Urban greenness

This analysis provides a synoptic view of urban greenness in summer for three reference years over an 18-year period as a measure of urban condition. It used the normalized difference vegetation index (NDVI) generated from moderate resolution imaging spectroradiometer (MODIS) at a spatial resolution of 230 m to estimate urban greenness for 996 of 1,010 population centres (i.e., those located south of 60° latitude).

The analysis used scaled NDVI, where values from 0 to 1 correspond to a vegetation gradient of non-vegetated (0) to highly vegetated (1). Population centre pixels were classified as either 'green' or 'grey.' The urban green class corresponds to areas with an NDVI greater than or equal to 0.5, representing urban areas with more vegetation. Areas with lower values are considered grey and are largely non-vegetated, though patches of grass, shrubs or crops, or other unhealthy/poor condition vegetation will be included (Figure A.1). Water areas were excluded from the analysis.

Greenness was assessed for the reference years 2001, 2011 and 2019 for the same physical area using the 2016 population centre boundary to ensure consistency. The mean NDVI was calculated using mean weekly best-quality maximum-NDVI corrected for cloud and other atmospheric residual contaminants[237] for nine weeks from June 25 to August 26 for each year.

234 Wang, S., et al, 2014, "Assessment of water budget for sixteen large drainage basins in Canada," *Journal of Hydrology*, Vol. 512, pp. 1-15, https://doi.org/10.1016/j.jhydrol.2014.02.058 (accessed December 1, 2020).

235 National Forestry Database, 2020, *Canada's National Forestry Database*, http://nfdp.ccfm.org/en/index.php (March 3, 2021).

236 Natural Resources Canada, Canadian Forest Service, 2020, *National Burned Area Composite (NBAC)*, http://cwfis.cfs.nrcan.gc.ca/datamart (accessed October 26, 2020); Guindon, L., et al., 2017, *Canada Landsat Disturbance (CanLaD): a Canada-wide Landsat-based 30-m resolution product of fire and harvest detection and attribution since 1984*, https://doi.org/10.23687/add1346b-f632-4eb9-a83d-a662b38655ad (accessed July 20, 2020); Data files downloaded from https://opendata.nfis.org/mapserver/nfis-change_eng.html (accessed July 20, 2020).

237 Bédard, F., 2010, "Satellite image data processing at Statistics Canada for the Crop Condition Assessment Program (CCAP)," *Methodology document for Statistics Canada Integrated Metadata base*, https://www.statcan.gc.ca/eng/statistical-programs/document/5177_D1_T9_V1 (accessed September 18, 2020); Davidson, A., 2018, *An Operational Canadian Ag-Land Monitoring System (CALMS): Near-real-time agricultural assessment from space*, Agriculture and Agri-Food Canada, 100 pp.

This assessment of greenness has several limitations associated with the use of NDVI to represent greenness, including the coarse resolution of the MODIS data and the selection of the 0.5 NDVI threshold to classify green or grey pixels. As well, no distinction was made between greenness resulting from publicly accessible or private green spaces. For trend analysis, assessment of additional time series data are required, while higher resolution data are needed for the identification of detailed urban green spaces. A next step for this work will be the assessment of green space extent and greenness condition using more spatially-detailed datasets and additional time periods.

For more information, see Grenier, M., et al., 2021, "Urban greenness, 2001, 2011 and 2019," *EnviroStats*, Statistics Canada Catalogue no. 16-002-X.

Figure A.1
Examples of urban pixels classed as green or grey

Note: The green or grey class is based on the MODIS NDVI value.

Landscape fragmentation, human landscape modification index (HLMI) and human freshwater influences index (HFII)

This report measures ecosystem degradation and human impacts on landscapes in several ways including estimating directly and indirectly modified areas, linear feature density, natural and semi-natural patch size, distance to natural and semi-natural patch, the human landscape modification index (HLMI) and the human freshwater influences index (HFII).

Directly modified land (circa 2016) includes areas used for agriculture (e.g., cropland, pasture and summerfallow) from the *Interpolated Census of Agriculture*, recent forest harvest (1986 to 2015) from *CanLaD* and built-up and artificial surfaces using the datasets described above in the extent section. Indirectly modified areas include all other terrestrial and freshwater extent.

Data on natural and semi-natural patch size and distance to patch (circa 2016) are calculated based on spatial data files from AAFC's *Land Use, 2015 beta*,[238] Statistics Canada's *Road Network File* and from *CanLaD*. Natural and semi-natural patches include all land classes except settlements (built-up and urban), roads, cropland (annual and perennial), harvested forest (from 2001 to 2015) and managed grassland (natural grass and shrubs used for cattle grazing). A single patch of natural and semi-natural land has a minimum size of 9 pixels (at 30 m x 30 m) with an area of 8,100 m^2. Distance to patch is the average distance from any location in the ecoprovince to the nearest patch of natural

238 Agriculture and Agri-Food Canada, 2020, *Land Use, 2015* (beta version).

and semi-natural land. Average natural and semi-natural patch size should be interpreted with distance to natural and semi-natural patch to get a more complete understanding of fragmentation. Note that the presence of islands can lower the average natural and semi-natural patch size.

Linear feature density (circa 2016) is calculated based on the length of linear features including roads from Statistics Canada's *Road Network File*, and rail lines, cutlines and electrical transmission lines from Natural Resources Canada's Topographic Data of Canada.[239] Linear feature density excludes other types of infrastructure, such as pipelines, and is represented in metres per square kilometre of the total ecoprovince area.

The HLMI is a composite index of the above variables calculated at the pixel level by Statistics Canada. It represents human modifications circa 2011 using the datasets described above with the exception of forest harvest data, which is for the period from 2001 to 2011. It aggregates three measures of human modifications and provides a score to indicate how much the land area has been modified from its natural state. This tool enables comparisons of the level of human modification or use. The index is based on three principles: the degree to which an area has been modified—from a natural or semi-natural state to the most modified state of built-up and artificial surfaces; the distance of an area to the nearest patch of natural and semi-natural land and the size of that patch; and the distance of an area to the nearest linear feature and the density of those linear features. The formula for calculating the HLMI is below.

1. Linear feature (LF) fragmentation index (LFFI) = (LF Density * 0.5) + (LF Distance *0.5)
2. Natural patch fragmentation index (NPFI) = (Size of closest natural and semi-natural patch *0.5) + (Distance to nearest natural and semi-natural patch *0.5)
3. Fragmentation index (FI) = (LFFI *0.5) + (NPFI *0.5)
4. Green index (GI) = Natural and semi-natural pixels (*1) + Forest harvest and managed grassland areas (*2) + Cropland (*3) + Urban and artificial surfaces (*4)
5. HLMI = (GI *0.5) + (FI *0.5)
6. Pixel values are re-scaled from 0 to 100.

Areas with lower scores are generally more intact and therefore potentially able to supply ecosystem services such as water filtration, climate regulation, habitat maintenance and pollination that would be more in line with their natural condition. Areas with higher scores represent progressively more altered or intensively-used ecosystems. Canada totals are an area-weighted average based on ecoprovince areas. Other indicators similar to the HLMI exist at a global scale, for example, the Human Footprint, the Global Human Modification of Terrestrial Systems and the Forest Landscape Integrity Index. These indicators differ in the variables used and methodology applied, but all represent the influence of human activities on terrestrial areas.[240]

The HFII presents an aggregated ranking by drainage region of the individual rankings of 13 variables and indicators. These variables were selected because they are associated with various anthropogenic influences on freshwater ecosystems. They include climate change, population density, the HLMI, water crossing density (e.g., bridges and culverts), dams, freshwater intake and nutrient emissions from industrial plants, farms and wastewater treatment plants (Table A.1). Higher ranked drainage regions (i.e., 1st, 2nd, 3rd, etc.) are subjected to a higher number of direct and indirect human influences on their freshwater ecosystems.

Water crossing density is calculated using Statistics Canada's *Road Network File*[241] and represents the number of bridges or culverts crossing a water body or water course per square kilometre. Dam density results were compiled using Natural Resource Canada's *CanVec* dam data integrated with data from an inventory of large dams produced

239 Natural Resources Canada, 2019, *Topographic Data of Canada – CanVec Series*, https://open.canada.ca/data/en/dataset/8ba2aa2a-7bb9-4448-b4d7-f164409fe056 (accessed December 9, 2020).

240 Venter, O., et al., 2016, "Sixteen years of change in the global terrestrial human footprint and implications for biodiversity conservation," *Nature Communications*, Vol.7, https://doi.org/10.1038/ncomms12558 (accessed May 21, 2021); Kennedy, C.M., et al., 2019, "Managing the middle: A shift in conservation priorities based on the global human modification gradient," *Global Change Biology*, Vol. 25., pp. 811-826, https://doi.org/10.1111/gcb.14549 (accessed May 21, 2021); Grantham, H.S., et al., 2020, "Anthropogenic modification of forests means only 40% of remaining forests have high ecosystem integrity," *Nature Communications*, Vol. 11, https://doi.org/10.1038/s41467-020-19493-3 (accessed May 21, 2021).

241 Statistics Canada, 2017, *Road Network File, 2016*, https://www150.statcan.gc.ca/n1/en/catalogue/92-500-X (accessed December 21, 2020).

by the Canadian Dam Association.[242] Where dams were coincident (within 1 km) between the two datasets they were counted once. Caution should be used when analyzing dam data as there are differences in coverage across provincial jurisdictions.

Table A.1
Human freshwater influence index component data (Part 1)

Drainage region	Drainage region code	Overall rank	Population density, 2011	Annual temperature change, 1948 to 2016	Temperature change for season of largest change, 1948 to 2016	Water crossing density, 2011	Dam density	Human landscape modification index, 2011
		Rank	persons/km²	°C		crossings/km²	dams / thousand km²	score (0 to 100)
Pacific Coastal	1	13	4.7	1.9	3.5	0.2	0.4	7.3
Fraser–Lower Mainland	2	8	10.4	1.9	3.2	0.3	1.5	14.8
Okanagan–Similkameen	3	6	21.8	2.0	2.5	1.0	6.5	19.6
Columbia	4	14	1.9	1.6	2.5	0.2	0.8	13.4
Yukon	5	21	0.1	2.8	6.2	0.0	0.1	5.4
Peace–Athabasca	6	12	0.9	2.2	4.7	0.1	0.2	13.0
Lower Mackenzie	7	20	0.0	2.7	5.2	0.0	0.0	3.7
Arctic Coast–Islands	8	24	0.0	2.4	3.7	0.0	0.0	0.5
Missouri	9	7	0.3	2.0	3.9	0.2	85.4	53.0
North Saskatchewan	10	2	10.9	2.0	4.0	0.7	12.9	42.8
South Saskatchewan	11	1	12.7	1.9	3.8	0.7	37.7	48.5
Assiniboine–Red	12	4	8.1	1.9	3.5	0.5	19.8	50.3
Winnipeg	13	16	1.0	1.7	2.8	0.1	1.3	12.5
Lower Saskatchewan–Nelson	14	15	0.7	1.9	3.5	0.1	0.5	12.9
Churchill	15	17	0.4	2.0	3.8	0.0	0.1	6.1
Keewatin–Southern Baffin Island	16	25	0.0	1.9	3.2	0.0	0.0	0.1
Northern Ontario	17	22	0.2	1.3	2.3	0.0	0.1	3.6
Northern Quebec	18	23	0.1	1.2	1.8	0.0	0.2	1.8
Great Lakes	19	5	54.7	1.1	1.4	0.9	3.6	24.6
Ottawa	20	11	14.9	1.1	1.2	0.6	5.3	18.3
St. Lawrence	21	3	59.9	0.9	1.1	1.8	14.8	25.3
North Shore–Gaspé	22	18	1.5	0.8	1.2	0.1	1.6	5.4
Saint John–St. Croix	23	10	10.3	0.9	1.3	0.6	6.8	20.2
Maritime Coastal	24	9	13.1	0.9	1.3	0.7	7.4	20.8
Newfoundland–Labrador	25	19	1.6	0.8	1.4	0.1	1.3	4.8

… not applicable

Notes: The human freshwater influences index is an overall ranking of drainage regions based on individual rankings of selected anthropogenic variables that affect freshwater ecosystems. The overall rank is determined by ranking each variable individually from highest to lowest impact and then calculating the average of the rankings. Lower values indicate a higher degree of human influence. Dam density was compiled using Natural Resource Canada's CanVec dam data integrated with data from an inventory of large dams produced by the Canadian Dam Association. Where dams were coincident (within 1 km) between the two datasets they were counted once. Caution should be used when analyzing dam data as there are differences in coverage across provincial jurisdictions.

Sources: Statistics Canada, Environment and Energy Statistics Division, 2021, special tabulation based on Environment and Climate Change Canada (ECCC), *Canadian Gridded Temperature and Precipitation Anomalies (CANGRD)*, https://open.canada.ca/data/en/dataset/3d4b68a5-13bc-48bb-ad10-801128aa6604#wb-auto-6 (accessed May 15, 2020); Statistics Canada, 2011, *Census of Population;* Agriculture and Agri-Food Canada (AAFC), 2015, *Land Use 2010*, https://open.canada.ca/data/en/dataset/18e3ef1a-497c-40c6-8326-aac1a34a0dec (accessed June 1, 2020); Natural Resources Canada (NRCan), 2017, *Topographic Data of Canada - CanVec Series*, https://open.canada.ca/data/en/dataset/8ba2aa2a-7bb9-4448-b4d7-f164409fe056 (accessed December 21, 2020); Statistics Canada, 2017, *Road Network File, 2016*, https://www150.statcan.gc.ca/n1/en/catalogue/92-500-X (accessed December 21, 2020); Statistics Canada, 2013, *Survey of Drinking Water Plants, 2011*, https://www150.statcan.gc.ca/n1/en/catalogue/16-403-X; Statistics Canada, 2014, *Industrial Water Use, 2011*, https://www150.statcan.gc.ca/n1/en/catalogue/16-401-X; AAFC, 2015, *Agri-environmental Indicator—Residual Soil Nitrogen (RSN)*, http://open.canada.ca/data/en/dataset/3f5acb7c-78e6-4127-8867-ddd70e396476 (accessed September 28, 2016); AAFC, 2015, *Agri-environmental Indicator—Risk of P release in agricultural land (P-Source)*, http://open.canada.ca/data/en/dataset/fc9e5c73-1c1a-47c1-9de4-612569b718fd (accessed September 28, 2016); ECCC, 2015, *National Pollutant Release Inventory, Pollution Data and Reports*, www.ec.gc.ca/inrp-npri/default.asp?lang=En&n=B85A1846-1 (accessed August 24, 2016); Statistics Canada, 2020, *Table 38-10-0099-01 Wastewater volumes processed by municipal sewage systems (x 1,000,000)*, https://www150.statcan.gc.ca/t1/tbl1/en/tv.action?pid=3810009901 (accessed December 16, 2020); Canadian Dam Association, 2019, *Inventory of Large Dams in Canada 2019*, https://cda.ca/publications/dams-in-canada-2019 (accessed October 29, 2020).

242 Natural Resources Canada, 2017, *CanVec Series*, https://open.canada.ca/data/en/dataset/fd4369a4-21fe-4070-914a-067474da0fd6 (accessed October 29, 2020); Canadian Dam Association, 2019, *Inventory of Large Dams in Canada 2019*, https://cda.ca/publications/dams-in-canada-2019 (accessed October 29, 2020).

Table A.1
Human freshwater influence index component data (Part 2)

Drainage region	Drainage region code	Overall rank	Nitrogen emissions, National Pollutant Release Inventory, 2014	Phosphorous emissions, National Pollutant Release Inventory, 2014	Residual soil nitrogen on agricultural land, normalized across the total area of the drainage region, 2011	Risk of phosphorous release from agricultural soils, normalized across the total area of the drainage region, 2011	Wastewater volumes processed by municipal sewage systems (x 1,000,000), 2013 to 2017 average	Wastewater volumes processed by municipal sewage systems (x 1,000,000), normalized across the total area of the drainage region, 2013 to 2017 average	Surface freshwater intake, normalized across the total area of the drainage region, 2013
		Rank		kg/km²		mg/kg		m³/yr	million m³/km²
Pacific Coastal	1	13	170	10	6.8	0.000	130.5	390	0.002
Fraser–Lower Mainland	2	8	672	181	105.5	0.006	455.1	1,952	0.003
Okanagan–Similkameen	3	6	100	0	184.5	0.021	31.3	2,009	0.010
Columbia	4	14	204	4	30.2	0.000	12.4	142	0.002
Yukon	5	21	5	0	0.0	0.000	4.4	13	0.000
Peace–Athabasca	6	12	1,927	3	215.1	0.011	41.2	85	0.001
Lower Mackenzie	7	20	84	0	0.1	0.000	1.4	1	0.000
Arctic Coast–Islands	8	24	29	0	0.0	0.000	1.0	1	0.000
Missouri	9	7	3,342	0	922.5	1.092	1.0	37	0.001
North Saskatchewan	10	2	4,708	3	1,314.5	0.645	154.6	1,029	0.006
South Saskatchewan	11	1	3,660	5	1,099.9	1.087	271.0	1,526	0.011
Assiniboine–Red	12	4	962	15	1,822.4	0.706	176.5	926	0.008
Winnipeg	13	16	107	3	30.3	0.000	12.0	112	0.001
Lower Saskatchewan–Nelson	14	15	22	0	337.0	0.017	16.4	45	0.000
Churchill	15	17	267	0	94.9	0.002	5.2	17	0.000
Keewatin–Southern Baffin Island	16	25	8	0	0.0	0.000	1.0	1	0.000
Northern Ontario	17	22	45	0	1.6	0.000	24.6	36	0.000
Northern Quebec	18	23	33	0	1.1	0.000	13.5	14	0.000
Great Lakes	19	5	2,876	22	405.6	0.021	1,695.2	5,333	0.074
Ottawa	20	11	518	6	172.6	0.006	315.9	2,159	0.002
St. Lawrence	21	3	1,813	48	690.5	0.062	1,881.1	15,843	0.017
North Shore–Gaspé	22	18	244	3	38.2	0.000	110.9	301	0.001
Saint John–St. Croix	23	10	1,324	31	142.0	0.004	54.2	1,293	0.004
Maritime Coastal	24	9	1,427	17	128.1	0.003	248.7	2,038	0.002
Newfoundland–Labrador	25	19	196	2	1.6	0.000	98.1	258	0.001

… not applicable

Notes: The human freshwater influences index is an overall ranking of drainage regions based on individual rankings of selected anthropogenic variables that affect freshwater ecosystems. The overall rank is determined by ranking each variable individually from highest to lowest impact and then calculating the average of the rankings. Lower values indicate a higher degree of human influence.

Sources: Statistics Canada, Environment and Energy Statistics Division, 2021, special tabulation based on Environment and Climate Change Canada (ECCC), *Canadian Gridded Temperature and Precipitation Anomalies (CANGRD)*, https://open.canada.ca/data/en/dataset/3d4b68a5-13bc-48bb-ad10-801128aa6604#wb-auto-6 (accessed May 15, 2020); Statistics Canada, 2011, *Census of Population;* Agriculture and Agri-Food Canada (AAFC), 2015, *Land Use 2010*, https://open.canada.ca/data/en/dataset/18e3ef1a-497c-40c6-8326-aac1a34a0dec (accessed June 1, 2020); Natural Resources Canada (NRCan), 2017, *Topographic Data of Canada - CanVec Series*, https://open.canada.ca/data/en/dataset/8ba2aa2a-7bb9-4448-b4d7-f164409fe056 (accessed December 21, 2020); Statistics Canada, 2017, *Road Network File, 2016*, https://www150.statcan.gc.ca/n1/en/catalogue/92-500-X (accessed December 21, 2020); Statistics Canada, 2013, *Survey of Drinking Water Plants, 2011*, https://www150.statcan.gc.ca/n1/en/catalogue/16-403-X; Statistics Canada, 2014, *Industrial Water Use, 2011*, https://www150.statcan.gc.ca/n1/en/catalogue/16-401-X; AAFC, 2015, *Agri-environmental Indicator—Residual Soil Nitrogen (RSN)*, http://open.canada.ca/data/en/dataset/3f5acb7c-78e6-4127-8867-ddd70e396476 (accessed September 28, 2016); AAFC, 2015, *Agri-environmental Indicator—Risk of P release in agricultural land (P-Source)*, http://open.canada.ca/data/en/dataset/fc9e5c73-1c1a-47c1-9de4-612569b718fd (accessed September 28, 2016); ECCC, 2015, *National Pollutant Release Inventory, Pollution Data and Reports*, www.ec.gc.ca/inrp-npri/default.asp?lang=En&n=B85A1846-1 (accessed August 24, 2016); Statistics Canada, 2020, *Table 38-10-0099-01 Wastewater volumes processed by municipal sewage systems (x 1,000,000)*, https://www150.statcan.gc.ca/t1/tbl1/en/tv.action?pid=3810009901 (accessed December 16, 2020); Canadian Dam Association, 2019, *Inventory of Large Dams in Canada 2019*, https://cda.ca/publications/dams-in-canada-2019 (accessed October 29, 2020).

Marine and coastal condition

Sea surface temperature and salinity data were taken from the *World Ocean Atlas* data selector,[243] projected to the Canadian Albers equal area projection and assigned to the underlying hexagonal grid using zonal statistics in ArcGIS Pro. For marine ecoregion and depth class averages, the data were averaged across the geography. As there are relatively few partial hexagons in the grid, weighting the averages by area made an insignificant difference. Stock sustainability data were obtained from the Fisheries and Oceans website[244] and were assigned to species group and regions using the stocks' fishing area available in the downloadable file for 2019.

Sea ice extent data were estimated using annual shapefiles from the National Snow and Ice Data Center[245] for the months of September, February and March, projected to the Canadian Albers equal area projection. These were then intersected with the marine ecoregion geography to estimate extent by marine ecoregion. For the Atlantic ecoregions the maximum value of February or March extent was taken for each year. These maximum extents were then averaged to produce decade averages for the Atlantic ecoregions while the September minimum values were averaged by decade for Arctic ecoregions.

Data on the area of aquaculture sites were taken or estimated from numerous sources, as referenced in Table 3.11 and Map 3.11. The area of sites was calculated directly from the polygon files used for British Columbia fish sites, and for sites in Prince Edward Island and Nova Scotia.[246]

Point data were found for Newfoundland aquaculture along with an estimate of total aquaculture area.[247] The area of sites for different regions around the island was estimated by dividing the total area by the number of sites.

For New Brunswick, coordinates and area of aquaculture sites were available and were used to create the map and table.

British Columbia shellfish aquaculture sites were mapped using a PDF map and a list of licenses by fisheries region. The area was estimated using an average area per farm of 8.3 hectares, taken from DFO (2017).[248]

The total area and location of sites for aquaculture in Quebec were taken from the ministère de l'Agriculture, des Pêcheries et de l'Alimentation (MAPAQ).[249]

Data for oil licenses were mapped using shapefiles from the Canada–Newfoundland and Labrador Offshore Petroleum Board, Canada–Nova Scotia Offshore Petroleum Board and Crown–Indigenous Relations and Northern Affairs Canada.[250]

243 Locarnini, R. A., et al., 2018, *World Ocean Atlas 2018: Volume 1: Temperature*, A. Mishonov (Technical ed.), NOAA Atlas NESDIS 81, https://www.nodc.noaa.gov/OC5/SELECT/woaselect/woaselect.html (accessed November 15, 2019).; Zweng, M. M., et al., 2018, *World Ocean Atlas 2018: Volume 2: Salinity*, A. Mishonov (Technical ed.), NOAA Atlas NESDIS 82, https://www.nodc.noaa.gov/OC5/SELECT/woaselect/woaselect.html (accessed May 31, 2020).

244 Fisheries and Ocean Canada, 2019, *Sustainability Survey data and summaries*, https://www.dfo-mpo.gc.ca/reports-rapports/regs/sff-cpd/survey-sondage/data-donnees-en.html (accessed April 1, 2021).

245 Fetterer, F., et al., 2017, *Sea Ice Index, Version 3, Northern Shapefiles,* updated daily, February, March and September, Boulder, Colorado USA, NSIDC: National Snow and Ice Data Center, https://doi.org/10.7265/N5K072F8 (accessed July 13, 2020).

246 British Columbia Ministry of Forests, Lands, Natural Resource Operations and Rural Development, 2011, *Saltwater Finfish Tenures – Coastal Resource Information Management System (CRIMS)*, GeoBC, https://catalogue.data.gov.bc.ca/dataset/saltwater-finfish-tenures-coastal-resource-information-management-system (accessed November 10, 2019); Nova Scotia Fisheries and Aquaculture, July 20, 2020, *Nova Scotia Marine Aquaculture Leases*, https://data.novascotia.ca/Fishing-and-Aquaculture/Aquaculture-License-and-Lease-GIS-Database/h57h-p9mm (accessed Feb 14, 2019); Mills, D., 2014, *PEI Aquaculture Licenses*, http://www.arcgis.com/home/webmap/viewer.html?webmap=16aa8830c7084a8a92ce066b525978b4 (accessed September 15, 2019).

247 Newfoundland Aquaculture Industry Association, 2016, *Industry by the Numbers*, https://naia.ca/index.php/aquaculture-nl/production-stats (accessed July 20, 2020); Aquaculture, Fisheries and Land Resources, Newfoundland and Labrador, 2015, *Licensed aquaculture sites Newfoundland and Labrador, 2015*, https://www.fishaq.gov.nl.ca/pdf/aquaculture_2015_year.pdf (accessed Feb 14, 2019).

248 Fisheries and Oceans Canada, 2017, *Pacific Region -Shellfish integrated management of aquaculture plan: Background and overview of the sector,* https://www.pac.dfo-mpo.gc.ca/aquaculture/management-gestion/shellfish-mollusques/background-contexte-eng.html (accessed April 15, 2019).

249 Ministère de l'Agriculture, des Pêcheries et de l'Alimentation du Québec, 2019, *Portrait-diagnostic sectorial de l'industrie de la mariculture au Québec*, https://www.mapaq.gouv.qc.ca/fr/Publications/Portrait-diagnostic_mariculture.pdf (accessed October 15, 2019) obtained from https://catalogue.ogsl.ca/data/mapaq/f9558184-92d8-4925-b280-bcfbd75ea20f/mariculture_mapaq_2017.xlsx

250 Canada-Newfoundland and Labrador Offshore Petroleum Board, n.d., *Mapping Information and Shapefiles*, https://www.cnlopb.ca/information/shapefiles/ (accessed February 26, 2019); Canada-Nova Scotia Offshore Petroleum Board, 2019, Maps and Coordinates, https://www.cnsopb.ns.ca/whate-we-do/lands-management/maps-and-coordinates (accessed November 30, 2020), Canada-Nova Scotia Offshore Petroleum Board, 2019, GIS Information, https://callforbids.cnsopb.ns.ca/2011/01/gis_information.html (accessed November 30, 2020), Crown-Indigenous Relations and Northern Affairs Canada, 2015, Oil and Gas Rights, https://open.canada.ca/data/en/dataset/208ddd6d-dea8-4d1c-bf62-5b49e8983a51#wb-auto-6 (accessed May 20, 2020).

Ecosystem services supply and use

Provisioning services

The System of Environmental Economic Accounting – Ecosystem Accounts (SEEA – EA) includes several categories of biomass provisioning services. The intent is to recognize the ecosystem contribution of provisioning services, though where this contribution is difficult to distinguish, gross biomass harvested is recognized as an adequate proxy measure. Each service is defined such that there is no double-counting of the ecosystem contribution of individual services. For example, the production of cultivated livestock is not included as a provisioning service where the biomass provision of fodder crops and grazed biomass are counted. Similarly, aquaculture production that relies on wild-caught fish or harvested crops as feed is excluded, since inclusion would result in double-counting, while production that requires no feed inputs (e.g., oysters, mussels) can be included. Note that the data reported in Table 4.1 includes different moisture contents.

Agricultural production is reported as a proxy of the provisioning service provided by agricultural ecosystems. Estimates of crop, honey and maple production include the majority of grain, oilseed, pulse, corn for silage, tame hay (alfalfa, other tame hay and forage seed), potato, vegetable, fruit, honey and maple production (as syrup). Estimates of fodder corn production are calculated using a standard percentage moisture content of 70%. Estimates of production of hay are based on a standard dry matter content of 90%. Estimates for fruit are for marketed production. The estimates may include some data assessed at data quality standard E (use with caution). Provincial data that are unavailable or data that are suppressed to meet confidentiality or data quality standards are not included in the total. The estimates exclude greenhouse vegetable, mushroom, tobacco, cannabis, nursery, sod, or Christmas tree production, as well as grazing on crop residue.

Forage production estimates for tame or seeded pasture and natural land for pasture (rangeland) are based on the areas reported on the Census of Agriculture multiplied by estimates of the average provincial animal unit month (AUM) taken from Yungblut (2012).[251] Biomass provisioning estimates exclude the production of meat, dairy, egg, wool and fur-bearing animals.

The volume of harvested timber reported in the National Forestry Database was converted to tonnage weight by adjusting for wood density.[252] The green weight with bark was estimated using forest product conversion factors for the United States for conifer and non-conifer saw/veneer and pulpwood/fuelwood logs. Non-commercial harvests (e.g., for residential firewood) are excluded.

Fisheries landings are defined as the part of the commercial catch that is put ashore. Seafisheries include groundfish, pelagic and other finfish and shellfish. The data may include some farmed shellfish production (e.g., Atlantic oysters). Freshwater landings data exclude Newfoundland and Labrador, Prince Edward Island, Nova Scotia, British Columbia and Yukon Territory.

Total aquaculture production of shellfish is reported and includes some wild production. It excludes aquaculture production of finfish, restocking of lakes and freshwater fisheries. Data are collected from each of the provincial departments responsible for aquaculture. Provinces and territories with data not available are not included in the total.

Economic data including GDP and employment by sector are available following the North American Industry Classification System (NAICS). An effort was made to align economic statistics on the sectors benefiting from ecosystem provisioning services (i.e., agriculture, forestry, fishing, hunting and trapping etc.); however, in some cases data were aggregated at a higher level. The report grouped the sectors according to previously defined industry groupings. For this reason, there are some differences in the treatment of sector-level aggregation. For example, GDP and employment data for the forest sector includes manufacturing activities, while the primary agriculture sector excludes manufacturing and aquaculture was omitted. GDP and employment data are available for fishing, hunting and trapping industries,

251 Yungblut, D. 2012, National Forage and Grassland Assessment, http://www.canadianfga.ca/wp-content/uploads/2011/04/V1-Final-June-2012-Report-National-Forage-and-Grassland-Assessment-formatted.pdf (accessed December 3, 2019).

252 National Forestry Database, 2021, Table 5.1 Net merchantable volume of roundwood harvested by jurisdiction, tenure, category and species group, http://nfdp.ccfm.org/en/index.php (accessed July 14, 2021); FAO, ITTO and United Nations, 2020, *Forest Product Conversion Factors*, Rome, Italy, https://doi.org/10.4060/ca7952en (accessed June 3, 2021).

to which aquaculture and fish processing were added. However, data on the contribution of the fishing and seafood sector to census subdivision (CSD) employment income was based on an aggregation of data from the 2016 Census, and includes only fishing, aquaculture (finfish and shellfish) and fish processing.

Regulating services

According to the SEEA - EA, ecosystem contributions to global climate regulation services include measurement of carbon sequestration and retention of carbon in ecosystems.[253] Under this standard, carbon sequestration reflects the ability of ecosystems to remove carbon from the atmosphere and store it for long periods of time. Net ecosystem carbon balance is considered an appropriate metric. Where net carbon sequestration is zero or negative, the service supplied by the ecosystem is zero. Carbon retention supplies a service through avoided carbon emissions and includes carbon in above ground and below ground biomass (including in the seabed) and soil organic carbon (including peatlands to a maximum of 2 m depth). It excludes inorganic carbon in freshwater, marine and subterranean ecosystems, fossil fuel deposits, as well as harvested wood products (carbon stored in produced assets) and stocks of crops or livestock (short-term storage). Measurement of carbon retention is a focus particularly for ecosystems where the stock of carbon is at risk of emission, e.g., as a result of fire, deforestation or peatland draining.

This report makes use of data related to carbon sequestration and retention that are produced by other departments to meet their existing reporting requirements;[254] however, there are some differences in focus and gaps exist, e.g., for marine and coastal ecosystems and unmanaged forests. For example, carbon stock change and fluxes of CO_2 to the atmosphere are the subject of reporting requirements for Land use, Land-Use Change and Forestry as part of the *National Inventory Report* (NIR) to the United Nations Framework Convention on Climate Change (UNFCCC). Carbon stock changes and fluxes are also modeled by NRCan CFS to meet other reporting frameworks such as the Montréal Process. These data are based upon models and are subject to limitations and uncertainty, as detailed in the original documentation.

Carbon sequestration service supply for arable and urban ecosystems is based on data reported in the common reporting format (CRF) tables as part of the NIR 2020. Values reported in CO_2 equivalents have been converted to carbon. Sequestration attributed to built-up and artificial surfaces is based on the net carbon stock change in living biomass for settlements remaining settlements as reported in CRF Table 4E. This estimate of carbon removals for urban ecosystems accounts for net carbon uptake by urban trees, in which biomass decay is implicit. It includes 69 population centres in Canada with a population over 30,000 (of 947 population centres on the 2011 Census), capturing major Canadian cities representing 62% of 1990 urban area and 79% of 1990 population.[255] It does not include emissions related to urban expansion. Sequestration attributed to arable land (cropland, summerfallow and improved pasture) is based on reporting of net removals for cropland remaining cropland as reported in the CRF Table 4B. This estimate is based on a gains-loss approach to carbon stock estimation using land management changes reported on the Census of Agriculture. Emissions associated with land conversions to cropland were not included in Table 4.4.

Carbon ecosystem indicators are modeled by the CFS for managed forests using the Carbon Budget Model of the Canadian Forest Sector (CBM-CFS3) and national compilation of forest inventories, forest growth and yield tables, large-scale disturbances and forest management activity data, as part of the National Forest Carbon Monitoring, Accounting and Reporting System (NFCMARS) supporting reporting in the NIR 2020.[256] The definition of forests is based on the definition in the Marrakesh Accords (i.e., 25% crown closure, with potential tree height at maturity of 5 m or greater and covering an area of 1 ha or greater). Forests are classified as managed or unmanaged based on the

253 United Nations, 2021, *System of Environmental-Economic Accounting — Ecosystem Accounting,* https://seea.un.org/ecosystem-accounting (accessed March 15, 2021).

254 Environment and Climate Change Canada, 2020, N*ational Inventory Report 1990-2018: Greenhouse gas sources and sinks in Canada,* https://publications.gc.ca/site/eng/9.506002/publication.html (accessed April 30, 2020); Montréal Process Working Group, 2015, “Criteria and indicators for the conservation and sustainable management of temperate and boreal forests,” The Montréal Process, Fifth Edition, https://www.montrealprocess.org/documents/publications/techreports/MontrealProcessSeptember2015.pdf (accessed October 27, 2020).

255 Ristow, M., J. W. Steenberg and P. N. Duinker, 2019, *An updated approach for assessing Canada’s urban forest carbon storage and sequestration,* Report submitted to Environment and Climate Change Canada; McGovern, M. and J. Pasher, 2016, "Canadian urban tree canopy cover and carbon sequestration status and change, 1990-2012," *Urban Forestry and Urban Greening,* Vol. 20, pp. 227-232, https://dx.doi.org/10.1016/j.ufug.2016.09.002 (accessed October 27, 2020).

256 Natural Resources Canada, 2020, *Carbon Accounting,* https://www.nrcan.gc.ca/climate-change/impacts-adaptations/climate-change-impacts-forests/carbon-accounting/13087 (accessed April 9, 2021); Kurz, W.A., et al., 2013, “Carbon in Canada’s boreal forest — A synthesis,” *Environmental Reviews,* Vol. 21, pp. 260-292, https://doi.org/10.1139/er-2013-0041 (accessed February 2, 2020).

occurrence of management activities for timber or non-timber and on the level of protection against disturbances.[257] Note that this definition of forest area differs from that used for the National Forest Inventory, which is based on the FAO definition (i.e., 10% canopy cover, 5 m height, 0.5 ha).[258]

Table 4.3 reports carbon stocks by Intergovernmental Panel on Climate Change (IPCC) carbon pool. Indicators reported in Table 4.4 include net primary productivity (NPP), net ecosystem productivity (includes heterotrophic respiration) and net biome productivity (NBP), which includes harvesting transfers and disturbance emissions, for managed forest land. Negative NBP represents a loss of carbon and therefore is not a carbon sequestration service. Note however that harvesting transfers include wood products that can store carbon in the built environment over the long term, in addition to wood products that are more quickly oxidized. The species-weighted density of commodities used to estimate carbon in harvested wood products (oven dry tonne wood material/m^3)[259] differs from the densities used for estimating the green weight of commercial timber harvests as a biomass provisioning service in Table 4.1. In addition, these two estimates use different data sources for fuelwood and firewood.

Kelp forests, seagrass meadows and salt marshes in coastal area have an important role in carbon cycling. Studies on Canadian seagrass meadows have currently produced a wide range of estimates for carbon accumulation in sediment at different sites and mapping of these ecosystems is ongoing. Section 2.1 provides an estimated minimum known extent.

257 Government of Canada, 2007, C*anada's initial report under the Kyoto Protocol,* https://unfccc.int/files/national_reports/initial_reports_under_the_kyoto_protocol/application/pdf/initial_report_of_canada.pdf (accessed April 20, 2021); Environment and Climate Change Canada, 2020, *National Inventory Report 1990 – 2018: Greenhouse gas sources and sinks in Canada, Part 2*, Catalogue no. EN81-4E-PDF, https://publications.gc.ca/site/eng/9.506002/publication.html (accessed July 20, 2020); Stinson, G., et al., 2011, "An inventory–based analysis of Canada's managed forest carbon dynamics, 1990 to 2008," *Global Change Biology*, Vol. 17, pp. 2227–2244, https://doi.org/10.1111/j.1365-2486.2010.02369.x (accessed April 4, 2020).

258 Natural Resources Canada, 2020, *The State of Canada's Forests: Annual Report, 2020*, https://www.nrcan.gc.ca/our-natural-resources/forests-forestry/state-canadas-forests-report/16496 (accessed December 15, 2020).

259 Environment and Climate Change Canada, 2020, *National Inventory Report 1990 – 2018: Greenhouse gas sources and sinks in Canada, Part 2*, Catalogue no. EN81-4E-PDF, https://publications.gc.ca/site/eng/9.506002/publication.html (accessed July 20, 2020).

B. Glossary

Abyssalpelagic: refers to waters at depths of greater than 4 km depth. The abyssalpelagic class includes areas where the maximum water depths exceeds 4 km.

Agriculture sector (primary): includes the following North American Industry Classification System (NAICS) codes: 111 – crop production, 112A – animal production (excluding aquaculture), 1151 – support activities for crop production and 1152 – support activities for animal production. Excludes agricultural input suppliers, food product manufacturing, wholesale and retail, and food services.

Ambient air concentrations: amount of air pollutants in outdoor air expressed in parts per billion (ppb) by volume for gases and micrograms per cubic metre ($\mu g/m^3$) for particulate matter. Average indicators are used to capture prolonged or repeated exposures over long periods or chronic exposure, while peak indicators are used to capture immediate or acute short-term exposures. The average and peak air quality definitions vary by pollutant. For more information, see here.

Ambient air quality: refers to outdoor air quality. The Canadian Ambient Air Quality Standards set limits, based on human health considerations for outdoor air concentrations of fine particulate matter ($PM_{2.5}$), ozone (0_3), sulphur dioxide (SO_2) and nitrogen dioxide ($N0_2$).[260]

Arable land: reported as the sum of cropland, tame or seeded pasture and summerfallow from the *Interpolated Census of Agriculture*. Other land on farms (e.g., idle land, land occupied by farm buildings, wetlands and woodlands) and natural pasture are not included.

Bathypelagic: refers to waters at depths of 1 km to 4 km. The bathypelagic class includes areas where maximum water depths are within this range.

Built-up and artificial surfaces: include areas that are predominantly built-up or developed including road surfaces, railway surfaces, buildings and paved surfaces, urban areas, industrial sites, mine structures and golf courses, as well the vegetated areas associated with these land covers, at a resolution of 30 m or greater.

Canadian Ambient Air Quality Standards (CAAQS): the CAAQS were developed by the Canadian Council of Ministers of the Environment, under the *Canadian Environmental Protection Act*, as outdoor air quality targets to drive air quality management across Canada. Standards exist for fine particulate matter ($PM_{2.5}$), ozone (0_3), sulphur dioxide (SO_2) and nitrogen dioxide ($N0_2$) with an averaging time (e.g., 24-hour, annual, 8-hour, 1-hour), numerical value and statistical form. For more information, see here.

Carbon sequestration: the removal and long-term storage of carbon from the atmosphere. The carbon sequestration service focuses on the amount of biocarbon accumulated in ecosystems net of respiration, decomposition and combustion in an accounting period.

Carbon retention: carbon is stored in ecosystems in living and dead biomass and soil organic carbon. The carbon retention service relates to the ability of ecosystems to retain carbon, thus avoiding emissions of carbon to the atmosphere. It is quantified as the stock of carbon retained (stored) in ecosystems including forests, wetlands (e.g., peatlands) and agricultural, coastal and marine areas at the beginning of the accounting period.

Climate normal: a three-decade average of a climatological variable such as temperature or precipitation.

Cropland: area used for growing crops. Total area of cropland from the *Interpolated Census of Agriculture* includes reported areas of hay and field crops, vegetables, nursery products, fruit, berries, grapes and nuts. Total area of cropland in the AAFC *Land Use* spatial data product includes annual and perennial crops.

Cutlines: a line cut through an area to facilitate cadastral or seismic surveys or create fire breaks. E.g., seismic cutlines are narrow corridors up to about 10 m wide cut through the landscape including forest, peatland and tundra. Often used to transport survey equipment for natural resource exploration.

260 Canadian Council of Ministers of the Environment, 2017, *Canada's Air*, https://ccme.ca/en/air-quality-report (accessed February 14, 2020).

Distance to natural and semi-natural patch: the average distance from any location in the ecoprovince to the nearest patch of natural and semi-natural land.

Degree of modification: the degree to which a landscape has been modified from a natural state. Heavily built areas with a large proportion of artificial surfaces and lower proportion of natural and semi-natural areas can be considered the most modified or the least intact ecosystems.

Drainage region: grouping of sub-sub drainage areas as defined by the *Standard Drainage Area Classification*, Statistics Canada's official classification of drainage areas. For more information, see here.

Ecoprovince: the second level (under ecozones) of the *Ecological Land Classification*, a hierarchical classification of ecological areas in Canada. For more information, see here.

Ecosystem: defined in Article 2 of the Convention of Biological Diversity as a dynamic complex of plant, animal and micro-organism communities and their non-living environment interacting as a functional unit.[261]

Ecosystem condition: the quality of an ecosystem measured in terms of its abiotic, biotic and landscape and seascape-level characteristics across a range of temporal and spatial scales.[262]

Ecosystem functions: the physical, chemical and biological processes (e.g., nutrient cycling, carbon cycling, etc.) that occur in ecosystems.

Ecosystem services: a wide range of services that flow from ecosystems and provide benefits to people, often grouped into three categories: provisioning services (e.g., supply of food, fuel, fibre and water), regulating services (e.g., filtration, purification, regulation and maintenance of air, water, soil, habitat and climate) and cultural services (e.g., nature-based recreation or education).

Ecozone: the first level of the *Ecological Land Classification*, a hierarchical classification of ecological areas in Canada. For more information, see here.

Epipelagic: refers to waters from the water surface to 200 m depth. The epipelagic class includes areas where the maximum water depth reaches 200 m. This region is further divided, with the coastal epipelagic class having a maximum depth of 50 m.

Evapotranspiration (ET): the process of evaporation from land surfaces and transpiration from plants. It is controlled by surface water availability and by meteorological variables such as net solar radiation, air temperature, humidity and wind speed.

Exclusive Economic Zone (EEZ): refers to the area of the sea in which a country has rights to the exploration and use of marine resources. The area covers from the coast to 200 nautical miles offshore.

Fishing and seafood sector: includes the following North American Industry Classification System (NAICS) codes: 1141 – fishing; 1125 – aquaculture and 3117 seafood product preparation and packaging.

Forest: ecosystems dominated by trees, including temperate forest and boreal forest. Canada's National Forest Inventory uses the FAO definition of forest, "land spanning more than 0.5 hectares where the tree canopy covers more than 10% of the total land area and the trees can grow to a height of more than 5 metres. It does not include land that is predominantly urban or used for agricultural purposes."[263] Canada's *National Inventory Report* to the UNFCCC uses the Marrakesh Accords definition of forest (25% crown closure, with potential tree height at maturity of 5 m or greater and covering an area of 1 ha or greater).[264]

261 United Nations, 1992, *Convention on Biological Diversity*, https://www.cbd.int/convention/text/ (accessed February 14, 2020).

262 United Nations, 2021, *System of Environmental-Economic Accounting — Ecosystem Accounting,* https://seea.un.org/ecosystem-accounting (accessed March 15, 2021).

263 Natural Resources Canada, 2020, *The State of Canada's Forests: Annual Report, 2020*, https://www.nrcan.gc.ca/our-natural-resources/forests-forestry/state-canadas-forests-report/16496 (accessed December 15, 2020).

264 Government of Canada, 2007, *Canada's initial report under the Kyoto Protocol,* https://unfccc.int/files/national_reports/initial_reports_under_the_kyoto_protocol/application/pdf/initial_report_of_canada.pdf (accessed April 20, 2021); Environment and Climate Change Canada, 2020, National Inventory Report 1990 – 2018: Greenhouse gas sources and sinks in Canada, Part 2, Catalogue no. EN81-4E-PDF, https://publications.gc.ca/site/eng/9.506002/publication.html (accessed July 20, 2020).

Forest sector: includes the following North American Industry Classification System (NAICS) codes: 113 – forestry and logging; 1153 – support activities for forestry and logging (e.g., forest conservation services, forest fire fighting services, forestry maintenance, log hauling, pest control and timber cruising and valuation); 321- wood product manufacturing and 322 – paper manufacturing.

Grassland, natural pasture and rangeland: areas dominated by grasses or grass-like plants including natural grasslands or native rangelands of the Canadian Prairies used for grazing, as well as other areas dominated by grassy vegetation (e.g., wetland, alpine meadows).

Groundfish: fish living near the bottom of the ocean. Also known as demersal or bottomfish.

Human landscape modification index (HLMI): a composite index used to measure direct human modifications to the landscape, based on the degree that an area has been modified from a natural or semi-natural state, the relationship of an area to the nearest patch of natural and semi-natural land and the size of that patch, and the relationship of an area to the nearest linear feature and the density of those linear features. Values range from 0 to 100, with higher scores indicating more intensively-used ecosystems and lower scores representing more intact ecosystems.

Human freshwater influences index (HFII): a ranked index of selected variables and indicators that reflect anthropogenic influences on freshwater ecosystems including population density, the HLMI, water crossings, dams, temperature change and nutrient emissions from industrial plants, farms and wastewater treatment plants.

Landscape fragmentation: the breaking up of areas of natural and semi-natural landscapes into smaller and more disconnected or isolated patches.

Linear feature density: a measure of linear features that cut across a landscape, calculated based on the length of roads, rail lines, cutlines and electrical transmission lines per unit area.

Managed forest: for the purposes of reporting on greenhouse gas emissions to the United Nations Framework Convention on Climate Change (UNFCCC), forest areas are classified as managed or unmanaged based on the occurrence of management activities for timber and non-timber resources (including parks) and on the level of protection against disturbances.[265]

Mesopelagic: refers to waters at depths of 200 m to 1,000 m. The mesopelagic class includes areas where maximum water depths are within this range.

Natural and semi-natural patch: includes all land classes except built-up and artificial surfaces (settlements and roads), cropland (annual and perennial), harvested forest (from 2001 to 2015) and managed grassland (grass and shrubs used for cattle grazing). A single patch of natural and semi-natural land has a minimum size of 9 pixels (at 30 m x 30 m) or 8,100 m^2.

Net primary productivity: gross primary productivity (the rate at which photosynthetic plants and bacteria use sunlight to covert CO_2 and water to carbon compounds used to fuel growth (biomass)) less cellular respiration.[266]

Net ecosystem productivity: net primary productivity less heterotrophic respiration.

Net biome productivity: net ecosystem productivity less disturbance losses. Equivalent to net ecosystem carbon balance at the landscape level.

Nitrogen dioxide (NO_2): important in the formation of ozone in the atmosphere and a precursor to fine particulate matter.

Ocean acidification: the process by which the pH level of the ocean decreases mainly because of the absorption of CO_2.

265 Stinson, G., et al., 2011, "An inventory–based analysis of Canada's managed forest carbon dynamics, 1990 to 2008," *Global Change Biology*, Vol. 17, pp. 2227–2244, https://doi.org/10.1111/j.1365-2486.2010.02369.x (accessed April 4, 2020); Ogle, S.M., et al., 2018, "Delineating managed land for reporting national greenhouse gas emissions and removals to the United Nations framework convention on climate change," *Carbon Balance and Management*, Vol. 13, no. 9, https://doi.org/10.1186/s13021-018-0095-3 (accessed April 9, 2021).

266 Malone, T., et al., 2016, "Chapter 6. Primary production, cycling of nutrients, surface layer and plankton," *The First Global Integrated Marine Assessment: World Ocean Assessment 1*, United Nations, https://www.un.org/Depts/los/global_reporting/WOA_RPROC\Chapter_06.pdf (accessed April 4, 2020).

Parkland: ecosystems characterized by tall herbaceous vegetation, scrub and scattered large trees. This ecosystem type occurs for example in the Parkland Prairies ecoprovince, including the Aspen Parkland ecoregion, which is a transitional area between the prairie grassland and the boreal forest.

Peatland: wetland ecosystems with peat deposits that are at least 40 cm thick.

Pelagic fish: fish that live in the water column and that are not dependent on the ocean floor or shoreline for habitat.

Population centre: has a population of at least 1,000 and a population density of 400 persons or more per square kilometre, based on population counts from the current Census of Population. All areas outside population centres are classified as rural areas. Population centres are classified into three groups: small (population between 1,000 and 29,999), medium (population between 30,000 and 99,999) and large urban (100,000 or more).[267]

Potential evapotranspiration (PET): represents the evapotranspiration that would occur without limitations on water supply. PET is therefore linked to the amount of energy available to generate ET in a specific area and is independent of water supply.

Salinity: estimate of the amount of salt dissolved in water.

Sea knoll: an isolated small elevation on the deep seafloor.

Seamount: an elevation of the seafloor 1,000 m or higher, either flat-topped or peaked.

Shellfish: aquatic shelled animals including molluscs (e.g., oysters and mussels) and crustaceans (e.g., crabs and lobsters).

Species abundance and richness: species abundance refers to the total number of individuals of a species in an area, population or community. Species richness refers to the total number of species in an area.

Stratification: the existence or formation of distinct layers in a body of water identified by thermal or salinity characteristics or by differences in oxygen or nutrient content.

Sulphur dioxide (SO_2): emitted when a fuel or raw material containing sulphur is burned or used in industrial processes such as metal ore smelting.

Summerfallow: total area of summerfallow from the *Interpolated Census of Agriculture*. Summerfallow is a land management practice that involves leaving land fallow in summer to conserve water or manage weeds.

Tame or seeded pasture: total area of tame or seeded pasture from the *Interpolated Census of Agriculture*. This category represents managed grazing lands supporting introduced forage species and receiving periodic cultural treatment, such as tillage, fertilization, mowing and irrigation.

Thermokarst topography: an uneven landscape in permafrost regions marked by small depressions and lakes, formed by subsidence and following melting of ground ice.

Total water storage change: an estimate of the change in the amount of water stored in the environment above and below the Earth's surface including groundwater, soil moisture, snow, ice and surface water. To convert water measured in depth in mm to a volume per area in m^3/m^2, divide by 1000.

Tundra: treeless areas of dwarf shrub and other low-lying sedges, mosses and lichen that develop north of the boreal zone and in alpine regions at higher elevation.

Turbidity: a measure of the relative clarity or cloudiness of a liquid, caused by suspended particles (e.g., clay, silt, metals, organic matter, microorganisms), that is measured in nephelometric turbidity units (NTU).

Urban densification: increase in the number of people or residential units within an established area.

267 Statistics Canada, 2017, *Census of Population, 2016, Dictionary*, https://www12.statcan.gc.ca/census-recensement/2016/ref/dict/index-eng.cfm (accessed August 20, 2020).

Urban greenness: a biotic condition variable for urban areas that classifies population centre areas as green or grey based on the normalized difference vegetation index (NDVI) from moderate resolution imaging spectroradiometer (MODIS). This assessment does not correspond to the actual area of vegetated or unvegetated land cover in cities; rather it measures whether a given pixel (230 m x 230 m) meets a set vegetation threshold (NDVI ≥ 0.5).

Water cycle: the natural cycle in which water evaporates from the Earth's surface including the oceans to the atmosphere and returns to the earth as precipitation.

Water yield: an estimate of freshwater runoff that provides information on Canada's renewable freshwater supply. It is derived from data on the unregulated flow of water in rivers and streams. Although water yield provides an estimate of renewable freshwater, it can include some water that is considered non-renewable (e.g., melt water from receding glaciers). To convert water measured in depth in mm to a volume per area in m^3/m^2, divide by 1000.

Wetland: areas that are permanently or temporarily saturated with water for periods long enough to promote wetland or aquatic processes, as indicated by poorly drained soils, hydrophytic vegetation and various kinds of biological activity adapted to a wet environment. Wetlands can be categorized as organic wetlands (more commonly referred to as peatlands) or mineral wetlands and are classified as bog, fen, swamp, marsh or shallow water (< 2 m).[268]

Windthrow: natural disturbance in forests caused by wind, leading to stem breakage or root system failure. May occur at the individual tree or stand level. Also known as blowdown.[269]

268 National Wetlands Working Group, 1997, *The Canadian Wetland Classification System*, 2nd Ed. B.G. Warner and C.D.A. Rubec (Eds.), Catalogue no. CW66-156/1997, Wetlands Research Centre, https://www.gret-perg.ulaval.ca/fileadmin/fichiers/fichiersGRET/pdf/Doc_generale/Wetlands.pdf (accessed April 29, 2021).

269 Mitchell, S., 2000, *Forest Health: Preliminary Interpretations for Wind Damage,* British Columbia Ministry of Forests, Forest Practices Branch, https://www.for.gov.bc.ca/hfp/publications/00166/WD_29Mar00.pdf (accessed May 5, 2021).

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