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STUDY GUIDE 2024

Biodiversity in a Changing Climate

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Acknowledgements

The following study guide was created by a team of students from the Ecosystem Management Technology Program at Sir Sandford Fleming College. The purpose of the study guide is to provide high school students with study materials that reflect the 2024 Ontario Envirothon Current Issue Topic. The study guide was produced for and edited by Forests Ontario with the support of Forest Ontario's Education Outreach Coordinator Madeleine Bray. Special thanks are also given to Sara Kelly, faculty member of the Ecosystem Management program at Fleming College.

Support for the 2024 Ontario Envirothon Study Guide has been provided by:



Tools and Resources

WEBSITES

- Interactive Map of Climate Change https://climateatlas.ca/map/canada/plus30_2030_85#
- State of Ontario's Biodiversity https://sobr.ca/_biosite/wp-content/uploads/state-of-biodiversity-report-E-FINAL-aoda-with-links-and-correction-1.pdf
- Vulnerable Birds in Ontario <https://www.audubon.org/climate/survivalbydegrees/state/ca/on>
- Ecological land classification <https://www.ontario.ca/page/ecological-land-classification>
- EDDMaps <https://www.eddmaps.org/>

VIDEOS

- Our World Ontario https://www.youtube.com/watch?v=I-TGQ_u2FRE&t=5s
- What is Biodiversity? <https://www.youtube.com/watch?v=y18o0mACCQs>
- Causes and Effects of Climate Change | National Geographic https://www.youtube.com/watch?v=G4H1N_yXBIA
- Rick Beaver & The Alderville Black Oaks Savanna <https://www.youtube.com/watch?v=ZeUkylJdySI>
- From the Ground Up – Regenerative Agriculture https://www.youtube.com/watch?v=6vQW8TL_KLc&t=51s

Key Ideas and Learning Objectives

KEY TOPICS

1. What is biodiversity and why it is important
2. How to measure biodiversity
3. What is climate change and the impacts it has on biodiversity
4. Policies, regulations, and laws related to biodiversity conservation
5. Socioeconomic aspects of biodiversity conservation in a changing climate
6. The role of various levels of government, businesses, individuals, and Indigenous groups in addressing biodiversity conservation in a changing climate

LEARNING OBJECTIVES

Students should be able to..

1. Describe biodiversity and its importance to ecosystems.
2. Understand the social, economic, and cultural importance of biodiversity.
3. Analyze the impact that climate change has on the diversity of living things and ecosystems.
4. Define and understand key terms, including biodiversity, climate change, conservation, preservation, ecosystem, representative conservation pathways, critical habitat, and phenology.
5. Assess the biodiversity of a region using relevant metrics and multiple spatial scales, specifically with respect to species at risk, water quality, soil quality, and habitat types
6. Understand how various levels of government, non-government organizations, Indigenous communities and organizations, and individuals are involved in conservation efforts in Ontario.
7. Understand traditional ecological knowledge with respect to biodiversity in Ontario.
8. Understand the effectiveness of federal, provincial, and local policy and initiatives focused on conserving biodiversity.
10. Describe innovative technologies and programs addressing biodiversity conservation.



1.0 Introduction to Biodiversity

Biodiversity is all around us! Biodiversity can be defined as the collection of all life forms that exist on Earth. This variety includes diverse **ecosystems**, ecological processes, species, and genes (Ontario Biodiversity Council, n.d.). Plants, animals, fungi, and microorganisms make up the natural world, working together to maintain and support life on Earth (Hancock, n.d.). Of an estimated 8.7 million species on this planet, only 1.2 million have been identified and described by scientists. There is research that looks to explore how much biodiversity is present at various spatial scales to strengthen our understanding of the relationships between species and ecosystems.

Global biological diversity is rapidly declining. This is due to climate change and other **anthropogenic** or human-caused activities such as land use change, over-exploitation, and pollution driving unprecedented rates of species extinction. Effective management of natural resources, **conservation** efforts, and climate change mitigation efforts are necessary to enhance resilience of nature against the impacts of climate change. The UN Convention on Biological Diversity states that biodiversity is our strongest natural defense against climate change (UN 2023). Conserving and restoring nature and biodiversity helps to mitigate climate change by sequestering carbon from the **atmosphere** and storing it in plants and soil. Biodiversity helps to enhance resilience to the impacts of climate change by increasing drought resilience, flood attenuation, and mitigating extreme heat.

The decrease in biodiversity means that there is an increase in **species at risk**. A species at risk is any native plant or animal in danger of extinction or disappearing from Ontario. There are four categories "at risk":

- ① Extirpated: **Native** species that no longer exist in the wild in Ontario but still exist elsewhere
- ② Endangered: Native species facing extinction or extirpation
- ③ Threatened: Native species at risk of becoming endangered in Ontario
- ④ Special Concern: Native species that are sensitive to human activities or natural events, which may cause it to become endangered or threatened

For more information on species at risk, see the Wildlife study guide and the 2023 Ontario Envirothon study guide on the topic. (<https://forestsontario.ca/en/resource/study-guide-2023-species-at-risk>)

Biodiversity plays a critical role in supporting the wellbeing of ecosystems. For humans, this means environmental, economic, and cultural benefits. Ontario's **Ecological Land Classification (ELC)** system describes ecosystems using geology, climate, vegetation, terrain and soil. The ELC has six units of classification: ecozones, ecoregions, ecodistricts, ecosections, ecosites, and ecoelements.

Ecozone: the highest level of ecosystem classification, defined by broad climate patterns and underlying bedrock. The Hudson Bay Lowlands, Ontario Shield, and Mixdewood Plains ecozones can be found in Ontario.

Ecoregion: a section of an ecozone, these are defined by patterns in temperature, precipitation, humidity, and other climate variables.

Ecodistricts: a subdivision of an ecoregion, these are defined by bedrock and topography

Ecosections: a subdivision of an ecodistrict, these are defined by slopes, landforms, soil texture, and soil moisture. These are not commonly used in Ontario.

Ecosites: smaller than ecosections, these are based mainly on physical features that influence plant species, including moisture, slope, and types of soil. Dunes, rock barrens, and sugar maple hardwood forests are all examples of ecosites.

Ecoelements: the smallest of Ontario's land classification units, every ecosection will have different ecoelements. Specific substrates and vegetation are ecoelements (Ontario, 2022)

Collectively, these components contribute to the maintenance of **ecological integrity** across various **landscapes** in Ontario (Ontario, 2022). Biodiversity is crucial to ecological integrity and supporting livelihoods and cultural traditions. Through the conservation and protection of these ecosystems, we can help to ensure a sustainable future for both nature and human populations.

1.1 How to measure and monitor biodiversity

Considering the importance of biodiversity, especially in the context of a changing climate, it is critical to develop best management practices and conservation strategies, along with tools that measure and monitor biodiversity facilitate that process.

The Ontario Biodiversity Council reports on Ontario's biodiversity on a five-year cycle to increase the understanding of the current health of Ontario's biodiversity and highlight areas for improvement. The indicators used for measuring and monitoring biodiversity span a variety of broad categories. They report on ecosystems and species, responses to conservation efforts, and pressures on biodiversity as they relate to the Biodiversity Targets set out in Ontario's Biodiversity Strategy and add valuable insights regarding trends in biodiversity. Some examples of these indicators include education, volunteer stewardship, habitat loss caused by fragmentation, and changes in species at risk status. In 2021, the Ontario Biodiversity Council published its third State of Ontario's Biodiversity Summary report, outlining the 26 indicators they use to measure the state of biodiversity across the province.

The Ontario Biodiversity Council's biodiversity targets and identified priority actions within Ontario's Biodiversity Strategy are intended for all people of Ontario everyone has a role to play in conserving biodiversity. They support the province in meeting its goals and objectives for protecting biodiversity and are integral to the development and implementation of future climate action to address the social, economic, environmental, and cultural challenges associated with rapid biodiversity loss (Ontario Biodiversity Council, n.d.). They also support goals and objectives set out nationally by the Government of Canada and internationally under the United Nations.

In summary, measuring and monitoring biodiversity is foundational for the future management and protection of biodiversity. It allows researchers, conservation organizations, decision-makers, and others to track their progress in meeting goals and targets, using a wide range of indicators to understand different aspects of the relationships between ecosystems and the species that rely on them to thrive in the context of a changing climate.

DISCUSSION QUESTIONS:

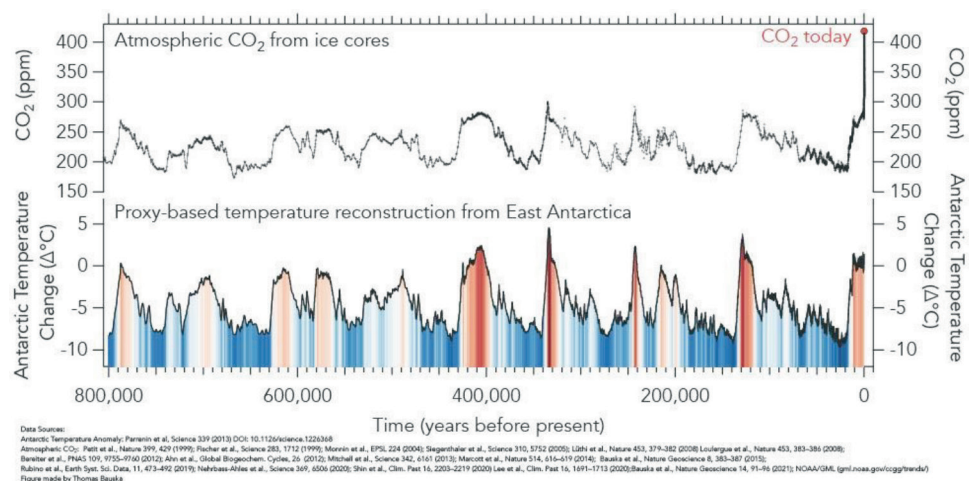
1. Define biodiversity and discuss its environmental, social, economic, and cultural significance.
2. How is biodiversity threatened by climate change? Provide an example of a negative effect climate change has on species diversity.
3. What areas of biodiversity are measured to monitor and document our progress with protecting Ontario's biodiversity?
4. Why might a coastal community, an agricultural worker, or a logging company be concerned about biodiversity?
5. What measures could we take to preserve current levels of biodiversity? What could we do to restore and enhance biodiversity?
6. How can enhancing or increasing biodiversity help to mitigate climate change?

2.0 A Changing Climate

2.1 What is climate change?

Climate change describes the long-term shifts in Earth's average weather conditions that is reflected by changes in temperature, humidity, wind, cloud cover, and **precipitation** (Environment and Climate Change Canada, 2019). While variability is a natural part of Earth's climate cycle (e.g. ice ages), the planet is currently experiencing an unprecedented, rapid increase in global temperature (Fig 1). The last eight years have been the eight hottest years ever recorded, with global average temperatures in 2022 being 1.15°C warmer than pre-industrial levels (World Meteorological Organization, 2023). According to Canada's Climate Change Report from 2019, Canada is warming at almost twice the global rate. From 1948-2019, average temperatures across Canada have increased by 1.7°C.

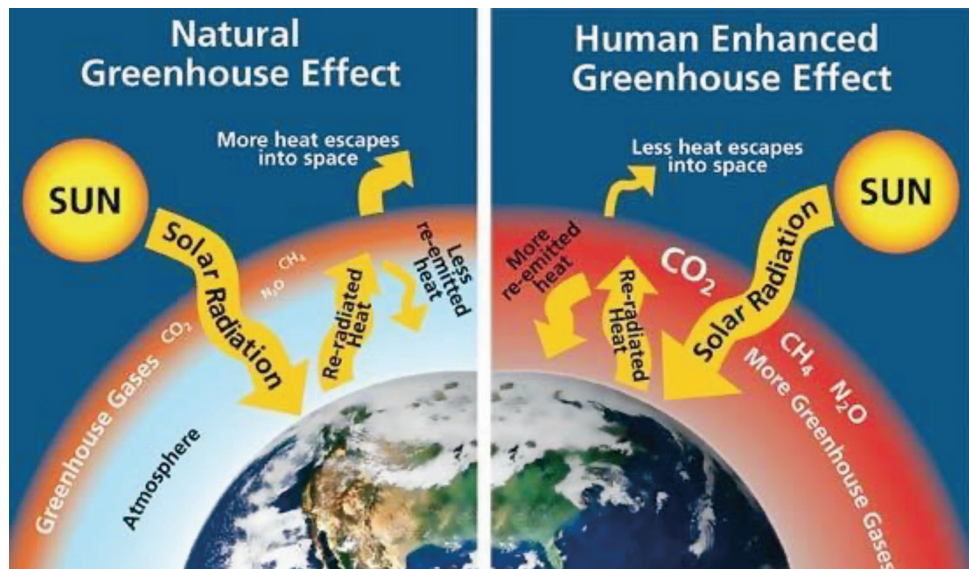
Figure 1 The earth's historic climate trends determined from ice core analysis. This graph shows the relationship between atmospheric CO₂ levels and average temperatures. It also depicts the rapid increase in CO₂ following the Industrial Revolution. Source: <https://www.bas.ac.uk/data/our-data/publication/ice-cores-and-climate-change/>



The vast majority of scientists agree that modern climate change is not a part of the natural climate cycle; it is being caused by human activity increasing the amount of **greenhouse gases** (GHGs) in our atmosphere. GHGs are long-lived molecules in the Earth's atmosphere that trap solar radiation from the sun and thus warmth. While the greenhouse effect is a natural and crucial part of Earth's atmosphere and climate system, humans have emitted significantly more GHGs than any natural system. More GHGs in the atmosphere means more solar radiation is being trapped close to Earth's surface, warming the planet (Fig 2; NASA, 2023b).

The main source of GHG emissions is the burning of **fossil fuels**, as a main byproduct of their combustion is CO₂. **Carbon dioxide (CO₂)** is the most abundant GHG. Deforestation and filling in wetlands to clear land for agriculture or development is diminishing the amount of **carbon sinks** able to store excess CO₂. Land conversion continues to increase as the human population grows and there is more demand for food and space to live (Environment and Climate Change Canada, 2019). In May 2013, atmospheric CO₂ levels reached the historic record high of 400ppm, a record that surpassed measurements from millions of years ago (Blunden, 2014). As of February 2023, the concentration of CO₂ in earth's atmosphere has risen to 419ppm (NASA, 2023a).

Figure 2. The natural greenhouse gas effect and how human activity is enhancing it. Source: <https://climatechange.lta.org/get-started/learn/co2-methane-greenhouse-effect/>



DID YOU KNOW? Researchers have pieced together ancient climate conditions from ice cores taken in Antarctica and Greenland (some can be 3km deep!). Air bubbles get trapped as snow accumulates to form ice sheets, and researchers analyze the bubbles in core samples to determine what the earth's atmosphere looked like as far back as 800,000 years ago (Bauska, 2022). This provides a baseline of the earth's climate to compare to current data.

2.2 Modelling Climate Change

The **representative concentration pathways (RCPs)** are a set of four scenarios developed by the International Panel on Climate Change to describe future climate conditions under different projections of GHG emissions and land use. Climate forcing scenarios are a method used by climate researchers to develop strategies for mitigation and adaptation. The current RCPs model climate conditions from 2013 to 2100. Having an industry standard tool like RCPs is useful because it makes research more comparable. The four RCP scenarios are:

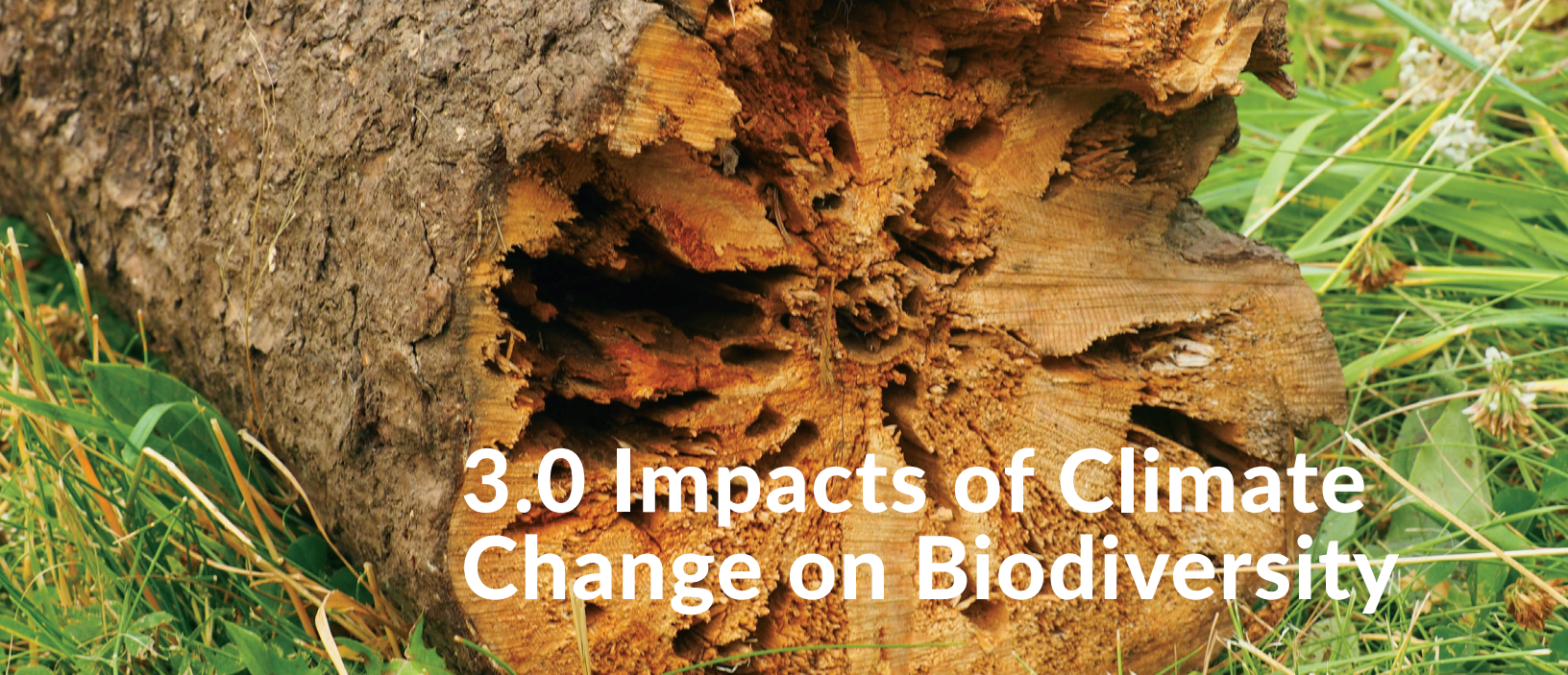
- RCP2.6: high degree of greenhouse gas emission mitigation where **radiative forcing** peaks at 2.6W/m² (watts per square metre) before 2100 and then declines. This is the scenario with the least amount of climate forcing. Under this scenario, the amount of global warming is projected to be below 2°C. To meet this goal, humans will need to drastically reduce GHG emissions by about two gigatons of CO₂ per year before 2100.

- RCP4.5: intermediate levels of mitigation where radiative forcing stabilizes at $4.5\text{W}/\text{m}^2$ after 2100.
- RCP6.0: intermediate levels of mitigation where radiative forcing stabilizes at $6.0\text{W}/\text{m}^2$ after 2100.
- RCP8.5: "worst case scenario" with little to no mitigation efforts, where radiative forcing exceeds $8.5\text{W}/\text{m}^2$ by 2100 and continues to rise. This is the scenario with the greatest amount of climate forcing.

For the purposes of this guide, most studies will refer to RCP 8.5, the "worst case scenario" with limited mitigation enacted in projections.

DISCUSSION QUESTIONS:

1. How do human activities like the burning of fossil fuels and deforestation contribute to climate change?
2. How does modern climate change differ from past variability in the Earth's climate cycle?
3. If greenhouse gas emissions continue to rise, how might your life be affected?
4. How can industry do more to reduce their contributions to climate change?



3.0 Impacts of Climate Change on Biodiversity

Climate change is impacting the Earth's natural and human systems in diverse ways. This guide is not comprehensive on the impacts of climate change; if you would like to read more, please see 2018's Current Issue Guide on Climate Change (<https://forestsontario.ca/en/resource/2018-climate-change>) and summary reports from the Intergovernmental Panel on Climate Change (IPCC).

One of the most notable impacts of climate change are increasing global temperatures. This drives changes in natural ecosystems, ice melt, warmer oceans, and more **extreme weather events**. The thawing permafrost in arctic regions threatens the stability of infrastructure in Canada's arctic and releases GHGs like CO₂ and methane (Climate Atlas of Canada, 2023).

Ice sheets are melting away 150 billion tons of freshwater per year in Antarctica and 270 billion tons of freshwater per year in Greenland since 2002, and this is responsible for 33% of sea level rise (NASA, 2023d). Even under a moderate climate scenario (RCP4.5), 150 million people will be below the high-tide mark and at risk of losing their homes to coastal flooding by 2050 and 200 million will be at risk by 2100 (Kulp & Strauss, 2019). Additionally, arctic sea ice has been shrinking by 12.6% each decade since 1981, which does not increase sea level but is reducing the earth's **albedo** and important habitat (NASA, 2023c).

In Ontario, warmer temperatures are reducing habitat suitability for species and causing range shifts. These warmer and drier conditions are also influencing growth rates of species, behaviour of wildlife, and overall ecosystem health and resiliency. Extreme weather events that go beyond already warmer temperatures or drier conditions are pushing the limits of what **native species** can withstand.

3.1 Range Shifts

One of the ways climate change is impacting biodiversity in Ontario is by altering the natural distributions of both native and **invasive species**. While some southern species may be able to take advantage of a warmer, drier climate and expand their ranges northward, there are also northern species and ecosystems that are losing suitable habitat to the effects of climate change. Many northern species are losing range, being outcompeted by southern species, and experiencing a loss of genetic diversity. These impacts are being felt from freshwater lakes to the boreal forest.

3.2 Loss of Habitat and Range in Ontario

The vast expanse of Northern Ontario ranges from Sudbury to the coast of Hudson Bay and includes large swaths of boreal forest, northern peatlands, and the province's only oceanic coastline. Northern Ontario comprises 88% of the province's land, though only 6% of the human population lives there, and is expected to be the most severely affected by climate change in the province. Northern Canada is warming at almost triple the rate of the global average (Government of Canada, 2019).

Ontario's northern species have evolved to thrive in cooler temperatures with long, cold winters and milder summers. Climate change is shifting the average temperature and precipitation levels faster than these species can adapt to new conditions. As a result, they are losing suitable habitat in their historic range and will either compete with southern species moving north or shift their range northward. However, some species can only go so far north, and many species cannot move fast enough to keep up with the rapidly changing conditions.

3.2.1. Aquatic species

Ontario's lakes are warming by an average of 0.2°C per decade, which may seem small on paper, but is causing drastic changes to aquatic ecosystems. The range of many freshwater fish species is moving northwards as the lakes in their historic ranges become too warm for them. Cold-water fish are most sensitive to temperature changes and are losing habitat due to warmer temperatures, reduced ice cover, and competition from cool-water fish expanding their range (Wu et al., 2023). This is leading to a decline in **cold-water species**, such as lake trout (Fig 3), and an increase in cool-water species like northern pike and yellow perch (Jansen et al., 2004).

Figure 3 Lake trout, a cold-water species that is experiencing population declines across Ontario.
Source: <https://ijc.org/en/decades-after-they-seemed-disappear-lake-trout-found-spawning-again-lake-superior-tributary>



Cold-water fish rely on the deep **hypolimnion layer** of the lake for survival, which becomes shallower and more **hypoxic** with less ice cover. A 4°C increase in temperature would cause significant declines in available lake trout habitat, with habitat almost disappearing entirely in spring and early summer. For cool-water fish like perch, a temperature increase of 4°C would increase available habitat, but they may struggle to withstand winter temperatures in these areas because they may not meet their food and dissolved oxygen requirements (Jansen et al., 2004). While some large predatory cold-water fish can adapt and move northward as conditions change, this is causing sharp declines in prey species in more northern environments that are now experiencing an enhanced level of predation (Wu et al., 2023).



FUN FACT Point Pelee is the most southern part of mainland Canada. Its unique location within important migratory pathways and on the shore of Lake Erie make it a popular stopping point for birds travelling elsewhere (or a good place for birds to hang out year-round!). 390 species of birds have been recorded here, including many Ontario rarities.

3.2.2 Birds

Climate change will force many birds in Ontario to alter their ranges to find suitable habitat and food availability. Currently, there are 82 species of birds in Ontario are considered highly vulnerable to the effects of climate change, 73 species are moderately vulnerable, and 37 species are slightly vulnerable. The species most at risk of losing range and thus facing population declines are boreal forest birds, aquatic or coastal birds, and arctic birds. Those less at risk are eastern forest birds and generalist feeders (Audubon, n.d.).

Species distribution models of birds in Ontario's national parks showed that the mixedwood plains region in Southern Ontario is expected to see high rates of **species turnover** and potential extirpation by 2050. Southern species are predicted to expand their ranges northward, with some species even becoming new year-long residents in Ontario (Gahbauer et al., 2022). Point Pelee, a key migratory hotspot for birds, is predicted to lose species richness and functional dispersion (Gahbauer et al., 2022). This is a reflection of the Point Pelee ecosystem having less adaptive capacity to respond to climate change.

3.2.3 Mammals

Mammals are also losing range and habitat suitability due to climate change. A species of particular concern is the polar bear (Fig 4). Ontario's Hudson Bay coast is home to the most southern population of polar bears in the world. It is important to monitor this population because they serve as an indication of how other polar bears living more northwards will be impacted by climate change. Polar bears depend on sea ice coverage to hunt, mate, and travel through their landscape, but the period of sea ice cover in southern Hudson Bay and James Bay has decreased by almost three weeks since the 1970s. This is leading to significant declines in body condition and survival rate of individuals in the population (Ontario Biodiversity Council, 2015b).

Boreal caribou are also susceptible to climatic changes. Caribou require large, undisturbed areas of mature upland conifer forest and lowland conifer forests. Threats to caribou habitat include habitat loss and fragmentation due to human activities such as forestry, mining, hydro corridors and roads. Climate change may impact caribou by reducing available habitat and affecting food sources. Forest conditions may become more suitable for moose and deer, resulting in an increase in the number of predators and more predation of caribou. By 2050, caribou are expected to lose 55% of their habitat in Ontario. If winter temperatures increase by more than 5.6°C by 2070, woodland caribou could be extirpated from Ontario (Masood et al., 2017).

Figure 4 Polar bears wading through wet terrain in the Hudson Bay lowlands. Source: <https://www.ontarioparks.com/parksblog/the-polar-bear-ontario%E2%80%99s-arctic-giant/>



3.2.4 Forests

Ontario is home to four major forest regions: the Hudson Bay lowlands, the boreal forest, the Great Lakes-St. Lawrence forest, and the Carolinian forest (Ontario Ministry of Natural Resources and Forestry, 2021). The boreal forest is expected to experience greater climate warming than any other forest biome in Canada (Daniel et al., 2017). The boreal forest makes up 2/3 of Ontario's forests and covers 50 million hectares of the province, about half the total land area (Fig 5).

Coniferous trees commonly found in the boreal forest such as Balsam Fir, Black Spruce, White Spruce, and Jack Pine are vulnerable to shifts in their optimal climate zone. The structure and composition of Canada's eastern boreal forest will be greatly altered, as coniferous trees would experience significantly lower growth rates as their range shrinks, and they meet competition from southern species migrating north. Most of that competition will be trees common to the Great Lakes-St. Lawrence and deciduous forests, such as Yellow Birch, White Pine, Eastern Hemlock, Red Maple, Sugar Maple, Red Oak, and American Beech (Boulanger et al., 2017; Goldblum & Rigg, 2005).

Figure 5. Dominant boreal conifers such as Black Spruce (*Picea mariana*) will lose suitable habitat as climate change creates a warmer, drier environment and facilitates competition from southern species. *Photo taken by Abbey Lewis in June 2022 near Brownrigg, ON*



CASE STUDY: The Ontario-Quebec Boreal Forest Bottleneck Region

The Ontario-Quebec boreal forest bottleneck region exists just south of James Bay along the border of these two provinces. This region is critical to maintaining connectivity across Canada's boreal forest, which is the largest intact forest ecosystem in the world (Allen, 2017).

In a paper presented in 2017, models using RCP 8.5 were used to investigate how vulnerable twelve key boreal-**obligate** species living in this region are to the effects of climate change and **habitat fragmentation** under a climate scenario with little to no intervention. The species they looked at were Spruce Grouse, Canada Jay, Boreal Chickadee (Fig 6), moose, Northern Flying Squirrel, Snowshoe Hare, marten, caribou, White Birch, White Spruce, Black Spruce, and Jack Pine. As these species are so dependent on the boreal ecosystem, the changes they experience from climate change serve as an indication of the current and future health of the entire forest.

Compared to the rest of Canada's boreal forest, the Ontario-Quebec bottleneck region will experience significantly more severe effects of climate change. While species richness is predicted to decline by -1.35 species in the entire boreal forest by 2080, this number is -6.93 in the bottleneck region. Significant habitat fragmentation is predicted for most species in the bottleneck region with drastic increases in the amount of habitat patches, how small habitat patches are, and isolation between patches. This will have serious consequences for connectivity and gene flow between populations of a species.

The only species predicted to expand their ranges northwards under these warmer, drier conditions in this study were Northern Flying Squirrels and Jack Pine. Contrastingly, caribou were predicted to lose 100% of suitable habitat in the bottleneck region by 2050. This extirpation was also projected for Boreal Chickadees (Fig 7), Spruce Grouse, and moose by 2080. Black Spruce, White Spruce, Canada Jays, and martens are predicted to lose more than 70% of their suitable habitat by 2080. Losing these key boreal species could fundamentally change the structure of Ontario's boreal forest ecosystem (Murray et al, 2017).

Figure 6. Boreal Chickadees (*Poecile hudsonicus*) are a boreal-obligate species predicted to lose 100% of habitat suitability in Ontario's boreal forest bottleneck region by 2080 under the RCP8.5 climate scenario. Photo taken by Abbey Lewis in June 2022 near Brownrigg, ON.



Figure 7. Predicted changes to habitat suitability by 2080 across Canada for the Boreal Chickadee. Murray et al. (2017) <https://projects.thestar.com/climate-change-global-species-shakeup/>



3.2.5 Peatlands

Ontario is home to 25% of the world's **peat** ecosystems and the second largest peatland complex in the world, which are the Hudson Bay lowlands (Cardoso, 2021). Peat ecosystems are terrestrial wetlands like bogs and fens where there is a slow rate of decomposition and thus an accumulation of peat. Sphagnum mosses are keystone species in Ontario's peat ecosystems and their dead biomass forms the bulk of the peat (International Peatland Society, 2018) (Fig 8).

Peatlands are important carbon sinks. The peat ecosystems of Ontario alone store an amount of carbon equal to 33% of all provincial GHG emissions each year (Far North Science Advisory Panel, 2010). However, these ecosystems are incredibly vulnerable to the effects of climate change including increased temperatures, drier conditions, and increased risk of fire (McLaughlin et al., 2021). Since peatlands are unique habitats that act as biodiversity hotspots for rare species, and migratory birds, the plants and animals that live there are at risk of habitat loss (Wilt, 2020). Loss of peatlands will also exacerbate the effects of climate change in Ontario. Without any intervention, it is predicted that the die-off of peat will be so drastic that carbon sequestration by the Hudson Bay lowlands will decline by 27% (McLaughlin et al., 2021).

Figure 8. Wulf's Peatmoss (*Sphagnum wulfianum*) is a species of Sphagnum moss found in peat ecosystems. Photo taken by Samuel Brinker in July 2022 at Conroy's Marsh Conservation Reserve, ON. <https://inaturalist.ca/observations/130243778>



DISCUSSION QUESTIONS

1. What is contributing to the significant increase in temperatures in Northern Canada compared to the rest of the world?
2. How does habitat fragmentation impact all members of the ecosystem? What are some ways to address the issue of fragmentation?
3. How might the entire ecosystem be impacted by the extirpation of a single species of plant or animal?
4. What other concerns might we have about the loss of terrestrial wetland ecosystems, such as peatlands?
5. How will range shifts have societal, cultural, and economic impacts?
6. How would a government organization monitor the range shift of an aquatic species? A terrestrial species?

CASE STUDY: Canada Lynx

Climate change-induced shifts in species distribution can impact the genetic structure of a species and thus its adaptive ability to successfully respond to a changing environment. This is a problem for one of Ontario's most iconic species, the Canada Lynx (Fig 9). They are a medium-sized wild cat that stalk the boreal forests of Canada and some northern states. Since the 1970s, the southernmost edge of the lynx's range in central Canada has retreated north by over 175 km. Lynx living in the southernmost range are more vulnerable to human disturbance, competition with bobcats, and scarcity of their main prey, the Snowshoe Hare (Hinterland Who's Who, n.d.).

A 2014 study examined the genetics of Ontario's lynx and found that lynx in the southern edge of their range had low genetic variability. This low genetic variability is ultimately related to shallower snow depths, warmer winter temperatures, and less available habitat (Koen et al., 2014). As climate change reduces snowfall and drives warmer winters in Ontario, this lynx population is at risk of extirpation from these southern areas. These environmental effects will only be exacerbated by the anthropogenic stressors mentioned above. Losing this range and this population would reduce the genetic diversity of the Canada Lynx.

Figure 9. Canada Lynx (*Lynx canadensis*) (Ryan, 2020). <https://inaturalist.ca/photos/116298857>



DISCUSSION QUESTIONS

1. Why do genetic losses result in population declines? How does climate change exacerbate this problem?



DID YOU KNOW? Of the 486 invasive vascular plants in Canada, almost 91% (441 species) are present in Ontario! The amount of traffic in and out of the province (cars, trucks, trains, planes, and boats) combined with a high number of disturbed sites in the province make Southern Ontario a perfect spot for new invasive plants to establish themselves.

3.3 Invasive species

Invasive species are species that are not native to an area and have been introduced, often due to human activity. When introduced to a new area, invasive species may be able to dominate and destroy the ecosystem because they have no natural predators or limitations in that environment. Some examples of invasive species in Ontario include Zebra Mussels in the Great Lakes brought here by cargo ships, or the Emerald Ash Borer carried in through wood packaging.

Zebra Mussels are an invasive species in Ontario concentrated in the Great Lakes basin (Fig 10). They negatively impact habitats by filtering plankton out of water bodies at a rate of up to 1L per day. As plankton are foundational to many aquatic food chains, their removal can be detrimental to native fish and aquatic wildlife. Furthermore, increased filtration allows sunlight to penetrate more easily and warm the water. Besides altering the temperatures of their aquatic ecosystems, clearer and warmer water promotes algal growth. Zebra Mussels can produce up to 1 million eggs per year and are thus difficult to manage because of how fast their population can grow (NCC, n.d.). Zebra Mussels are more tolerant to warmer temperatures than most native aquatic species living in the Great Lakes. Thus, they are better suited to adapt and thrive as climate change warms the lakes and waterbodies in Southern Ontario. As climate change also generates more extreme weather events, Zebra Mussels have greater potential to grow their population. A 60% increase in the intensity of three summer storms is enough to significantly expand mussel colonies in Ontario as it stirs up new plankton for mussels to feed on (Van Cappellen, 2015).

Figure 10. iNaturalist observation : Zebra Mussel (*Dreissena polymorpha*) Cleeb, 2023 <https://www.inaturalist.org/>



WHAT IS THE DIFFERENCE BETWEEN PESTS AND INVASIVE SPECIES? Both pests and invasive species can harm ecosystems, whether they be native or introduced. While a pest can be native or invasive, all invasive species are considered pests (National Park Service, n.d.).

Generally, invasive species are better adapted to withstand a variety of conditions and can outcompete local species. As the climate changes, the range of many invasive species will move north in the same way that the range of native species will change.

Southern Ontario, for example, already has more mild winters than the rest of the province due to its position between the great lakes. As this area warms, it will create conditions favourable to invasive species that, up until recently, were limited to the United States of America. Organizations like the Invasive Species Centre (ISC) monitor for potential future invasives and bring awareness so that communities and organisations that may become a part of an invasive's range will know what to look for and how to manage it. Two such threats to Ontario's biodiversity are Spotted Lanternflies and Oak Wilt.

Oak Wilt is a fungus. It was first spotted in Ontario in the summer of 2023, with the first noted instance in the Niagara Peninsula, and the second in Midhurst, near the northwest shore of Lake Simcoe.

DISCUSSION QUESTIONS:

1. What are some mitigation strategies for invasive species? Consider both terrestrial and aquatic ecosystems.
2. What are some ways that invasive species become introduced to a new area?
3. How might invasive plant species impact both native plant and animal species?
4. How can invasive species exacerbate the effects of climate change, or vice versa?

3.4 Lower growth rates of vegetation

Many species of plants in Ontario are experiencing lower growth rates under warmer, drier climatic conditions. This mainly impacts northern species, but not exclusively. Drier conditions have been associated with greater vulnerability to insects, disease, and forest fires, and generally lower habitat suitability for trees in Canada's boreal forest (Brecka et al., 2020). Historic records show that warmer temperatures are negatively correlated with growth of Balsam Fir and White Spruce (Goldblum & Rigg, 2005). Should little to no GHG mitigation be put in place, the biomass of Ontario's boreal forest is expected to decline significantly by 2200, with the most dramatic losses occurring before 2100. Significant droughts are also expected. This will have important impacts on Ontario's timber industry as the species most affected by climate change are also the most commercially valuable trees in the boreal forest. Climate change will favour southern species that can tolerate the warmer, drier climate and periods of drought (Brecka et al., 2020).

Urban forests are also vulnerable to climate change as it compounds the existing stress of living in a highly disturbed environment. 50% of native urban tree species in the Greater Toronto Area (GTA), for example, are highly vulnerable to drought. As a result, many cities and towns will plant non-native species such as Norway Maple or ginkgo that can withstand the heat island effect, road salt, and other stressors found in urban environments in addition to periods of drought. One way to keep native species in urban environments without sacrificing hardiness is by using native cultivars, which are plants engineered to be more resilient to extreme weather (Khan & Conway, 2020).

3.5 Phenological changes

Phenology refers to the study of seasonal changes in plants and animals, especially in relation to weather and climate. Food webs, **ecosystem services**, global water and carbon cycles, and the abundance and distribution of species are all influenced by phenology, while phenology itself is heavily influenced by changes in temperature and precipitation.

Phenology plays an important role in the functioning and wellbeing of ecosystems. Predators and prey, insects and host plants, parasites and host insects, and insect pollinators and flowering plants have close interactions and depend on each other for survival. Increasing temperatures can cause the timing of important events in their life cycles to become out of sync.

Warming temperatures can cause numerous issues. For example, plants that begin growing earlier in the year due to warmer temperatures may be more susceptible to frost damage.

Forests in Ontario are greening up earlier and showing an increase in duration of the **growing season**. This early flush of leaves is causing asynchrony between the spring green-up and migratory bird arrival and may be leading to population declines, as green-up is a key indicator of food availability for migratory species.

Plants and animals both are shifting the timing of key life events in response to climate change. Many birds have evolved to use a specific nesting time to ensure that insects or other food sources are available to feed their hatchlings. However, insects usually emerge in unison with the leaves of their host plant. Bird species that overwinter closer to breeding grounds, migrate more slowly, and arrive earlier may be better equipped to keep pace with change. For example, the Eastern Phoebe varies its arrival date substantially in response to changes in green-up so can match the timing of food availability, while the Bobolink adjusts only a small amount, making it more at risk of reduced breeding success or adult survival.



DID YOU KNOW? Some refer to phenology as "nature's calendar". When the trees bloom in the spring and the leaves change colour in the fall, you don't have to check a calendar to know the time of year (USA National Phenology Network, n.d).

Phenology is important to understand when:

- Managing forest pests and invasive species
- Predicting human health incidents, like allergies and disease
- Optimizing planting, fertilizing, and harvesting crops
- Knowledge of timing of ecosystem processes, like carbon cycling
- Assessing the susceptibility of species, populations, and communities to climate change (USA National Phenology Network, n.d)

Figure 11. A Northern Leopard Frog (*Rana pipiens*) on the left, and an American Toad (*Bufo americanus*) on the right, two of the most affected amphibian species (Pictures by Vanessa Smith, 2022).



3.5.1 Changing emergence time of Ontario's amphibian species

Amphibians are known to have specific reproductive needs and a **biphasic** life history and are easily affected by environmental changes. Not all temperate amphibian species react the same to environmental and climatic conditions, and even individuals of the same species can respond differently across their home range. A study examining calling phenology and spring emergence timing of eight frog species in southern Ontario found that only northern leopard frogs emerged significantly earlier with warmer local temperatures over four decades. Both Northern Leopard Frogs and American Toads began calling significantly earlier in the season as temperatures warmed (Klaus & Loughheed, 2013) (Fig 11). Changes in reproductive behaviours and emergence timing due to climate change will likely become directly related to population declines and changes in range of Ontario's native frog species. Thus, decreases in biodiversity can be expected.



You can download eBird, Merlin, or iNaturalist free through your app store and become a citizen scientist today! Citizen science provides data that is more accessible, affordable, and less time-consuming for researchers to use.

3.5.2 Changes to migration patterns and phenology of bird species

Warmer spring temperatures in Ontario and across their migratory range signal to birds that it's time to breed and/or migrate. However, warm spring temperatures may be detrimental to the survival of hatchlings and migrants. When hatchlings emerge prematurely in the season there are often not enough resources available to feed them. Premature hatchlings are also vulnerable to cold temperatures that can still fluctuate so early in the season. A study modelled migration patterns for the Eastern Bluebird in Ontario using 10 years' worth of citizen science data from eBird (Fig 12). They found that unlike many species that are experiencing northward shifts in their range due to climate change, the population hotspots of Eastern Bluebirds during their breeding season have been moving southward. Additionally, there were dramatic longitudinal shifts of population hotspots towards the continent's center during the migration period (Sonnleitner et al., 2022).

Tree Swallows (Fig 13), which have a similar ecology to Eastern Bluebirds, have also experienced a shift in the timing of their egg-laying dates. Aerial insectivores like these species have seen population declines up to 70% across North America, with tree swallow populations declining by around 50% from 1966-2014 (Guidotti et al., 2020).

Figure 12. The Eastern Bluebird (*Sialia sialis*) (left) and one of their tree cavity nests. (Hillermann Nursery & Florist, 2021). <https://www.hillermann.com/blog/2021/1/19bird-of-the-week-11921-eastern-bluebird>
Nest photo taken by Abbey Lewis in June 2022 near Sultan ON



Figure 13. Tree Swallows (*Tachycineta bicolor*) are a species of aerial insectivore experiencing severe population declines in Ontario. Photo taken by Abbey Lewis in June 2022 at Wakami Lake Provincial Park, ON.



DISCUSSION QUESTIONS:

1. How is phenology affected by climate change?
2. How could changes in phenology lead to decreases in biodiversity?
3. List three examples of phenology and three of Ontario's affected species.
4. How might phenological changes have societal, cultural, and economic impacts.



WHAT IS THE DIFFERENCE BETWEEN SOIL AND DIRT?

Soil is alive! It is its own living ecosystem with living organisms, nutrients and minerals. Dirt is "dead" meaning that it has no nutrients, minerals or living organisms found within it. Soil organisms are essential for most of the ecosystem services provided by soils from the provision of healthy food and the improvement of agricultural production to water filtration, carbon sequestration, the degradation of target contaminants, and the supply of medicine. Soil organisms include microorganisms, microfauna, mesofauna, macrofauna and megafauna. In addition, a variety of symbiotic relationships occur between soil microorganisms and algae, fungi, mosses, lichens, plant roots, and invertebrates.

3.6 Agricultural and soil impacts

Agriculture is the art and science of cultivating the soil, growing crops, and raising livestock that provides most of the world its foods and fabrics. It is highly dependent on climatic conditions and seasonal temperatures have a strong influence on the **growing season** in Canada. Southern Ontario, the hub of agriculture in the province, is expected to experience more hot summer days (above 30°C) and **frost-free winter days** over the next 50 years. High persistent temperatures increase the risk of drought which can severely impact food production and increase the risk of wildfires. High temperatures can also lead to more thunderstorms which means the increased risk of flash flooding, lightning, hail, and tornados (Climate Atlas, n.d).

Temperature does not just affect crops but also livestock. Hot temperatures put stress on the animals, and reduce weight gain and milk production in cattle. Heat can even be deadly: in 2002, heat waves in Quebec killed half a million poultry, despite the use of modern shelter and ventilation systems (Government of Canada, 2008). From 2010-2012, hundreds of dairy cattle died in Ontario because of extreme heat (Bishop-Williams et al, 2015).

How is the agriculture sector combating these issues? One adaptation strategy is **regenerative agriculture**, which is used to enhance crop production and soil ecosystem health. It integrates diversity into cropping, which fosters greater resilience to climate change. Regenerative farming is made up of five core principles (Smith, 2023) (Fig 14):

- 1 Minimize soil disturbance: adopt no till or reduced till techniques
- 2 Maximize crop diversity: expand crops in rotation and adopt **intercropping**
- 3 Keep the soil covered: The impact of rain drops or burning rays of sun or frost can all harm the soil.
- 4 Maintain living root year-round: Plant cover crops between cash crops to prevent soil erosion and increase carbon inputs
- 5 Integrate livestock: crop residues and cover crop grazing, manure, compost inputs

Figure 14. Principles of regenerative agriculture
<https://www.grainmillers.com/our-company/regenerative-agriculture/>



DISCUSSION QUESTIONS:

1. How does crop rotation and intercropping improve soil quality?
2. How might cover crops be beneficial for surrounding ecosystems?
3. How can we help mitigate the impacts of extreme heat on livestock?
4. How can regenerative agriculture prevent decreases in water quality due to agricultural run-off?

3.7 Extreme weather

Extreme weather events are weather phenomena that are unusually severe or have a significant impact on the environment or community (Herring, 2020). In Ontario, such events have been shown to have a detrimental effect on biotic integrity in both aquatic and terrestrial ecosystems. Over the past century, Southern and Central Ontario have experienced a significant increase in **meteorological extremes** including snowstorms, rainstorms, and heat waves. This increase is attributed to climate change, which not only causes a rise in temperature but also alters atmospheric circulation leading to changes in hydrological patterns. This is predicted to result in increased cloudiness, extreme precipitation, and flooding.

It is forecasted that these extreme precipitation events will occur infrequently which increases the risk of drought. When climate change shifts average temperatures and weather conditions to a new level, events that go beyond these altered conditions will have serious impacts for Ontario's species that are not adapted to handle these extremes. In recent years, Ontario has faced several extreme weather events. This includes severe floods in Thunder Bay in 2012 and Toronto in 2005 and 2013, an F2 tornado that tore through south-central Ontario in 2022, widespread freezing rain events across the province, and summer heat waves that top 40°C in the GTA. Ontario experiences the most meteorological disasters of any province. 42% of these events are floods, 14% are winter storms and wildfires, 13% are tornados, 12% are thunderstorms, 3% are droughts, and 1% are heatwaves and hurricanes (Shah, 2022).

3.7.1 Forest fires

Heat waves are defined as a significant increase in temperature over a certain duration or frequency at regional and global scales (Blagrove et al., 2022). In recent years, the province of Ontario has experienced a marked increase in temperatures, with the heat waves of 2022 breaking previous records. Over the past 58 years, the average temperature in Ontario has increased by 1.2°C (Thompson et al., 2012). The combination of rising temperatures and infrequent precipitation has led to a steady increase in wildfires across Canada.

Although wildfires are a natural occurrence in Ontario, climate change has intensified their frequency and severity (Climate Atlas Canada, n.d). Weather conditions such as temperature, moisture, precipitation, and wind all contribute to the likelihood of intense fire conditions (Wang, et al., 2014). The lack of moisture in the air makes vegetation more vulnerable to drying out and catching fire, particularly in the presence of a heat source like lightning or human activity. As temperatures rise, so does the frequency of thunderstorms, estimated to further increase the probability of wildfires caused by lightning strike (Climate Atlas Canada, n.d.). Other factors such as Spruce Budworm outbreaks also contribute to greater fire risk. Although naturally occurring wildfires can have ecological benefits such as promoting successional species or aiding seed release in certain trees, frequent and intense wildfires can damage forest ecosystems.

Ontario's boreal forest is an area most at risk for forest fires (Fig 15). Climate change in this region is creating drier fuels, larger fires, and more crown fires that are difficult to suppress. These larger crown fires are going to be more difficult for current forest managers to tackle, which will also exacerbate the spread and damage they cause (Wotton et al., 2017). Large and intense wildfires in the boreal forest will decrease species richness of conifers and other boreal-obligate species that are affected. It will be more difficult for boreal forests to bounce back from these fires as climate change also establishes less favourable growing conditions for coniferous trees.

Figure 15. Under climate change, wildfires in Ontario's boreal forest are expected to increase in frequency and severity. Photo taken by Abbey Lewis in June 2022 near Shining Tree, ON.



3.7.2 Precipitation and Evaporation

Precipitation is a crucial component of the hydrological cycle and includes various forms such as rain, drizzle, snow, ice rain, and hail. In Canada, the impact of climate change on precipitation is expected to manifest in the form of more frequent and prolonged droughts and flooding events (Government of Canada, 2019). The warming of the atmosphere caused by climate change leads to an increase in atmospheric moisture, resulting in more intense precipitation events and thus intense flooding events. Furthermore, a warming climate will lead to precipitation falling more as rain than snow, which has detrimental effects on snowmelt and the supply of cold water to creeks, streams, rivers, and lakes. Heavy precipitation also poses a risk to water quality by increasing solute runoff from soil, triggering landslides, and causing flooding (Center for Climate and Energy Solutions, n.d).

The temporal and volume changes in flooding, resulting from altered snowmelt and evaporation rates, may have a significant impact on the biodiversity of lakes and wetlands. If spring snowmelt occurs while the ground remains frozen, water flows directly into lakes instead of being absorbed by soils in wetlands. However, increased evaporation and less snowmelt may also result in a drier season. Fluctuations in water levels can negatively affect the growth of vegetation. This in turn negatively impacts the wildlife that relies on that vegetation for food, migration, and to nurture offspring (Fig 16). For instance, if ducks do not have an optimal habitat featuring 50% open water and 50% vegetation cover, they are forced to nest in areas where they're more prone to predation (Fig 17). For mammalian species, such as muskrats, a shortage of specific vegetation resulting from lower water levels forces them to abandon their habitats. Wetlands are essential to fish species, as they serve as both feeding grounds and spawning sites. In cases where winter water levels are

low, the movement of ice may uproot aquatic vegetation, and lower oxygen levels may enhance the vulnerability of fish, which may become entrapped under ice in shallow waters (Mortsch, 1998).

Figure 16. Waterfowl like these ducks require wetland habitat with 50% open water and 50% vegetation cover. Photo taken by Abbey Lewis in November 2021 at the Burlington RBG, ON.



Figure 17. Changes to hydrology, including ice cover and snowmelt in winter, can affect habitat suitability for waterfowl like these Mallards. Photo taken by Abbey Lewis in December 2021 at the Burlington RBG, ON



Waterfowl species found in the boreal forests of Canada during spring have seen significant population declines. This decline has been attributed to the melting of permafrost, de-watering of small wetlands, and changes in **surface hydrology**, which are all linked to rising temperatures. In the Great Lakes-St. Lawrence region, waterfowl such as Black Ducks, Greater Scaup, and Canvasbacks have declined in population due to similar hydrological changes alongside habitat loss and reduced water quality. These findings suggest that the warming climate is having a profound impact on waterfowl populations in Ontario and underscores the need for conservation efforts to mitigate these effects (Browne et al., 2010).

DISCUSSION QUESTIONS

1. How are naturally occurring wildfires beneficial for ecosystems? Why are frequent and intense wildfires harmful for ecosystems?
2. What factors are increasing the likelihood of wildfires?
3. How are intense precipitation events harmful for ecosystems?
4. Why is more precipitation as rain than snow harmful for ecosystems?
5. How does a decrease in precipitation events affect ecosystems?
6. How might extreme weather events have social, cultural, and economic impacts?
7. How could we mitigate the negative effects of extreme weather events?

3.8 Ice cover loss

The loss of ice cover in Ontario's lakes is significantly impacting biodiversity and ecosystem health. Ice cover plays a crucial role in facilitating the natural seasonal cycles of lakes by allowing them to turn over and mix oxygen and nutrients throughout the water body. The seasonal cycle consists of four phases: summer stratification, fall turnover, winter stratification, and spring turnover. These cycles depend on atmospheric temperature and wind to mix the lake. Therefore, the loss of ice cover disrupts these natural processes and can have far-reaching consequences for the health and biodiversity of the lakes.

During summer months, warmer temperatures cause water to become denser, preventing wind from easily mixing the water. This leads to the stratification of oxygen and nutrients within the lake. The **epilimnion layer** at the top of the lake becomes rich in dissolved oxygen, while the hypolimnion layer at the bottom becomes a storage for nutrients. The stratification continues until the fall, when the cooling temperatures allow for wind to mix the water, distributing both oxygen and nutrients throughout the lake, supporting biodiversity within the lake.

This cycle is essential to the aquatic biota living within it, especially for Northern Ontario and its cold-water species. Winter stratification influences the spatiotemporal redistribution of sulfates and alters the dissolved oxygen concentrations at different depths. Ice cover influences temperature, light, and nutrient regimes. The amount of ice cover ensures that temperatures remain cool, lake bottoms remain oxygenated, and nutrients are available to the epilimnion layer of the lake for the following summer season. With ice cover percentage decreasing, temperatures warming, and ice thickness decreasing on lakes in Ontario are not able to support biodiversity as they once did (Woolway, 2021).

There has been a decline in ice cover across the Great Lakes (NOAA, 2023) (Fig 17). Lake Erie's ice cover was 78% from 1991-2000, and 70.3% from 2010-2020 (Ontario Biodiversity, 2021). However, it's important to note that the Great Lakes are large and diverse. Certain parts may have higher ice coverage than others based off geographic location. Long-term data from the Experimental Lakes Area (ELA) in Northern Ontario can be used to model and predict how northern lakes will respond to situations like climate change. A 2021 study modelled ice cover of boreal lakes under climate change and predicted an average four days less of ice cover per decade (Higgins, 2021). The period of ice cover is also decreasing for Central Ontario lakes. Lake Opeongo in Algonquin Provincial Park is becoming ice-free far sooner each year (Friends of Algonquin Park, 2022). In 1964, the ice-free date was April 30th (Friends of Algonquin Park, 2022). However, in 2022 the ice-free date for Lake Opeongo was April 10th and the lowest recorded ice-off date was March 29th in 2012. Cisco, a species

of fish found in the Laurentian Great Lakes, has experienced greater embryo mortality as a result of ice cover reduction. Cisco spawn in the fall and lay their embryos under the ice during the winter, so the length of ice cover is crucial for determining the timing of its spawning and offspring development. A thicker layer of ice provides better conditions for the developing embryos by reducing the amount of light shining through the ice. Longer light exposure significantly increases the mortality rate for embryos (Stewart et al., 2021).

Many species within the freshwater lakes of Ontario rely on this seasonal process, cold temperatures, and ice cover to survive. As mentioned, ice cover affects the distribution of solutes which affects turbidity (Woolway, 2021). Turbidity increases with less ice cover because the mixing period is not as long. Therefore, solvents do not have a lot of time to be reabsorbed into the soil. When Lake Erie had an ice-free year in 2012, there was a sharp decline in phytoplankton and algae. This was due to the increase in turbidity affecting the amount of light availability in the water and therefore, reducing phytoplankton photosynthesis (Beall et al, 2015). A change this significant at a foundational trophic level has cascading effects on its ecosystem.

DISCUSSION

1. How is ice cover shortening the hypolimnion layer?
2. How would complete ice cover loss affect the water quality, soil quality and biodiversity of aquatic ecosystems?
3. What fish species in the north are being most affected by ice cover loss?
4. In your opinion, what region of the great lakes is most affected by ice cover loss?



4.0 Policies, Laws, and Regulations

There are many policies, laws and regulations surrounding biodiversity conservation throughout Ontario and Canada, and these laws hold high importance as they provide a set of rules which prioritize or require environmental protection. Even with these laws, it can be challenging to prevent species from becoming extirpated, endangered or extinct. The conditions which lead to a species becoming at risk for extinction vary. However, these conditions are usually always related to human activities such as overharvesting, habitat destruction, pollution, climate change, and introduction of invasive species and diseases. To ensure human activity is not having a detrimental impact on biodiversity in Ontario and Canada, a series of provincial and federal acts were established to manage and protect our most vulnerable species.

4.1 Provincial

ENDANGERED SPECIES ACT (ESA)

Ontario is home to over 30,000 known species, with about 250 species considered provincially at-risk. Roughly 40% of **species at risk** (SAR) in Canada are found in Ontario, and most of these are found on private land in Ontario's southern regions. To protect SAR from extinction, the **Endangered Species Act** (ESA) was adopted in 2007. The ESA actively addresses issues related to species who have been officially listed as at-risk (Ontario, 2023).

The purpose of the Endangered Species Act is broken into three parts:

- ① Science-based assessment: species are assessed by an independent body based on the best available science and **Traditional Ecological Knowledge (TEK)**
- ② Automatic species protection: species classified as endangered or threatened automatically receive legal protection. When a species is classified, its habitat is also protected to promote the recovery of SAR
- ③ Promote stewardship activities: stewardship activities that aid in the protection and recovery of SAR are taken on. For example, building birdhouses for tree swallows

How does a species gain protection from the Endangered Species Act? The Committee on the Status of Species at Risk in Ontario (COSSARO) assesses and classifies each species. This committee works independently and is composed of 12 members total, including ecologists, scientific professionals, and Traditional Ecological Knowledge holders. Classification becomes law once the Species at Risk in Ontario (SARO) list is amended.



FUN FACT More than 200 species of plants and animals are at risk of disappearing from Ontario.

FISH AND WILDLIFE CONSERVATION ACT (FWCA)

The Fish and Wildlife Conservation Act (FWCA) was adopted in 1997 to regulate the harvesting of fish and wildlife within Ontario. The act focuses on hunting regulations and the protection and conservation of wild game. The FWCA is broken up into 12 parts. Part 2 features general restrictions in place to protect species and their locations. The restrictions in part 2 include:

- 1 Prohibitions on hunting and trapping certain species. Example: "specially protected species"
- 2 Requirement for hunting or trapping licences. Example: "wild game"
- 3 Hunting safety. Example: regarding attire, firearm regulations, hours allowed to hunt
- 4 Protection of property. Example: if wildlife is damaging or about to damage property, you may harass, capture, or kill

Part 3 focuses on wildlife in captivity. For example, you cannot possess wildlife or keep wildlife in captivity without appropriate licenses. Such regulations apply mainly to wildlife rehabilitation centres or animal caregivers.

Part 4 focuses on the purchase, sale and transportation of fish and wildlife. For example, it is illegal to sell or distribute certain species of wild game, including their bones, hides, and pelts, unless covered under the appropriate licenses.

In conclusion, each part of the FWCA has an important and specific focus. If you're an avid hunter or angler in the province of Ontario, this act and the associate hunting regulations summary (<https://www.ontario.ca/document/ontario-hunting-regulations-summary>) and fishing regulations summary (<https://www.ontario.ca/document/ontario-fishing-regulations-summary>) is the place you'll want to go to ensure you're complying with the required laws and regulations.

Figure 18. White-Tailed Deer is a commonly hunted species in Ontario (iNaturalist, pjacyk, 2023, <https://www.inaturalist.org/observations/151703274>)



INVASIVE SPECIES ACT (ISA)

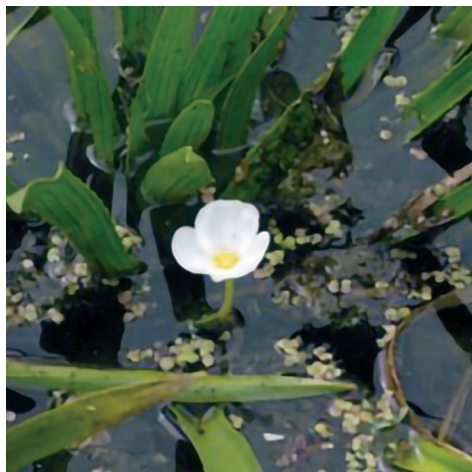
The Invasive Species Act (ISA), adopted fully in 2015, is the newest piece of environmental legislation in Ontario. The purpose of the ISA is to enable a legislative framework that better prevents, detects, responds to, and, where feasible, eradicates invasive species. Prior to this legislation there were no laws or regulations that prevented the movement, possession, or sale of invasive species in Ontario (excluding some fish and plants).

There are two classes of invasive species listed under this act:

- ① Prohibited: no person shall bring into Ontario, possess, transport, propagate, buy, sell, lease or trade an invasive species
- ② Restricted: no person shall bring an invasive species into Provincial Parks and Conservation Reserves

Regarding these classes, there are lists in section O. Reg. 354/16 of the act that state which species belong to which class, as well as the fines associated with possessing prohibited species in Ontario.

Figure 19. Water Soldier is an invasive aquatic plant species listed as prohibited under the Invasive Species Act. (iNaturalist, konstantin_m, 2011, <https://www.inaturalist.org/observations/147476457>)



CROWN FOREST SUSTAINABILITY ACT (CFSA)

The *Crown Forest Sustainability Act* (CFSA) requires forest management plans in Ontario to be prepared in accordance with the Forest Management Planning Manual (FMPM) and other manuals. Planning teams include staff of the Ministry of Natural Resources and Forestry (MNRF) and representatives from multiple disciplines and expertise. The FMPM requires that planning teams implement the direction set out in forest management guides when developing forest management plans to be considered for approval by the MNRF.

The CFSA identifies two key principles for the determination of sustainability of **Crown** forests:

- 1 Large, healthy, diverse and productive Crown forests and their associated ecological processes and biological diversity should be conserved.
- 2 The long-term health and vigour of Crown forests should be provided for by using forest practices that, within the limits of silvicultural requirements, emulate natural disturbances and landscape patterns while minimizing adverse effects on plant life, animal life, water, soil, air and social and economic values, including recreational values and heritage values.

Ontario's forest management guides related to the conservation of biodiversity provides direction consistent with the CFSA principles, including direction for forest management plans to maintain or enhance natural landscape structure, composition and patterns that provide for the long-term health of forest ecosystems in an efficient and effective manner. At larger scales, forest managers are required to manage different forest types and ages to move toward or maintain an amount and arrangement representative of a natural range of forest conditions. An estimate of the natural range of forest conditions are based on the knowledge of regional natural disturbance regimes, historical information, and forest dynamics. At smaller scales, forest operations are required to be modified to retain special features and sensitive habitat (e.g., fallen logs, bird nests, woodland pools) and conserve water and soil resources. Forest managers apply these guides to conserve and protect habitat for all life forms (wildlife, birds, fish, plants).

4.2 Federal

SPECIES AT RISK ACT (SARA)

One of the federal acts put in place is the Species at Risk Act (SARA). It was adopted in 2002. The purpose of SARA is to prevent wild species in Canada from disappearing and to facilitate the recovery of wild species that are extirpated, endangered, or threatened. SARA also aims to manage species of special concern to prevent them from becoming endangered or threatened. SARA applies to federal lands and to all areas where birds that are protected under the Migratory Bird Convention Act exist. They can also put stop orders on non-federal lands if they believe that there an unmitigated threat to a federally listed species. They also form agreements with provinces and territories to collaborate on the conservation of species at risk. (Government of Canada, n.d.).

Like the ESA in Ontario, there is an arms-length body of experts that assesses and identifies species at risk. This is COSEWIC, the Committee on the Status of Endangered Wildlife in Canada.



DID YOU KNOW? All of Ontario's 8 turtles are listed as a species at risk! This includes the Blanding's, Eastern Musk, Spiny Softshell, Northern Map, Midland Painted, Snapping, Spotted and Wood turtle (Ontario Turtle Conservation Center, 2023).

Figure 20. (Blanding's Turtle, photographed by Phil Careless, 2022)



CANADIAN ENVIRONMENTAL PROTECTION ACT (CEPA)

Another important federal act is the Canadian Environmental Protection Act (CEPA). CEPA was adopted in 1999 and its purpose is to contribute to sustainable development by preventing pollution. The CEPA provides a legislative basis for a range of federal environmental and health protection programs, which include activities related to:

- The assessment and management of risk from chemicals, polymers, and living organisms
- Programs related to air and water pollution, hazardous waste, air pollutant and greenhouse gas emissions
- Ocean disposal
- Environmental emergencies

DISCUSSION QUESTIONS

1. How does each Act above contribute to biodiversity conservation?
2. Why is it important for committees such as COSSARO to include members with different expertise, backgrounds, and / or motivations?
3. What is the difference between the Endangered Species Act and Species at Risk Act?
4. List and define the four classifications for a species at risk. Which are most concerning?



5.0 Management Solutions

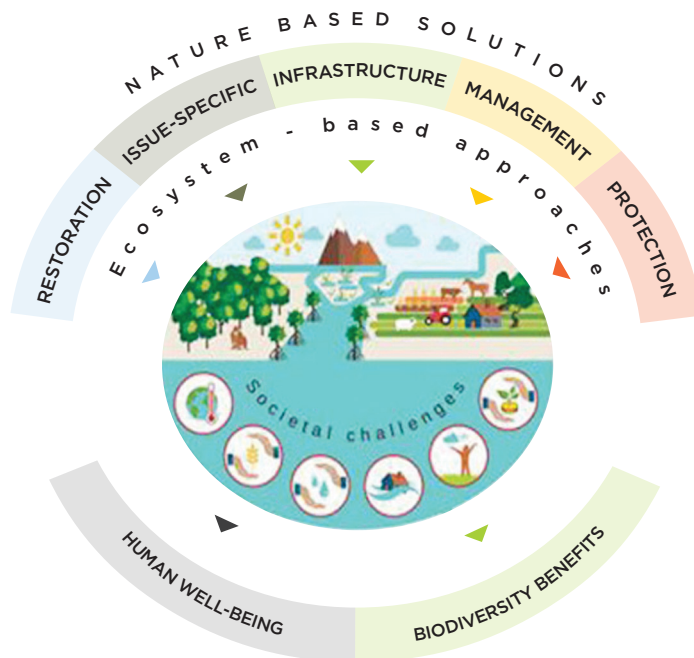
5.1 Nature-based Solutions

Climate change is a global issue that, accelerated by anthropogenic activities, is causing increased loss of biodiversity. Losing biodiversity endangers all life on Earth. As climate change escalates, innovative solutions are required to effectively manage biodiversity loss. **Nature-based solutions** (NBS) have emerged as a promising approach for the sustainable management, protection, and restoration of biodiversity and ecosystem services. NBS offer an integrated approach that addresses environmental, social, cultural, and economic challenges. There is evidence that supports the effectiveness of NBS as a means of promoting ecological sustainability, while offering direct and indirect social and economic benefits.

The **International Union for Conservation of Nature (IUCN)** describes the three main ways NBS address climate change:

- ① Decrease greenhouse gas emissions related to deforestation and land use
- ② Capture and store carbon dioxide from the atmosphere
- ③ Enhance resilience of ecosystems, and as such support societies to adapt to climate hazards such as flooding, sea-level rise, and more frequent and intense droughts, floods, heatwaves, and wildfires (IUCN, n.d.)

Figure 21. Conceptual framework of Nature-based Solutions. Source: IUCN, 2019 <https://www.iucn.org/news/ecosystem-management/201901/informing-global-standard-nature-based-solutions>



For more information on this topic, please see 2021's [Current Issue Guide on Nature-Based Solutions to Climate Change](https://forestontario.ca/en/resource/2021-nature-based-solutions-to-climate-change) (<https://forestontario.ca/en/resource/2021-nature-based-solutions-to-climate-change>).

The difference between Conservation and Nature-based Solutions

Although the principles of conservation and NBS are similar in their focus on resource management, it is important to distinguish between the two approaches when addressing biodiversity loss in the context of a changing climate.

Conservation entails protecting plant and animal species, habitats, and ecosystems through the establishment of policies, laws, and regulations, and the allocation of land for the preservation of significant species and their habitats, such as provincial parks, national parks, and conservation areas.

On the other hand, NBS encompasses a wide range of strategies for managing natural resources, with the belief that healthy, well-managed ecosystems can be self-sustaining while addressing many of the societal challenges faced today (World Wildlife Fund, 2020). This may include the development of green infrastructure, the construction of wetlands, or the adoption of regenerative agricultural practices. The adoption of a NBS approach promotes ecological sustainability while addressing important social, economic, and cultural concerns.

CASE STUDY: Expansion of the Carden Alvar Conservation Area

In April 2022, there was an expansion of the Carden Alvar Conservation Area through collaboration between the Couchiching Conservancy and the Nature Conservancy of Canada (NCC).

The Carden Alvar is located on the Cedarhurst Alvar property, just 35 kilometers northeast of Orillia, ON. This alvar contains significant natural habitat for the province. Alvar ecosystems are characterized by naturally open habitats with shallow mineral soils, located on limestone and dolostone bedrock. This rare ecosystem provides **critical habitat** for many specialist species that are recognized by Canada under the Species at Risk Act including Grasshopper Sparrow (special concern), Bobolink (threatened), and Eastern Meadowlark (threatened). 75% of alvars in North America are in Ontario, highlighting the importance of protecting this unique Ontarian landscape in the face of climate change.

The purchase of this land acts as a NBS working towards protecting biodiversity while simultaneously providing Ontarians with significant social and economic benefits. The Carden Alvar provides over \$10 million in ecosystem goods and services. This private property also features many other diverse habitats including forests, wetlands, and grasslands that store carbon and act as a buffer for severe weather events. Additionally, they are essential for flood water storage and removal of air pollution.

The foundations for the management of this land are based on the concept that allowing natural processes to occur throughout the ecosystem will promote sustainability on a local and global scale and will help mitigate the negative impacts of climate change. In the case of the expansion of the Carden Alvar, the purchase of this land is a nature-based solution. It helps protect the alvar from anthropogenic activities that are accelerating climate change and may be detrimental to the ecosystem's ability to provide valuable goods and services (Couchiching Conservancy, 2021).

DISCUSSION QUESTIONS:

1. Describe the relationship between nature-based solutions and biodiversity.
2. What are ecosystem services and what are the social and economic benefits?
3. How might restoring a wetland provide environmental, social, cultural, and economic benefits?
4. Urban tree canopies can help reduce stormwater runoff and the "urban heat-island effect", where urban areas have significantly higher temperatures. Why might the following stakeholders benefit from urban tree canopies: city residents, environmental groups, city government and local businesses?

5.2 Traditional ecological Knowledge (TEK)

As a result of the deep connection Indigenous peoples have with their culture and the land, they were among the first individuals to notice and directly feel the negative effects of climate change. Partnerships between Indigenous Elders and Knowledge Keepers and western knowledge is essential for pursuing climate action to protect and restore biodiversity and for developing holistic management strategies to mitigate climate change (Climate Atlas of Canada, n.d.).

TEK, also known as **Indigenous Knowledge (IK)**, refers to the accumulation of knowledges, practices, and beliefs regarding the relationships between living things and ecosystems. TEK is acquired through direct contact with the land and is passed down from generation to generation and is a valuable resource that can inform sustainable development strategies and should be preserved. Relationships between people, plants, animals, and landscapes are directly linked to hunting, fishing, gathering, and agricultural practices, where together, they create the foundation for how Indigenous people care for the land (Charles & Cajete, 2020). TEK plays an integral role in protecting biodiversity and is a worldview that provides important insight and perspectives on climate change adaptation.

5.2.1. TEK and Biodiversity

Indigenous peoples are recognized as leaders for global biodiversity conservation. Through their understanding of the complex relationships between species and ecosystem structure, function, and composition, TEK has been foundational for the preservation of biodiversity across their landscapes for many centuries. Additionally, Indigenous peoples have a strong understanding and respect for the direct and indirect benefits of biodiversity including medicinal uses, knowledge of habitat preference, life history, and behaviour (Mekonen, 2017).

5.2.2. TEK and Western Science

Traditionally, western science is built upon theoretical models, hypothesis testing, and scientific methods, while TEK is driven by intimate relationships to the land through cultural practices and knowledge sharing. TEK is complementary and equivalent to western science and the importance of it is gaining recognition globally. Looking toward the future of protecting the earth's biodiversity, hybrid management of natural resources between scientists, policy makers and Indigenous knowledge holders is proving to be the most sustainable, integrated approach to mitigating the negative effects of climate change (Mekonen, 2017).

CASE STUDY – Ecological Restoration of Grasslands at the Alderville Black Oak Savanna

Alderville Black Oak Savanna. (2019). From: *The Importance of Grasslands*.
<http://aldervillesavanna.ca/index.php/mandate/>

Alderville is home to the Mississauga Anishinabeg of the Ojibway Nation and is along the Rice Lake Plains in Ontario. When the Ojibway first arrived to the Rice Lake Plains around the 1700s, they found Iroquoian peoples of the Haudenosaunee settled in agricultural villages. Here the Iroquoian peoples burned the land to grow crops, which led the Ojibway to call the area Pemdashkotayang, Lake of the Burning Plains. The Ojibway peoples permanently settle in the Rice Lake Plains in 1835 just south of Rice Lake, to what is now known as Alderville First Nation. In the late 1850s, as European settlement and agricultural development increased around Rice Lake, burning of the land slowed down. This resulted in the eradication of the natural ecosystems.

Rick Beaver, a local Indigenous elder, biologist, and artist, was able to stop development of this land during the 1990s following the identification of specialist species growing across the landscape. The plants found were known to inhabit two endangered grassland ecosystems: Tallgrass Prairie and Black Oak Savanna. Following this discovery, the land was protected from development and since this time, has been under active management and restoration into a thriving grassland ecosystem that is rich in biodiversity, providing critical habitat for many plant and animal species. This area is now known as the Alderville Black Oak Savanna.

Grassland ecosystems are among the most endangered ecosystems across Canada making up less than 3% of the landscape and continuing to decline globally in the face of climate change. The Alderville Black Oak Savanna is currently the largest intact tract of native grassland habitat in the Rice Lake Plains and eastern Ontario. It supports these globally rare ecosystems through ecological restoration, education, outreach, and research. Many of the restoration efforts at the Alderville Black Oak Savanna revolve around **prescribed burns**, which are a form of land management that deliberately uses fire to reduce the encroachment of **undesirable species** while promoting the growth and establishment of native species that are dependent on fire for growth and reproduction. Prescribed burns, a modern term, were a common practice among Indigenous communities prior to European settlement and were used for the stewardship of forest and **rangeland** ecosystems (Indigenous Corporate Training Inc., 2019).

TEK is foundational for all the processes involved with prescribed burns, as it can help determine the best time and locations to conduct the prescribed burns (Indigenous Corporate Training Inc., 2019). In the case of the Alderville Black Oak Savanna, this tool is used across the landscape as a continuation of the traditional practices of the Michi Saagiig and has shown to be an extremely effective approach to restoring and maintaining the integrity of the Tallgrass Prairie and Black Oak Savanna ecosystems within the Rice Lake Plains.

Figure 22. Prescribed burn at the Alderville Black Oak Savanna (Alderville Black Oak Savannah, 2019)



DISCUSSION QUESTIONS:

1. Why is TEK important for restoring grassland ecosystems?
2. Why is the relationship between IK and western knowledge important for ecological restoration?
3. How do prescribed burns enhance biodiversity?
4. What other nature-based solutions can you think of that are directly related to TEK?

5.3 Resource Extraction

5.3.1 Fisheries

Before the rise of large commercial fisheries in the Great Lakes region, Indigenous communities had been managing marine and freshwater ecosystems for thousands of years using traditional knowledge and practices (Castañeda et al, 2020). For these communities, fishing was not only a means of sustenance, but also a cultural practice and an important economic activity. The Mi'kmaw concept of netukulimk, for example, reflects a holistic approach to fishing that emphasizes the nutritional and economic well-being of the community while also ensuring the ecological integrity, diversity, and productivity of the ecosystem for future generations (Castañeda et al, 2020).

Indigenous fishing practices involved a variety of fishing gear and techniques, including nets, hooks, longlines, spears, harpoons, traps, and weirs. Some of these methods were highly specialized and used only in specific ecological contexts, such as traps made from cedar and willow that were used to capture salmon during tidal flows (Castañeda et al, 2020). These practices were deeply rooted in Indigenous cultures, and the knowledge and techniques were often passed down from generation to generation.

Fisheries remain an important resource in Ontario, contributing to Canada's economy. As of 2019, Canada contributed \$6.9 billion in fish and seafood products to the global economy (Ontario, 2010). Ontario's western fishing practices date back to the 1700s, with settlers finding brooks, streams, rivers, and lakes abundant with fish. However, commercial fishing began to have an impact on the Great Lakes in 1850 as settlers moved into the southern regions of Ontario. The DFO is developing a sustainability plan for the fisheries sector within Canada (Government of Canada, 2019). This sustainability plan has five steps:

- 1 Planning
- 2 Making science-based decisions
- 3 Managing environmental impacts
- 4 Enforcing the rules
- 5 Monitoring results

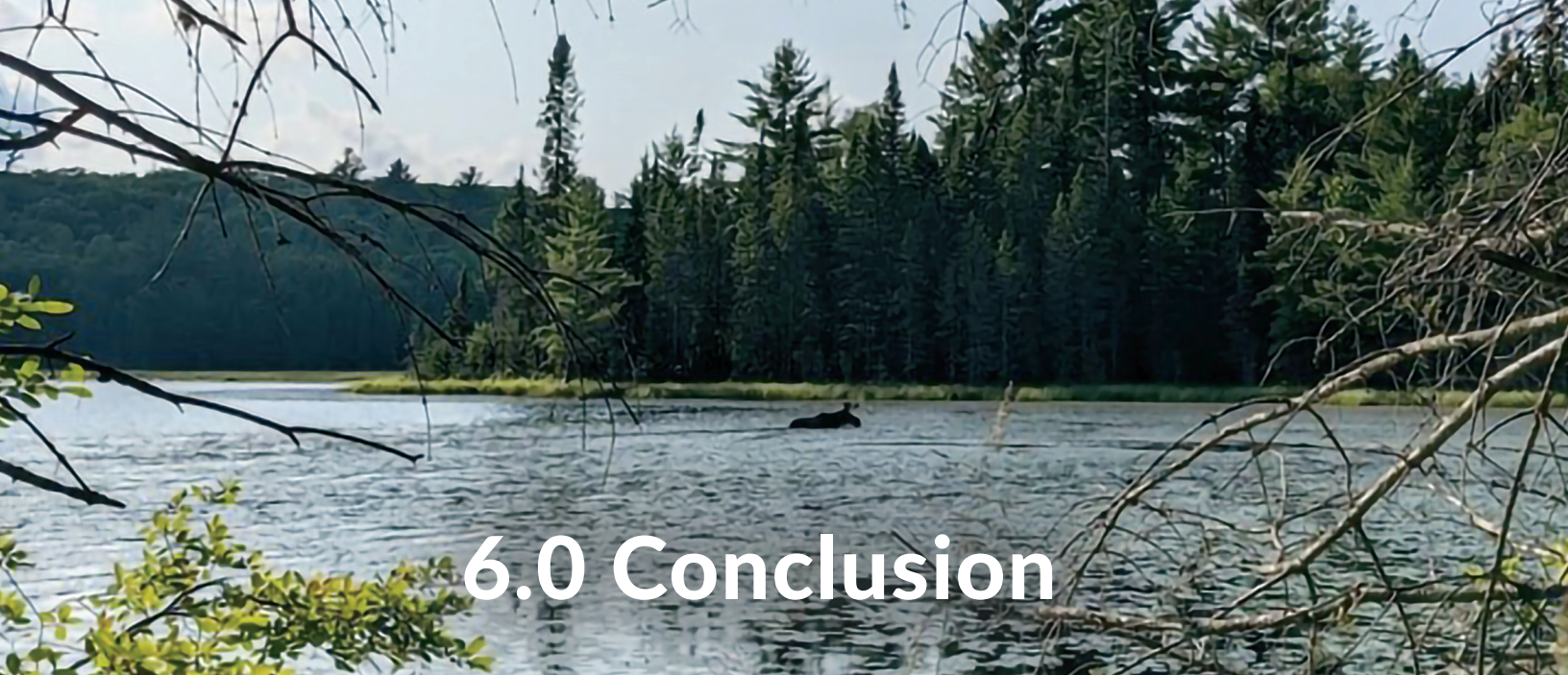
5.3.2 Forest management

The practice of forest harvesting in Canada dates back more than two centuries, but it was not until 1825 that large-scale **logging** became common across the country (Wynn, 2015). The Ontario Ministry of Natural Resources and Forestry (MNRF) has implemented sustainable forestry practices to maintain healthy and productive forests, promote strong forestry industries, preserve biodiversity for wildlife and watersheds, and support Ontario communities and recreational opportunities (Ontario, 2022). To manage Crown forests, the MNRF has developed a comprehensive framework that includes legislation, regulations, policies, and standards, which are incorporated into forest management plans (Ontario, 2022). Additionally, the MNRF has implemented a compliance program that includes forest audits and public reporting on various aspects of forest management (Ontario, 2022).

Forest management plans in Ontario can be found on the Natural Resources Information Portal: https://nrip.mnr.gov.on.ca/s/fmp-online?language=en_US.

DISCUSSION QUESTIONS:

1. How is the removal of mature and dying trees beneficial for forest ecosystems?
2. How can silvicultural systems be useful for combating invasive species?



6.0 Conclusion

In conclusion, biodiversity in Ontario is essential for the survival of humans and all wild species. Biodiversity is not evenly distributed across the planet, with certain areas, known as hotspots, exhibiting greater biodiversity than others. Unfortunately, human activities have led to issues such as climate change and environmental degradation have led to the rapid decline of global biological diversity, causing accelerated rates of species extinction (Lanting., 2022). Conservation efforts and climate change mitigation are necessary to preserve endangered species and their habitats.

The increasing temperatures cause an increase in precipitation, droughts, and forest fires leading to a decrease in biodiversity. Because of the increased temperature, the air has more ability to hold moisture, allowing there to be heavier precipitation (Government of Canada, 2019). Although there is a higher percentage of precipitation, there will be extreme droughts caused by heatwaves causing cooler-temperature climates to lose a majority of their biomass.

These extremes result in range shifts of cold-water species, interbreeding, hybrids, genetic loss, pests, and invasive species, as well as ecosystem loss.

There is great hope for the protection of biodiversity throughout Ontario thanks to effective management practices such as NBS and TEK. By implementing these practices and educating the younger generations about the importance of biodiversity, we can ensure a brighter future for our ecosystems and the species that rely on them. It is essential that we continue to work towards better management practices and raise awareness about the importance of biodiversity, as it is essential to our own well-being and the health of the planet. Ontario must be committed to working together to protect and nurture the natural world that sustains us.

Appendix A: Glossary

- A** **Albedo:** The fraction of light reflected by a surface. The Earth's albedo determines how much solar energy (light) is reflected to space (NASA, n.d.).
- Anthropogenic:** Human activities such as burning fossil fuels.
- Atmosphere:** The layer of gases that surround a planet.
- B** **Biodiversity:** Biodiversity refers to the different types of all living organisms and their interactions within and between ecosystems (Smithsonian National Museum of Natural History, n.d.).
- Biphasic:** Consisting of two phases. It is used in biology to represent life cycles which alternate between larvae and adults (Rieger, 2015).
- C** **Carbon dioxide (CO₂):** The most emitted and most abundant greenhouse gas found in the earth's atmosphere. Increased CO₂ levels are the main cause of climate change (Environment and Climate Change Canada, 2019).
- Carbon sinks:** Anything that absorbs more carbon than it releases.
- Climate change:** The long-term shifts in Earth's average weather conditions that is reflected by changes in temperature, humidity, wind, cloud cover, and precipitation (Environment and Climate Change Canada, 2019).
- Conservation:** The act of protecting Earth's natural resources for current and future generations (National Geographic Society, 2022).
- Cold water species:** Sensitive species types that require a set range of lower temperatures to survive.
- Critical habitat:** Specific areas within the geographical area occupied by the species at the time of listing that contain physical or biological features essential to conservation of the species and that may require special management considerations or protection.
- Crown:** The Crown incorporates all the rights, power, claims and prerogative of the government, whether administrative, legislative, or judicial. In other words, it is an abstract concept that represents the state and its government.
- E** **Ecological integrity:** Having an intact native species population.
- Ecosystems:** Geographic area where plants, animals, and other organisms, as well as weather and landscape, work together to form a bubble of life (National Geographic, n.d.).
- Ecosystem Services:** Ecosystem services are defined as the direct and indirect contributions of ecosystems to human well-being, and have an impact on our survival and quality of life. There are four types of ecosystem services: provisioning, regulating, cultural and supporting services (Pearce, 2023).
- Ecological Land Classification (ELC):** The Ecological Land Classification (ELC) is Statistics Canada's official classification for ecological areas in Canada (Government of Canada, 2023).
- Epilimnion layer:** The epilimnion is the upper, warmer layer of water in a stratified lake or other aquatic ecosystem. Contains most of the dissolved oxygen and phytoplankton.

Endangered Species Act (ESA): A Provincial act in Ontario which protects Species-at-Risk from extinction by actively addressing issues related to species who have been officially listed at-risk (Ontario, 2023).

Extreme weather events: Extreme and unusual weather conditions that occur infrequently, such as hurricanes, tornadoes, floods, droughts, heatwaves, and blizzards.

F Fossil Fuels: A non-renewable, carbon-rich energy source that is burned to generate energy. Fossil fuels were formed by the decomposition of carbon-based organisms that died millions of years ago

Frost-free winter days: The number of days between the date of the last spring frost and the date of the first fall frost. The average length of the growing season is an important consideration when selecting or predicting what plants might grow well in a region. A longer frost-free season means plants and crops have a longer window to grow and mature.

G Greenhouse gases: Any gas that has the property of absorbing infrared radiation (net heat energy) emitted from Earth's surface and reradiating it back to Earth's surface, thus contributing to the greenhouse effect (Mann, 2023).

Growing season: The part of the year during which rainfall and temperature allow plants to grow.

H Habitat fragmentation: The breaking apart of a landscape that results in smaller, lower quality habitat patches for vegetation and wildlife (Murray et al., 2017).

Hypoxic: Oxygen deficiency in a biotic environment.

Hypolimnion layer: Bottom layer of a lake that is thermally stratified. Where nutrients and cold water species are typically located during summer stratification.

I Indigenous knowledge: The knowledge, practices, and beliefs developed over generations by Indigenous communities through their interactions with the natural environment.

Intercropping: An agricultural practice that involves growing two or more crops in proximity to each other.

Invasive species: An introduced, nonnative organism (disease, parasite, plant, or animal) that begins to spread or expand its range from the site of its original introduction and that has the potential to cause harm to the environment, the economy, or to human health (U.S. Geological Survey, n.d.).

Invasive Species Act (ISA): The purpose of the ISA is to enable a legislative framework that better prevents, detects, responds to, and, where feasible, eradicates invasive species.

International Union of Conservation of Nature (IUCN): A membership Union of government and civil society organizations who works to advance sustainable development and create a just world that values and conserves nature (IUCN, n.d.).

L Landscapes: Assemblages of different ecosystems (the physical environments and the species that inhabit them, including humans) create landscapes on Earth (Bynum., 2021)

Logging: Logging is the practice of cutting down trees and processing them into wood products such as lumber.

- M Meteorological extremes:** Weather events that occur naturally but have large impacts on wildlife and habitat. Instead of just heavy rain, flooding occurs, instead of long heat days, an entire heat wave occurs. Also including snowstorms, rainstorms, and heat waves (Shah et al, 2022).
- N Native Species:** A species that originated and developed in its surrounding habitat and has adapted to living in that environment (Lilly Center for Lakes & Streams, 2021).
- Nature-based Solutions (NBS):** Using nature to tackle various challenges, such as climate change. This is done by restoring and managing natural ecosystems to benefit both people and the environment.
- O Obligate:** Necessary; obligate species are dependent on a certain habitat or specific environmental conditions to survive and/or reproduce.
- P Peat:** A partially decomposed organic soil layer which has accumulated under conditions of waterlogging, oxygen deficiency, high acidity, and nutrient deficiency. In Ontario, peat is mainly formed from the decomposition of bryophytes, herbs, shrubs, and small trees (International Peatland Society, n.d.).
- Prescribed burns:** Intentional fires set by professionals to manage vegetation, prevent uncontrolled wildfires, and promote ecological health.
- Precipitation:** Process where water in the form of rain, snow, sleet, or hail falls from the atmosphere to the Earth's surface. This is driven by atmospheric conditions and the water cycle.
- R Radiative forcing:** The difference between incoming and outgoing radiation of a planet (NOAA, n.d.) A positive radiative forcing tends on average to warm the surface of the Earth, and negative forcing tends on average to cool the surface. The current net solar radiation has been calculated to 168 Watts per square meter on the Earth's surface.
- Rangeland:** Natural landscapes dominated by native herbaceous or shrubby vegetation. They are grazed by livestock and wild herbivores, and managed for multiple purposes such as livestock production, wildlife habitat, recreation, and conservation (Britannica, T. Editors of Encyclopaedia, 2022).
- Regenerative agriculture:** Regenerative agriculture is a conservation and rehabilitation approach to food and farming systems.
- Representative concentration pathways:** A set of four scenarios developed by the International Panel on Climate Change to describe future climate conditions under different projections of GHG emissions and land use.
- S Species at risk:** A species at risk is any native plant or animal in danger of extinction or disappearing from Ontario.
- Species Turnover:** The rate of size and change in species composition.
- Surface hydrology:** Includes the study of surface water movement and the distribution of surface water in space and time.
- T Traditional Ecological Knowledge (TEK):** Practices and beliefs of indigenous and local communities that have been developed over centuries by living in close relationship with the natural environment. The knowledge can be used for the sustainable management and conservation of natural resources.

U **Undesirable species:** A certain species that is not desirable for a specific reason within a habitat.

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