Envirothon Study Guide

Biodiversity in a Changing World

2009

This Study Guide is to be used to help Envirothon teams prepare for the Ontario Envirothon Program.

FORESTS ONTARIO

Preface

This report was written by Angela Gillespie, Denise Derrick, Jessica Danard and Tamara Tucker, in partial fulfillment of the Credit for Product II course in the third year of the Ecosystem Management Technology Program 2008 at Sir Sandford Fleming College. This study guide was written for Kristina Quinlan of the Ontario Forestry Association, submitted as a deliverable of the project.

This study guide contains background information on biodiversity in a changing world, case studies, activities, references and information as to how the current issue affects the core topics of forestry, aquatics, soil and wildlife. Also included is an Ontario Mammals Identification Guide, an Ontario Bird Identification Guide, an Ontario Winter Tree Identification Key and a Soils of Canada Classification booklet.

The objective of this study guide is to provide Ontario Envirothon participants with information on the 2009 special topic: biodiversity in a changing world. Activities and case studies are highlighted throughout the study guide to ensure a comprehensive understanding of the current and future threats to biodiversity in Ontario.

We would like to thank our faculty advisor, Sara Kelly, for her guidance and input throughout the course of the project. We would also like to take this opportunity to thank Kristina for her support as our mentor during this process. Sincere thanks also go to Don McLeod who provided our team with the valuable resource of his personal collection of wildlife photographs. We sincerely hope that this study guide will be of value to Ontario Envirothon Students in the future. Please feel free to contact us at envirothon.study.guide@gmail.com if you have any questions, comments or concerns.

Angela Gillespie, Denise Derrick, Jessica Danard and Tamara Tucker

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Introduction to Biodiversity

Students will…

- Understand the importance of biodiversity.
- Understand what effects habitat change can have on the biodiversity of an area.
- Understand how human activity affects biodiversity.
- Be able to estimate the plant biodiversity in a given area.
- Be able to offer solutions for increasing biodiversity.
- Understand the effects that non native species have on biodiversity.
- Have a general knowledge of the species at risk in Ontario and what efforts are being made to help with their recovery.

Introduction

Biological diversity – or biodiversity – includes all of the life on Earth and the natural patterns it forms. Biodiversity includes genetic, species and ecosystem diversity. Abiotic components are also part of an ecosystem's biodiversity as they contribute to ecosystem functioning. It is biodiversity that drives many natural processes and functions that are required for the survival of humans. These processes include purification of air and water, recycling of nutrients and fertilization of crops. Without these vital ecosystem services, humans would not be able to survive.

Ontario is split into four main ecological regions: Hudson Bay Lowlands, Ontario Shield, Mixedwood Plains and the Great Lakes. These ecological regions contain different characteristics and habitat types and are therefore able to contain unique species diversity. The abundance of ecosystem types found across Ontario allows for vast diversity of plants and animals by providing various habitat types (Figure 1). Some of these ecosystem types include:

- wetlands: fens, bogs, marshes and swamps;
- grasslands: long grass and savannahs;
- alvars;
- forests: mixed, coniferous, hardwood;
- cliffs; and,
- lakes and running waters.

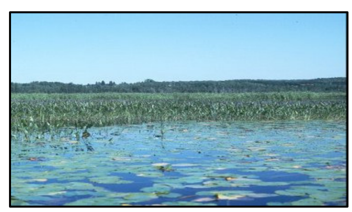


Figure 1: A typical marsh ecosystem in Ontario (Environmental Haliburton, 2008)

Biodiversity found within Ontario has developed through hundreds of thousands of years of evolution. However, the biodiversity within Ontario and throughout the world is being destroyed faster than nature can restore it. What concerns biologists the most is the rate at which species are becoming extinct. According to the 2005 Ontario Biodiversity Strategy approximately 40% of designated species at risk in Canada occur in Ontario. However, Ontario has been a leader in enacting legislation towards the protection of species at risk with legislation such as the Species at Risk Act and the Endangered Species Act.

> *Ontario is home to hundreds of vertebrate species, including more than 80 mammals and more than 470 bird species, about 60 reptile and amphibian species, more than 160 species of fish, and over 20,000 species of insects, spiders and other invertebrates. There are more than 3,380 species of plants and more than 1,000 species of fungi and algae, and hundreds of lichens and mosses.*
>
> (Ontario Biodiversity Strategy, 2005)

The Value of Biodiversity

Biodiversity contributes to the maintenance of the biosphere by providing several crucial ecosystem functions. These functions include generation and renewal of soil fertility, including nutrient cycling, purification of air and water, production of biological energy, provision of food and fiber and detoxification and decomposition of wastes.

Protecting biodiversity is in our self interest. The diversity of organisms on our planet supports humans industries such as agriculture, cosmetics, pharmaceuticals, pulp and paper, horticulture, construction and waste treatment. Decreased biodiversity will result in threatened food supplies, sources of wood, medicines and energy. Much of Ontario's economy is based on converting natural resources into usable products. Natural resources such as fish, timber, minerals, and wildlife are processed and sold to provide income to hundreds of thousands of families in Ontario.

The diversity of life also provides recreational benefits that have become part of Ontario's culture. Activities such as fishing, hunting, hiking, photography and camping are all based around the biodiversity found within Ontario (Figure 2). With a loss of species diversity in Ontario there will be a corresponding loss of economic gain and recreational enjoyment.

Figure 2: Biodiversity allows Ontario residents to enjoy time on the lake (Uchi Lake Lodge)

Preserving Ontario's biodiversity also has an ecological benefit. Increased biodiversity in an area results in increased redundancy and resiliency of the ecosystem. Redundancy occurs when there is more than one species that performs a vital ecosystem function. High redundancy is beneficial to ecosystems because if one species is removed from the ecosystem there will be another species to perform its function. Resiliency is the ability to recover from, or to resist being affected by a disturbance. Biodiversity plays crucial roles in ecosystem resilience by ensuring ecosystems are capable of reorganizing after a disturbance. Resiliency increases when there is high redundancy within an ecosystem as species are able to replace each other in times of disturbance.

Threats to Biodiversity

The threats facing Ontario's plant and animal species are constantly increasing. However, there are five main threats that are impacting all species across Ontario, pollution, habitat loss, invasive species, unsustainable use and climate change.

Pollution of the natural ecosystems includes contamination by humans with chemicals extracted from the Earth's crust and manufactured chemicals. These include hormone disrupting substances, ozone depleting chemicals and polychlorinated biphenyls (PCBs). These chemicals have severe impacts on plant and animal populations within Ontario, including humans, causing issues such as cancer, birth defects, chronic illness, reproduction changes and increased ultraviolet radiation.

Another major cause of declining biodiversity in Ontario is the loss of habitat for many native plant and animal species. Increased human development has led to alteration and fragmentation of natural habitat, if not complete loss. Habitat loss is most significant in southern Ontario where urbanization, agriculture and road density are the greatest. However, human practices in the north also contribute to habitat loss through resource extraction and hydro-electric power development. Recreational land use is also a contributing factor to declining biodiversity in our province.

Invasive species are becoming more and more of an issue in Ontario. The spread of invasive species can have negative effects on the environment, the economy and society. These species often compete with native Ontario species over resources and habitat, resulting in a reduction of native flora and fauna. One example of such a species is the zebra mussel (Figure 3). This fresh water mussel was introduced into Ontario's lakes and has disrupted ecosystem composition and structure, clogged water intake pipes and effected public beaches.

Figure 3: Zebra Mussel (WCO, 2007)

Unsustainable use is the harvest of individuals at a rate higher than can be sustained by the natural reproductive capacity of the species. Reduction in population levels due to harvesting can have dramatic impacts on the population, such as reduced genetic variability. Wildlife managers attempt to control harvesting rates by using permits and licenses for certain game species.

Current concerns regarding climate change and the impacts on the environment have focused a great deal on impacts on biodiversity. Increasing global temperatures will result in altered conditions and changing landscapes. These changes will result in changes in habitat for many plant and animal species. Climate change is expected to impact biodiversity in the following ways:

- insect and/or disease breakout patterns may change or become more severe;
- plant species will change their distribution, resulting in new types of forest;
- animal species distributions will continue to change; and,
- an increase in the frequency of extreme events may affect habitats.

Species at Risk in Ontario

- 6 extinct species (no longer exist in the wild anywhere).
- 9 extirpated species (no longer exist in Ontario, but are found elsewhere in the wild).
- 40 endangered species (facing imminent extinction or extirpation in Ontario).
- 32 endangered species that are candidates for regulation under the act.
- 44 threatened species (at risk of becoming endangered if limiting factors are not reversed).
- 46 species of special concern (species with characteristics that make them sensitive to human activities and/or natural events).

(Ontario's Biodiversity Strategy, 2005)

Global Change and Biodiversity

Five main changes are expected to occur across the globe that will have impacts on the diversity of species found within Ontario. These changes and impacts are outlined in Table 1. Global change will not only have local impacts on biodiversity, but will impact the levels of biodiversity worldwide leading to a massive decline in the number of plant and wildlife species.

Table 1: Impacts of Global Change on Biodiversity (Sage 2008)

Expected Changes	Impacts of Changes
1. Atmospheric Carbon Dioxide Enrichment	• increased photosynthesis
	• faster plant growth
	• reduced transpiration
	• increased occurrence and intensity of fire
	• change in competitive patterns
	• altered quality of forage
	• ocean acidification and calcification failure
2. Climate Change -warming of 7-8°C in Ontario in the long-term	• drier soils
	• warmer winters
	• disruptions in natural cycles
	• increased frequency of storms
	• altered photosynthesis
3. Land Use Change	• increased agricultural production
	• reduced diversity of crops
	• increased occurrence and intensity of fire
4. Terrestrial Eutrophication -increase in the amount of terrestrial nitrogen through use of fertilizers	• increased growth of weeds
	• reduced biodiversity due to the lack of ability to compete with weeds
5. Invaders	• infected and consume natives
	• altered hydrology of an area
	• altered soil properties
	• altered regional climate
	• loss of species
	• altered disturbance regimes
	• out-compete native species

The above impacts of global change can ultimately have devastating impacts on local biodiversity. Reduced resiliency of an area can result in increased vulnerability. With fewer species contributing to the overall functioning of an ecosystem there is a reduced ability to respond to large disturbances.

Solutions for Increasing Biodiversity

> **FUN FACT**
> "Canada was the first industrialized nation to ratify an international agreement to conserve the world's biological diversity. The treaty, known as the "Convention on Biological Diversity," took effect in December 1993" (Natural Resources Canada, 2008).

Changes in the global environment are constantly occurring. These changes are going to become more severe as our world faces climate change. There are several ways in which our society can reduce the impacts on biodiversity due to global change. Decreasing habitat loss is one of the most effective ways of preserving the biodiversity in an area. As mentioned above, habitat loss is one of the major threats facing species throughout Ontario and across Canada. Increased development and road construction has led to decreased habitat and increased fragmentation between habitats. Regional planners can be proactive when developing plans for a new community ensuring habitat assessment is completed prior to construction allowing the best quality habitat to be preserved in an area.

Increasing public awareness of biodiversity loss is also an important step to saving the biodiversity that remains in our communities (Figure 4). The Canadian Biodiversity Information Network (2006) (http://www.cbin.ec.gc.ca) provides some tips on how to increase biodiversity in your community:

- develop a community-based monitoring program in your community;
- transform an empty lot into wildlife habitat;
- create natural spaces around buildings;
- join a conservation group;
- fish sustainably;
- assist in completing a wildlife survey or bird count; and,
- take part in an endangered species recovery project.


Figure 4: Volunteers re-planting native vegetation (Evergreen, 2008)

Implementing legislation to protect species that are currently or will become at risk in the near future is the most powerful way to help to preserve biological diversity within Ontario. Legislation such as the provincial Endangered Species Act and the Species at Risk Act help to protect species by providing legislation ensuring the protection of their habitat, food sources and developing recovery plans to increase their population numbers. Recovery plans identify ways to manage and improve the status of species that are designated threatened, endangered or extirpated and provide advice on how to recover the species. These plans consist of two parts: a recovery strategy and one or more action plans.

Case Study: Project Paradise

Within Hamilton, Ontario is a damaged wetland owned and managed by the Royal Botanical Gardens known as Cootes Paradise (Figure 6). During the late 19th century, a large number of species began declining within the marsh due to human overuse and the introduction of invasive species, such as carp. Over 85% of its plant cover was lost by 1985. The permanent disappearance of aquatic flora has a direct negative impact on the water quality, biodiversity and the ecological function of the fish and wildlife inhabitants of Cootes Paradise and lower tributaries. As human development continued, subsequent declines in biodiversity of plant and wildlife species resulted.

Figure 5: Cootes Paradise, Hamilton, Ontario (Waterfront Trail, 2002).

In 1993, Project Paradise was created by the Royal Botanical Gardens to help rehabilitate the area and reverse the ecological decline. Increasing biodiversity within this wetland was the main objective of the project. This was accomplished by minimizing the number of spawning carp and replanting native vegetation.

The five identified stresses inflicted on Cootes paradise include:

1. overgrazing by carp and Canada Geese;
2. high nutrient levels;
3. water turbidity;
4. sediment accumulation; and,
5. the controlled water level in Lake Ontario.

Restoration efforts in Cootes Paradise have been designed such that they help increase the biological diversity of all forms of life. Vegetation surveys began in the 1940s to help botanists identify changes in plant species composition and density. These restoration efforts will also help measure the extent of invasive exotic plants, such as purple loosestrife and manna grass. Monitoring the fish community in Cootes Paradise will help to detect significant changes in diversity and population abundance. Factors such as spawning, feeding and schooling behaviours all impact the success of fish populations. Similarly, surveys of wildlife populations in Cootes Paradise will also provide records of the current and future species found in the area. Bird-monitoring programs, such as annual visual surveys, marsh bird call counts, nest box surveys and bird banding, are also contributing to the growing records for Cootes Paradise. Some generic data collected on wildlife populations include the number and type of species, nesting locations and breeding success migration patterns and range of habitat. Due to their sensitivity to environmental conditions, amphibians have also been closely monitored at this site. Records of fluctuations in their populations are valuable indicators of habitat quality.

Table 2: Examples of some of the species found in Cootes Paradise (Steward, 2002).

Fish	**Mammals**
• Brown bullhead	• White-tailed Deer
• White perch (invasive)	• Red Squirrel
• Largemouth bass	• Oppossum
• Carp (invasive)	• Mink
• Yellow perch	• Muskrat
Birds	• Cottontail Rabbit
• Double Crested Cormorant	• Beaver
• Caspian tern	• Raccoon
• Osprey	• Red Fox
• Black-crowned night heron	**Vegetation**
• Pileated Woodpecker	• Oak, Maple and Pine trees
• Protonothary Warbler	• Sassafras tree
	• Kentucky Coffee tree
	• Tulip tree

Activity: Estimating Biodiversity in Your Area

The aim of this activity is to help students estimate the biodiversity in their area. Measuring biodiversity is complex because the genetic, species and ecosystem diversity must be included in the calculation. For simplicity, this activity will only look at estimating the number and abundance of species inhabiting a community or habitat.

The most basic measure of biodiversity is a count of the total number of species present in a community – this is termed species richness (S). However, it is important to take the abundance of species into consideration when determining the diversity within a region. For example, consider the two communities below:

	Number of Individuals	
	Community A	Community B
Species 1	98	33
Species 2	1	33
Species 3	1	34
Total	100	100

Both communities have a species richness of S=3, however, it is clear that they do not have the same abundance of each species and therefore are not equally as diverse. To ensure the abundance of species is included in the calculation, we must use a diversity index to calculate local species diversity.

The two most commonly used diversity indices are the Shannon Index and the Simpson Index. Both indices use the variable p_i, which is the proportion of species in the population:

$$p_i = \frac{\text{number of individuals of species i}}{\text{total number of individuals in the population}}$$

$$\text{Shannon index: } H = -\,\Sigma\,(p_i * \ln p_i)$$

$$\text{Simpson index: } D = 1 / \Sigma(p_i^2)$$

There is a measure called **species evenness**, which attempts to measure the equality of the abundances for each species. The formulas for evenness are given below, where S = the number of species:

$$\text{Shannon evenness index: } J = H / \ln(S)$$

$$\text{Simpson evenness index: } E = D / S$$

Example Calculations

Community A | Community B

$$p_i = \frac{\text{number of individuals of species i}}{\text{total number of individuals in the population}}$$

The proportion of each species is the number of the species of interest divided by the total number of species.

Community A

Species 1=98/100=0.98
Species 2=1/100=0.01
Species 3= 34/100=0.34

Community B

Species 1 = 33/100=0.33
Species 2= 33/100=0.33
Species 3=1/100=0.01

Shannon index: $H = - \Sigma (p_i * \ln p_i)$

The Shannon index is the negative sum of all of the proportions multiplied by the natural log rhythm of the proportion of each species.

Community A

H= -[(0.98*ln0.98)+(0.01*ln0.01)+(0.01*ln0.01)]
H= -[(-0.0198) + (-0.0461) + (-0.0461)]
H= 0.112

Community B

H=-[(0.33ln0.33)+(0.33ln0.33)+(0.34ln0.34)
H=-[(-0.333) + (-0.333) + (0.367)]
H= 1.033

Simpson index: $D = 1 / \Sigma(p_i^2)$

The Simpson index is the inverse of the sum of each proportion squared.

Community A

$D= 1/[(0.98)^2 + (0.01)^2 + (0.01)^2]$
D= 1/0.96
D= 1.04

Community B

$D= 1/[(0.33)^2 + (0.33)^2 + (0.34)^2]$
D= 1/0.33
D= 3.03

Both of these diversity indices are used to compare diversity between two areas and they both account for species abundance and evenness. This example demonstrates that increased evenness of species results in higher diversity value (Community B).

Shannon evenness index: $J = H / \ln(S)$

The Shannon evenness index is the Shannon diversity index divided by the natural log rhythm of the number of species.

Community A

J= 0.112/ln(3)
J= 0.102

Community B

J= 1.033/ln(3)
J= 0.94

Simpson evenness index: $E = D / S$

The Simpson evenness index is the Simpson diversity index divided by the number of species.

Community A

E= 1.04/3
E= 0.35

Community B

E= 3.03/3
E= 1.01

Again, these indices indicate that when species numbers are relatively similar, higher evenness values result, for both Shannon and Simpson indices.

The Species-Area Curve

Larger areas or habitats are able to support larger numbers of species. This trend is called the species-area relationship, increase in area results in an increase in species richness. Figure 5 shows a typical species area curve. Note that the y-axis is a cumulative count of the number of species – that is for each new area you add the new species to the already existing total. Initially, there will be a large number of new species added to the total in each area, however, as sampling continues, the chances of finding a new species gradually decreases (Figure 5).

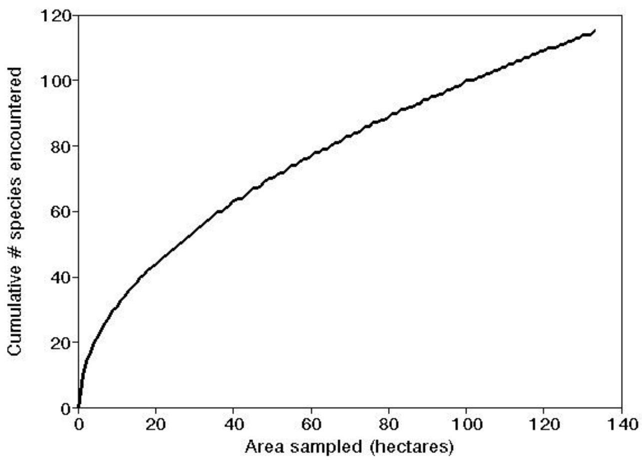


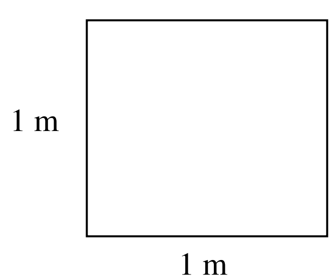
Figure 6: Species-Area Curve (Palmer, 2007)

Estimating Your Local Biodiversity

It is very difficult to inventory the local wildlife found in a habitat as most animals avoid humans. For this activity, we will only use plant species found within small plots so that students can gain an understanding of the general process. If inventories of local wildlife are available to students from local conservation authorities or community interest groups, this information can be used as part of the calculation, as long as the inventory was determined for an area of a pre-determined size (i.e. 4m by 4m plot).

Methods:

1. Find an area to set up plots – a nearby forest, meadow or field will work.
2. Create 1 meter by 1 meter plots using meter sticks to measure the distances. Use stakes and flagging tape to mark the boundaries of the plot.



3. Within each plot record the number of plant types. Identify plants to order wherever possible.
4. For each habitat type, calculate the species richness (S), species diversity (H and D) and species evenness (J and E).
5. Record the number of species found in the first plot, and then any additional species found in the following plots.

Example Data Sheet:

Plant type	Abundance
Plot 1	
Red Maple	1
Red Osier dogwood	2
Aster	5
Total number of plant types	3
Plot 2	
Red Osier dogwood	1
*Common Thistle	6
*Goldenrod	4
Total number of new plant types	2

*indicates species was not found in previous plots.

6. Each plot will represent 1 meter squared of area – therefore, for each additional plot, add 1 square meter to the area.
7. Record your data on a species-area graph.

Questions for Discussion

1. Are there any species at risk in your area? What is the main reason for the decline of this species? How can your school try to help recovery efforts? (http://www.mnr.gov.on.ca/mnr/speciesatrisk/)
2. How have humans impacted local plant and wildlife populations in your region? List both the positive and negative impacts.
3. Can you think of any major or minor disturbances/natural disasters that have occurred in Ontario in your lifetime? What were its impacts on biodiversity in your area?

Aquatic Biodiversity

Students will…

- Understand the vast diversity of fish, invertebrates and vertebrates in aquatic ecosystems.
- Be able to identify some of the aquatic organisms in local and provincial areas.
- Recognize the roles of different aquatic organisms play in the aquatic ecosystem.
- Understand the different aquatic environments needed for specific species to thrive.
- Understand the role that invasive species have played in Ontario's biodiversity.

Introduction to Aquatic Ecosystems

The province of Ontario is a mosaic of many different landforms with varied geological composition and unique surface ecosystems. Each region contains thousands of lakes, steams and wetlands that vary greatly from one another depending on their location and surrounding environment. From cold, clear lakes on the Canadian Shield in Northern Ontario to dense, dynamic cattail marshes along the southern Great Lakes, Ontario's aquatic ecosystems are bursting with life (Figure 7).

Figure 7: Lake Huron (Claveau, 2008)

Environmental scientists spend a great deal of their time doing in-field research to better understand the natural world. Scientists working in the field of aquatics are becoming increasingly interested in aquatic biodiversity and the factors that influence and change it. As some species begin to disappear and new ones arrive, it has become more important than ever to understand the various factors that shape and affect Ontario's aquatic biodiversity.

What is aquatic biodiversity?

Aquatic biodiversity can be defined as the number and abundance of species that live in aquatic ecosystems. In Ontario, aquatic ecosystems include freshwater ecosystems such as lakes, streams and wetlands and marine ecosystems including our northern shore, James Bay and Hudson's Bay.

Lakes can range in size from the Great Lakes to small open bodies of water, such as a pond in your backyard. The term 'stream' encompasses any flowing body of water, from small spring-fed creeks to mighty rivers that can power electric generation stations. Wetlands are extremely diverse ecosystems, ranging from swamps where water-tolerant trees can grow, to cattail marshes to fens and bogs.

What causes change in aquatic biodiversity?

There are many factors that can affect and change biodiversity within aquatic ecosystems. Aquatic biodiversity can experience a decline due to loss or fragmentation of habitat, pollution or the introduction of an invasive species. Human activity and development have had an immense affect on biodiversity in all ecosystem types, and aquatic ecosystems are no exception.

Take for example the construction of a subdivision at the edge of a town or city (Figure 8). Before construction begins, land is often leveled and cleared, which often means wetland areas are drained or filled in, and streams disappear after they are filled with loose soil from the site. Wetland birds that spend part of their year among reeds will need to find a new seasonal home, and fish that depend on small tributary streams for spawning will have difficulty producing offspring to ensure healthy future populations of their species.

Figure 8: Stream-side construction site (NCSU, 2007)

Biodiversity as a whole, as well as specific species are dependant on healthy ecosystems for survival. Activities as described above can have devastating effects on local aquatic biodiversity, and can eventually result in specific species no longer existing in that area. If this type of pattern happens all across a region (for example, throughout Ontario), it can result in species extinction, which is a loss of biodiversity.

Climate change can also largely influence changes in aquatic biodiversity. For example, the longer, hotter summers that have become fairly frequent result in higher temperatures in bodies of water such as lakes and streams that used to be much cooler. Fish species each have their own unique set of tolerances, including maximum water temperature in which they can survive. Coldwater fish species have felt the effects of climate change in their habitats, and as a result many are coming closer to the state of being endangered or extinct.

Invasive species are a more recent but highly influential factor that has the ability to change an ecosystem's biodiversity very quickly. Different types of aquatic and wetland invasive species will be discussed throughout this section of the study guide.

Measuring Aquatic Biodiversity

As the state of aquatic biodiversity becomes increasingly of concern and importance, it is equally important to find ways to monitor and measure biodiversity. This is done so that scientists can communicate their findings with other scientists,

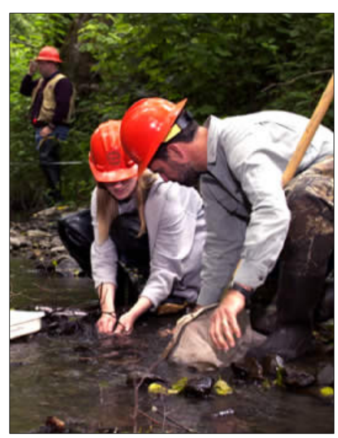


Figure 9: Benthic Macroinvertebrate Monitoring (Placo, 2008)

with politicians and with the general public (Figure 9). This sharing of information allows for a greater understanding of the importance of aquatic biodiversity and how it is changing.

Measuring aquatic biodiversity can be accomplished in many ways. Everything from fish to bird to insect to plant species can be in one way or another counted and therefore measured and evaluated. Methods for collecting this kind of information will be discussed later in this section.

The presence, absence and abundance of species give scientists an idea of the state of aquatic biodiversity within a particular aquatic ecosystem. If the same type of information is collected from the same ecosystem every year (for example, electro-fishing the same segment of a stream every summer), the biodiversity of that area can be monitored. This is how change in biodiversity over time is detected.

Lakes and Ponds

Lakes can be described as large bodies of open water with varying depths. Ponds are similar, however much smaller, with less surface area and shallower depths. A key feature to differentiate between these two ecosystems is the presence of “beach” areas. Lakes are large enough for the wind to generate wave action which creates beach areas, while ponds lack this feature.

Lakes and ponds are called “lentic” (standing water) ecosystems. In Ontario, they are depressions in the landscape caused by glacial movement, and then filled with melt water. Today, lakes and ponds are home to thousands of organisms, both plant and animal.

<u>Lake Biodiversity</u>

Lakes can be divided into different zones (Figure 10). Each zone caters to different types of organisms in terms of the food, shelter and general habitat conditions (such as light, water temperature, dissolved oxygen, etc.) that it offers.

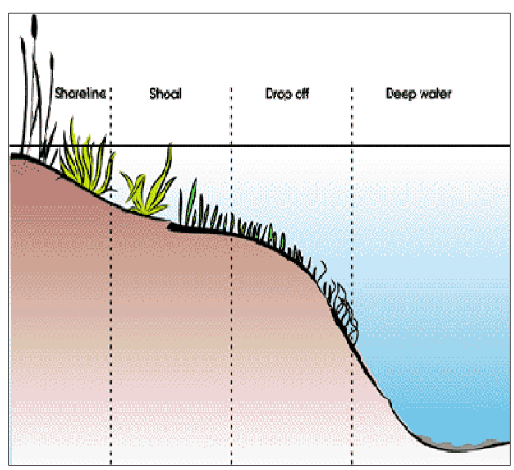


Figure 10: Cross Section of a Lake Ecosystem (Kidfish, 2008)

The shoreline (or littoral zone) is a very productive area that supports many forms of life. It is an intersection between aquatic and terrestrial ecosystems (also called the shoreline ecotone). The wide variety of life that use this zone include birds such as the great blue heron, terrestrial mammals such as white-tailed deer for drinking, amphibians such as frogs in their various life stages, insects and minnows, just to name a few!

Various types of fish inhabit the other zones of the lake, depending on their biological requirements. For example, carp prefer to live in warm, shallow water and would most likely be found in the shoal area of a lake. Lake trout are a cold water fish species that prefer to live in deep areas of lakes where the water is cooler and there is less light. (Please see Appendix B for more information on the specific requirements of fish species in Ontario).

The very bottom of the lake is called the benthic zone. Here, a variety of benthic organisms live among or on top of decomposing plant matter and sediments. Benthos can also live in different aquatic environments, such as in the littoral zone of a lake or in a stream bed (this will be discussed in further detail in the Streams and Rivers section). Different benthic organisms have different habitat requirements, similar to fish, and are found in their respective appropriate environments.

<u>Highlight Lake Native Species - Walleye</u>

Walleye are a native species to Ontario. They are found in great abundance in the Great Lakes basin, but also in Northern Ontario in many water bodies. Walleye can thrive in a variety of conditions and habitats, ranging from cold clear lakes and streams to weedy cool waters. However, their ideal temperature is around 23° C. Due to their large eyes, walleye tend to frequent areas where there is minimal light, such as weed beds or other areas with sufficient cover (Figure 11). They tend to come close to the shore at nighttime to feed, especially in the spring and fall seasons.

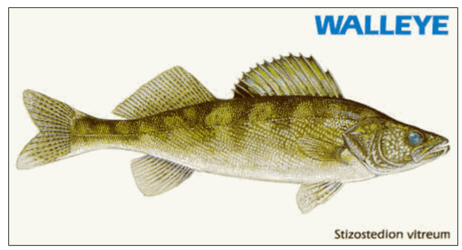


Figure 11: Walleye (ODWC, 2008)

Due to their sensitivity to light, walleye are affected by the presence of zebra muscles. This invasive species feeds on various forms of plankton and other particles in the water column. This filtration feeding makes for clearer water bodies with increased light penetration, which is not a favorable condition for walleye.

Walleye are a popular sport fish in Ontario. Beyond being an important species in lake environments, their populations are the source of economic income for many businesses, as well as a food source for many people.

To learn more about how to identify walleye and other native Ontario fish species, please see Appendix B.

Streams and Rivers

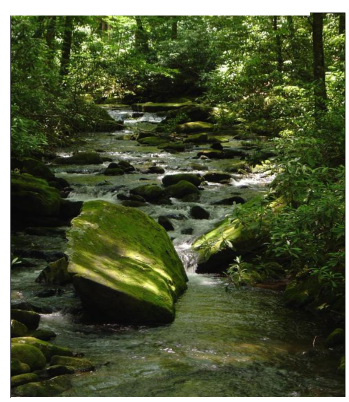


Figure 12: A Stream Ecosystem (SRWC, 2007)

Streams are dynamic aquatic ecosystems that connect all types of aquatic ecosystems across Ontario. Streams usually originate deep in a forested, hilly area where ground water has broken through the ground. They then trickle down across the landscape, feeding lakes, ponds and wetlands, and joining up with each other to make larger rivers (Figure 12).

Stream Biodiversity

Streams and rivers pass through all types of ecosystems in Ontario, and therefore play a significant role in supporting the province's biodiversity. Within streams themselves, many forms of life have found their niche and place in the food web. Some organisms will spend their entire lifetime in a stream ecosystem, while others will visit to complete different parts of their lifecycle. For example, many species of fish travel up river networks to find the quiet beginnings of a stream before they are ready to spawn (Figure 13).

Figure 13: Fish swimming upstream to spawning grounds. (NA, 2008)

Stream ecosystems are also a very important habitat area for benthic macroinvertebrates (BMIs). BMIs are invertebrates (animals without a backbone) that live in the benthic zone (bottom) of various types of aquatic ecosystems, especially streams. Some will stay there for the duration of their life, while others are only there for the larval life stage.

BMIs play an important role in stream biodiversity as they are the connection between decomposing plant and algal material and larger organisms such as fish. Without healthy populations of a variety of BMI species, the biodiversity of higher organisms would be crippled.

Another factor that makes BMIs of such great interest is that their populations are easy to sample, making stream biodiversity easier to measure. To learn more about this process or about how to identify benthic macroinvertebrates, please see the activity at the end of this section and Appendix B.

Highlight Stream Native Species – Brook Trout

Brook trout (also called speckled trout) are a world-renowned prize game fish, and inhabit many of the streams of Ontario during certain times of the year (Figure 14). It is very common to find brook trout in the many streams of northern Ontario; however they also frequent some of the less-disturbed streams of southern Ontario.

Figure 14: Brook Trout (NBNR, 2008)

One of the main limiting factors for brook trout is water temperature. This species requires a constant supply of cold, clear water throughout the year. To keep the water cool and to provide cover for these fish, locations with overhanging branches or logs and rocks in the stream make for areas of suitable habitat.

When summer temperatures heat up water bodies, brook trout will move into deep pools where it is cooler. It is at this point that they are dependant upon the benthic macro invertebrate population as a food source.

Climate change is causing an increase in summer water temperatures, increasing the stress the brook trout experience in this season. This could have a negative effect on brook trout populations, as well as other aquatic species with similar requirements, and affecting the overall state of Ontario's aquatic biodiversity.

Wetlands

Wetlands are a diverse and extremely interesting type of ecosystem, where land and water meet and overlap. Some wetlands are inundated with water all year long, while others are seasonally wet. Either way, all wetlands are the product of water being trapped in a certain area that creates a new ecosystem that caters to many types of species.

Wetland Types

Wetlands do not all look or behave the same, or contain the same types of species. In Ontario there are four main types of wetlands: swamps, marshes, bogs and fens. While all four are areas of land covered or saturated with water for all or part of the year, they also have many differences.

Swamps

Swamps are wetlands that are covered by water-tolerant tree and shrub species. They are seasonally flooded with water, for a short or long period of time, depending on the swamp location, water source and many other factors (Figure 15). Swamps are rich in nutrients and generally considered to be very productive ecosystems.

Figure 15: A Swamp Ecosystem (Environment Canada, 2005)

Swamps also support a wide range of wildlife. Many types of birds have nests in swamps, and turtles are also known to take advantage of the swamp habitat. Dependant on flooding, swamps are often located nearby a water source that floods annually, such as in the flood plain of a river. Due to the seasonal changes that swamp experience, they play important roles in the lifecycles of many plants and animals, making them important areas for safeguarding biodiversity.

Marshes

Figure 16: A Marsh Ecosystem (Environment Canada, 2005)

Marshes are wetlands that are covered by standing or very slowly moving water. While some marshes experience a loss of surface water during dry seasons, the soil and root base of plants is always saturated. This allows for growth of the many species of emergent plants typical to marsh ecosystems. Marshes are very rich in nutrients and are considered to be the most productive type of wetland in Ontario.

Due to their high productivity and habitat types offered, marshes are home to many different species. Everything from large birds of prey to reptiles and amphibians to fish depend on marshes as their primary habitat.

Bogs

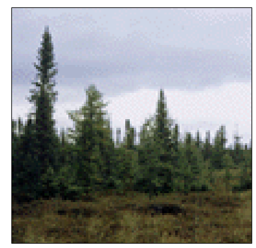


Figure 17: A Bog Ecosystem (Environment Canada, 2005)

Very common throughout northern Ontario, bogs are wetlands that are covered in thick layers of sphagnum moss (peat) (Figure 17). Bogs generally have poor drainage, and as a result are low in nutrients and relatively unproductive. Bogs are also very acidic due to their large amounts of decomposing plant matter.

Bog wetlands can support many species of shrubs and ground cover plants, many which are important food sources for local wildlife. Birds, reptiles and amphibians also find bog ecosystems ideal for their habitat requirements.

Fens

Figure 18: A Fen Ecosystem (Environment Canada, 2005)

Fens are wetlands with high water tables and slow internal drainage (Figure 18). Generally more productive and with higher nutrient levels than bogs, fens can support a wide variety of sedges, as well as shrubs and sometimes trees. Like bogs, fens are more common throughout northern Ontario. Reptiles, amphibians and many species of butterflies are supported by fen ecosystems.

<u>Highlight Wetland Native Species – Blanding's Turtle</u>

Figure 19: Blanding's Turtle (Environment Canada, 2006)

The Blanding's turtle is a freshwater species of turtle found only in North America. It can be identified by its smooth and round dark green shell and vibrant yellow under body (Figure 19).

Blanding's turtles are very well adapted for colder climate conditions, and actually prefer cooler temperatures as they cannot tolerate extreme heat. Contrarily, their young cannot hatch in temperatures below 22°C, limiting this unique species to a small area concentrated around the more southerly Great Lakes in Ontario (Figure 20).

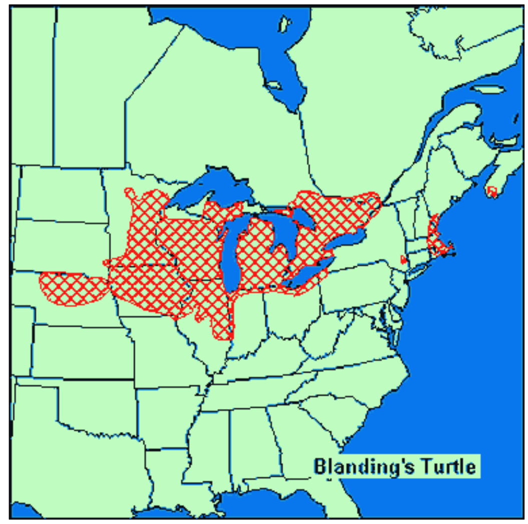


Figure 20: Blanding's Turtle Range (Bouvier, 2001)

Blanding's turtles can live in a variety of wetland and aquatic environments, including marshes, swamps and bogs as well as ponds and other small areas of open water. Clean, shallow water is required for survival, as well as sandy areas for nesting. These two requirements are threatened by human development in natural areas, as wetlands are filled in or contaminated, and sandy areas occur most often along road sides which cause a direct threat to the turtle's survivorship.

Highlight Wetland Native Species – Common Cattail

The common cattail is one of the most characteristic plants of Ontario's wetlands (Figure 21). Their presence can identify soils saturated with water, where their roots (called rhizomes) grow very quickly, creating large, dense stands of this plant.


Figure 21: Common cattail (Moran, 2008).

Cattails offer ideal habitat for many species, including songbirds, waterfowl, reptiles, amphibians and fish. Many other species, such as deer, raccoons, rabbits and wild turkeys take advantage of the excellent cover and protection that cattail stands offer. The common cattail is also an important building material for many species, such as muskrats that use the tall strong stocks to build their lodges, and birds that use the "fluff" to insulate their nests.

Besides providing excellent habitat for many species, cattails also purify the water in wetlands, which improves living conditions for many species, including humans. The common cattail is an important part of wetland ecosystems as it promotes and safeguards biodiversity.

Invasive Species

Many new species have been introduced to Ontario's aquatic ecosystems, some having little to no impact on the natural environment, while other have caused immense distortions to the composition of native species.

The new species well-suited for life in Ontario tend to be "advantageous". This means that their populations can get out of control very quickly and disrupt the balance of native species within an ecosystem. In these cases, introduced or exotic species are called "invasive".

In extreme cases, invasive species have been known to out compete many kinds of natural vegetation. This type of invasion can create a monoculture of the exotic species, thoroughly decreasing the biodiversity of the ecosystem.

To protect aquatic ecosystems from further damage, proactive and reactive measures are in place to prevent the spread of invasive species presently in Ontario, and the introduction of new ones. Examples of such measures include programs that educate anglers about appropriate bait, and what to do if they catch an invasive fish species.

Many invasive species are a result of hobbies, such as gardening or keeping an aquarium. Many plants thought to be desirable in gardens will spread to natural areas, where their effect is less than desirable. Information is now circulating to educate gardeners about plants they may use that could harm natural biodiversity.

The release of aquarium pets into natural water bodies contributes to the increase of exotic invasive aquatic animal species. Programs are in place to help aquarium owner's deal with unwanted pets, as well as to provide information about choosing aquarium species wisely.

The Canadian and Ontario governments have established legislation in a number of governmental departments to prevent and prohibit the import of invasive species. More information about these laws, acts and bill can be found at: http://www.ffdp.ca/hww - Hinterland Who's Who.

The Ontario Federation of Anglers and Hunters has also taken a very active role in the prevention of the spread and introduction of invasive species in Ontario. They have established many education programs to promote invasive species awareness among anglers and the general public alike. For more information on their programs, and on specific invasive species in Ontario, visit: http://www.invadingspecies.com/indexen.cfm.

Case Study – Purple Loosestrife in Ontario's Wetlands

Figure 22: Purple Loosestrife (OFAH, 2008)

Purple loosestrife is a tall, vibrant flowering wetland plant (Figure 22). It was introduced into Ontario and North America at the beginning of the 19th century, as it was brought over by European settlers who enjoyed it as a garden plant. Seeds were also present in the ballast water of ships as a result of soil being used to weigh down ships during long voyages.

Purple loosestrife quickly became a threat to native wetland vegetation, with seeds capable of germinating in soil immediately after release or surviving in water for extended periods of time (as in the case of ballast water) to germinate at a later date. Mature purple loosestrife plants are also capable of spreading through underground root systems, making it an extremely aggressive colonizer.

Approximately two hundred years after its first introduction to Ontario, purple loosestrife is now prominently established across Canada and the United States, with a particularly dense distribution in Ontario. Since purple loosestrife is capable of spreading extremely quickly and aggressively, it poses a great threat to native wetland vegetation. It is known to out-compete native plants and replace them within the wetland ecosystem. This poses an imminent threat to wetland biodiversity, as a large variety of native plants are being replaced by one foreign species.

The expanse of purple loosestrife is also a threat to wetland wildlife. While purple loosestrife is very well adapted to live in Ontario wetlands, Ontario wildlife have not adapted to use it for their many needs. Native plant species provide a wealth of wildlife species with food, shelter and construction materials. When purple loosestrife moves into a wetland ecosystem, not only does it effect plant populations but wildlife populations as well, putting the overall biodiversity of the ecosystem in jeopardy.

Figure 23: Removal of Purple loosestrife (OFAH, 2008)

Several mitigation methods and techniques have been developed in attempt to control purple loosestrife populations in Ontario. Depending on the size and location of the infestations, different methods and techniques, or a combination of several, may be used to eliminate the species.

For small stands of purple loosestrife on private property, landowners are encouraged to dig up the plants, including their roots. This will eliminate all current plants as well as prevent spread through root systems or seed dropping. Plants can also be cut off at the base; however this does not necessarily destroy the underground root systems, which may still thrive and produce new plants. Both methods are best done throughout late spring a early summer, when the plant is easy to recognize but has not yet released its seed. As with any invasive plant species, these efforts most often need to be repeated for several years in a row to thoroughly extinguish the plant's presence in one location.

Figure 24: Predators of Purple loosestrife (OFAH, 2008)

For larger areas of purple loosestrife, a biological control method has been developed. The plant's only known natural predator, two specific species of beetles (*Galerucella pusilla* and *Galerucella calmariensis*) are now being released into large-scale purple loosestrife stands. While these beetles will not completely eliminate the purple loosestrife population, they are able to slow the spread of the plant by feeding on their leaves while reduces growth and spread. The beetle release program began in 2003 in partnership between the Ontario Federation of Anglers and Hunter, the Ontario Ministry of Natural Resources and Ontario Beetles. However, there is concern over the release of these beetles as they are non-native species to Ontario and can therefore have drastic impacts on the surrounding ecosystem.

Activity: Benthic Macroinvertebrate Collection

The “kick and sweep” sampling method is an effective method of measuring the biodiversity of freshwater ecosystems, using benthic macroinvertebrates as biodiversity indicators. BMIs can be sampled in many types of aquatic and wetland ecosystems, including lakes, shorelines, wetlands and ponds, however in this activity a shallow stream ecosystem will be used.

The goal of this activity is to sample a meter squared area of a stream, collect the BMIs and then identify them. As discussed earlier, different BMI species indicate different stream health factors, therefore helping to determine the overall health and biodiversity of the ecosystem.

<u>Materials Required</u>:

1. Rubber boots or hip waders
2. Personal floatation device (PFD)
3. Net
4. Stopwatch
5. Basin to hold BMIs (preferably white)
6. Meter stick
7. BMI identification and tally sheet and pencil
8. Tweezers
9. Container with tight fitting lid
10. Hand lens
11. Field guides

<u>Instructions</u>:

1. Select a 1 meter-square site to carry out your kick and sweep exercise. Best sites are riffle zones (areas of shallow, fast moving water over rocks and gravel).
2. Approach the site from downstream, as to not disturb the site. Only the person performing the kick and sweep should stand in the steam.
3. Have a member of your team *not* in the stream set the stopwatch for one minute.
4. The team member in the stream should position the net in the water, very close to the streambed and directly downstream from their feet.
5. When the stopwatch starts, the team member in the stream will begin shuffling their feet to disturb the BMIs. They will continue doing this within the 1 meter square area for one minute, ensuring that the net is always directly downstream from their feet to collect the BMIs.
6. After the kick and sweep in the stream is completed, BMIs should be placed in the container with a tight fitting lid along with a small amount of water from the stream.
7. Return to the classroom with your team to carry out the identification of the BMIs.

8. Use the BMI identification and tally sheet (see Appendix A or access original documents at http://obbn.eman-rese.ca/PartnerPages/obbn/online_resources.asp-?Lang=en-ca) to keep track of the results of your kick and sweep.
9. Research the different BMI species found in your kick and sweep to better understand the health and biodiversity of the stream.

* Be sure to return the BMIs to the stream after identification has been completed!!

Questions for Discussion

1. Identify three factors that could cause change in aquatic biodiversity, and describe *how* and *why* these factors affect change.
2. Explain the connection between global climate change and changes in aquatic biodiversity.
3. Why is it important to monitor aquatic biodiversity? Provide an example of a monitoring method, and describe how it would help scientists to track changes in aquatic biodiversity.
4. What effect does the introduction or expansion of an aquatic invasive species have upon the biodiversity of an ecosystem? Provide an example of an invasive species and describe how it directly affects native aquatic species (both plant and animal) and biodiversity (http://www.invadingspecies.com).

Forest Biodiversity

Students will…

- Learn how to identify native trees using a tree key.
- Understand what role non native species have played in Ontario's forest biodiversity.
- Learn of the threats to the biodiversity in Ontario's forests.
- Understand what role trees have in a given ecosystem.
- Understand what affects forest management has on biodiversity.
- Understand the biodiversity in the various forest regions.

Introduction to Forests

Definition of Forests

The definition of a forest is "lands on which trees are the principal plant life, usually conductive to wide biodiversity" (Natural Resources Defense Council, n.d.). As you can see by this definition, forests are very important to biodiversity.

Different Forest Types in Ontario

There are many ways to name forest types in Ontario. Various areas can be given many designations. One way of designating areas is by Forest Regions. When using this criteria Ontario is divided into Boreal-forest and barren in the very northern part of the province, Boreal-forest and grass, Great Lake-St. Lawrence and Deciduous in the very Southern part of Ontario. This can be seen in Figure 25 below.

FORESTRY FACT

"The Carolinian forest [Deciduous forest] is the most threatened forest type in Canada, largely because it is located in a densely populated area. The warm climate of this region accounts for the diversity and uniqueness of its species" (Natural Resources Canada, 2008).

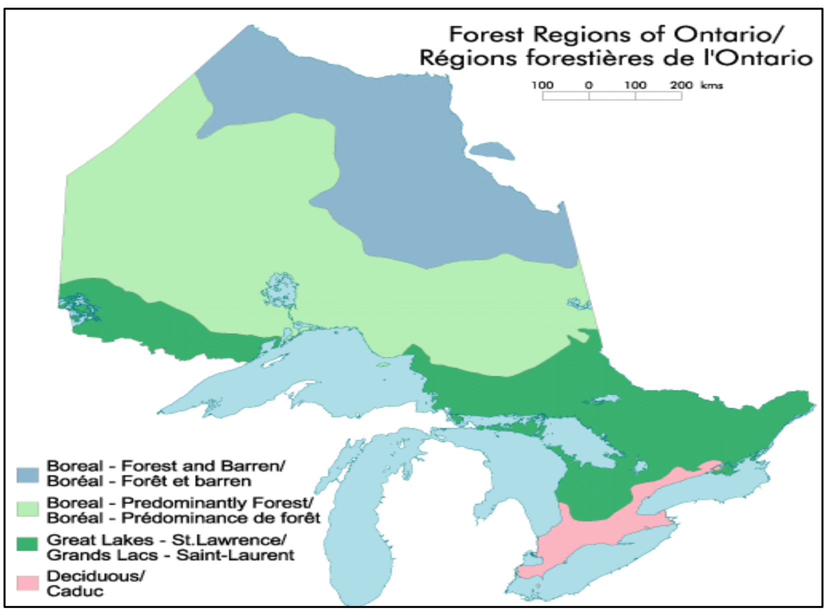


Figure 25: Map of Forest Regions in Ontario (Environment Canada, 2005)

Another way to name Ontario's Forest Regions is by Ecozones. Ontario is divided into three Ecozones of Hudson's Plains in the North, the Boreal Shield in the middle and Mixed wood Plains in the South. This can be seen in Figure 26 below:

Figure 26: Ecozones of Ontario (Pearson and Courtin, 2002)

FORESTRY FACT

"Sixty-six per cent of Ontario or about 70.4 million hectares – almost 174 million acres – is forested" (Queen's Printer for Ontario, 2003).

Threats to Forest Biodiversity

The main threats to forest biodiversity include:

- habitat loss, fragmentation, degradation;
- invasive alien species;
- pollution; and,
- climate change.

Many human impacts are creating habitat loss, fragmentation and the degradation of the landscape. The buildings of roads, urban sprawl, recreation, logging and agriculture greatly decrease the number of species. This not only affects forest biodiversity but the biodiversity of all species living with and depending on the trees. With fragmentation, seeds are not able to spread and invasive species are more likely to expand into forest ecosystems and out compete native vegetation. Pollution is also an issue because toxic chemicals are released into the soil, water and air. Trees live in close association with the soil, water and air and contamination of these environmental elements will often severely harm the tree and could lead to death. Climate change is also a major threat to forest biodiversity. With temperature changes, trees may not be able to adapt quickly enough. The inadequate amount of rainfall also affects trees in a negative way.

Non-Native Species

Non-native Plant Species

Some common trees that threaten biodiversity in Ontario include:

- Norway maple (*Acer platanoides*)
- Tree-of-heaven (*Ailanthus altissima*)
- Silver birch (*Betula pendula*)
- Norway spruce (*Picea abies*)
- White poplar (*Populus alba*)
- European buckthorn (*Rhamnus cathartica*)
- Black locust (*Robinia pseudoacacia*)

The Norway maple (Figure 27) is originally from Europe and Asia and is being planted as ornamental street trees in Ontario. This tree is very aggressive, grows well in poor soils and is shade tolerant. The Norway maple sends out a chemical in the soil which stops other plants from growing near by. This tree is out competing the native Sugar maple which is now a cause for concern for maple syrup producers.

Figure 27: Norway Maple Leaf (Hendry, 2007)

Figure 28: European Buckthorn Leaf (Hendry, 2007)

The European buckthorn (Figure 28) is also a very destructive invasive species. Originally from Europe, this tree is spread easily by birds. It is found in wooded areas, fields and fence rows. This tree is out-competing native tree species because of its ability to spread quickly. Both the Norway maple and European buckthorn are affecting the biodiversity of Ontario's forests.

Non-native Insect Species

There are many insect species that do a great amount of damage to trees in Ontario. Some of these insects include:

- Gypsy moth;
- Asian longhorned beetle (Figure 29);
- Emerald ash borer (Figure 29);
- Spruce bud worm; and,
- European wood wasp.

Figure 29: Emerald Ash Borer (left) and Asian Longhorned Beetle (right) (NRC, 2008)

Most of these invasive species are arriving in Ontario by cargo ships. They slip by attached to shipping containers and wooden palettes. Even with strict inspections of cargo coming into our province, these tiny insects manage to find their way in.

The Emerald Ash Borer is a very damaging insect. It kills ash trees and has been known to move to other trees. This insect is primarily found in London, Middlesex County.

The Asian longhorned beetle was initially found in the Toronto area. This insect kills maples, elms, poplars and willows. The city quickly dealt with this problem and no new cases have been reported since 2004.

The European wood wasp attacks mostly conifer species and was first found in southeastern Ontario in 2005. To eradicate this insect, traps were placed in 131 pine stands across southern Ontario in 2006 by the Federal government. This insect has not been seen outside of Southern Ontario.

The Gypsy Moth is a very harmful insect species in Ontario. This insect will feed on approximately 500 tree species but it prefers oak trees. Since it can lay up to 1000 eggs this insect can severely harm a tree by completely defoliating it.

FORESTY FACT
In 1869, a French naturalist tried to breed the European gypsy moth with the North America silkworms to start a silk industry in North America. This did not work and the moths ended up escaping, leading to the gypsy moth problem today (Nystrom, 2007).

Role of Trees in a Given Ecosystem

Forests provide many goods or services including:

- carbon storage and sequestration;
- soil formation;
- waste treatment;

- biological control;
- air quality enhancement;
- storm water control;
- recreation and cultural opportunities;
- raw material (timber); and,
- genetic resources.

Trees play a crucial role in many ecosystems. Trees are very important to animals as they create habitat and food. Insects, birds and mammals eat the leaves, flowers, fruit, bark and twigs of many trees. Birds and animals use trees for nesting areas. Many animals use trees as a shelter from harsh weather. Other plants have a symbiotic relationship with trees and require their presence for survival. For example, trees create lower light levels with high humidity and create protection from rain, snow and wind, so that planes like the Ostrich fern can thrive.

Trees are also very valuable to humans. Trees offer us shade and create beautiful colours for us to enjoy in the fall. It has been stated that people who can see green space from their hospital window will recover faster than someone who can not. Trees provide us with many products such as wood to create furniture, houses and fuel, and materials such as sap and nuts for food and bark for medicines.

Trees are also playing a significant role in the battle against climate change. Trees take in carbon dioxide from the atmosphere and store it in their cellulose. One tree can store around 13 pounds of carbon each year. Trees are also responsible for helping to purify the air we breathe. Trees filter out many chemicals such as ozone, carbon monoxide, nitrogen dioxide and lead.

Affects of Forest Management on Biodiversity

Since forests provide us with much needed timber it is unlikely that the forestry industry will cease to exist. If the harvesting of timber continues at its current rate, sustainable forestry practices need to be used to protect both the populations of trees within a forest and the biodiversity of wildlife within a forest.

Figure 30: Example of a Forest Fire (Chapman, n.d.)

Forest fires (Figure 30) are very important in promoting biodiversity in some forest ecosystems. Some species, such as the Jack pine need the intense heat from fires to open up their cones to germinate. Forest fires are being suppressed because of the continual logging of the forests and the danger fires pose to humans. Some people argue that clear cutting has the same effect as forest fires, however clear cutting is not as beneficial, as the fires add nutrients to the soil while clear cutting removes much needed nutrients.

Other concerns from forest management are the effects of road construction and the impact of large trucks using them. The effects of tree planting and removal of dead wood from the forest are also of concern because these can have drastic impacts on the regeneration of forests. It is recommended that woody debris be left on forest floors as it provides nutrients, habitat and food sources for many forest organisms and will therefore result in increased biodiversity within the forest ecosystem. Many animals are also affected by certain types of forest management due to the continual destruction of their habitat.

Forest fragmentation is also of great concern. This refers to when forest areas become isolated from one another and are unable to spread seeds between the areas, therefore limiting biodiversity. Fragmentation of habitat also has impacts on wildlife populations because they cannot travel safely or at all between the areas.

Many steps are being taken to protect the biodiversity of forests in both Ontario and Canada. The Ontario Ministry of Natural Resources has produced Forest Management Guides to ensure the protection of Ontario forests and wildlife within the forests. Guidelines have been put in place to protect habitat for many species, such as Moose, Marten, White-tailed Deer, Pileated Woodpecker and Waterfowl. For more information on the Forest Management Guides see http://ontariosforests.mnr.gov.on.ca/guides.cfm. The federal government has also taken an interest in the protection of Canada's forests and has included a chapter on sustainable forestry in the Canadian Biodiversity Strategy.

Sustainable forestry practices mitigate the affects of forest management on biodiversity by considering three main components: the economy, the environment and society (Figure 31). Forest managers look at the social impacts of their operations, such as the destruction of recreational opportunities. They also take environmental concerns into consideration, including the destruction of habitat. Sustainable forestry practices also consider the long-term economic benefits timber can offer. Indicator species are also used, such as beetles, to get a greater understanding of the overall impact on the forest. With the use of sustainable forestry practices, the affects of forest management on biodiversity will be limited.

Figure 31: Example of Sustainable Forestry Practices (Canadian Council of Forest Ministers, n.d.)

There are three main harvesting methods used for timber extraction. Clearcutting, or the removal of an entire stand of trees, results in the highest number of trees removed from an area. The shelterwood system harvests trees in stages over a short time period to allow for regeneration of forests under the shelter of existing trees. The last harvesting method is the selection system, which removes timber as single trees or in small groups. As mentioned previously, forest managers must consider many different factors when determining which harvesting method to use. Different forest ecosystems require different management strategies and therefore must be considered on an individual basis.

Biodiversity in Various Forest Regions

The Hudson's Bay Lowlands

This area contains 20 percent of Ontario's forests. The dominant tree species of this area include stunted tamarack and black spruce. This area contains very little biodiversity as a result of the cold climate.

FORESTRY FACT
Forests and woodlands once covered almost half the global land area, and now cover one quarter of the global land area (Environment Canada, 2006).

Boreal Forest

This area contains 59 percent of Ontario's forests which makes it the largest forest region in the province. The dominant tree species are white and black spruce, tamarack, balsam fir, jack pine, white birch and poplar. Forest fires help maintain biodiversity in this region by creating favourable conditions for new growth many tree species.

Great Lakes-St. Lawrence Forest

This area contains 20 percent of Ontario's forests. Common species found here are eastern white pine, red pine, eastern hemlock, white cedar, yellow birch, sugar and red maple, basswood, red oak, jack pine and white birch. This area is high in biodiversity because it is a transitional zone between the Northern Boreal forest and the Southern Deciduous forest.

Deciduous Forest

This area contains 1 percent of Ontario's forests. Common species found here include black walnut, sycamore and white oak. The biodiversity of this are is poor because early settlers cleared most of the land for agriculture and urbanization is occurring rapidly.

(See Appendix C for common tree species of these regions)

Case Study: Asian Longhorned Beetle

The Asian Longhorned Beetle (*Anoplophora glabripennis*) was first found in Canada in 2003 in the Toronto and Vaughan regions. This insect is native to China and Korea (Figure 29).

The Asian Longhorned Beetle goes through four life stages including egg, larva, pupa and adult. Because of the cold climate of Ontario, it takes two years for the beetle to complete its life cycle. This beetle is often confused with the Whitespotted Sawyer which is a native insect that does not pose a threat to trees in Ontario. The scutellum (the part of the middle segment of the body which you can see from above) is black in the Asian longhorned beetle and white in the Whitespotted Sawyer.

The Asian Longhorned Beetle does not attack conifer trees. The maple tree is one of its favourite species to attack, along with the Horse chestnut, Birch, Poplar and Elm trees. As you can see, this beetle would have a severe impact on our forests if it was not controlled. There are many signs you can look for to see if the beetle is attacking your trees. There would be signs of oviposition pits (area where eggs are laid), frass (excrements from beetle mixed with plant material), hollow bark, cracks in bark, exposed feeding gallery, exit holes, adults feeding, branch dieback and death of tree. You can see some of these signs in Figure 32. When Toronto was looking for this beetle, workers often looked in industrial areas because wooden packaging, such as cargo skids, is what brought the beetles here.

Figure 32: Picture of feeding galleries, exit holes and frass in a tree infested with Asian Longhorned Beetles.
(Ric et al., 2006)

The Asian Longhorned Beetle poses threats to many ecosystem components. Trees offer many things to city life such as cleaning the air, shade, habitat for animals, etc. which would be lost if the beetles killed all the trees. Financial gain from wood products and maple syrup would be lost. Also biodiversity would be affected since trees play a key role in forest dynamics!

In Toronto, to help eradicate this pest the municipal government working with the Canadian Food Inspection Agency (CFIA) did a series of activities. They surveyed trees to determine the areas of infection. They then used containment methods, such as removal of infested trees and reduction in the movement of firewood within southern Ontario, to keep the beetle from spreading. These government agencies also replanted trees to replace the trees that were lost to the beetle.

Case Study: Butternut Canker

Butternut canker (Figure 33) is a disease mostly found on butternut trees but can be found on some other trees in the walnut family (e.g. Black walnut). The disease causes a fungus to grow on the tree and will eventually kill it. 90% of trees in some areas of the United States have been killed by this disease. The first introduction of this disease in Ontario was in 1991. Figure 33 shows the range of Butternut canker in Ontario.

This fungus is very hard to see because it is located under the bark. The fungus causes black cankers that can excrete black sap. The disease starts off at the top of the tree and makes its way down. Rain helps it spread by carrying the spores downward. This disease eventually causes the tree to stop producing nuts and it will end up dying. The disease enters the tree by any openings in the bark such as insect holes, buds and leaf scars.

Some common symptoms you can look for are:

- branches dying at the top of the tree
- shredded bark with calluses
- black fluid oozing from cracks in the bark (mostly happens in the spring)
- below stem and branches that are infected, epicormic branching will occur

Many people are afraid to keep planting butternut trees in the chance that they may get Butternut canker. A lot of people also have the mind set to just kill the tree once it is infected but some trees may become resistant. Many organizations are encouraging people to keep their Butternut trees and report the disease. This will help create a database and establish tolerant species.

Many species will suffer if the Butternut becomes extinct. The Butternut tree is very important to the wood industry as it makes great furniture. The husks of the nuts are also used to make yellow dye. Also, Butternut nuts are a food source for many species of wildlife. If this tree is lost, the biodiversity of the forest will suffer. Habitat and food for animals will be lost. This beautiful tree that is native to Canada and an integral part of forest ecosystems is very valuable to forest biodiversity.

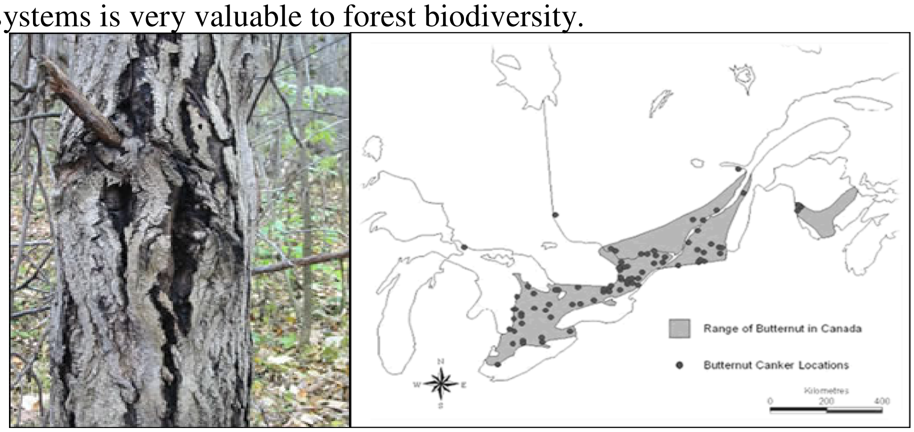


Figure 33: Butternut with Butternut canker and range of trees with Butternut canker (Forest Gene Conservation Association, 2005)

Activity: Measuring Biodiversity in Forests

The diversity of trees within a forest is dependent on many factors. Even within the defined 'forest ecosystem types' there will be different species of trees present due to variations in local climate. For this activity, students will be required to travel to several different forest areas to examine local differences in tree biodiversity.

Materials Required

1. diameter tape
2. Appendix C: Winter Tree Identification Key
3. metre tape
4. 2.5 meter long rope and stake
5. data sheet
6. pencil and paper
7. calculator (or a different random number generator)
8. Trees of Ontario or Trees of Canada book

Instructions

In a group, brainstorm various forest locations that are accessible to the public in your area. Try to include forest ecosystems that will have a variety of species diversity. Within each forest complete the following steps:

1. Before going out the sites, familiarize yourself with steps involved in identifying tree species.
2. For each forest location, record the conditions of the site. For example, write how moist the soil is, the type of ground vegetation (or if ground vegetation is present), etc.
3. Along a trail, use a calculator or random number table to get a compass bearing. Follow this compass bearing for 20m.
4. The point at which you stop will be the center of your plot.
5. Set up a plot with a five meter diameter. Use flagging tape or other markers to set your boundaries.
6. Identify and record the species present and their abundance for each plot.
7. Once back in the lab (or in the field) identify if the species is native or non-native.
8. In each forest location complete five plots to get a representative sample of the tree diversity.

Repeat this procedure for every forest location you can go to. When you return to the lab, compare the different forest ecosystem types based on the diversity of trees found within each one.

To measure the species diversity and evenness you can use the Shannon and Simpson indices. Numerical examples are provided in the "Introduction to Biodiversity" section.

After doing this activity you will have a good idea of the surrounding biodiversity of the area and if non-native species are playing a role in limiting the biodiversity of this area.

$$p_i = \frac{\text{number of individuals of species i}}{\text{total number of individuals in the population}}$$

Shannon index: $H = - \Sigma (p_i * \ln p_i)$

Simpson index: $D = 1 / \Sigma(p_i^2)$

Shannon evenness index: $J = H / \ln(S)$

Simpson evenness index: $E = D / S$

Example of Record Sheet

Date:			
Forest Name:			
Forest Location and Size:			
General Observations and Surrounding Land Use:			
Species	**Number of Individuals in Plot**	**Native**	**Non-Native**
Sugar maple		x	
White ash		x	
European buckthorn			x

Questions for Discussion: Activity

1. How do conditions between the different forest types differ?
2. What are the implications of the different levels of biodiversity within a forest area?
3. How will the differences in tree diversity impact wildlife diversity within the forest?

Questions for Discussion

1. Do you think the Sustainable Forest Management Plan is enough for protecting biodiversity in forests? In no, what else do you think forest managers can do? (http://www.cbppl.com/SFM/locked/SFM%20Plan%20v2.pdf)
2. Forest fires are crucial for the boreal forest region but pose serious threats to human safety. What do you suggest forest managers do to promote a healthy boreal forest without impacting humans?
3. Gypsy moths are frequently transported to different areas by fire wood. Do you think there is a big enough emphasis on the importance of not bringing firewood to other regions? What do you suggest cities do to protect their trees?
4. The spread of invasive trees is almost unstoppable with seeds being transported by birds. Are their any solutions you can think of to stop these trees from spreading?
5. Trees provide many benefits to many ecosystems. Make a list of how trees benefit you in your day to day life.

Soil Biodiversity

Students will…

- Understand how various soil types affect biodiversity.
- Learn the role that soil has in ecosystem biodiversity
- Be able to identify the various soil types
- Understand why different habitats and areas of the province contain different types of soils.

Introduction to Soil

The existence of all life on earth can be traced back to soil and its ability to support millions of forms of life. Soils biotic and abiotic characteristics allow for soil to be used for many functions:

- habitat for invertebrates, microbes, mammals, amphibians and reptiles;
- act as an anchor for hundreds of thousands of plant species;
- provide nutrients to support vegetative growth; and,
- create a foundation for the construction of buildings.

For these reasons, it is important to study and understand the significance of soils role in promoting biodiversity.

Soil biodiversity is defined as the variety of life found in soil, including numerous species of invertebrates and microorganisms, soil flora, plant roots, mammals, birds, reptiles and amphibians. Soil communities are among the most species-rich areas in terrestrial ecosystems. Most of the organisms inhabiting soil ecosystems are found within the top 10 cm of the soil profile. However, there are many factors that influence the diversity of organisms within soil ecosystems.

Soil structure and texture both have impacts on the biodiversity within the soil and the diversity of plants and animals living on the soil. Soil texture is defined by the proportion of sand, silt and clay particles bound together by organic matter. The amount of organic matter found in soil has a large impact on the surrounding biodiversity as it impacts soil fertility, soil structure, workability and water holding capacity. These factors influence the volume and species of plants that are capable of growing in the soil, impacting the wildlife in the surrounding area. There are various classifications for soil texture, for example: loamy sands are soils with a high content of fine sand and silt. To determine soil structure, scientists use the soil texture triangle

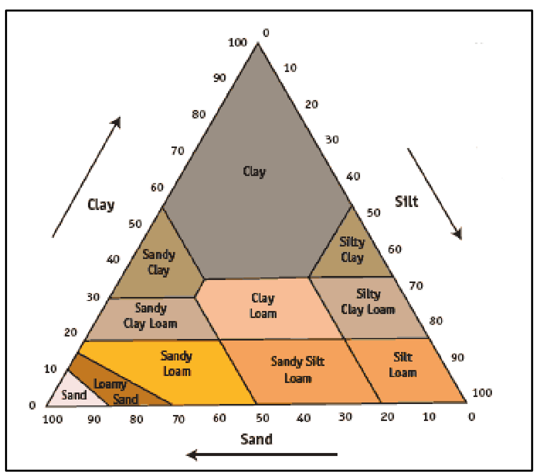


Figure 34: Soil texture triangle
(The Scottish Government, 2005)

(Figure 34). The percentage of clay, sand and silt must be known and the intersection of the three lines coming from the percentage indicates the soil type.

Soil structure is the arrangement of particles in blocks or aggregates within the soil. Soil structure is important because it affects the stability of soil and its resistance to degradation under pressure. Structure is strongly influenced by texture, organic matter, compaction and biological activities. Much like soil texture, soil structure can also impact the organisms living within the soil. Good structure generally means the presence of large pores between particles. Soils with good structure increase water holding capacity, promote root growth, maintain aeration and drainage provide a better habitat for organisms and reduce erosion risk. All of these factors contribute to the biodiversity within and on top of soil. (See the Chapter 3: The Physical Nature of Soils in the Envirothon Soil Module for more information on soil texture and structure).

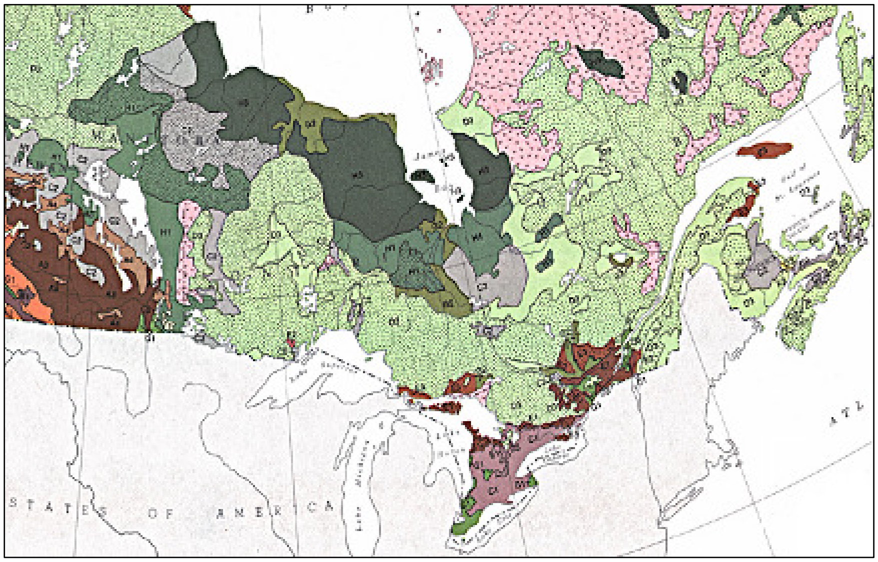
Soil Formation and Variability

The formation of soil from rock can take thousands of years, and for this reason, soil types vary throughout Ontario. There are several main factors that contribute to the formation of soil. Understanding the soil forming factors helps us better understand why soils differ from place to place and how they contribute to different habitat types and support different forms of life.

Soil forming factors:

- Parent material: differences in soil are first evident in the various forms of parent material, as the physical and chemical properties of the parent rock are reflected in the characteristics of soil.
- Climate: climate provides the energy that drives physical, chemical and biological reactions on the parent material. The most significant climatic factors are temperature and moisture.
- Presence of soil organisms: organisms within the soil are responsible for aiding the process of organic matter accumulation and conversion of organic nutrients into mineral matter that can be taken up by plants (discussed in further detail below).
- Relief: relief, the configuration of land in terms of its altitude and slope degree, can change the microclimate and drainage ability of soil and therefore also contributes to soil formation.

Due to the variations in soil formation, all regions in Ontario contain specific soil profiles (Figure 35). These differences in soil characteristics result in differences in habitat type and biodiversity. More information can be found in Chapter 2: The Process of Soil Formation in the soils module. Appendix D outlines the soil types of Canada, their identifying characteristics and where they are commonly found.



Colour	Soil Order
	Chernozemic
	Solonetzic
	Luvisolic
	Podzolic
	Brunisolic
	Regosolic
	Gleysolic
	Organic

Figure 35: Soil Profiles of Ontario. (The Atlas of Canada, 2005).

Biodiversity within Soil

Soil ecosystems are one of the most diverse ecosystems on our planet. However, very few studies have examined the vast diversity of organisms living within the soil. Many organisms make up the diversity of life within soil ecosystems, including invertebrates and microorganisms, soil flora, plant roots, mammals, birds, reptiles and amphibians. The invertebrates and microorganisms make the majority of the biomass in soil communities. These include bacteria, fungi, protozoa, nematodes, mites, collembola, oligochaetes (earthworms), myriapods (millipedes and centipedes), mollusks and insects (ants, termites, beetles). Figure 36 is an example of the feeding relationship between organisms in a soil ecosystem.

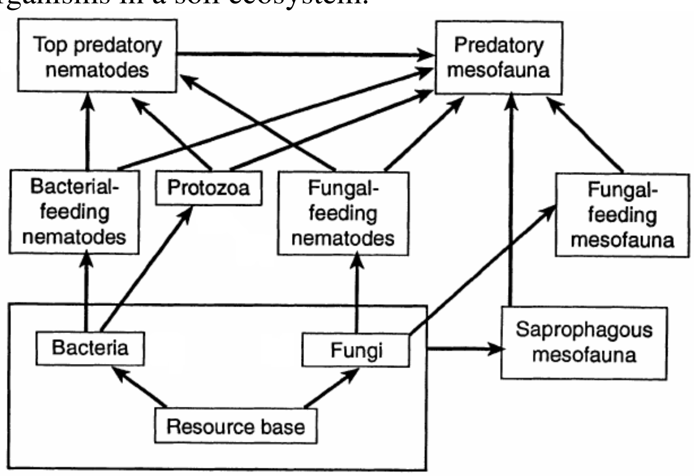


Figure 36: Feeding interactions between the classes of organisms found within a soil community. Arrows show direction of energy flow. (Wardle et al, 1998)

SOIL FACT
Soil biodiversity is extremely important for successful crop production. However, poor agricultural practices can degrade soil quality and promote the loss of topsoil. Agriculture has also resulted in local reductions and extirpations of fauna associated with these lands.

Soil ecosystems with higher levels of biodiversity result in more productive, sustainable communities. These communities are also more resistant to changes in surrounding biotic and abiotic conditions. Increased biodiversity leads to increased redundancy in an ecosystem. High redundancy allows one species to substitute for another, such that functions are continuously achieved, even with the loss of one species. With increased redundancy, soil ecosystems also have higher resistance to perturbations. More diverse systems are also more resilient following perturbations. Resilient ecosystems can withstand shocks and rebuild themselves when necessary. This is beneficial in changing environments.

The vast diversity of species found in soil communities impact soil quality and functioning by providing essential services to the abiotic components of the soil. Table 3 outlines the functions preformed by soil biota and their importance to ecosystem functioning. Due to the extensive functions of soil biota, declining soil biodiversity and its consequences on soil food web interaction processes will have dramatic negative impacts on ecosystem processes, ecosystem stability, community composition and community stability.

Table 3: Soil biota functions that can be used to evaluate the links between diversity and ecosystem function.

Function	**Comments**
Degradation of organic matter	The most obvious function carried out by soil biota. Up to 80% of the organic material fixed by primary producer's flows to the detrital food chain.
Cycling of nutrients	As organic matter is processed, nutrients are released into the environment and become available for recycling back to primary producers.
Sequestration of carbon	Organic residues from decomposition become part of the stable structural carbon pools of terrestrial ecosystems.
Production and consumption of trace gases	As soil biota degrade organic material, recycle its nutrients, and sequester its carbon, they also carry out other functions that are important. Soil microbial activity leads to the production and consumption of a variety of trace gases (carbon dioxide, nitrous oxide, methane, carbon monoxide and sulfur gases), many of which are important greenhouse gases.
Degradation of water, air and soil pollutants	Soil and sediment biota processes (degrade, produce, alter) a variety of water, soil and air pollutants of anthropogenic origin, including pesticides and industrial compounds.
Development and maintenance of physical structure	Soil biota help to produce and maintain the physical structure of terrestrial ecosystems. Organisms are critical agents in soil formation. This role is expressed directly via the burrowing and tunneling activities of fauna and their production of sticky compounds, and indirectly via the production of structural organic matter.

There are several factors that can contribute to the biodiversity within soil. These factors include soil texture, soil structure, abiotic conditions (sunlight, rainfall, wind) and interactions with other organisms. As the knowledge of soil biology increases, the threats to soil biodiversity also become evident. Indirect effects on biodiversity include structural decay, erosion and organic matter decline. These factors influence habitat for organisms within the soil and contribute to biodiversity decline. Direct impacts on biodiversity include contamination of soils through salinization and pollutants. The impact of global change on biodiversity within soil ecosystems is not yet known, however, communities with high resiliency will not be impacted as greatly as communities with low resiliency. Climate change will have impacts on local communities as there is a strong connection between soil formation, soil structure and climate.

SOIL FACT
Earthworms have been known to have lived for as long as six years, but the average lifespan of an earthworm is about 20 months. This soil organism does not have lungs but breathe through its skin. Therefore any soil contamination will have dramatic impacts on local earthworm populations.

Soils Role in Terrestrial Biodiversity

Not only do soil ecosystems contain a vast number of invertebrates and microorganisms, they also impact the terrestrial biodiversity of plants and wildlife. As mentioned above, soil structure influences the water storing capacity, available nutrients and the types of microorganisms present in the soil. All of these factors directly impact the vegetation communities that are capable of growing in the given conditions.

The presence of certain soil organisms directly influences the ability of some plant species to grow due to direct relationships between microorganisms and nutrient availability. For example, the presence of nitrogen fixing bacteria is crucial for the survival of all legume species. Rhizobia, a nitrogen fixing bacteria, chemically convert nitrogen from the air to make it available for uptake by the vegetation. This type of relationship, in which one organism lives on another and is required for the survival of one of the organisms, is referred to as an obligate symbiotic relationship.

As soil structure and biodiversity influences vegetative growth, it also impacts the diversity of wildlife that can be supported in an area. Many animals are insectivores and rely on invertebrates found within the soil for survival. Other animals are herbivores and depend on vegetation for their main food source. Soil structure has the ability to directly influence both the vegetation and wildlife species that are capable of surviving in an area. Figure 37 shows the interactions between soil organisms, vegetation communities and terrestrial wildlife.

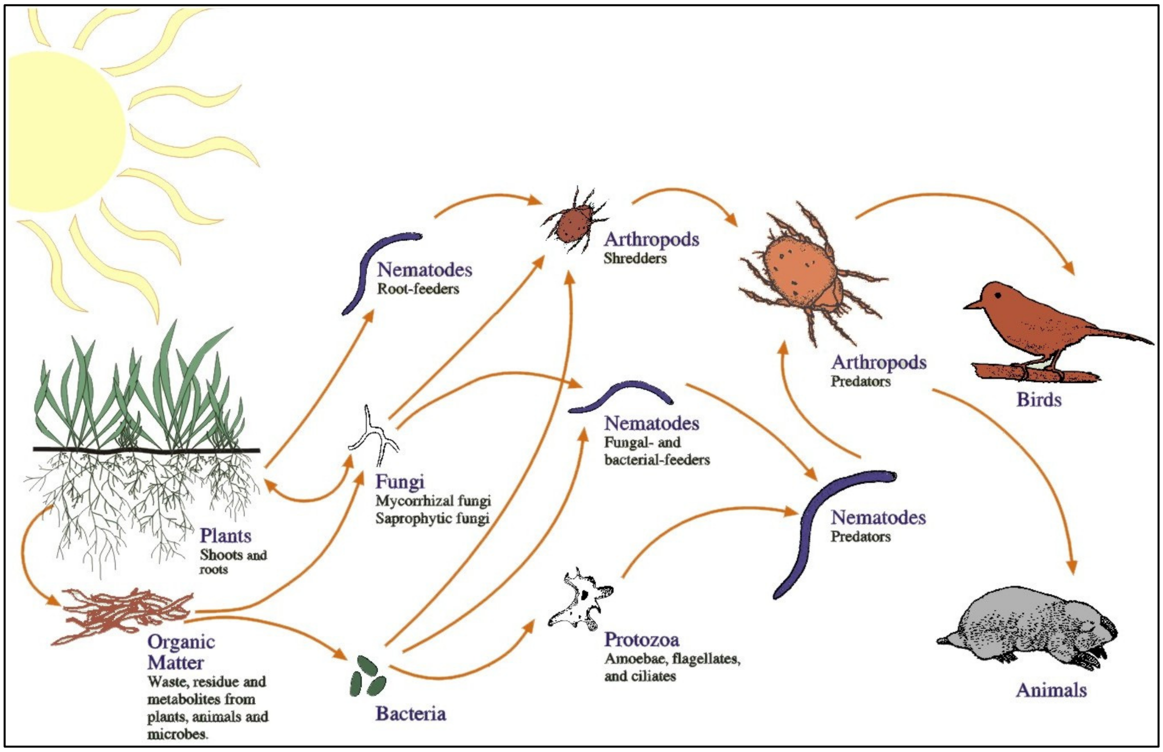


Figure 37: Relationships between soil food web, plants, organic matter, and birds and mammals. (Tugel et al, 1999).

Figure 38: Snapping turtle laying eggs in soil (Jung, 2003)

Soil ecosystems also act as habitat for many fossorial species. Mammals such as voles, mice and groundhogs use soil to create burrows for protection of predators and areas to store food. Amphibians, such as frogs and salamanders use soil as an area to spend their winter hibernation. The snow on top of the soil provides and insulating layer resulting in warmer soil temperatures compared to air temperature. However, with changes in local climate, there is an increase in the fluxes of weather and temperature resulting in negative impacts on these amphibian populations. Soil is also used as nesting sites for some species, such as turtles which travel outside of water in search of sandy soils (Figure 38). The texture of sandy soils allows turtles to dig large holes to lay their eggs. The soil acts as an incubator until the eggs hatch.

Soil Biodiversity in a Changing World

Changes in climate have profound impacts on soil structure. As discussed above, soil structure impacts soil biodiversity. Therefore changes in global climate will result in changes in soil biodiversity. Fluctuations in temperature, moisture and land use changes will directly impact soil organisms. Increased carbon dioxide in the atmosphere will indirectly influence soil organisms through changes in plant communities. Not only will these changes impact the organisms living within the soil, but it will also change the species richness and composition of the organisms that rely on the soil organisms for survival.

Global change will bring variations in organic matter input, increases in atmospheric carbon dioxide, changes in microclimate, land use changes and changes in below ground processes. These changes in biotic and abiotic variables will impact soil structure and therefore soil biodiversity (Figure 39). As mentioned above, these changes will also impact the diversity of surrounding plant and animal communities. Changes in soil structure will have cascading effects on the surrounding communities. For example, if changes in climate result in the loss of one species of nitrogen fixing bacteria, the loss of a plant species that rely on the presence of that bacterium may result. This can then result in the loss of wildlife species that rely on the plant species if their adaptive capacity is limited.

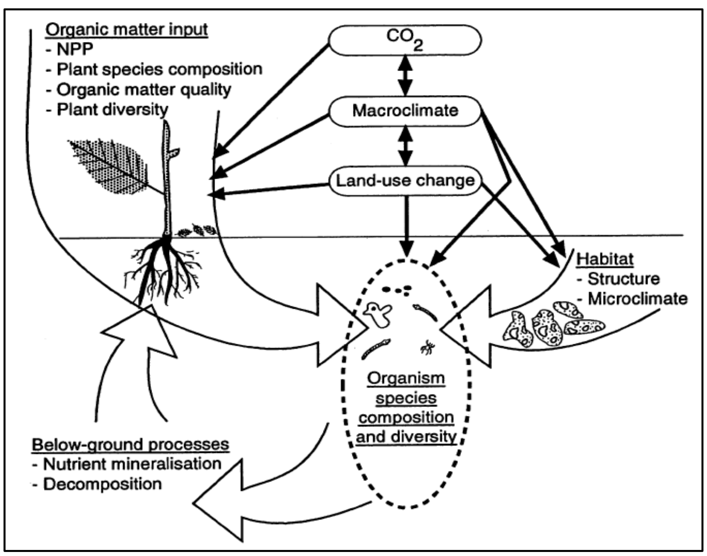


Figure 39: Diagram of relationships of soil biota and plants with global change (Wardle et al, 1998)

Similarly, global changes can have impacts on vegetation communities that can ultimately influence soil biodiversity. It has been predicted that global climate changes will result in diminished quality of organic matter input and shifts in vegetation composition through changes in carbon dioxide levels. Changes in the quality of organic matter input will influence organisms that are active in decomposition of organic matter, such as fungi. Changes in vegetation boundaries will result in some plant species inhabiting areas that were previously inhabitable. Unlike plant species, the limited capacity of soil microorganisms to migrate could result in changes in the functional composition of soil communities. Shifts in plant communities could strongly influence processes such as decomposition and nutrient mineralization through regulation of soil organisms. To fully understand the impacts of a changing environment on soil biodiversity more research must be focused on the impacts of changing conditions on soil communities.

Case Study: Biodiversity in Soil: The Ground Beetle

To demonstrate the vast diversity of invertebrates found within soil ecosystems, this case study will examine the presence of ground beetles (Family: Carabidae) in Ontario. In Ontario, there have been reports of up to 3800 species of beetles. Ground beetles account for nearly 15 percent of all beetles in Ontario, with approximately 500 species. This family of beetles lives on the soil surface, occupies every habitat (forest, meadow, mountain, bog and sand dune) and varies in size between 1.5 and 30 mm.

Ground beetles are mostly opportunistic predators, eating various forms of soil biota, both on and below the soil surface. In agricultural systems, the presence of ground beetles helps to reduce the number of other, possibly destructive, invertebrates. For this reason, these beetles have been used as a form of pest control. Studies have shown that high ground beetle populations indicate a healthy ecosystem.

One subfamily of the ground beetle, the tiger beetles (subfamily: Cicindelinae) has 14 species found within Ontario. Ten of those 14 species are relatively widespread and common throughout Ontario. However, the remaining four species are rare and their occurrences have been tracked by the Natural Heritage Information Centre.

The Beach Dune Tiger Beetle (*Cicindela hirticollis*) is a ground beetle species that inhabits in sandy beach and dune areas (Figure 41). It is one of the most widespread beetle species occurring across Canada, the United States and Mexico. Historically, this species was reported to be common in Ontario; however, there have been relatively few observations of this species along its proposed habitat, along the sandy shores of the Great Lakes and large rivers. Recent searches for this species along these habitats have proven unsuccessful indicating that this species may have disappeared from most previously documented sites. The cause of the decline is not yet known, however increased use of these areas by humans may have contributed.

The ground beetle is just one example of an invertebrate that lives in close association with the soil. Soil texture and structure impacts the fauna of ground beetles as well as the forms of microorganisms that will be found in a community. Ground beetles rely on other invertebrates within the soil as a food source and they themselves are a food source for insectivorous mammals. The eggs of ground beetles are laid in the soil and the larva lives in the soil until its adult stage. Therefore the soil plays an important role in the life of a ground beetle and small changes in soil structure or type could have large impacts on the survival of ground beetles.

Figure 40: Image of a Beach Dune Tiger Beetle (Nova Scotia Museum of Natural History, 2001)

Case Study: Bioremediation – The Use of Soil Biota in Environmentally-friendly Treatments for the Decontamination of Soils

As discussed in this section, soil contains a vast diversity of microorganisms, some of which function to 'clean' the surrounding soil. Bioremediation is the process that uses microorganisms, fungi, green plants or their enzymes to return an environment altered by contaminants to its original condition. The goal of bioremediation efforts is to "reduce the potential toxicity of a chemical contaminant in the soil by using microorganisms to transform, metabolize, remove or immobilize toxicants" (UNEP 2001). Bacteria and fungi found within soil are nature's recyclers. They have a capability to transform natural and synthetic chemicals into sources of energy and raw materials for their own benefit.

Soil bioremediation is most commonly used at sites in which pollutants have been released or spilled. The rate at which microbial communities adapt their metabolism to toxic compounds is crucial in bioremediation.

In Ontario, uranium mining has contributed a great deal to water and soil contamination. Soil properties that affect uranium mobility and uptake by biota include aeration, carbonate content and cation exchange capacity. Acidic soils with low absorptive potential, alkaline soils with carbonate minerals and the presence of citric acid increase mobility and plant accumulation of uranium.

Microorganisms can degrade soluble organo-uranium compounds in soil using carbon and energy. Scientists have recently discovered a bacterium that can sequester or reduce uranium in soil, *Geobacter metallireducens*. Fungi (*Asperigillus ochraceus* and *Penicillium funiculosum*) were also able to take up large amounts of soluble uranium. Bioaccumulation of uranium in soil invertebrates has not been significant in any studies to date.

Only a small number of microbial organisms capable of bioremediation in soil communities have been identified. Extensive research is required to identify the best microorganisms for all contaminants. This knowledge is helpful when understanding the ability of soil to maintain a biological buffering barrier for pollution. However, scientists must also focus on any long-term impacts that bioremediation will have on the surrounding abiotic and biotic soil components.

Activity: Measuring Soil Biodiversity

Soil biodiversity can be measured in any area containing soil. This activity involves students going to areas with various landscapes (man-made fields, forests, meadows, etc.) and measuring the soil biodiversity. Collecting data in areas with differing land uses provides data for comparison of soil biodiversity. Collecting soil at various depths and comparing the biodiversity of organisms at each depth is also interesting.

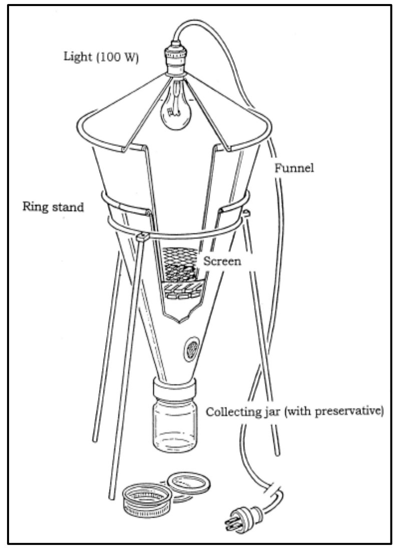


Figure 41: Berlese-Tullgren funnel (Ministry of the Environment, 1998)

Materials Required

1. Shovels
2. Plastic bags
3. Meter stick
4. Marker
5. Berlese-Tullgren funnel or funnel and beaker
6. Light source
7. Preservative
8. Invertebrate identification key
9. Dissecting scope or hand lens
10. Pencil
11. Calculator

Instructions

1. At each site, collect samples of soil using shovels for digging and plastic bags for collection. Try to collect soil samples at the same depth at each site for comparison, or if you want to compare the biodiversity of organisms at various depths in one site, remove the first sample at the first layer of soil.
2. Make sure you mark all samples with a description of the site and the depth the soil was collected at. Samples should contain approximately the same volume of soil.
3. Bring the soil samples back to the lab and place the soil in Berlese-Tullgren funnels (Figure 40). These funnels extract microarthropods from soil samples. Berlese-Tullgren funnels can be purchased from Carolina Biological Supply (www.caronlina.com) or they can be made using lab components – i.e. funnel supported by beaker filled with preservative.
4. Use a light source to drive invertebrates to the bottom of the funnel, where they will fall into alcohol or another preservative. Each sample should be approximately the same amount of soil, so they each sample represents equal volumes of habitat. These samples should be left for at least 3-5 days.
5. Once all of the invertebrates are collected in the preservative, students can begin identifying the soil biota using dissecting microscopes. Identification only needs to be down to class or order for non-insects and to order for insects. Identification should be done using a dichotomous key provided by the teacher.
6. Record the abundances in each sample by counting the total number of each taxon.

There are two main measures of biodiversity. The first is species richness. Species richness is the number of individuals of each species in a given area. This is determined by adding up each species or taxa found in each sample. However, the greater the sample size, the more species you are likely to find.

Species evenness is also a diversity index. It measures biodiversity by quantifying how equal the communities are numerically. Species evenness is calculated using Shannon's Index, H'. This measurement is advantageous because it corrects for sampling effort. Rare species contribute very little to species evenness.

Shannon's index:

$$\boxed{H' = -\sum_{i=1}^{S} p_i \ln p_i}$$

p = the proportion of all observations in the i[th] species category
S = the total number of species

Shannon's index is unitless, however, the higher the value, the higher the species diversity. For a quick calculation, many websites have Shannon's Index Calculators in which the species name and the number of species for each group can be inputted and the species richness and Shannon's Index can be calculated (See: http://monticello.bc.edu/uei/sh_weave.php).

Compare the diversity of soil biota found in each habitat type or at each depth of soil.

Example:

	Number of Individuals	
	Community A	Community B
Species 1	98	33
Species 2	1	33
Species 3	1	34
Total	100	100

Community A

$$p_i = \frac{\text{number of individuals of species i}}{\text{total number of individuals in the population}}$$

Species 1=98/100=0.98
Species 2=1/100=0.01
Species 3= 34/100=0.34

Shannon index: $H = -\Sigma\,(p_i * \ln p_i)$

H= -[(0.98*ln0.98)+(0.01*ln0.01)+(0.01*ln0.01)]
H= -[(-0.0198) + (-0.0461) + (-0.0461)]
H= 0.112

Community B

Species 1 = 33/100=0.33
Species 2= 33/100=0.33
Species 3=1/100=0.01

H=-[(0.33ln0.33)+(0.33ln0.33)+(0.34ln0.34)
H=-[(-0.333) + (-0.333) + (0.367)]
H= 1.033

Questions for Discussion: Activity

1. Where did the class find the highest biodiversity? Why do you think it was found in this habitat type/depth?
2. What factors contribute to the differences in biodiversity at each site/depth?
3. How does the diversity of organisms impact the surrounding wildlife in these areas?

Questions for Discussion

1. What direct effects are soil invertebrates likely to have on large animal food chains?
2. The composition and biodiversity of soil organism may have a greater affect on litter decomposition than previously recognized. In what ways can changes in the soil invertebrate community affect litter decomposition?
3. How does soil biodiversity change between seasons? Will you have the same diversity of organisms in the summer and in the fall?
4. How does soil biodiversity impact local agriculture? What would the impacts of changing biodiversity due to changing climate have on agriculture?

Wildlife Biodiversity

Students will…

- Be able to identify signs of wildlife using an animal tracking guide.
- Understand the biodiversity of wildlife in the various regions of Ontario.
- Learn about invasive species and the role they play in Ontario's biodiversity.
- Learn how wildlife management has affected Ontario's wildlife biodiversity.
- Understand the role of each species and the effects on the ecosystem when biodiversity is limited.
- Understand why animals become extirpated and extinct and provide examples.

Wildlife Biodiversity Across Ontario

Hudson Plains Region

This area covers the most northern part of Ontario. It is very cool here, and much of the land is wetland. Vegetation types range from sparse sedges and lichens to open forest in the more southern areas of the ecozone. Because much of this area is wetland, migratory waterfowl such as Canada geese, snow geese, and king eider ducks can often be found here. Smaller mammals such as weasels and muskrats are the most commonly found wildlife, but larger mammals such as moose and black bear are also present. Due to the relatively unfavourable living conditions in this northern ecozone, the level of biodiversity is not very high.

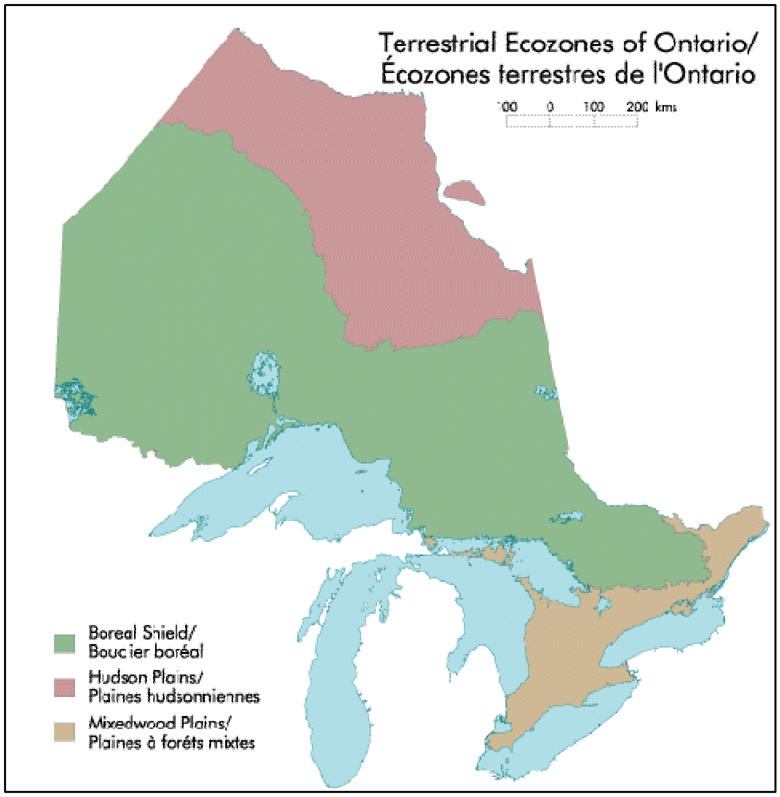


Figure 42: Map of Ontario displaying Terrestrial Ecosystems (Environment Canada, 2005)

Boreal Shield Region

This region covers the majority of the landmass in Ontario. It is characterized with short warm summers and long cold winters. Much of the land is forested with coniferous trees, and mammal species that can be found here include black bears, wolves, raccoons, white-tailed deer, and bobcats. This area is also adorned with many freshwater lakes, so it is a prime attraction for masses of waterfowl in the spring such as ring-necked ducks and buffleheads. Other birds that are native to this area include white-throated sparrows, great horned owls and evening grosbeaks. Due to its more diverse landscapes and relatively few human settlements, the Boreal Shield has a high level of biodiversity.

Mixedwood Plains Region

This is the smallest eco-region of Ontario, but has the most fertile soils, abundant precipitation and favourable climate conditions. These reasons are why most of Ontario's human population lives in the Mixedwood Plains region. Human impacts such as urbanization and agricultural development have (for the most part) negatively impacted biodiversity in this area. In fact, over half of the animals on Canada's species at risk list are native to this ecozone. Larger mammals such as black bear and white-tailed deer are present here, but in lower numbers than in areas further north. Smaller, more opportunistic mammals such as raccoons, grey squirrels, groundhogs and skunks have found ways to survive and sometimes flourish in more urbanized areas. Because human influence has simplified the once complex food webs in this region, the biodiversity here is significantly lower than that of the rest of the province.

Role of Species and Limited Biodiversity

There are certain essential roles that organisms play in an ecosystem. There must be a reasonable balance of species in each of these roles for an ecosystem to be considered healthy. The following table shows examples of species in each of these major roles, and how they are connected.

Table 4: Roles of different species in biodiversity

Species Role	**Decomposers**	**Scavengers**	**Prey**	**Predators**
Examples of Species Types	• Insects • Worms • Bacteria • Micro-organisms	• Birds • Rodents • Some mammals • Some reptiles	• Songbirds • Rodents • Reptiles • Amphibians • Ungulates	• Mammals • Birds of • Prey • Reptiles • Amphibians
Role in Ecosystem/ Biodiversity	• Breaking down fine dead organic matter to replenish the soil • Can act as indicators of biodiversity and ecosystem health	• Consuming carrion in greater quantities • Reduces chances for spread of disease • Speeds up decomposition	• Primary consumers, provide food for predators • By feeding on vegetation, maintains ecosystem and creates habitat	• Secondary consumers • Keep prey populations in check • Occupy top level in food chain • Representative of biodiversity and ecosystem health

Biodiversity in Ecosystems

An ecosystem that is considered to have a high level of biodiversity will exhibit complex food webs with a variety of species. Typically, these systems will include a wide variety of plant species, more herbivore or prey species and two or three top carnivore species. An ecosystem with lower biodiversity will contain less species all together, and therefore a food web which is less complex. Generally, it will have less primary producers, fewer herbivorous species, and one top carnivore species.

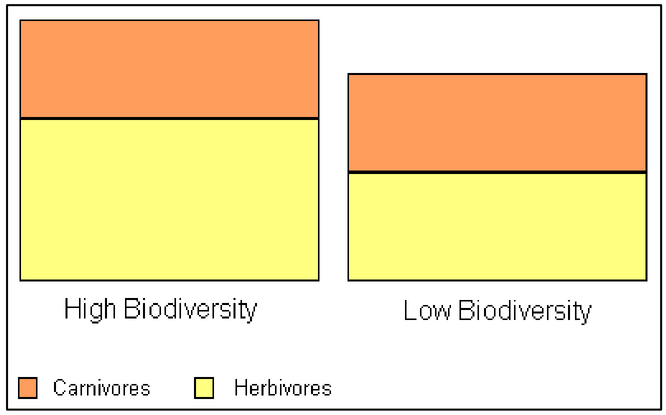


Figure 43: Bar graph exhibiting the relationship between carnivore and herbivore species and how it relates to biodiversity.

Different types of ecosystems naturally have different levels of biodiversity dependant on factors such as geographical location, land types, climate, etc. For example, a marsh ecosystem will have a much higher biodiversity than that of a desert.

It isn't necessarily negative when an area naturally has lower biodiversity. However when the biodiversity and health of an ecosystem that is naturally high is reduced by human influence, the outcome for that ecosystem can be disastrous. Some ways that humans can negatively impact biodiversity are:

- Habitat degradation (e.g. by pollution, alteration, human presence, etc.)
- Habitat fragmentation or reduction
- Introduction of aggressive alien species
- Removal of keystone species

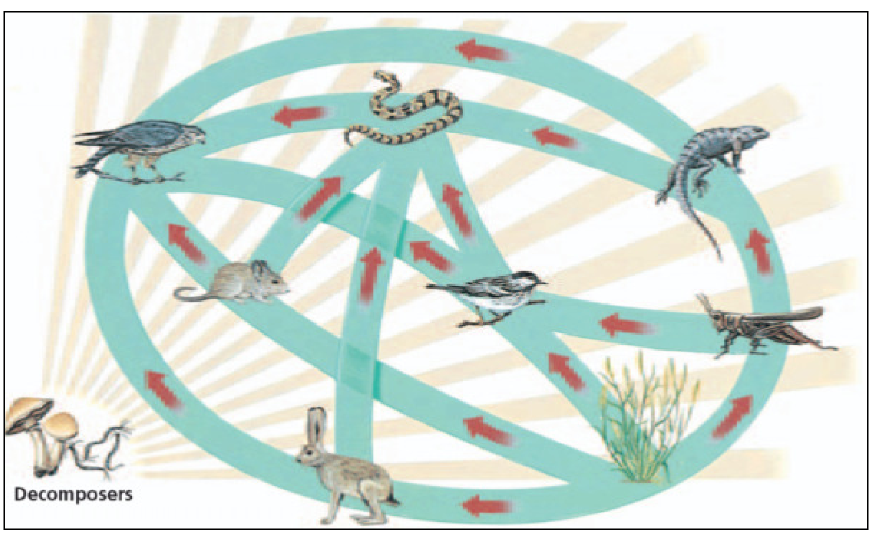


Figure 44: Image depicting a healthy food web found in grassland or field ecosystems (Castleford School, 2007)

Alien or Invasive Species and Biodiversity

An "alien" species can be any kind of organism that establishes itself in an area where it would not be found naturally as a result of intentional or unintentional human activities. This includes species from other countries and provinces, but can also be species that have moved from one region of Ontario to another. An alien species becomes invasive when its population increases too aggressively and quickly for the invaded ecosystem to be able to adjust. Invasive species pose a threat to the delicate balance of an ecosystem, and can cause harm not only to the environment, but also the people whose economy or health depend on it.

<u>Effects of Invasive Species on Biodiversity</u>

As we know, an ecosystem with good biodiversity will include a wide range of species playing various important and interactive roles that keep the ecosystem functioning in a healthy way. An invasive animal can threaten biodiversity by aggressively out-competing one or more native species in an ecosystem, causing them to move out of their own natural range (see extirpation), or to simply die off. Invasive species do this by taking over the native species habitat, food, water or other essential resources. Most often, species that are most effected are specialists who require very specific ecological conditions to survive.

The Brown-headed Cowbird is an example of a historically non-native species to Ontario that can cause population decline of sensitive birds with small populations such as the Kirtland's Warbler and Black-capped Vireo. The cowbird is a brood parasite which means that it does not make its own nest, and instead lays its eggs in the nests of other birds. The unsuspecting mothers then hatch and raise the cowbird young as their own. Newly hatched Brown-headed Cowbirds have also been known to push the eggs that belong to the mother bird out of the nest. If the mother's eggs do hatch, the cowbird young tend to be more aggressive in feeding, and often the other young do not survive. Human activities such as expanded agriculture, the creation of transportation corridors, and deforestation are all factors that have aided in the spread of the Brown-headed Cowbird as a species.

Figure 45: Mature Brown-headed Cowbird (Marie Read, 2003)

Figure 46: Young Brown-headed Cowbird (left) gaping for food in the nest of a host (US Regents, 2004)

Examples of Invasive Wildlife

The following chart gives a few examples of invasive wildlife in Canada.

Table 5: Examples and information about invasive species in Canada

Common Name	**Scientific Name**	**Region of Invasion**	**Native Range**	**Origin of Invasion**	**Negative Impacts**	**Control Methods**
European hare	*Lepus europaeus*	Southern Ontario	Germany	Escaped from a single farm	- Damage to agricultural crops - competes with eastern cottontail for food and habitat	None
White-tailed deer	*Odocoileus virginianus*	P.E.I., Nova Scotia	Eastern North America	Introduced for recreational hunting	- overgrazing and crop damage - vector for parasites of native hoofed species - danger of vehicle collisions	Hunting
Nutria (rodent)	*Myocastor coypus*	Ontario, B.C.	South America, southern U.S.	Introduced for farming and fur production	- explosive populations during the summer - forage heavily on wetland plants, habitat alteration - aggressive competition with muskrat	Does not survive well through the winter
Red-eared slider (turtle)	*Trachemys scripta*	Southern Ontario, B.C.	South-eastern U.S.	- Intentional release - escape from pet trade	- Low threat - Competes with native species for food and habitat - Can carry salmonella	Cold Winters
Eurasian tree sparrow	*Passer montanus*	Ontario and Quebec	Europe and Asia	Intentional release in 1870 to control insects and aesthetic reasons	- Generally minimal - Some competition with native species	None
European starling	*Sturnus vulgaris*	North America	Europe and Asia	Intentionally released in 1890 by an individual trying to introduce all birds mentioned in the works of Shakespeare	- Predates on eggs and hatchlings of native birds - Competition for habitat - mostly naturalized	None

Wildlife Management and Biodiversity

The proper management of wildlife becomes an increasingly important issue as the severity of threats to biodiversity such as invasive species, habitat loss, and climate change increase as time goes on. The most common method of wildlife management is conservation. This can range from little to no human interaction (sometimes called preservation) to full management measures such as seasonal hunting and other methods of population control. Deciding what degree of wildlife management is most appropriate for an area depends on certain factors involving the environment, the economy, and society.

The title "Wildlife Manager" or "Conservation Officer" applies to a person whose job is to monitor the natural environment, specifically wildlife populations and health. When necessary, wildlife managers will take measures with different degrees of involvement to influence wildlife populations causing them to either increase, decrease, or remain the same.

Degree of Involvement

Some key factors to consider when deciding the degree of involvement to employ in conservation wildlife management are:

- The carrying capacity of the ecosystem
- The arrangement of wildlife needs such as food, water, shelter and mates
- The size and type of habitat required by wildlife
- Factors that influence wildlife mortality such as disease, invasive species, human encroachment

As was previously mentioned, preservation is at one end of the scale of conservation. Preservation involves very little to no human involvement in the natural system. Ecosystems are left to exist as they would naturally, and human access is strictly prohibited. The practice of preservation is often used when dealing with sensitive species and ecosystems that do not do well in situations that involve human disturbance.

In situations where more human involvement is needed, action can be taken to alter the population of a target species. When the population of a species grows beyond the carrying capacity of its environment, there are many negative effects on the ecosystem such as limited food and habitat, starvation, extirpation, and increased incidence and spread of disease. This can lead to a larger population of unhealthy animals, and the likelihood of environmental degradation. Some major conservation practices that can be used to reduce population sizes that are exceeding the carrying capacity of an ecosystem are hunting, trapping and fishing. On the other hand, there are some situations where a species population is in decline due to events such as overhunting, loss of habitat, disease epidemics, or severe climate. Some ways to recuperate a species whose population is in decline are by limiting hunting, fishing and trapping practices, as well as supplemental feeding or emergency feeding, or habitat restoration.

Outcomes of Wildlife Management

Wildlife reserves are a good example of what wildlife managers establish in circumstances where a natural area and its inhabitants need to be protected. These areas can also vary in degree of protection, but most do not allow hunting or trapping, and are sometimes used for scientific study.

Another possible outcome of wildlife management that should be taken into consideration is that reducing or increasing the population of a certain species can also affect the populations of other species that occupy the same food chain or habitat. For example, if the population of a prey species is drastically reduced, it is possible that its predators will suffer, while another prey species that shares the same food source or other habitat requirements may flourish. When a species has been completely lost due to the absence of another species, it is referred to as "coextinction". Species connectivity is an important relationship that directly influences biodiversity.

The goal of wildlife management is sustainability. Wildlife managers know that the preservation of biodiversity is directly related to sustainability, and therefore that it is in their best interests to do what is required to retain biodiversity where possible.

Wildlife Conservation Agencies

Ministry of Natural Resources Conservation (MNR, Ontario)
The MNR protects natural resources in Ontario from degradation, pollution and abuse through interaction with the public and law enforcement. Their efforts cover program areas such as Fish and Wildlife, Forestry, Lands/Waters, Species at Risk, Petroleum, Parks, Agriculture, Fire and Aggregates.

Canadian Wildlife Service Ontario Region (CWS, Environment Canada)
The CWS is a federal organization that works with the MNR in wildlife management. Wildlife matters that are the responsibility of the Canadian Government include: "protection and management of migratory birds, nationally significant habitat and species at risk, as well as work on other wildlife issues of national and international importance." Various research and incentive programs are also carried out by the CWS.

Figures 47: Logos for MNR (top) and CWS (bottom). (MNR, 2007)

Extirpation and Extinction

There are many threats and dangers to wildlife in any area. Different stresses within ecosystems – both natural and anthropogenic can result in devastating effects on wildlife populations. Natural disturbances such as forest fires, tornados, floods and droughts can impact the reproductive success and the survival of many species. Changes in global systems are also having impacts on local wildlife by influencing cycles and changing ecosystem functions. Many species rely on specific patterns, such as day length, temperature and precipitation as reproductive signals to start searching for a mate, and changes in these patterns result in decreased reproductive success and potentially the loss of a species. Human induced stresses, such as habitat loss, resource extraction and extensive harvesting of a species or of a food source can also result in reduced survival of a species. Wildlife managers attempt to control the amount of pressure placed on a species through hunting permits and legislation, however reduced wildlife populations due to over harvesting are common in many parts of North America.

The loss of a species from a geographical area can be classified into two areas: extirpation and extinction. Extirpation is the elimination of a species or subspecies from a particular area, but not from its entire range. In Ontario, there are 11 species of animals and plants that are extirpated from their Ontario range. In contrast, extinction is the elimination of an entire species from the entire earth. In Ontario there are 181 species at risk of being extinct (Table 6). This is the highest number of at risk species in any of the Canadian provinces or territories. Table 6 outlines both the extirpated and extinct species in Ontario.

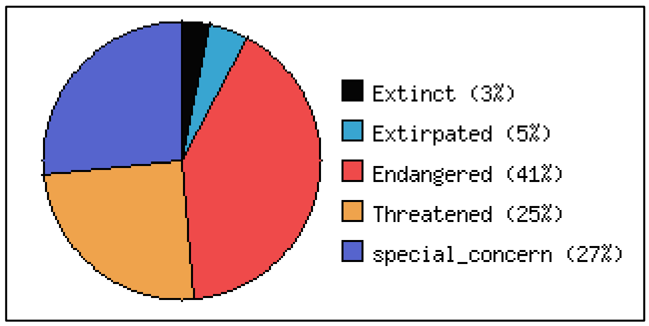


Figure 48: Species at Risk in Ontario (ROM)

Table 6: List of Extirpated and Extinct Species in Ontario (ROM)

Class	Common Name	Scientific Name
Extirpated Species		
Amphibians	Spring Salamander	*Gyrinophilus porphyriticus*
	Tiger Salamander	*Ambystoma tigrinum*
Birds	Greater Prairie Chicken	*Tympanuchus cupido*
Fish	Gravel Chub	*Erimystax x-punctatus*
	Paddlefish	*Polyodon spathula*
	Shortnose Cisco	*Coregonus reighardi*
Plants	Blue-eyed Mary	*Collinsia verna*
	Illinois Tick-trefoil	*Desmodium illinoense*
	Incurved Grizzled Moss	*Pytchomitrium incurvum*
Extinct Species		
Birds	Passenger Pigeon	*Ectopistes migratorius*
Fish	Blackfin Cisco	*Coregonus nigripinnis*
	Blue Pike	*Stizostedion vitreum glaucum*
	Deepwater Cisco	*Coregonus johannae*
Mammals	Eastern Elk	*Cervus elaphus canadensis*
Plants	Macoun's Shining Moss	*Neomacounia nitida*

Table 7: Species at risk of extinction in Ontario (COSEWIC 2006)

Number of Species	Level of Risk
6	Extinct
9	Extirpated
78	Endangered
47	Threatened
49	Special concern
189	Total

In Ontario, the Endangered Species Act is the main Provincial legislation protecting wildlife that has been classified as at risk of extinction. The Endangered Species Act provides broad protection provisions for species at risk and their habitats, enhanced support for volunteer participation from private landowners and partners, a greater commitment to recovery of species and effective enforcement provisions. This new piece of legislation includes stronger protection measures for species at risk and their habitats and the creation of stewardship programs for the purpose of promoting stewardship to assist in the protection of species at risk.

The Species at Risk Act (SARA) is Federal legislation that has been developed to ensure the national protection of any species at risk of extinction. The purpose of this act is to "prevent Canadian indigenous species, subspecies and distinct populations from becoming extirpated or extinct, to provide for the recovery of endangered or threatened species, and encourage the management of other species to prevent them from becoming at risk" (SARA 2007). Within SARA, the legal protection of wildlife species and the conservation of their biological diversity are outlined. The Act also established the Committee on the Status of Endangered Wildlife in Canada (COSEWIC) to assess and identify species at risk in Canada.

As mentioned above there are several causes for a species to become extirpated or extinct. Five main causes for extirpation and extinction are listed below.

1. Genetic and demographic phenomena
    - Most common in small and isolated populations
    - Reduced genetic diversity within a population
2. Genetic pollution
    - Increase in reproduction with other species resulting in hybridization
    - Leads to the development of new species and the extinction of old
3. Habitat degradation
    - Reduction in the quality or quantity of a habitat
    - Increased toxicity or contamination of habitats
4. Predation, competition and disease
    - Introduction of predators and competitors will result in decreased population numbers
5. Coextinction
    - The loss of one species results in a corresponding loss in another species

Changes in the global climate have resulted in some species increasing their geographical range. This has resulted in increased stress for species with limited ranges due to the increased in competition. Global warming has also reduced the ranges of species living in extreme environments. For example, animals living in extremely cold environments have fewer habitats.

The extirpation or extinction of a species can have cascading effects on the surrounding ecosystem. Ecosystems are highly complex systems that contain extensive connections to all forms of life. The removal of one of these forms of life from the ecosystem can result in alterations in natural cycles or can result in the further loss of species. The loss of one animal, such as an herbivore, can have dramatic impacts on the vegetation, other herbivores and carnivores within the ecosystem. The vegetation that was consumed by the now extinct species will thrive due to a reduction in predation. Similarly, other herbivores may increase in numbers due to reduced competition for food sources or habitat if there was an overlap in the two species ecological niches. Unlike herbivores, any carnivores that consumed the extinct species will have reduced food sources and will therefore have increased stress and may result in a decline in the population. This is referred to as coextincton. Changes in one component of an ecosystem, such as the removal of a species, can result in impacts on all levels of the system.

Example of Extinct Species: The Eastern Elk

Figure 49: The Eastern Elk (ROM)

The Eastern Elk was a subspecies of the American Elk which became extinct in the late 1800’s. This species grazed on grasses in the summer and browsed on twigs and shrubs during winter months. This species of Elk was found across most of the northern hemisphere, however the subspecies was found mostly in Quebec and Ontario.

The main threats that caused the extinction of this subspecies included overharvesting and loss of forest habitat. Extensive hunting for the collection of their antlers and teeth used in necklaces contributed to their decline.

Example of Extirpated Speices: The Tiger Salamander

Figure 50: The Tiger Salamander (ROM)

The Tiger Salamander is now ranked extirpated in Ontario. There have not been any sightings of this species since the 1950's when specimens were collected from Peelee Island. Currently the species is found in the prairies and in British Columbia and is widespread in the United States (Figure 51).

The main threats for this species include water pollution, fish stocking of lakes and disease. Pesticide runoff into lakes and ponds is known to impact the development and survival of many salamander species. Fish predation has been known to impact the survival of this species in deep lakes or pond. Viral diseases are known to have caused die-offs in Tiger Salamander populations in Manitoba, Saskatchewan and some U.S. regions.

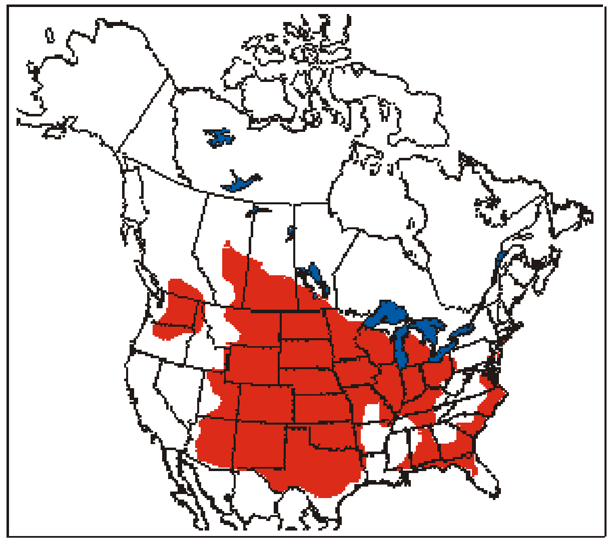


Figure 51: Current range of the Tiger Salamander (ROM)

Case Study – The Nutria

Figure 52: Nutria (NTA, 2005)

The nutria is a large, semi-aquatic rodent native to South America (Figure 52). They were first imported to North America in the 1930's when they were brought to Louisiana to establish a fur farming industry. It is not known if they were released intentionally or accidentally, but it was quickly realized that the nutria was well adapted to life in the costal wetlands of Louisiana.

They have since spread across the United States, causing severe damage to wetland ecosystems. The nutria has very recently been reported to have entered Ontario, giving resource managers a cause for concern. This species feeds on wetland vegetation at an alarmingly fast rate, and has been known to completely wipe out entire vegetated areas.

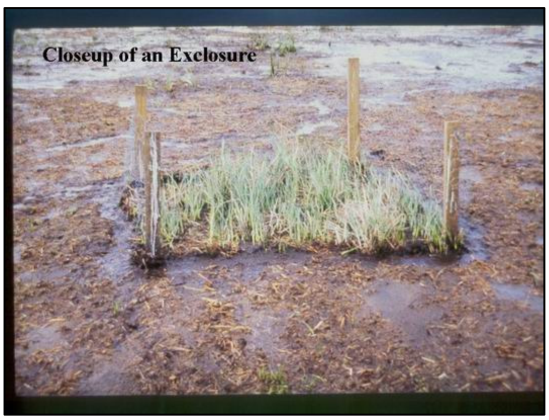


Figure 53: An enclosed area shows the different between areas affected by Nutria and protected. (LDWF, 2007).

The nutria is similar in biology and niche to the muskrat, which is native to Ontario wetlands. Another concern surrounding the invasion of the nutria is that muskrat populations may suffer, due to increased competition for food and habitat space. Nutria are also known to have a tendency to over-harvest their preferred foods, reducing available food sources for other wildlife and damaging the productivity of vegetation stands (Figure 53).

Nutria pose a threat to other wildlife species and humans through parasites that they carry. These parasites are released into the water where nutria swim, and can then be transferred to other wildlife. Humans are affected by these parasites by something called "nutria itch", which results from swimming in waters contaminated with parasites from nutria.

Scare tactics such as loud noises and water sprays have proven to be effective short-term deterrents, however the animal will most often return in the future. Baited live traps can also be quite effective to reduce population numbers. Figure 54 shows the tracking and scat of nutria.

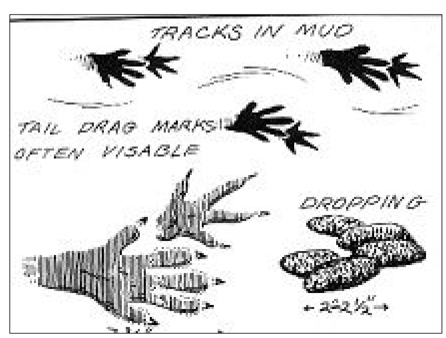


Figure 54: Nutria Signs (NTA, 2005)

Activity: Animal Tracking

This activity is best performed within a day or two of a fresh snowfall. Tracking can be done anywhere from a school yard, tree stand, open field, a park or even your own back yard!

Materials Required

1. A Ruler
2. The Envirothon Tracking Guide
3. Binoculars (optional)
4. A Camera (optional)
5. Warm clothing

Instructions

Take a walk in the area of your choice. Use your keen observation skills to spot any tracks, sign or scat along the way. Your ruler may come in handy to identify tracks or scat of similar species such as grey squirrel and red squirrel tracks, or eastern cottontail and white-tailed deer scat. You may use binoculars to spot things like nests or wildlife that may be found in treetops. You might also want to use a camera to document your findings for future reference or for further research as some signs of wildlife are more difficult to identify than others.

NOTE: It is very important that scat is not handled during identification. Wildlife scat can harbour bacteria and other harmful things that can make a human very sick.

Questions for Discussion

1. Explain the differences between the three terrestrial ecozones of Ontario.
2. Describe the differences between an ecosystem that is considered to have high biodiversity and one with low biodiversity and how humans play a role in that.
3. What are the differences between an alien species and an invasive species?
4. Generally speaking, how do invasive species affect biodiversity?
5. What is a Nutria? Is it beneficial or detrimental to Ontario? Why?
6. What effects do wildlife management practices have on wildlife?
7. Explain the differences between extirpation and extinction, and give three species examples for each.
8. What is SARA? What is its purpose? (http://www.mnr.gov.on.ca/mnr/speciesatrisk/)
9. CRITICAL THINKING: Is there any relationship between the area in Ontario which has the highest occurrence of species at risk and the area that has the highest human density of human settlement? Why would this be?

Biodiversity Across Ontario

South West Region

Clear Creek Forest

Located in the Municipality of Chatham-Kent, Clear Creek Forest is 324 hectares of primary hardwood forest communities, secondary upland forests, cultural meadows, cultural thickets and cropped fields. The property is surrounded by agriculture, rural residential, a cemetery, aggregate extraction, and campgrounds. This forest contains examples of 18 taxa considered to be of Carolinian affinity, including Red Oak, Sugar Maple and American Beech. Shumard Oak, a tree species designated special concern by COSEWIC, is also found in the area. In addition, twenty-four rare vascular plants have been recorded. Ten mammal species inhabit this forest, including Southern Flying Squirrel which has been designated vulnerable in Ontario. Ten species of amphibians and reptiles have been recorded in this forest as well.

Northern Bruce Peninsula

The Northern Bruce Peninsula is known worldwide for its diversity of orchids and ferns and it is one of the best hotspots for biodiversity in the Great Lakes region. There is a large variety of rare habitats within the Bruce Peninsula, such as alvars, sand beaches, fens and meadow marshes. Over 13 percent of the Northern Bruce Peninsula is classified as wetland habitat, allowing for a vast diversity of plants and animals to inhabit this area. These wetlands act as an important stopover site for migratory birds during their spring and fall migrations.

Central Region

Southern Manitoulin Island Coast

This area is globally significant because it contains many rare habitats that support many species at risk, including the Lakeside Daisy and Hill's Thistle. The Manitoulin Island region has been found to have the greatest richness of globally significant species and communities of any ecological district within the Canadian portion of the Great Lakes Basin. The island provides important habitats for colonial nesting waterbirds and migratory birds.

The Eastern Georgian Bay Coast

Along the coast of Georgian Bay one can find high biodiversity values, making this area of top conservation concern. The coastline along the mainland is comprised of rocky shores, deep cut bays, wetlands and cobble beaches with the largest archipelago of freshwater islands in the world. This area provides nesting habitat for nationally and globally rare colonial waterbird species which are found along the Georgian Bay coast in their highest densities in Ontario. This area contains two identified "Important Bird Areas" and acts as a migratory corridor for waterfowl, shorebirds and land birds. Vast communities of vegetation are found along the coast line providing nesting and feeding habitat for many disjunct species and breeding birds. The greatest diversity of reptile populations in Canada is found in this region with many at risk species including

Ontario's only lizard, the Five-lined Skink. Larger mammal species, such as the Black Bear, Fisher and Eastern Wolf are also common in this area.

Lake Ontario East Region

Rice Lake Plains

The Rice Lake Plains is located at the eastern end of the Oak Ridges Moraine with a size of approximately 100,000 acres. Located southeast of Peterborough, this area was historically covered with tall grass prairies and oak savannah. However, today, only a fraction of this native habitat is present due to changing land use. Globally, these habitats are rare, and oak savannahs are considered one of the most endangered ecological communities in North America. This area contains rare species, such as the Eastern Hog-nosed Snake. Fortunately, through the cooperation of many conservation groups, this unique habitat is being restored to its original structure.

Frontenac Arch

This unique landform is a 50 km long extension of exposed Precambrian rock that runs through southeastern Ontario. This arch is an important link for habitats of the Canadian Shield to the Algonquin Highlands with those of the Adirondack Mountains due to the unique overlap of the northern Canadian Shield forests and the southern Carolinian forests. A high diversity of herpetofauna is found along the Frontenach arch, including a number of rare species, such as the Eastern Spiny Softshell, the Least Bittern, the Cerulean Warbler, Blunt-lobed Woodsia and the Eastern Ratsnake. It is also home to Ontario's only lizard, the Five-lined Skink.

Central Region

Western Lake Superior Coast

Along the Western coast of Lake Superior the climate is more temperate and the area acts as a transition zone between moist mixed forests to the south and drier boreal forests to the north. This section of coastline is one of the last remaining portions of the Great Lakes that is still healthy. This area is also home to a wide variety of animals, including bald eagles, peregrine falcons, loons, herons, Canadian Lynx, wolves and the 'coaster' brook trout. However, species such as the Woodland Caribou are now extirpated here.

Toronto Region

The Oak Ridges Moraine

The Oak Ridges Moraine is an important land mass found in Ontario. This moraine filters ground water and provides habitat for a vast diversity of plant and wildlife species. This elevated area also acts as a wildlife corridor, connecting many habitats throughout the region. The Oak Ridges Moraine is approximately 30% forested, including extensive 'interior' habitat, which is critical for many native species. Threatened species that are currently found on the moraine include American Ginseng, threatened by habitat loss and medicinal use, Red-shouldered Hawks, threatened due to loss of nesting habitat, and the Southern Flying Squirrel, again, threatened due to habitat loss.

North-West Region

Cavern Lake Nature Reserve

Approximately 40 kilometers east of Thunder Bay, Cavern Lake Nature Reserve contains a small canyon with prominent slopes, a lake and a cave. With an area of 189 hectares, this area is home to a variety of plants of arctic and alpine affinity, such as the Northern Woodsia, Arctic Pyrola, Fragrant Shield fern and Alpine Bistort. Boreal forests make up the majority of the woodland, with trees such as White Birch, Trembling Aspen, Spruces, Balsam Fir and Jack Pine. The cave provides a winter hibernation habitat for four different species of bat, including the rare Keen's Long-eared Bat, the little Brown Bat, the Big Brown Bat and the Red Bat.

Ottawa Region

The Britannia Conservation Area

This conservation area is known as one of the best birding areas in the Ottawa region. Located within the city limits, the Britannia Conservation Area overlooks the constriction of the Ottawa River containing a great diversity of habitats. Some of the more common birds found in the area include Black-crowned night herons, Blue and Green Winged Teal and Wood Ducks. This area is especially significant during migration, as the pond, the mature White Pine stand and deciduous woods combine to make a hotspot for tired birds. Not only is this area rich in bird species, it is also home to Painted and Snapping turtles, various flower species and many fish and invertebrate species.

Organizations involved in Monitoring and Increasing Biodiversity

Convention on Biological Diversity (www.cbd.int)

- Strategic Plan for the Convention on Biological Diversity
  - The purpose of the Plan is to effectively halt the loss of biodiversity so as to secure the continuity of its beneficial uses through the conservation and sustainable use of its components and the fair and equitable sharing of benefits arising from the use of genetic resources.

Canadian Biodiversity Strategy (www.cbin.ec.gc.ca/strategy)

- Three objectives of the Canadian Biodiversity Strategy are:
  - the conservation on biodiversity;
  - the sustainable use of biological resources; and,
  - the fair and equitable sharing of benefits resulting from the use of genetic resources.

Ontario Biodiversity Strategy (www.mnr.gov.on.ca/MNR/biodiversity/learn.html)

- Two goals define the conservation path proposed in this Strategy:
  - Protect the genetic, species and ecosystems diversity of Ontario.
  - Use and develop the biological assets of Ontario sustainability, and capture benefits from such use for Ontarians.

Species at Risk Act (www.sararegistry.gc.ca/sarredirect/)

- The Species at Risk Act (SARA) was created to protect wildlife species from becoming extinct in two ways:
  - By providing for the recovery of species at risk due to human activity; and
  - By ensuring through sound management the species of special concern don't become endangered or threatened.
- The Act became law in June 2003. It includes prohibitions against killing, harming, harassing, capturing or taking species at risk, and against destroying their critical habitats.

Ontario Endangered Species Act (www.mnr.gov.on.ca/MNR/Csb/news/2007)

- The 2007 Ontario Endangered Species Act includes:
  - A clear role for science in determining the status of species at risk,
  - Stronger protection measures for species at risk and their habitats,
  - A balance between protection measures and flexibility to accommodate other land use considerations, and recognition that such flexibility can sometimes help achieve the desired outcome of protection and recovery,
  - Greater transparency through public reporting requirements,
  - Effective enforcement measures,
  - Recognition of Aboriginal and treaty rights protected under the Constitution Act, in addition to a commitment to ongoing dialogue with Aboriginal peoples as the new legislation is implemented,

    - The creation of a stewardship program for the purpose of promoting stewardship and other related activities to assist in the protection and recovery of species at risk.

Green Belt Plan (www.mah.gov.on.ca/Page189.aspx)

- The second main goal of the Green Belt Plan is to protect the environment:
    - Protection, maintenance and enhancement of natural heritage, hydrologic and landform features and functions, including protection of habitat for flora and fauna and particularly species at risk.

Places to Grow Act (www.placestogrow.ca/)

- This Act outlines legislation so that Ontario communities can expand sustainably without compromising important habitat for plants and animals.

Natural Heritage Information Centre (http://nhic.mnr.gov.on.ca/nhic_.cfm)

- The Natural Heritage Information Centre (NHIC) compiles, maintains and distributes information on natural species, plant communities and spaces of conservation concern in Ontario. This information is stored in a spatial database used for tracking this information. The Centre also has a library with conservation-related literature, reports, books, and maps, which are accessible for conservation applications, land use planning, and natural resource management.

Natural Spaces Program (www.naturalspaces.mnr.gov.on.ca)

- The Natural Spaces Program is a voluntary partnership program that will help reduce loss of greenspace in southern Ontario by encouraging landowners to restore and protect natural areas on their properties. The Program covers the part of Ontario that is south of a line between Midland, Peterborough and Ottawa. By coordinating and linking together the protection efforts of individual landowners, the Natural Spaces Program aims to establish a connected natural heritage system across this area of southern Ontario.

Trees Ontario Foundation (www.treesontario.on.ca)

- The vision of Trees Ontario Foundation is to enhance the health and integrity of the environment through tree planting and sustainable management of Ontario's forests. One of their main guiding principles is to promote the importance of species diversity in maintaining ecological processes.

Ontario Forestry Association (www.oforest.on.ca/)

- The Ontario Forestry Association is a non-profit, registered charity. The OFA is dedicated to raising awareness and understanding of all aspects of Ontario's forests, and to develop commitment to stewardship of forest ecosystems. The OFA has been involved in public education around forestry and environmental issues since the 1940s. Over the years we have been involved in major initiatives involving restoration, commemoration and the management of our forests and natural environment. To this day, the OFA continues to increase public education and knowledge of forestry and environmental issues.

World Wildlife Fund (www.wwf.ca)

- The mandate of the WWF is to stop the degradation of the planet's natural environment and to build a future in which humans live in harmony with nature, by:
    - Conserving the worlds biological diversity,
    - Ensuring the t he use of renewable natural resources is sustainable,
    - Promoting the reduction of pollution and wasteful consumption.

Conservation Ontario (www.conservationontario.ca)

- Conservation Authorities are mandated to ensure the conservation, restoration and responsible management on Ontario's water, land and natural habitats through programs that balance human, environmental and economic needs. Their objectives include:
    - Ensuring the Ontario's rivers, lakes and streams are properly safeguarded, managed and restored;
    - To protect, manage and restore Ontario's woodlands, wetlands and natural habitat;
    - To develop and maintain programs that will protect life and property from natural hazards such as flooding and erosion;
    - To provide opportunities for the public to enjoy, learn from and respect Ontario's natural environment.

Ducks Unlimited (www.ducks.ca)

- Ducks Unlimited Canada (DUC) has been committed to wetland conservation for more than 65 years. DUC is a national, private, non-profit organization. DUC's conservation efforts take many forms. On-the-ground work is guided by the wetland and environmental research of DUC's scientists. DUC works to change policy in favour of wetland habitat conservation. DUC delivers wetland and environmental education programs to teach Canadians about wetlands and the need to conserve them.

Ontario Nature (www.ontarionature.org)

- The goal of Ontario Nature is to protect and restore nature in Ontario. Ontario nature is the leading voice in the promotion and preservation of Ontario's natural environment through the creation of pars and nature reserves, the responsible management of forests, and the protection of rare and endangered species.

Ontario Stewardship (www.ontariostewardship.org)

- A program of the Ontario Ministry of Natural Resources linking landowners, land interest groups and agencies to encourage responsible land care on private land.

Biodiversity Websites

- Ontario Ministry of Natural Resources
  http://www.mnr.gov.on.ca/MNR/biodiversity/

- Ontario's Environmental Registry
  http://www.ebr.gov.on.ca/ERS-WEB-External/

- Biodiversity Institute of Ontario
  http://www.biodiversity.uoguelph.ca/

- Canadian Biodiversity Information Network
  http://www.cbin.ec.gc.ca/index.cfm?lang=e

- Canadian Wildlife Service
  http://www.cws-scf.ec.gc.ca/theme.cfm?lang=e&category=2

- Sierra Club of Canada
  http://www.sierraclub.ca/national/programs/biodiversity/index.shtml

- Environment Canada: Species at Risk
  http://www.speciesatrisk.gc.ca/default_e.cfm

- The Canadian Biodiversity Web Site
  http://canadianbiodiversity.mcgill.ca/

- United Nations Convention on Biological Diversity
  http://www.cbd.int/convention/articles.asp

- Biodiversity and World map
  http://www.nhm.ac.uk/research-curation/projects/worldmap/

- Biodiversity Conservation Network
  http://www.worldwildlife.org/bsp/bcn/

- World Conservation Monitoring Program
  http://www.unep-wcmc.org/

- The World Conservation Union (IUCN)
  http://iucn.org/

Glossary

Alien species: plants, animals, and micro-organisms that have been accidentally or deliberately introduced into habitats outside their normal range.

Alvars: A plant community dominated by mosses and herbs, occurring on shallow, alkaline limestone soils.

Anthropogenic: Made by people or resulting from human activities.

Benthic: the collection of organisms living on or in sea or lake bottoms.

Brood Parasite: a bird that lays its eggs in the nest of another species of bird in order to have that bird take on the parenting responsibilities of the hatchlings; sometimes called nest parasite; brown-headed cowbird is an example of a bird that practices brood parasitism.

Carrying Capacity: the maximum number of individuals of a given species that a site can support.

Clay soils and sandy clay loams: (containing >18% clay particles) tend to be imperfectly or poorly drained. Even when the drainage system is working well, the range of moisture contents when clay soils are suitable for cultivation is small. These soils are prone to drainage related problems and poaching, compaction and smearing.

Clear Cutting: Harvesting of all trees in a large area, leaving extensive cutovers.

Committee on the Status of Endangered Wildlife in Canada: A committee established by the federal government to assess and identify species at risk in Canada for the Species at Risk Act.

Coextinction: is the loss of one species upon the extinction of another.

Ecological Niche: A particular physical habitat or resource that is exploited by an organism.

Eco-region: an area defined by environmental conditions and natural features; a region defined by its ecology.

Ecotone: a transitional zone between two communities containing the characteristic species of each.

Ecozone: the largest scale biogeographic division of the earth's surface based on the historic and evolutionary distribution patterns of plants and animals.

Endangered Species Act: a provincial act that has been passed to ensure the protection of Ontario species at risk and their habitat.

Extinction: the elimination of an entire species.

Extirpation: the elimination of a species or subspecies from a particular area, but not from its entire range.

Eutrophication: an increase in chemical nutrients – typically chemical compounds containing nitrogen or phosphorus – in an ecosystem, either terrestrial or aquatic.

Fossorial: an animal adapted for burrowing or digging.

Indicator Species: A species whose presence, absence, or relative well-being in a given environment is indicative of the health of its ecosystem as a whole.

Invasive species: harmful alien species whose introduction or spread threatens the environment, the economy and/or society, including human health.

Keystone Species: A species whose presence and role within an ecosystem has a disproportionate effect on other organisms within the system. A keystone species is often a dominant predator whose removal allows a prey population to explode and often decreases overall diversity. Other kinds of keystone species are those, such as coral or beavers, that significantly alter the habitat around them and thus affect large numbers of other organisms.

Larva: the newly hatched, immature form of an animal that undergoes metamorphosis, differing markedly in form or appearance from the adult.

Lentic: relating to or living in still waters (as lakes or ponds)

Littoral Zone: of or on a shore

Loamy sands: soils with a high content of fine sand and silt are susceptible to soil problems - watch out for surface capping, compaction and erosion damage unless high organic matter levels are maintained.

Lotic: pertaining to or living in flowing water.

Macro Invertebrate: creatures without a backbone that can be seen with the naked eye.

Monoculture: a single, homogeneous culture without diversity or dissension.

Nitrogen fixation: the process by which nitrogen is taken from its natural, relatively inert molecular form (N_2) in the atmosphere and converted into nitrogen compounds (such as, notably, ammonia, nitrate and nitrogen dioxide) useful for other chemical processes.

Pupa: a developmental stage of many insects, intermediate between the larva and the adult; this stage is generally inactive and encased in a case or cocoon.

Redundancy: A characteristic of species within an ecosystem where certain species contribute in equivalent ways to an ecosystem function such that one species may substitute for another. Note that species that are redundant for one ecosystem function may not be redundant for others.

Relief: the configuration of land in terms of its altitude and slope degree.

Resilience: the ability of communities to recover from (or to resist being affected by) some shock, insult, or disturbance.

Sandy loams and sandy silt loams: (soils with <18% clay) - most suitable soils for all enterprises in wetter areas and suitable for more intensive cropping.

Soil biodiversity: the variety of life that lives in soil (includes: numerous species of invertebrates and microorganisms, soil flora, plant roots and we as mammals, birds, reptiles and amphibians).

Soil structure: the arrangement of particles in blocks or aggregates within the soil. Structure is strongly influenced by tillage, cropping, texture, organic matter, compaction and biological activities and can be affected by drainage status and weathering.

Soil texture: defined by the proportion of sand, silt and clay particles bound together by organic matter.

Soil quality: the capacity of a soil to function, within land use and ecosystem boundaries, to sustain biological productivity, maintain environmental quality, and promote plant, animal and human heath.

Species at Risk Act (SARA): a federal act that has been established to protect species at risk in Canada and their habitat.

Species evenness: a diversity index, a measure of biodiversity which quantifies how equal the community is numerically.

Species richness: the number of individuals of each species in a given area.

Sustainability: A state or process that can be maintained indefinitely.

Symbiotic relationships: may involve an organism living on another (ectosymbiosis), inside another (endosymbiosis), or organisms related by mutual stereotypic behaviors. Further, symbiotic relationships, may be either obligate, which is to say necessary to the survival of at least one organism, or facultative, where the relationship is useful but not vital.

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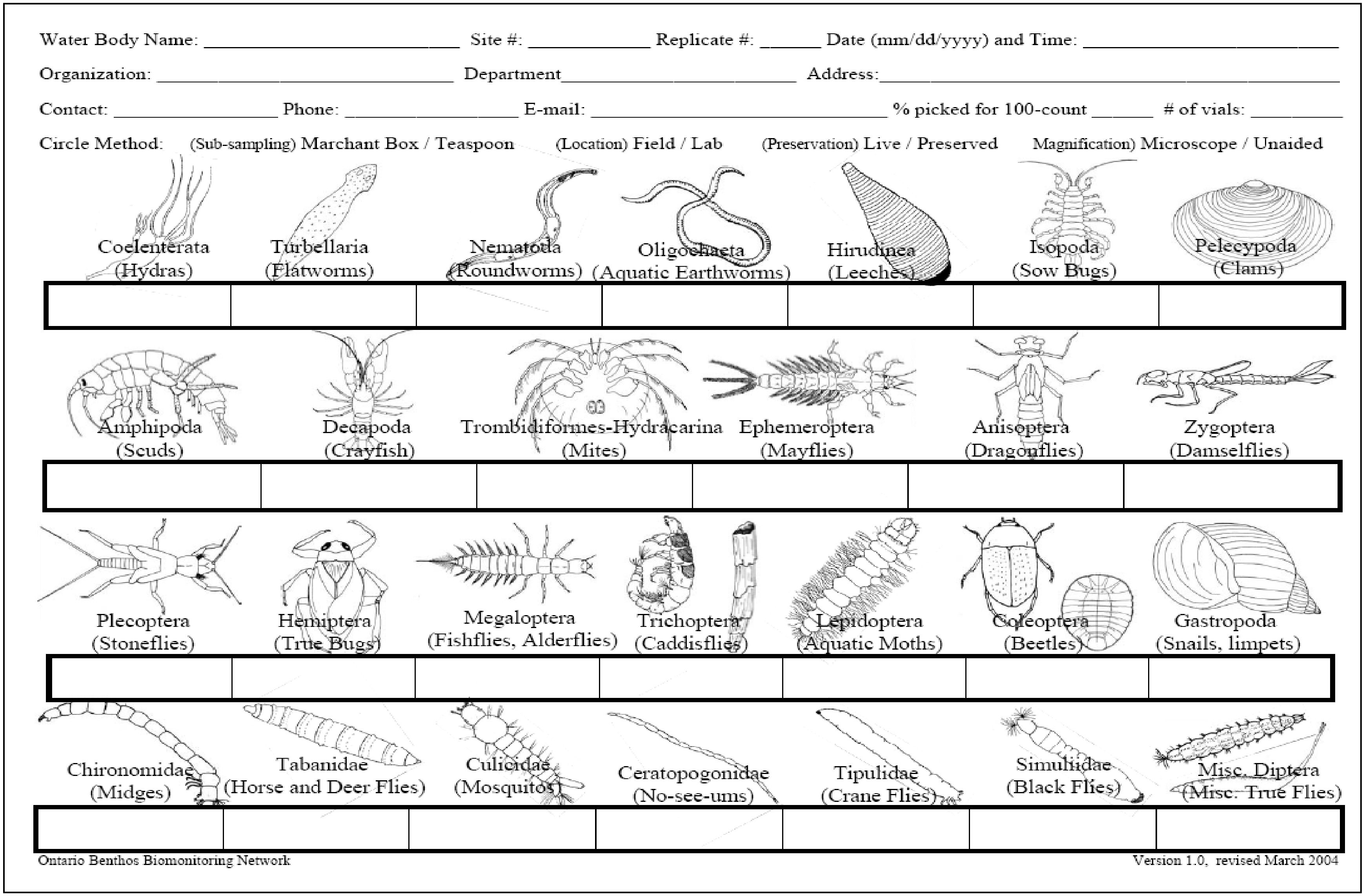
Appendix A: Benthic Macroinvertebrate Index



Water Body Name: __________________________ Site #: ____________ Replicate #: ______ Date (mm/dd/yyyy) and Time: __________________________

Organization: ______________________________ Department________________________ Address:____

Contact: ________________ Phone: _________________ E-mail: ______________________________ % picked for 100-count ______ # of vials: _________

Circle Method: (Sub-sampling) Marchant Box / Teaspoon (Location) Field / Lab (Preservation) Live / Preserved Magnification) Microscope / Unaided

Coelenterata (Hydras)	Turbellaria (Flatworms)	Nematoda (Roundworms)	Oligochaeta (Aquatic Earthworms)	Hirudinea (Leeches)	Isopoda (Sow Bugs)	Pelecypoda (Clams)

Amphipoda (Scuds)	Decapoda (Crayfish)	Trombidiformes-Hydracarina (Mites)	Ephemeroptera (Mayflies)	Anisoptera (Dragonflies)	Zygoptera (Damselflies)

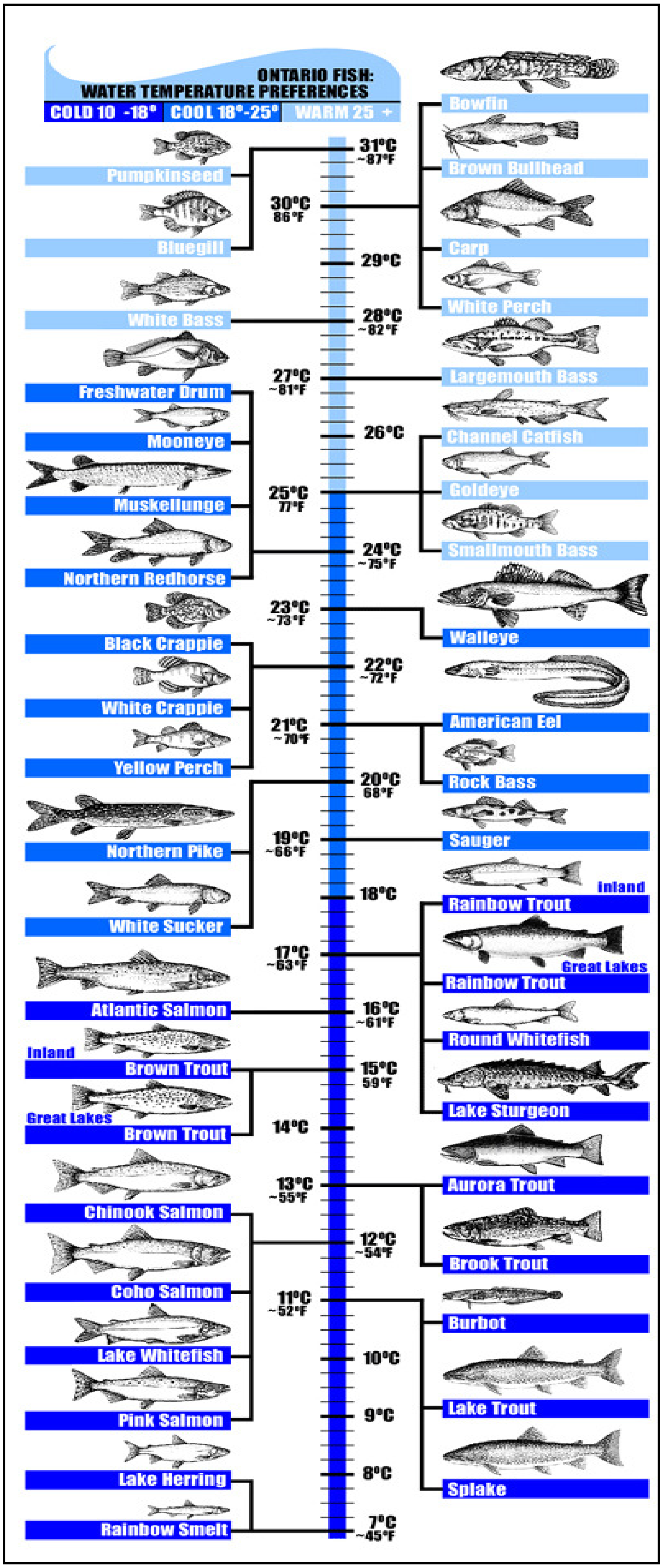
Plecoptera (Stoneflies)	Hemiptera (True Bugs)	Megaloptera (Fishflies, Alderflies)	Trichoptera (Caddisflies)	Lepidoptera (Aquatic Moths)	Coleoptera (Beetles)	Gastropoda (Snails, limpets)

Chironomidae (Midges)	Tabanidae (Horse and Deer Flies)	Culicidae (Mosquitos)	Ceratopogonidae (No-see-ums)	Tipulidae (Crane Flies)	Simuliidae (Black Flies)	Misc. Diptera (Misc. True Flies)

Ontario Benthos Biomonitoring Network Version 1.0, revised March 2004

(OBBN, 2004)

Appendix B: Common Fish of Ontario Identification



ONTARIO FISH:
WATER TEMPERATURE PREFERENCES
COLD 10 -18°
COOL 18°-25°
WARM 25 +
31°C ~87°F
30°C 86°F
29°C
28°C ~82°F
27°C ~81°F
26°C
25°C 77°F
24°C ~75°F
23°C ~73°F
22°C ~72°F
21°C ~70°F
20°C 68°F
19°C ~66°F
18°C
17°C ~63°F
16°C ~61°F
15°C 59°F
14°C
13°C ~55°F
12°C ~54°F
11°C ~52°F
10°C
9°C
8°C
7°C ~45°F
Pumpkinseed
Bluegill
White Bass
Freshwater Drum
Mooneye
Muskellunge
Northern Redhorse
Black Crappie
White Crappie
Yellow Perch
Northern Pike
White Sucker
Atlantic Salmon
Inland
Brown Trout
Great Lakes
Brown Trout
Chinook Salmon
Coho Salmon
Lake Whitefish
Pink Salmon
Lake Herring
Rainbow Smelt
Bowfin
Brown Bullhead
Carp
White Perch
Largemouth Bass
Channel Catfish
Goldeye
Smallmouth Bass
Walleye
American Eel
Rock Bass
Sauger
Inland
Rainbow Trout
Great Lakes
Rainbow Trout
Round Whitefish
Lake Sturgeon
Aurora Trout
Brook Trout
Burbot
Lake Trout
Splake

(OMNR, 2006)

Fish Identification

Here are the types of fish that anglers are likely to catch in Ontario's lakes and streams. Information is provided on the following:

L: length.

D: distribution/habitat.

S: similar fish.

K: key identifying characteristics that separate them from those similar fish.

The Ontario record for many of these species can be found on pg. 50.

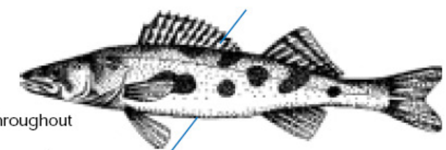
The fish illustrations were drawn by Rebecca Brebner, with the exception of the muskellunge and the sturgeon, which were drawn by Andreas Radman of the Ontario Ministry of Environment, the bluegill which was drawn by Curtis Atwater, the Great Lakes phase of the rainbow and brown trout which were drawn by Virgil Beck and provided by the Wisconsin Department of Natural Resources. These illustrations were redrawn based on original fish illustrations from two publications: Bulletin 184, Fisheries Research Board of Canada – "Freshwater Fishes of Canada" by Scott and Crossman, and "Fish of Ontario" (poster) distributed by the Ministry of Natural Resources.

Walleye

L: 25 - 85 cm (10 - 33 in.).
D: lakes and rivers throughout most of Ontario.
S: sauger, yellow perch.
K: white tip on lower tail fin; no distinct blotches or bands on adults.

Favorite Baits: spinners, jigs, crank baits, worms, minnows, leeches

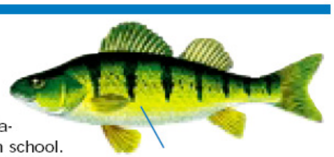
Sauger



L: 25 - 41 cm (10 - 16 in.).
D: large, shallow, turbid waters throughout Ontario.
S: walleye, yellow perch.
K: lacks white tip on lower tail fin; distinct blotches or bands on adults; spots on dorsal fin.

Favorite Baits: same as walleye

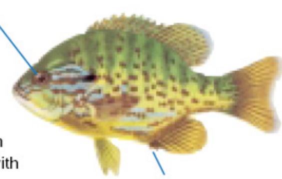
Yellow Perch



L: 15 - 30 cm (6 - 12 in.).
D: clear waters with some vegetation throughout Ontario; often school.
S: walleye, sauger, white perch.
K: 6 to 8 dark, vertical bands on sides, alternating with light yellow to yellow-green.

Favorite Baits: small jigs, small spoons, small minnows, worms

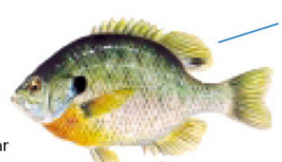
Pumpkinseed



L: 18 - 23 cm (7 - 9 in.).
D: clear, shallow, weedy waters north to Temagami.
S: rock bass, bluegill.
K: 3 anal fin spines; wavy, blue-green stripes on sides of head; ear flap with orange or red spot.

Favorite Baits: small jigs, worms

Bluegill



L: 15 - 30 cm (6 - 12 in.).
D: warm, vegetated, still waters throughout southern Ontario.
S: rock bass, pumpkinseed.
K: 3 anal fin spines; black spot at rear end of dorsal fin; ear flap black.

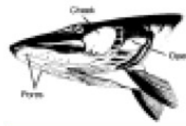
Favorite Baits: small jigs, worms, flies

Northern Pike

L: 45 - 100 cm (18 - 39 in.).
D: quiet, vegetated waters throughout Ontario.
S: muskellunge.
K: light yellowish spots on dark green background; tips of tail fin more rounded than muskellunge; see also head close-up below.

Favorite Baits: spoons, large spinners, large crank baits, minnows

Northern Pike
Cheek fully scaled, upperhalf of opercle only scaled, 10 pores on undersides of lower jaw.



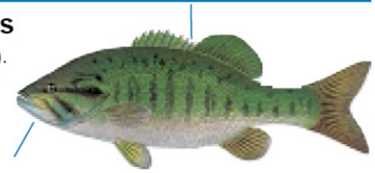
Muskellunge
Cheek and opercle both scaled only on upper half, 12-18 pores on undersides of lower jaw.

Muskellunge

L: 71 - 137 cm (28 - 54 in.).
D: discontinuous in southern and near northeastern Ontario, and the Lake of the Woods/ Rainy River area.
S: northern pike.
K: dark vertical bands on light background, at times spotted or clear; tips of tail fin more pointed than northern pike; see also head close-up above.

Favorite Baits: large bucktail spinners, large body baits, sucker minnows

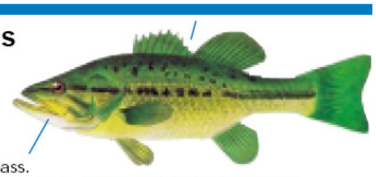
Smallmouth Bass



L: 25 - 50 cm (10 - 20 in.).
D: clear, rocky waters with little vegetation from southern Ontario to Timiskaming and northwestern Ontario.
S: largemouth bass.
K: upper jaw does not extend beyond eye; shallow notch between dorsal fins; body often with dark, broken bars.

Favorite Baits: jigs, spinners, crank baits, minnows, crayfish

Largemouth Bass



L: 25 - 55 cm (10 - 22 in.).
D: warm, weedy, slow or still waters primarily in southern Ontario.
S: smallmouth bass, rock bass.
K: upper jaw extends beyond eye; deep notch between dorsal fins; body often with a broken horizontal stripe.

Favorite Baits: spinnerbaits, crank baits, plastic worms, minnows, frogs

Rock Bass

L: 15 - 20 cm (6 - 8 in.).
D: warm, slow or still shallows with rocky bottoms, northward to Lake Abitibi.
S: pumpkinseed, bluegill.
K: large, red eye; six anal fin spines; regular rows of spots on the side in adults.

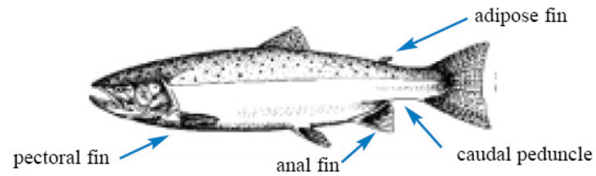
White Sucker

L: 30 - 50 cm (12 - 20 in.).
D: warm, shallow lakes and tributary rivers across Ontario.
S: other suckers (e.g. redhorse).
K: torpedo-shaped; round in cross-section; scales smaller than redhorse sucker.

(OMNR, 2006)

Salmon and Trout Identification

The following features are useful in identifying salmon and trout:



Chinook Salmon

L: 30 - 100 cm (12 - 39 in.).
D: found in all Great Lakes and some tributaries.
S: coho, Atlantic and pink salmon, rainbow trout (steelhead), brown trout.
K: black mouth and black gums; tail entirely spotted; leading ray on anal fin extends 1/3 the length of the fin; short, narrow caudal peduncle.

Favorite Baits: spoons, wobbling plugs, dodger and flies

Rainbow Trout/Great Lakes (Steelhead)

L: 35 - 60 cm (14 - 24 in.).
D: found in all Great Lakes and many tributaries.
S: chinook, coho, pink and Atlantic salmon; brown trout.
K: white mouth and gums; body silver with dark spots; spots all over tail in radiating rows; leading anal fin ray extends the length of the fin; long, stocky caudal peduncle.

Coho Salmon

L: 30 - 75 cm (12 - 30 in.).
D: found in all Great Lakes and some tributaries.
S: chinook, Atlantic and pink salmon, rainbow trout (steelhead), brown trout.
K: dark mouth and light grey gums; tail spotted on upper lobe only; leading ray on anal fin extends 1/2 - 2/3 the length of the fin; short, narrow caudal peduncle.

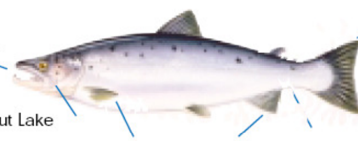
Favorite Baits: spoons, dodger and flies

Rainbow Trout/Inland

L: 15 - 40 cm (6 - 16 in.).
D: south of a line from Kenora to Kesagami Lake.
S: brook and brown trout; juvenile Atlantic salmon.
K: many small black spots on body; spots over tail in radiating rows; pink lateral stripe; leading anal fin ray extends the length of the fin; long, stocky caudal peduncle.

Favorite Baits: spinners, spoons, roe, worms, flies

Atlantic Salmon

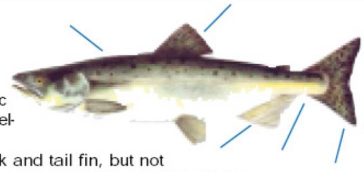


L: 25 - 70 cm (10 - 28 in.).
D: reintroduced to Lake Ontario; occasionally in upper Great Lakes and some tributaries, and Trout Lake near North Bay.
S: chinook, coho and pink salmon, rainbow trout (steelhead), brown trout.
K: white mouth and gums; few large, black spots on gill cover; no spots on tail; leading ray on anal fin extends the length of the fin; long, narrow caudal peduncle; dark-coloured pectoral fins.

Brown Trout/Great Lakes

L: 35 - 60 cm (14 - 24 in.).
D: found in all Great Lakes and some tributaries.
S: chinook, coho, pink and Atlantic salmon; rainbow trout.
K: white mouth and gums; silvery with dark spots on body; only occasional vague spots on tail; only salmon or trout with orange on adipose fin; leading anal fin ray extends the length of the fin; short, stocky caudal peduncle; light-coloured pectoral fins.

Pink Salmon



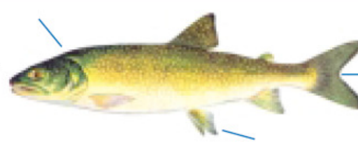
L: to 46 cm (18 in.).
D: found in all Great Lakes.
S: chinook, coho and Atlantic salmon, rainbow trout (steelhead), lake trout.
K: large black spots on back and tail fin, but not on dorsal fin; forked tail; leading ray on anal fin extends 1/3 - 1/2 the length of the fin; narrow caudal peduncle.

Brown Trout/Inland

L: 20 - 40 cm (8 - 16 in.).
D: occasional south of the French River, mostly in Great Lakes tributaries.
S: rainbow and brook trout; juvenile Atlantic salmon.
K: large black, blue or red spots on body, often surrounded by lighter ring; tail with few spots; only salmon or trout with orange on adipose fin; leading anal fin ray extends the length of the fin; short, stocky caudal peduncle.

Favorite Baits: spinners, spoons, worms, flies

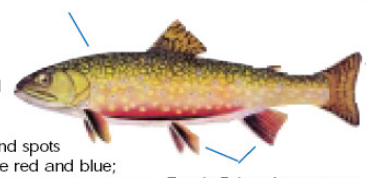
Lake Trout



L: 30 - 80 cm (12 - 31 in.).
D: cold waters of deep lakes throughout much of Ontario.
S: brook trout.
K: light wormlike markings and spots on dark background, none red; deeply forked tail; white leading edge on lower fins, but no black line.

Favorite Baits: spoons, jigs, crank baits, lake trolls

Brook Trout



L: 15 - 40 cm (6 - 16 in.).
D: cold, clear streams, small lakes, Lake Superior.
S: lake trout.
K: light wormlike markings and spots on dark background, some red and blue; square tail; white leading edge on lower fins, set off by black line.

Favorite Baits: spinners, spoons, worms, flies

Channel Catfish

L: 36 - 53 cm (14 - 21 in.).
D: Great Lakes and larger lakes and rivers south of the French River and from Lake Nipigon west.
S: brown bullhead.
K: deeply forked tail.

Brown Bullhead

L: 20 - 36 cm (8 - 14 in.).
D: warmer, slow waters throughout southern Ontario and generally south of highways 11 & 17 in the north.
S: channel catfish.
K: square tail.

(OMNR, 2006)

White Bass

L: 20 - 30 cm (8 - 12 in.).
D: clear water near rock reefs and sand bars in lower Great Lakes area.
S: white perch.
K: dark spots in horizontal lines, often faint and irregular; second anal spine distinctly shorter than third.

White Perch

L: 15 - 25 cm (6 - 10 in.).
D: Lakes Ontario and Erie, lower Niagara River and Welland Canal.
S: white bass, yellow perch.
K: colour variable, but spots or stripes not obvious; second and third anal spine roughly equal in length.

Lake Whitefish

L: 30 - 65 cm (12 - 26 in.).
D: Great Lakes and deep, cold, inland lakes across Ontario.
S: cisco, round whitefish.
K: mouth overhung by snout (see below); body oval in cross-section.

Favorite Baits: small jigs, small spoons, small minnows

Profiles of whitefish and herring showing differences due to position of snout or upper jaw.

Lake Whitefish
A. The mouth is overhung by the snout or upper jaw; rounded profile.

Cisco (Lake Herring)
B. The mouth is not overhung by the snout; pointed profile.

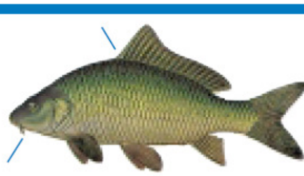
Cisco

L: 20 - 30 cm (8 - 12 in.)
D: cold waters from Great Lakes to Hudson Bay
S: lake and round whitefish, rainbow smelt
K: mouth not overhung by snout (see above); mouth ends before middle of eye.

Rainbow Smelt

L: 15 - 25 cm (6 - 10 in.).
D: throughout Great Lakes area, including some inland lakes.
S: cisco.
K: mouth extends beyond centre of the eye; tongue with prominent teeth.

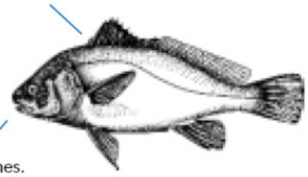
Carp



L: 30 - 75 cm (12 - 30 in.).
D: shallow, warm waters, primarily in southern Ontario.
S: freshwater drum.
K: "whiskers" beside mouth; one dorsal spine.

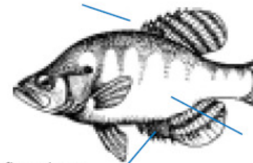
Favorite Baits: dough, corn, worms, prepared carp bait

Freshwater Drum



L: 45 - 50 cm (18 - 20 in.).
D: large, shallow waterbodies with mud or sandy bottoms, mostly in lower Great Lakes.
S: carp.
K: no "whiskers"; 8-9 dorsal spines.

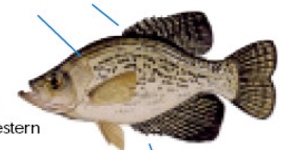
White Crappie



L: 20 - 30 cm (8 - 12 in.).
D: mouths of tributary streams or weedy, sheltered bays in lower Great Lakes area.
S: black crappie.
K: six dorsal fin spines; 6 or 7 anal fin spines; sides with faint bars.

Favorite Baits: small jigs, small minnows, worms

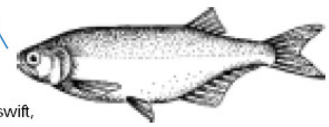
Black Crappie



L: 18 - 25 cm (7 - 10 in.).
D: clear, weedy lakes and slow rivers primarily Great Lakes, south central near northeast and parts of northwestern Ontario.
S: white crappie.
K: 7-8 dorsal fin spines; 6 or 7 anal fin spines; irregular mosaic of distinct black blotches.

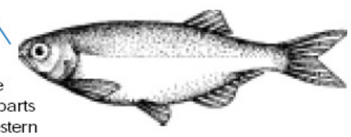
Favorite Baits: small jigs, small minnows, worms

Goldeye



L: 25 - 38 cm (10 - 15 in.).
D: parts of northeastern and northwestern Ontario, often in swift, silty waters.
S: mooneye.
K: iris of eye large and bright golden, forward scales with golden luster.

Mooneye



L: 25 - 30 cm (10 - 12 in.).
D: clear rivers and shallow lake waters, southern as well as parts of northeastern and northwestern Ontario.
S: goldeye.
K: iris of eye large and golden, but not as bright as goldeye; scales silvery.

Sturgeon

L: 90 - 145 cm (3 - 5 ft.).
D: larger rivers and lakes, usually less than 30 feet deep.
S: none.
K: underslung mouth; whiskers; bony plates on sides.

Burbot (Ling)

L: to 38 cm (15 in.).
D: cool waters of lakes and rivers throughout Ontario.
S: bowfin.
K: single "whisker" on tip of chin; long, thin anal fin.

Bowfin

L: 46 - 61 cm (18 - 24 in.).
D: swampy, vegetated bays of warm lakes and rivers, primarily in southern Ontario.
S: burbot.
K: no "whiskers"; anal fin short but deep.

(OMNR, 2006)

Appendix C: Winter Tree Identification Key

Appendix D: Canadian Soil Classification

Appendix E: Ontario Mammal Tracking and Identification Guide

Appendix F: Ontario Bird Identification Guide