Ontario Envirothon Study Guide

Ontario Envirothon

AQUATICS

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

FORESTS ONTARIO

The Ontario Envirothon Modules assist students and teachers in preparing for the Ontario Envirothon program.

Every year, more than 500,000 students, teachers and families across North America take part in the unique learning experience of Envirothon. The program engages high-school students in learning more about four main areas of the environment—soils, aquatics, wildlife and forests.Students learn in the classroomand through interactive workshops aimed at strengthening scientific knowledge of our natural ecosystems and helping develop foundational skills needed to pursue studies and careers in the environmental sciences.

The program supports students in developing:

- A scientific understanding of natural ecosystems (soils, wildlife, forests, aquatics).
- Practical experience in resource management practices and technologies.
- The ability to apply scientific knowledge and creativity in developing innovative and sustainable solutions to major environmental challenges.
- Stronger communication, collaboration and problem solving skills.

North American Envirothon (NAE), a program of the National Conservation Foundation, partners with 56 provinces and states that coordinate events in which students receive training in essential resource management technologies and practices such as invasive species monitoring, habitat restoration, water and soil analysis, and forest management. Students are then tested on their ability to apply these practices.

Acknowledgements

This study was prepared in partnership with Bruce Doran and Dr. Brian Hickey, formerly with the St. Lawrence River Institute of Environmental Sciences. Originally produced in August 2001 and revised July 2015.

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Updated: July 2015

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Learning Objectives

Overall Objectives

Students must be able to…

A. Understand and describe the abiotic characteristics and processes of aquatic ecosystems
B. Understand and describe the biotic characteristics and processes of aquatic ecosystems
C. Describe the variety of aquatic environments, their characteristics and succession, and how they are affected by internal and external processes
D. Understand and describe practices involved in the conservation and management of healthy aquatic ecosystems and water resources

Specific Objectives

Students must be able to…

A. Understand and describe the abiotic characteristics and processes of aquatic ecosystems.

1. Identify the physical characteristics of water and explain how those characteristics relate to or affect aquatic organisms
2. Identify the chemical properties of water and explain how those properties relate to or affect aquatic organisms
3. Know the processes and phases for each part of the water cycle and understand the water cycle's role in soil nutrient erosion, salinization of agricultural lands, and climatic influences
4. Understand the concept and components of a watershed and be able to identify stream orders and watershed boundaries. Know the features of a healthy watershed and an unhealthy watershed
5. Know how to perform and interpret chemical water quality tests and understand why aquatic organisms and water quality is affected by the physical, chemical and biological conditions of the water

B. Understand and describe the biotic characteristics and processes of aquatic ecosystems.

1. Describe the flow of energy through aquatic systems, emphasizing aquatic food chains and webs
2. Describe the cycling of nutrients within aquatic systems, including additions from upland systems, with particular attention to carbon, phosphorous and nitrogen
3. Describe normal succession in Ontario’s lakes, streams and wetlands
4. Define and illustrate carrying capacity, including the importance and effects of critical habitat
5. Knowhow to perform and interpret biological water quality tests, using benthic macroinvertebrate testing, and understand why aquatic organisms and water quality is affected by the physical, chemical and biological conditions of the water

C. Describe the variety of aquatic environments, their characteristics and succession, and how they are affected by internal and external processes.

1. Describe with detail the composition of Ontario’s aquatic communities (lakes, rivers, streams, wetlands, etc)
2. Relate the elements of aquatic communities to the physical characteristics and processes of their environments
3. Define habitat requirements for a variety of aquatic plant and animal species and illustrate with specific examples
4. Explain or show how a range of aquatic organisms have adapted to the characteristics of aquatic environments
5. Identify simple and diverse aquatic systems found in Ontario, and illustrate the advantages of biological diversity
6. Define a wetland and identify and describe the four major types of wetlands: swamps, marshes, fens, and bogs

7. Describe the values and benefits of wetlands
8. Understand the functions and values of riparian zones and identify riparian zone areas

D. Understand and describe practices involved in the conservation and management of healthy aquatic ecosystems and water resources

1. Identify the rights of Ontario's First Nations with regard to aquatic resources
2. Identify Ontario's rare, threatened and endangered aquatic species, as identified by COSEWIC, and explain how and why selected species were reduced to those levels
3. Identify and describe a variety of non-native and invasive aquatic species affecting Ontario's aquatic ecology
4. Identify local and global sources of point and non-point source pollution and discuss methods to reduce pollution in Ontario's aquatic ecosystems
5. Understand and describe the effects that climate change has on aquatic ecology
6. Interpret a variety of laws, agreements, treaties, etc. that govern Ontario's water resources and aquatic environments
7. Identify a variety of major stakeholders and agencies, including Federal, Provincial and Municipal government bodies, that provide oversight of water resources in Ontario

Application/Analysis

Students must be able to…

1. Identify, using a field guide, dichotomous key or index, plants and animals commonly found in Ontario wetlands
2. Identify site-specific plants and animals that would be found in a given wetland
3. Identify a specific aquatic community (lake, river, stream, wetland, etc.) based on a small sample cluster of aquatic plant and animal species
4. Identify the habitat requirements of common Ontario aquatic plants and animals on site
5. Collect and interpret data using a variety of tools, including, but not limited to:
   - hand lens
   - secchi disk
   - ekman dredge
   - D-net
   - pH testing kit or pH meter
6. Carry out a number of tests (visual, water, soil, vegetation, etc) to determine if a site is best described as a swamp, marsh, fen or bog
7. Compare and contrast the physical characteristics of lakes and streams, as well as the adaptations of life to those environments
8. Understand and illustrate carrying capacity
9. Use a variety of tools to carry out water quality assessments (alkalinity, CO2, nitrate, phosphate, chloride, turbidity, pH, hardness)
10. Calculate stream velocity and flow rate
11. Understand and report on the effects of point and non-point source pollutants on aquatic life

Synthesis/Evaluation

Students must be able to…

1. Demonstrate, using examples from Ontario, how current water use affects aquatic resources
2. Examine the effect of the introduction of non-native species in aquatic ecosystems, including origin, means of introduction, methods of control, and results (success/failure) of methods
3. Assess the application of current aquatic ecosystems and water resource management and control
4. Recommend plans for aquatic ecosystems and water resource management and control

1.0: Physical and Chemical Properties of Water

Water is one of the most essential substances and is needed by all organisms. It is the **medium** in which all cellular chemical processes occur and it provides many other functions necessary for life (e.g. transportation of solutes, pH and temperature buffer).**Aquatic organisms** depend even more heavily on water to obtain shelter and food. Aquatic ecosystems provide unique opportunities and challenges which aquatic organisms must adapt to in order to survive and reproduce.

1.1 Molecular composition of water

Water is composed of two **hydrogen atoms** both **bonded** to one atom of **oxygen** (H_20). Their arrangement is such that the molecule resembles the shape of a popular cartoon mouse character. This arrangement causes water to have weak charges at both ends of the molecule; a positive charge around the hydrogen atoms and a negative charge around the oxygen atom. Water is known as a **polar compound**, that is, a substance where molecules have weak charges at opposite ends.

The **polarity** of water contributes to some of its physical characteristics. It is the reason why water is such a good solvent, especially for salts and sugars.Due to their charges, water molecules will position themselves so that hydrogen atoms of one molecule will form weak bonds with oxygen atoms of another molecule.This bond between water particles is known as hydrogen bonds; it explains certain properties of water such as **surface tension** and the buoyancy of ice (Figure 1).

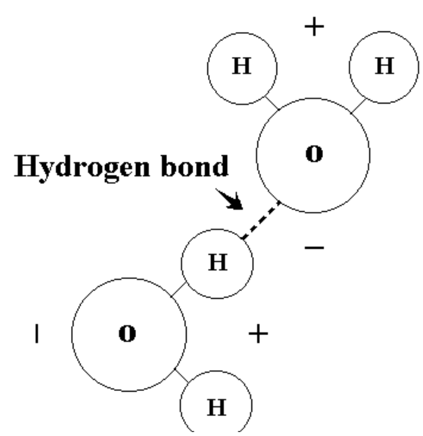


Figure 1. Hydrogen bond between two water molecules. Notice the polarity of each molecule.

1.2 Specific heat

Specific heat is defined as the capacity of a substance to absorb thermal energy (heat) in relation to the rate of temperature change at a constant **volume**. If a substance has a low specific heat it will absorb and release great amounts of heat with large changes in its temperature. Conversely, the temperature of a substance with a high specific heat will only change slightly even though it absorbs and releases lots of heat.

Water is a liquid that has a high specific heat.It will take in or lose thermal energy before it changes temperature.In fact, it is due to the hydrogen bonds that water has a high specific heat; these bonds will absorb and release an abundance of thermal energy, bringingabout only slight changes in water temperature. This property of water is quite important to aquatic communities because it prevents aquatic organisms from being exposed to wide fluctuations in temperature. In Ontario, aquatic organisms are subjected to much narrower temperature ranges (4^oC to 27^oC) as compared to terrestrial organisms which must cope with annual temperatures that can range between -40^oC to +35^oC. Also, because water warms up and cools off more slowly than air, aquatic organisms are not at the mercy of sudden changes in air temperatures. For example, if a cold air mass quickly covers an area, terrestrial organisms will immediately be exposed to cold temperatures whereas aquatic organisms are insulated by water. Therefore, water acts as a buffer for aquatic organisms: they are not exposed to extreme cold or heat and temperature variations occur slowly which allow them time to adapt.

1.3 Density of water

As with all other liquids, freshwater **density** increases as it cools.It attains its maximum density at 3.98^oC but unlike other liquids, water becomes less dense as it freezes. Because of hydrogen bonds, water molecules arrange themselves in a highly organized fashion forming a crystalline structure. This structure has an effect of increasing the spaces between individual molecules, hence explaining why solid water (ice) expands. The increased spacing between molecules causes a drop in the density of ice. Since ice is less dense than water it will float on top of liquid. In fact, when observing ice formation on a lake or pond, ice will first start forming on the surface and then extend downward into the water. Usually, in cold winter months, the ice layer will reach a maximum thickness of 2-5 metres and the remainder of the water will stay as a liquid underneath the ice.This property of water has important implications for aquatic life. Since the ice layer floats, aquatic organisms can continue to live in the deeper waters and remain active – albeit at a lower rate.

1.4 Turbidity

Turbidity refers to how clear water is. The greater the amount of total suspended solids (TSS) in the water, the murkier it appears and the higher the measured turbidity. The major source of turbidity in the open water zone of most lakes is typically phytoplankton, but closer to shore, particulates may also be clays and silts from shoreline erosion,re-suspended bottom sediments,and organic detritus from stream and/or wastewater discharges. Dredging operations, channelization, increased flow rates, floods, or even too many bottom-feeding fish (such as carp) may stir up bottom sediments and increase the cloudiness of the water.

High concentrations of **particulate matter** can modify light penetration, cause shallow lakes and bays to fill in faster, and smother benthic (the very bottom of the lake) habitats - impacting both organisms and eggs. As particles of silt, clay, and other organic materials settle to the bottom they can suffocate newly hatched larvae and fill in spaces between rocks which could have been used by aquatic organisms as habitat. Fine particulate material can also clog or damage sensitive gill structures, decrease organisms resistance to disease, prevent proper egg and larval development, and potentially interfere with particle feeding activities.If light penetration is reduced significantly, macrophyte growth may decrease, which would in turn impact the organisms dependent upon them for food and cover. Reduced photosynthesis can also result in a lower daytime release of oxygen into the water. Very high levels of turbidity for a short period of time may not be significant and may even be less of a problem than a lower level that persists longer. Figure 2 below shows how aquatic organisms are generally affected.

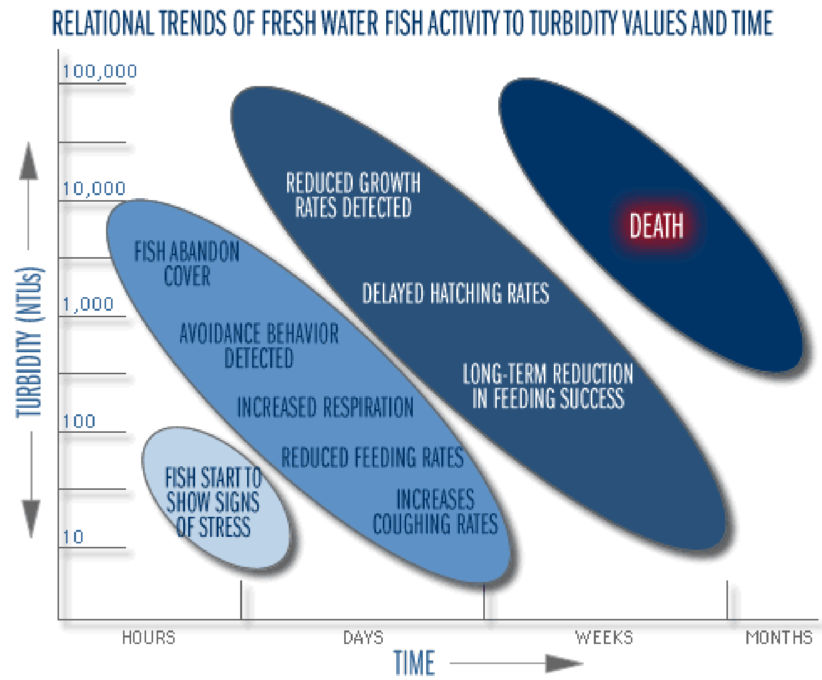


Figure 2. Schematic adapted from "Turbidty: A Water Quality Measure", Water Action Volunteers, Monitoring Factsheet Series, UW-Extension, Environmental Resources Center. It is a generic, un-calibrated impact assessment model based on Newcombe, C. P., and J. O. T. Jensen. 1996. Channel suspended sediment and fisheries: a synthesis for quantitative assessment of risk and impact. North American Journal of Fisheries Management. 16: 693-727.

1.4.1 Impacts of Turbidity on Humans

The major effect turbidity has on humans might be simply aesthetic - people don't like the look of cloudy water. However, turbidity also adds real costs to the treatment of surface water supplies used for drinking water, since the turbidity must be virtually eliminated for effective disinfection to occur. Particulates also provide attachment sites for heavy metals such as cadmium, mercury and lead, and many toxic organic contaminants such as PCBs, PAHs and many pesticides.

1.4.2 Nephelometric Turbidity Units (NTU's)

NTU's are the units we use when we measure *Turbidity.* The term *Nephelometric* refers to the way the instrument (Nephelometer, also called a turbidimeter) estimates how light is scattered by suspended particulate material in the water. This measurement generally provides a very good correlation with the concentration of particles in the water that affect clarity, such that the more particles you have suspended in the water, the cloudier it appears which means you have a higher overall turbidity.For example, a perfectly clear lake would have a value of 0 NTU's, while a particularly turbid lake would have a value of 400 NTU's or greater (See Figure 3).

In lakes and streams, there are 3 major types of particles responsible for scattering light: **algae**, **detritus** (dead organic material), and **silt** (inorganic, or mineral, suspended sediment).The algae grow in the water and the detritus comes from dead algae, higher plants, zooplankton, bacteria, fungi, etc. produced within the water column, and from watershed vegetation washed in to the water. Sediment comes largely from shoreline erosion and from the re-suspension of bottom sediments due to wind mixing.

Figure 3.Average turbidity values of lakes impacted by silts and clays.

1.4.3 Measuring Turbidity in Lakes

The **Secchi disk** depth provides an even lower "tech" method than a turbidimeter for assessing the clarity of a lake. A Secchi disk is a circular plate divided into quarters painted alternately black and white (Figure 4).The disk is attached to a rope and lowered into the water until it is no longer visible. Higher Secchi readings mean more rope was let out before the disk disappeared from sight and indicates clearer water. Lower readings mean less rope was let out and indicate turbid or coloured water. Clear water lets light penetrate more deeply into the lake than murky water, this light allows photosynthesis to occur and oxygen to be produced. The rule of thumb is that light can penetrate to a depth of about 2 - 3 times the Secchi disk depth.

Clarity is affected by algae, soil particles, and other materials suspended in the water. However, Secchi disk depth is primarily used as an indicator of algal abundance and general lake productivity.Although it is only an indicator, Secchi disk depth is among the simplest and most effective tools for estimating a lake's productivity. Secchi disk readings can be used to determine a lake's trophic status. Though trophic status is not related to any water quality standard, it is a mechanism for "rating" a lake's productive state since unproductive lakes are usually much clearer than productive lakes.

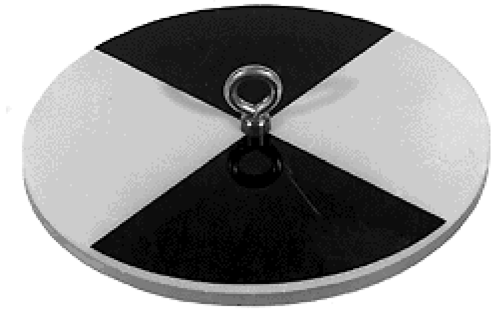


Figure 4.A Secchi Disc is a" low-tech" tool to assess the clarity of water in lakes and ponds. Secchi measurements are made in the shade with the sun to your back to make an accurate and reproducible reading.

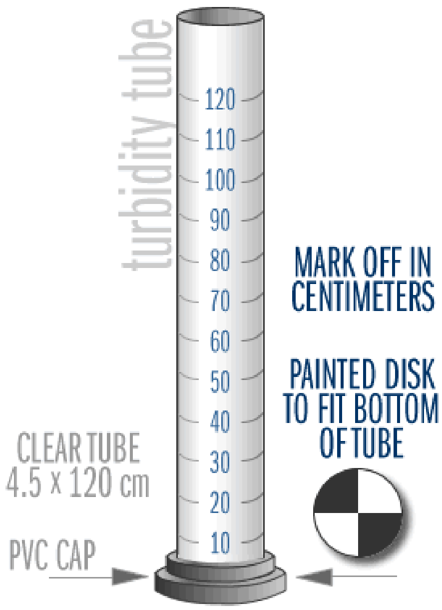
Secchi disk readings vary seasonally with changes in photosynthesis and therefore, algal growth. In most lakes, Secchi disk readings begin to decrease in the spring, with warmer temperature and increased growth, and continue decreasing until algal growth peaks in the summer. As cooler weather sets in and growth decreases, Secchi disk readings increase again. In lakes that thermally stratify, Secchi disk readings may decrease again with fall turnover. As the surface water cools, the thermal stratification created in summer weakens and the lake mixes. The nutrients thus released from the bottom layer of water may cause a fall algae bloom which would result in a decrease in Secchi disk reading.

Rainstorms may also affect readings. Erosion from rainfall, runoff, and high stream velocities may result in higher concentrations of suspended particles in inflowing streams and therefore decreases in Secchi disk readings. On the other hand, temperature and volume of the incoming water may be sufficient to dilute the lake with cooler, clearer water and reduce algal growth rates. Both clearer water and lower growth rates would result in increased Secchi disk readings.

The natural color of the water also affects the readings.In most lakes, the impact of color may be insignificant. But some lakes are highly colored. Lakes strongly influenced by **bogs**, for example, are often a very dark brown and have low Secchi readings even though they may have few algae.Pollution tends to reduce water clarity. **Watershed** development and poor land use practices cause increases in erosion, organic matter, and nutrients, all of which cause increases in suspended particulates and algae growth.

1.4.4 Measuring Turbidity in Rivers/streams

Turbidity is a standard measurement in stream sampling programs where suspended sediment is an extremely important parameter to monitor. A common, inexpensive method to monitoring turbidity in a river/stream is to use a device called a Turbidity tube. A Turbidity tube is a simple adaptation of the Secchi diskto be used in streams. It involves looking down a tube at a black and white disk and recording how much stream water is needed to make the disk disappear (Figure 5).



Steps to Using a Turbidity Tube

1. Pour sample water into the tube until the image at the bottom of the tube is no longer visible when looking directly through the water column at the image. Rotate the tube while looking down at the image to see if the black and white areas of the disk are distinguishable.
2. Record this depth of water on your data sheet to the nearest 1 cm. Different individuals will get different values and all should be recorded, not just the average. It is a good idea to have the initials of the observer next to the value to be able identify systematic errors.
3. If you see the image on the bottom of the tube after filling it, simply record the depth as > the depth of the tube. Then construct a longer tube, more appropriate for your stream.

Figure 5. Turbidity tube yields data for streams that is similar to a Secchi depth measurement in lakes.

1.5 Stream Flow

Stream flow, also called discharge and indicated by the symbol Q, is a measure of the volume of water that passes through a specific point in a river or stream during a set unit of time. The volume of water that passes by a specific point is often expressed in cubic meters per second (m^3/sec). Flow is a fundamental property of streams that affects everything from the temperature of the water and concentration of various substances in the water to the distribution of habitats and organisms throughout the stream.

Low flow periods in summer allow the stream to heat up rapidly in warm weather while in the fall and winter temperatures may plummet rapidly when flow is low. Flow directly affects the amount of oxygen dissolved in the water. Higher volumes of faster moving water, especially "white water," increases the turbulent diffusion of atmospheric oxygen into the water. Low flow conditions are much less conducive to oxygenation and when water temperature is high, dissolved oxygen (DO, see Section 1.10) levels can become critically low. The amount of sediment and debris a stream can carry also depends on its flow since higher velocity increases stream bank and stream channel scouring and erosion, and also keeps particulate materials suspended in the water. **Precipitation** that causes higher flows may also wash higher amounts of particulate and dissolved materials from the watershed directly into the stream. Stream flow, acting together with the downward slope (gradient), and the geology of the channel (its bottom substrate), determines the types of habitats present (pools, riffles, cascades, etc), the shape of the channel, and the composition of the stream bottom.

The volume of stream flow is determined by many factors. Precipitation is of course the primary factor– the more rain or snowmelt, the higher the flow. However, there is usually a lag period between the time a storm reaches its highest intensity and the time the stream reaches its peak flow. This lag time is affected by land use practices in the watershed. Vegetation increases the time it takes water to reach the stream by allowing it to slowly infiltrate into the soil before it reaches the stream. Wetlands and ponds in the watershed also add to this temporary storage. If it rains hard enough and long enough, the ground may saturate with water and then the precipitation will run off directly into the stream. In winter and spring, the potential of the natural soil and vegetation to absorb water is also affected by the depth to which it is frozen. This is why even moderate spring rainstorms may bring severe flash flooding. Precipitation also melts snow and ice that further contributes to the problem. In this way, stream flow patterns in Ontario, generally speaking, follow seasonal trends characterized by low or base-flow conditions in the summer and winter, and high flow periods during the spring.

1.5.1 Expected Impact of Pollution

The increased and variable flows associated with **stormwater runoff** pose a direct threat to the aquatic organisms in Ontario’s streams by modifying their physical habitat. Organisms are adapted to certain ranges and intensities of water velocity. Urbanization increases impervious surfaces such as roofs, roads and parking lots which speed the delivery of water into streams. Higher velocities alter habitats by moving cobbles and boulders and flushing large woody debris(snags and shoreline brush).Increased flows create secondary impacts by increasing erosion, modifying the channel and riparian zone in addition to delivering added "natural" pollutants (leaves, soil, animal droppings), road surface chemicals (metals, hydrocarbons, salts), lawn materials (grass and garden clippings, fertilizer nutrients, pesticides), and just plain litter - cigarette butts, cans, paper, and plastic bags. Increased erosion severely affects habitats by producing increased **sedimentation** of fine silt that fills the spaces between gravel and cobbles where aquatic invertebrates live, scours organisms and clogs their gills.

1.6 Carbon Dioxide

Most of the **carbon dioxide** that enters aquatic systems originates from the atmosphere, biological activities and the breakdown of limestone. **Carbon** is a component of most biological molecules necessary for life. Carbon dioxide is usually not limited in freshwater systems but the dissolved amounts may fluctuate. For example, if photosynthesis is occurring at a high rate the amount of dissolved carbon dioxide decreases; the opposite is true if the rate of decomposition is high. Carbon dioxide in water tends to be from bicarbonates which help to buffer water against rapid shifts in **pH**. For example, if an acid is added to water, the hydrogen ions will combine with the bicarbonate ions and prevent a change in pH. This buffering capacity (known as alkalinity) has important implications for aquatic ecosystems since it protects organisms against pH fluctuations.

1.7 pH

The **pH** of a sample of water measures the concentration of hydrogen ions. The term pH was derived from the manner in which the hydrogen ion concentration is calculated - it is the negative logarithm of the hydrogen ion (H^+) concentration. What this means to those of us who are not mathematicians is that at higher pH, there are fewer free hydrogen ions and that a change of one pH unit reflects a tenfold change in the concentrations of the hydrogen ion. For example, there are 10 times as many hydrogen ions available at a pH of 7 than at a pH of 8. The pH scale ranges from 0 to 14. A pH of 7 is considered to be neutral. Substances with pH of less than 7 are acidic; substances with pH greater than 7 are basic (See Figure 6 below).

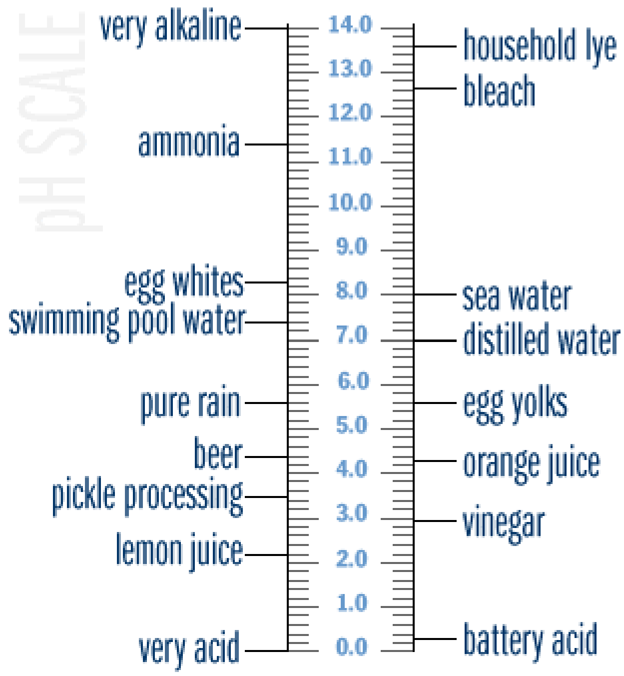


Figure 6. pH Scale

The pH of water determines the **solubility** (amount that can be dissolved in the water) and **biological availability** (amount that can be utilized by aquatic life) of chemical constituents such as nutrients (phosphorus, nitrogen, and carbon) and heavy metals (lead, copper, cadmium, etc.). For example, in addition to affecting how much and what form of phosphorus is most abundant in the water, pH may also determine whether aquatic life can use it. In the case of heavy metals, the degree to which they are soluble determines their toxicity. Metals tend to be more toxic at lower pH because they are more soluble.

1.7.1 Reasons for Natural Variation in pH

Photosynthesis uses dissolved carbon dioxide which acts like carbonic acid (H_2CO_3) in water. CO_2 removal, in effect, reduces the acidity of the water so pH increases. In contrast, respiration of organic matter produces CO_2, which dissolves in water as carbonic acid, thereby lowering the pH. For this reason, pH may be higher during daylight hours and during the growing season, ranging between 7.5 and 8.5, when photosynthesis is at a maximum. On the other hand, respiration and decomposition processes lower pH.pH can also vary with depth due to changes in photosynthesis and other chemical reactions. Near the bottom of the lake, decomposition releases $CO_{2,}$ and because there is no light for plants to fix it, CO_2 accumulates and the pH decreases, ranging generally between 6.5 to 7.5.

1.7.2 Expected Impact of Pollution

When pollution results in higher algal and plant growth (e.g., from increased temperature or excess nutrients), pH levels may increase, as allowed by the buffering capacity of the lake. Although these small changes in pH are not likely to have a direct impact on aquatic life, they greatly influence the availability and solubility of all chemical forms in the lake and may aggravate nutrient problems. For example, a change in pH may increase the solubility of phosphorus, making it more available for plant growth and resulting in a greater long-term demand for dissolved oxygen.

1.8 Hardness

Hardness of water indicates the amount of dissolved solids, namely calcium, calcium carbonate or magnesium. Water is considered soft if it has less than 10 ppm (part per million) of dissolved solids and hard if it has over 40 ppm of dissolved solids. Generally, hard water can harbour more living matter than soft water. This is explained partly by the fact that hard water has more calcium which can be utilized by many organisms to make body structures. Therefore, hard water not only harbours a great abundance of organisms but may also be essential for the survival of certain species such as clams and snails. Lakes with high concentrations of the ions calcium (Ca^{+2}) and magnesium (Mg^{+2}) are called hardwater lakes, while those with low concentrations of these ions are called softwater lakes. For humans, hard water is not a health risk, but a nuisance because of mineral buildup on fixtures and poor soap and/or detergent performance.

1.9 Temperature

Most aquatic organisms are **poikilothermic** - i.e. "cold-blooded"- which means they are unable to internally regulate their core body temperature. Therefore, temperature exerts a major influence on the biological activity and growth of aquatic organisms. To a point, the higher the water temperature, the greater the biological activity.Fish, insects, zooplankton, phytoplankton, and other aquatic species all have preferred temperature ranges and generally speaking, growth rates will double if temperature increases by 10°C within their "preferred" range.As temperatures move away from this preferred range the number of individuals of the species decreases until finally there are few, or none. For example, we would generally not expect to find a thriving trout fishery in ponds or shallow lakes because the water is too warm throughout the ice-free season.

Temperature is also important because of its influence on water chemistry.The rate of chemical reactions generally increases at higher temperature, which in turn affects biological activity. An important example of the effects of temperature on water chemistry is its impact on oxygen. Warm water holds less oxygen than cool water, so it may be saturated with oxygen but still not contain enough for survival of aquatic life. Some compounds are also more toxic to aquatic life at higher temperatures because the increased temperatures can increase their solubility (eg. some heavy metals like cadmium or zinc).

1.9.1 Reasons for Natural Variation in Temperature

The most obvious reason for temperature change in lakes is the change in seasonal air temperature. Daily variation also may occur, especially in the surface layers, which are warm during the day and cool at night. In deeper lakes (typically greater than 5 m for small lakes and 10 m for larger ones) during summer, the water separates into layers of distinctly different density caused by differences in temperature. Unlike all other fluids, however, as water approaches its freezing point and cools below 4°C, the opposite effect occurs and its density then begins to decrease until it freezes at 0°C. This is why ice floats. This process is called thermal stratification (See Figure 7). The surface water is warmed by the sun, but the bottom of the lake remains cold. You can feel this difference when diving into a lake. Once the stratification develops, it tends to persist until the air temperature cools again in fall. Because the layers don't mix they develop different physical and chemical characteristics. For example, **dissolved oxygen**, pH, nutrient concentrations, and species of aquatic life in the upper layer can be quite different from those in the lower layer. It is almost like having two separate lakes stacked on top of each other. The most profound difference is usually seen in the oxygen profile since the bottom layer is now isolated from the atmosphere, the major source of oxygen to the lake.

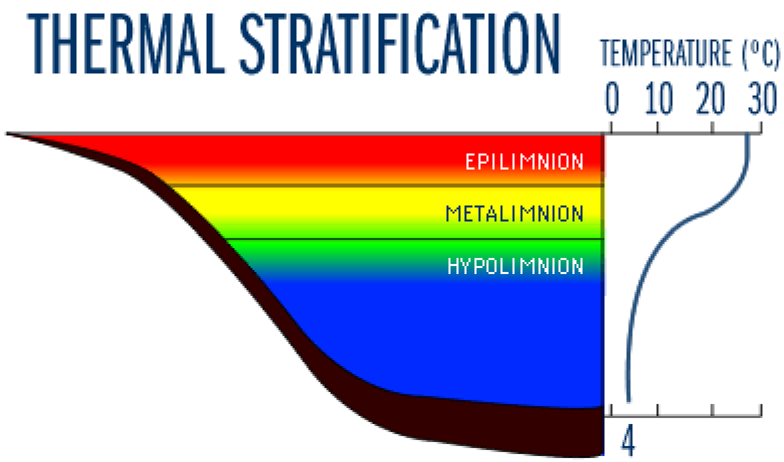


Figure 7. Example of how lakes can stratify thermally during the summer months

In the fall, the water at the surface cools down to about the same temperature as the water in the bottom layer of the lake. Consequently, thermal stratification is lost and blowing winds can cause turbulent mixing of the two water masses (fall turnover). A similar process may also occur during the spring as colder surface waters warm to the temperature of bottom waters and the lake mixes (spring turnover). The lake mixing associated with a turnover often corresponds with changes in many other chemical parameters that in turn affect biological communities. Watch for these changes in your lake this fall and spring.

Because light deceases exponentially with depth in the water column, the sun can heat a greater proportion of the water in a shallow lake than in a deep lake. This means shallow lakes can warm up faster and to a higher temperature. Lake temperature is also affected by the size and temperature of inflows (e.g. a stream during snowmelt, or springs or a lowland creek) and by how quickly water flushes through the lake. Even a shallow lake may remain cool if fed by a comparatively large, cold stream.

1.9.2 Expected Impact of Pollution

Thermal pollution (i.e., artificially high temperatures) almost always occurs as a result of discharge of municipal or industrial effluents. Except in very large lakes, it is rare to have an effluent discharge. In urban areas, runoff that flows over hot asphalt and concrete pavement before entering a lake will be artificially heated and could cause lake warming, although in most cases this impact is too small to be measured. Consequently, direct, measurable thermal pollution is not uncommon. In running waters, particularly small urban streams, elevated temperatures from road and parking lot runoff can be a serious problem for populations of cool or cold-water fish already stressed from the other contaminants found in urban runoff. During summer, temperatures may approach their upper tolerance limit. Higher temperatures also decrease the maximum amount of oxygen that can be dissolved in water, leading to oxygen stress if the water is receiving high loads of organic matter. Water temperature fluctuations in streams may be further worsened by cutting down trees which provide shade and by absorbing more heat fromsunlight due to increased water turbidity.

1.10 Dissolved Oxygen

Biological activity peaks during the spring and summer when photosynthetic activity is driven by high solar radiation. Furthermore, during the summer most lakes in temperate climates are stratified. The combination of **thermal stratification** and biological activity causes characteristic patterns in water chemistry. Figure 8 shows the typical seasonal changes in dissolved oxygen (DO) and temperature. The top scale in each graph is oxygen levels in mg O_2/L. The bottom scale is temperature in °C. In the spring and fall, both **oligotrophic** (less productive) and **eutrophic**(more productive) lakes tend to have uniform, well-mixed conditions throughout the water column. During summer stratification, the conditions in each layer diverge.

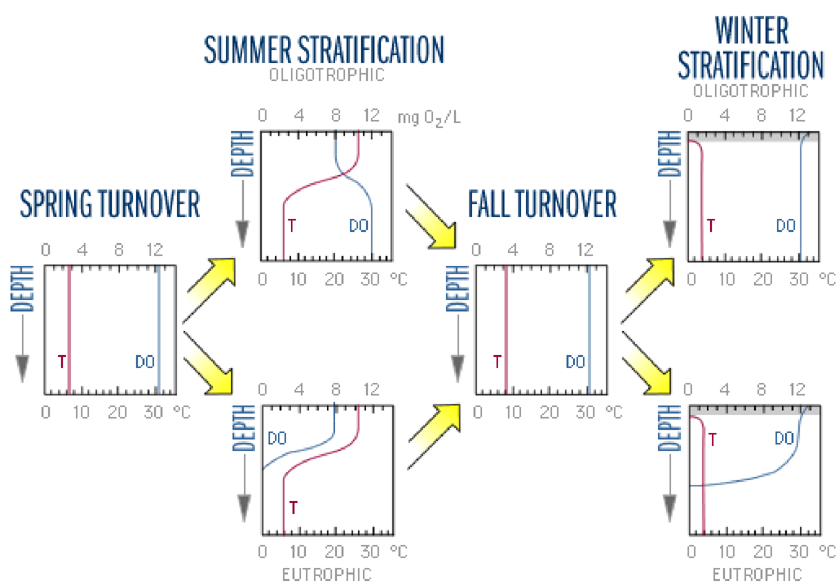


Figure 8. Typical seasonal changes in dissolved oxygen and temperature (adapted from Figure 8-1 in Wetzel, R.G. 1975. Limnology. W.B.Saunders Company).

The top water layer is known as **epilimnion** and the deep cool layer is known as the **hypolimnion**(see Figure 7). The DO concentration in the epilimnionremains high throughout the summer because of photosynthesis and diffusion from the atmosphere. However, conditions in the hypolimnion vary with trophic status. In eutrophic lakes, hypolimnetic DO declines during the summer because it is cut-off from all sources of oxygen, while organisms continue to respire and consume oxygen. The bottom layer of the lake and even the entire hypolimnion may eventually become anoxic, that is, totally devoid of oxygen. In oligotrophic lakes, low algal biomass allows deeper light penetration and less decomposition. Algae are able to grow relatively deeper in the water column and less oxygen is consumed by decomposition. The DO concentrations may therefore increase with depth below the thermocline where colder water is "carrying" higher DO leftover from spring mixing (recall that oxygen is more soluble in colder water). In extremely deep, unproductive lakes such as Lake Superior, DO may persist at high concentrations, near 100% saturation, throughout the water column all year. These differences between eutrophic and oligotrophic lakes tend to disappear with fall turnover (Figure 8).

In the winter, oligotrophic lakes generally have uniform conditions. Ice-covered eutrophic lakes, however, may develop a winter stratification of DO. If there is little or no snow cover to block sunlight, phytoplankton and some macrophytes may continue to photosynthesize, resulting in a small increase in DO just below the ice. But as microorganisms continue to decompose material in the lower water column and in the sediments, they consume oxygen, and the DO is depleted. No oxygen input from the air occurs because of the ice cover, and, if snow covers the ice, it becomes too dark for photosynthesis. This condition can cause high fish mortality during the winter, known as "winter kill." Low DO in the water overlying the sediments can exacerbate water quality deterioration; because when the DO level drops below 1 mg O_2/L chemical processes at the sediment-water interface frequently cause release of phosphorus from the sediments into the water. When a lake mixes in the spring, this new phosphorus and ammonium that has built up in the bottom water fuels increased algal growth.

1.11 General Lake Chemistry

Water is a good **solvent** and picks up impurities easily. Pure water – tasteless, colorless, and odorless – is often called the universal solvent. When water is combined with carbon dioxide forming a very weak carbonic acid, an even better solvent is produced. As water moves through soil and rock, it dissolves very small amounts of minerals and holds them in solution which can influence the overall water chemistry of a lake.

In the absence of any living organisms, a lake contains a wide array of molecules and ions from the weathering of soils in the watershed, the atmosphere, and the lake bottom. Therefore, the chemical composition of a lake is fundamentally a function of its climate (which affects its hydrology) and its basin geology. Each lake has an ion balance of the three major anions and four major cations (see Table 1 on next page).

Ion balance means the sum of the negative ions equals the sum of the positive cations when expressed as equivalents.These ions are usually present at concentrations expressed as mg/L (parts per million, or ppm) whereas other ions such as the nutrients phosphate, nitrate, and ammonium are present at µg/L (parts per billion, or ppb) levels.

Table 1. Major anion and cations found in Lake water

ION BALANCE FOR TYPICAL FRESH WATER			
Anions	**Percent**	**Cations**	**Percent**
HCO_3^-	73%	Ca^{+2}	63%
SO_4^{-2}	16%	Mg^{+2}	17%
Cl^-	10%	Na^+	15%
		K^+	4%
other	< 1%	other	< 1%

Humans can have profound influences on lake chemistry. Excessive landscape disturbance causes higher rates of leaching and erosion by removing vegetative cover, exposing soil, and increasing water runoff velocity. Lawn fertilizers, wastewater and urban stormwater inputs all add micronutrients such as nitrogen and phosphorus, major ions such as chloride and potassium, and, in the case of highway and parking lot runoff, oils and heavy metals. Emissions from motorized vehicles, fossil fuel-burning electric utilities and industry, and other sources produce a variety of compounds that affect lake chemistry.

Perhaps the best understood ions are H^+ (hydrogen ion, which indicates acidity), SO_4^{-2} (sulfate) and NO_3^- (nitrate) which are associated with acid rains. Mercury (Hg) is another significant air pollutant affecting aquatic ecosystems and can **bioaccumulate** in aquatic food webs, contaminating fish and causing a threat to human and wildlife health. Concentrations of other ions, especially bicarbonate, are highly correlated with the concentrations of the hardness ions, especially Ca^{+2}. The ionic concentrations influence the lake´s ability to assimilate pollutants and maintain nutrients in solution. For example, calcium carbonate ($CaCO_3$) in the form known as marl can precipitate phosphate from the water and thereby remove this important nutrient from the water.

1.12 Nutrient cycling

Carbon, nitrogen and phosphorous are some of the most important elements which determine the level of productivity in an aquatic system. Carbon enters into aquatic systems through soil surface runoffs (eg. organic residues), leachates from carbonate rocks, the atmosphere and from aquatic organisms. Phosphorous enters into aquatic systems through soil runoffs either from natural or made-made sources (eg. fertilizers) as well as from decomposition of organic matter. Man-made and natural nitrogen compounds also enter aquatic systems through runoffs, the atmosphere, decomposition of organic matter and by nitrogen fixation. **Nitrogen fixation** is a natural process where certain bacteria and algae (eg. cyanobacteria) transform biologically unavailable gaseous nitrogen into a water soluble form, such as nitrate and ammonium, which can be used by aquatic plants. Without the presence of nitrogen “fixers” very little nitrogen would be available for living organisms and most life on the planet would cease to exist.

1.12.1 Limiting factors and pollution

In aquatic systems nitrogen and especially phosphorous are known as limiting factors. In natural ecosystems these two elements are usually in short supply and therefore limit the growth of aquatic plants.If nitrogen or phosphorous are added to an aquatic system, aquatic plant growth will be stimulated causing the eutrophication of the water body. **Eutrophication** can be a natural or anthropogenic process where the release of nutrients stimulates aquatic plant growth and eventually increases animal populations. This process can be seen in time in oligotrophic lakes where the accumulation of surface runoffs and organic matter in their basins will transform it slowly to a eutrophic lake.

However, anthropogenic eutrophication can also have negative effects on aquatic ecosystems. Increased nitrogen or phosphorus inputs from agricultural fertilizers or wastes and domestic sewage can dramatically change the aquatic community. It stimulates the growth of algae (eg. algal blooms) which can cover the surface and prevent sunlight from penetrating into the water.Algal growth and the presence of suspended particles from pollution sources increases water turbidity thereby decreasing the amount of sunlight available for aquatic plants found in the water column. This situation has an effect of decreasing the amount of dissolved oxygen within the aquatic system. Plants found underneath the surface cannot add oxygen to the water since they become light starved and die.In addition, algae from the surface eventually die and sediment to the bottom where they decompose. Bacterial growth and decomposition on the bottom occurs at a high rate due to the abundance of organic matter from dead plant tissues and domestic wastes.Bacterial decomposition uses up dissolved oxygen which has an effect of creating anoxic conditions within the aquatic habitat.

2.0 Aquatic Systems & Associated Organisms

Not all aquatic organisms can be found in every type of freshwater system. Each kind of aquatic system provides challenges which organisms need to be adapted to in order to survive. Therefore the distribution and abundance of certain species within aquatic habitats may be limited.

2.1 Lotic Systems (Streams and Rivers)

Running water habitats are collectively known as lotic systems. Generally, streams and rivers tend to be cooler and more aerated than ponds and lakes. Organisms found within streams and rivers tend to be adapted to live in cool waters that are oxygen rich. Even though many of these organisms have gills and other body structures that absorb dissolved oxygen from water, several would be unable to live in low oxygen environments such as those found in still waters. Therefore, organisms found in lotic environments need the high oxygen levels of streams and rivers in order to survive.

Inhabitants of streams and rivers must overcome the water current to be able to survive in lotic systems. In order not to be washed downstream, inhabitants have adapted to anchor themselves or developed behaviours that protect them from the current. Generally, fast flowing systems lack plankton and other floating plants since these would be constantly washed downstream. Usually plants found in lotic systems tend to be rooted or anchored to the bottom substrate.Animals found in lotic systems tend to have dorsal-ventrally flattened or streamlined bodies. Also, many have strong legs with grasping claws, while others prefer to build heavy tube-shaped homes or hide underneath rocks and stones. All of these features are essential to allow these organisms to remain in place; still water organisms lack many of these adaptations and therefore cannot live in extreme currents. Lotic systems can be separated into two major groups: streams and rivers. The following is a description of each system and its inhabitants.

2.1.1 Streams

Streams are smaller and feed into rivers. Their substrate is generally composed of stones, rocks, pebbles and some silt in areas where water current is weaker. Organic matter does not accumulate in any great extent since it is constantly washed downstream. Streams tend to be cooler than rivers and therefore will contain more dissolved oxygen.

Organisms found in streams are adapted to swift and strong currents. Sometimes the only plants found are mosses and algae (eg. diatoms) clinging to rocks. Benthic organisms found at the bottom of the basin, such as riffle beetle larvae,dobsonfly larvae, blackfly larvae, caddisfly larvae, stonefly nymphs and mayfly nymphs make up the majority of animals. Some snails and fish, such as brook trout and dace, will also inhabit these systems.

Streams in Ontario fall under two major categories: agricultural and woodland streams. Agricultural streams are those found meandering in agricultural lands and since they are exposed directly to sunlight tend to harbour lots of algal growth. On the other hand, woodland streams are shaded and have less plant growth within them. Input of organic material and energy in woodland streams come from dead plant matter and leaf litter (detritus). In both habitats, insects like riffle beetles, mayflies, blackflies and caddisflieseither graze on algae found on rocks, consume dead plant material or filter water to collect organic matter.These organisms are in turn eaten by predators such as stoneflies, dobsonflies and fish. Stream systems tend to have the simplest food webs since not many species can live in a turbulent environment.

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 in section 6.0 and Appendix B.

2.1.2 Rivers

Rivers are larger and obtain all discharge material from streams. There are many different types of rivers all varying in depths and width and amount of water current. Depending on their current their substrate may resemble that of streams or lakes.

Rivers with torrential currents have little organic matter accumulating on the substrate and many of the inhabitants will be similar to those found in streams. Rivers with slow currents may have organic matter and silt as their substrate and may even have organisms normally found in still waters. These rivers may have rooted plants such as cattails, pondweeds, coontails and may even have plankton in eddies or bays where water current is lacking. The animal community of slow flowing rivers may be similar to streams but may also contain still water inhabitants such as crustaceans, worms, dragonflies, damselflies, midges, beetles, true bugs, snails, clams, fish and amphibians.

Food webs in slow flowing rivers are more complex than streams since more species are capable of living in these habitats. Energy and organic sources may come from both detritus and photosynthesis. Filter-feeders, grazers and shedders consume this plant material and may be preyed upon by larger predators.

Example – 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 9). It is very common to find brook trout in the many streams of northern Ontario; however they also frequent

Figure 9: *Brook Trout*
Source: Ontario.ca

some of the less-disturbed streams of southern Ontario.

One of the main factors which influence the brook trout is water temperature. This species requires a habitat with a constant supply of cold and clear water throughout the year.Thus, these fish can be found in areas where overhanging branches, logs and rocks provide cover and keep the water cool.

When summer temperatures warm up water bodies, brook trout will move into deep pools where it is cooler. It is at this point that they are dependent 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 experiences 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.

2.2 Lentic Systems (Ponds and Lakes)

Standing waters are collectively known as lentic systems. Unidirectional water flow is minimal and these waters tend to be warmer than streams and rivers. Oxygen levels in lentic systems are generally lower than lotic systems but some standing waters may contain enough dissolved oxygen to support the growth of some lotic adapted organisms. Lentic systems differ greatly from one another in size, temperature regimes, dissolved oxygen and chemical levels.For example, standing water hardness depends on the surrounding land mass and types of substrates found within the habitat. In most lentic systems, silt and organic matter accumulates on the bottom of the basin which can have special implications for aquatic organisms.

Organisms found in lentic systems do not need special adaptations to remain in place since water current in their habitat in minimal. Several will use the water surface as a home while others will be found deep on the bottom. Deep basins tend to have variations in temperature and oxygen levels with surface waters being warmer and containing more dissolved oxygen; this thermal and oxygen stratification will influence the distribution of species within deep basins.

Lentic systems can be separated into three major groups: wetlands, ponds and lakes. The following is a description of each system and its inhabitants.

2.2.1 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.Wetlands are similar to ponds in that they tend to be shallow with warm waters. It is difficult to categorize wetlands as purely aquatic since many have a recurrent dry and wet phase.However, they are important reproductive sites for many species that require water at some stage of their life cycle.

Example – Blanding's Turtle

The Blanding's turtle is a freshwater species of turtle found only in North America (Figure 10). It can be identified by its smooth and round dark green shell and vibrant yellow throat and chin. Blanding's turtles are very well adapted for colder climate conditions, and actually prefer cooler temperatures as they cannot tolerate extreme heat. Contrarily,

Figure 10*: Blanding's Turtle*
Source: Ontario.ca

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.

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. Additionally sandy areas occur most often along road sides which cause a direct threat to the turtle's survival.

Example – Common Cattail

The common cattail is one of the most characteristic plants of Ontario's wetlands (Figure 11). Their presence can identify soils saturated with water, where their roots (called rhizomes) grow very quickly, creating large, dense stands of this plant.

Figure 11*: Common Cattail*
Source: USDA Plants Database

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.

2.2.2 Ponds

Ponds are generally smaller and warmer than lakes and are shallow enough to allow rooted plants to grow on the bottom of the basin.Ponds tend to be more productive than lakes and support more aquatic organisms per volume of water. Usually water temperatures throughout ponds tend to be uniform and the bottom rarely becomes anoxic. Silt and organic matter accumulates on the bottom of ponds and with time may fill up the basin.

Several of the organisms found in ponds are similar to those found in river systems and in lakes. Generally, organisms using pond habitats are those which require high to moderate dissolved oxygen levels and warm water temperatures.Many ectotherms such as insects and amphibians will use ponds since they provide the right temperature regimes to allow proper larval development. Pond water hardness tends to higher than in lakes and therefore organisms that require "hard" water will be found in ponds. Fishless ponds also provide an excellent habitat for some species such as mosquitoes, which seek these waterbodies in order to escape predation.

Organisms will use different zones of a pond depending on their adaptations. Some will use the water surface and these organisms are collectively referred to as neuston. Examples of these include plants like phytoplankton, duckweeds and water lilies and animals such as mosquito larvae, snails, flatworms, water striders and "whirligig" beetles.Other organisms like some phytoplankton, zooplankton, beetles, hemipterans, fish, amphibians and reptiles will use the water column as a habitat. Most animals in ponds will be found at the bottom of the basin (benthos) or on plants (epiphytes), consuming detritus or organisms hidden in the substrate or among the plants. The benthic animal community is composed of invertebrates (animals without a backbone) such as beetles, hemipterans, dragonfly nymphs, damselfly nymphs, mayfly nymphs, caddisfly larvae, midge larvae, spiders, mites, worms, leeches, snails and clams.

Pond food webs can be quite complex due to the diversity of animal and plant life. Generally, the initial energy source of ponds comes from the photosynthetic activities of phytoplankton and plants. These are then eaten by herbivorous primary consumers which in turn may become preyed upon by consumers and predators higher up in the food chain.

2.2.3 Lakes

Lakes are larger and generally cooler than ponds. Much variation exists between lakes in their size, depth and chemical composition but all have one trait in common: their basins are too deep to allow the growth of rooted aquatic plants on the bottom. Lakes can be divided into three major categories based on their trophic status or productivity.

- **Oligotrophic lakes:** These deep and cold lakes tend to be the least productive with low levels of photosynthesis occurring and little organic matter accumulation on the bottom. Dissolved oxygen levels do not change dramatically with depth. Generally, these lakes harbour the fewest organisms.
- **Eutrophic lakes**: Shallower and warmer than oligotrophic lakes and are the most productive of all lake types. Photosynthesis occurs at high levels and lots of organic matter accumulates on the bottom. Due to microbial decomposition of detritus on the bottom, oxygen levels decrease dramatically with depth. Generally, these lakes have the highest levels of biomass.
- **Mesotrophic Lakes:**Represent an intermediate condition falling between oligotrophic and eutrophic lakes.

While lakes may be lumped into a few trophic classes, each lake has a unique constellation of attributes that contribute to its trophic status. Three main factors regulate the trophic state of a lake:

1. Rate of nutrient supply– influenced by the bedrock geology of the watershed, as well as soil and vegetation patterns and human land use practices and management.
2. Climate – amount of sunlight, temperature and hydrology (precipitation + lake basin turnover time)
3. Shape of lake basin (morphometry) – influenced by maximum and mean depth, volume and surface area and watershed to lake surface area ratio ($A_w : A_o$).

Trophic status is a useful means of classifying lakes and describing lake processes in terms of the productivity of the system. Basins with infertile soils release relatively little nitrogen and phosphorus leading to less productive lakes, classified as oligotrophic or mesotrophic. Watersheds with rich organic soils, or agricultural regions enriched with fertilizers, yield much higher nutrient loads, resulting in more productive, eutrophic (even hyper-eutrophic) lakes.

Ontario lakes during the course of the summer undergo thermal stratification. The top water layer known as epilimnion is warm and the deep cool layer is known as the hypolimnion. These two water layers are separated by a thin water layer known as the metalimnion where we find the greatest temperature change. These differences in temperature have important implications to aquatic organisms; species will occupy depths to which they are adapted. For example, cold water fish such as salmon and lake trout will be found in deep waters whereas warm water fish such as sunfish and perch will be found in warm, shallow waters. In lakes, organisms form distinct communities depending on the region which they are found. Aquatic ecologists divide lakes habitats into distinct regions, with each harbouring specific organisms.

- **Lake Surface:** Several organisms will use surface tension as a “substrate” for their activities.This community can be quite similar to that found in ponds, especially in shallow areas of lakes. The neustonic community can include plants like phytoplankton, duckweeds, water lilies and other floating plants and animals such as mosquito larvae, snails, flatworms, water striders and “whirligig” beetles. Generally, many of these organisms are only found in shallow water near the shoreline (eg. littoral zone).
- **Littoral Zone:** Region of lakes which extends from the shoreline to the limit of occupancy of rooted plants.Animal and plant communities in this region can be quite similar to those found in ponds. Generally, this is the zone where we find the greatest biodiversity and is an important reproductive site for snails, insects, fish, amphibians and waterfowl.Water in this region is usually warm and well oxygenated.
- **Limnetic Zone:** Region of open water bounded by the littoral zone. In this region there are no rooted aquatic plants and organisms found here live in the water column. Inhabitants of the limnetic zone are classified as nekton and plankton. Nekton includes organisms like fish and insects. Plankton can include plants (phytoplankton) such as algae and animals (zooplankton) like copepods and rotifers.These organisms can be found throughout the water column or in specific layers depending on their adaptations. The limnetic zone can be further subdivided into two major layers:
- **Trophogenic Zone:** Corresponds to the lighted zone and serves as habitat to phytoplankton and plant-based animal communities. Generally, water temperatures and dissolved oxygen levels are higher in this region. Organisms needing sunlight and higher dissolved oxygen levels will be found here.
- **Tropholytic Region:** Also known as the profundal zone; corresponds to the deep, cold and dark zone. Here photosynthesis does not occur and very little oxygen is added to the water. Organic matter from above accumulates on the bottom and due to microbial activities (which use oxygen) water in this zone can become anoxic. Organisms, such as midgefly larvae are found here since they are adapted to live in low oxygen environments.
- **Benthic Zone:** Corresponds to the lake basin which extends from the littoral zone to the tropholytic zone. Benthos organisms found in littoral zones are those which require high dissolved oxygen levels and warm water to complete their development. Benthos found in tropholytic zones, such as *Tubifex* worms, are adapted to live in waters with little dissolved oxygen.

Example - Walleye

Walleye are a native species to Ontario (Figure 12). 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. They tend to come close to the shore at night-time to feed, especially in the spring and fall seasons.

Figure 12: *Walleye*
Source: Ontario.ca

Due to their sensitivity to light, walleye are affected by the presence of zebra mussels. 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; not a favorable condition for walleye. Walleye like turbid waters. The impacts of zebra a mussel is driving walleye deeper and depriving the species of its habitat.

Walleye are also a popular sport fish in Ontario. Beyond that they are an important species in lake environments, their populations are the source of economic income for many businesses and they are a food source for many people. To learn more about how to identify walleye and other native Ontario fish species, please see Appendix A.

2.3 Samplers and Collection Methods in Lentic and Lotic Systems

Samplers fall under two major categories: quantitative and qualitative. Qualitative samplers are those which are used to sample a habitat to determine the species living in the ecosystem. Quantitative samplers are those which collect a certain volume or area of a habitat and determine the number of individuals of each species. Qualitative samplers are used to figure out what is 'out there', whereas quantitative samplers are used to calculate the abundance of species in a habitat.

Each aquatic sampler has been designed to function in specific habitats and to collect particular organisms. Therefore, choosing the right sampler is important if you wish to study a certain group of organisms.

2.3.1 Samplers for lotic environments

Qualitative samplers

The best qualitative sampler to collect benthos in streams and shallow rivers is the kick net (Figure 13). It consists of a net attached to two rods. Usually two people are required to use this sampler. The kick net is stretched and held flush to the substrate. A person standing upstream in front of the sampler kicks the substrate as to dislodge benthos which are then carried by the stream and become trapped in the net.

***Figure 13**: Kick Net*
Source: Rickly Hydrological Co

Another sampler sometimes used along river edges is the D-frame net (Figure 16). This net is swept in front of the person and is used to collect organisms on the substrate and in the water column.This sampler is often used to collect organisms in areas where there are lots of vegetation.

Quantitative samplers

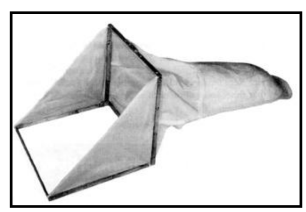


***Figure 14**: Surber Sampler*
Source: Rickly Hydrological Co

The Surber sampler (Figure 14) is the most commonly used sampler to collect benthos in streams with rocky bottoms. It consists of a metal frame with netting material attached to one end. The open end of the sampler is placed directly on the substrate. Rocks found within the area enclosed by the open end are rubbed by hand to dislodge benthoses which are then carried by the current into the net. Care must be taken not to disturb too much debris since the net is fragile and can clog up. This sampler can be used to determine the total number of species per unit area.

The Hester-Dendy multiple plate sampler (Figure 15) and the rock basket sampler are devices used to measure the abundance of organisms which attach themselves to solid surfaces. These samplers can be placed directly on the substrate or can be left hanging in the water column.

Figure 15. Hester-Dendy multiple plate sampler
Source: Rickly Hydrological Co

2.3.2 Samplers for lentic habitats

Qualitative sampler

The D-frame dip net (Figure 16) is commonly used to collect organisms in the margins of ponds or lakes. It is used to collect organisms found on plants, on the substrate and in the water column.

Figure 16: D-frame Net Source: Rickly Hydrological Co

Quantitative sampler

Figure 17: *Plankton Net Source: Rickly Hydrological Co*

The plankton net (Figure 17) is used to capture plankton found in the water column. The net is towed by boat and placed at a specific depth. Plankton abundance is determined by dividing the total number of organisms collected by the volume of water sampled by the net.

The Macan sampler is used to collect aquatic plants and associated organisms. It is only used in shallow areas. It consists of a box which has sharp jaws at one end that can be opened and closed. To collect organisms, the opened sampler is placed directly on the substrate and then it is closed to cut the aquatic plants. One can determine abundances based on the total area sampled by the device.

The Ekman grab (Figure 18) is used to collect benthos found on the soft substrate of shallow waters. It consists of a metal box with two spring mounted jaws which can open and close at one end. With the jaws opened, the sampler is lowered onto the substrate. A messenger (weight) is then released down the rope to which the Ekman grab is attached causing the jaws to collect some substrate as they shut. It is important that no large solid objects are found in the substrate since these will prevent the jaws from closing completely. This sampler is used to determine the abundance of benthos per unit area of substrate.

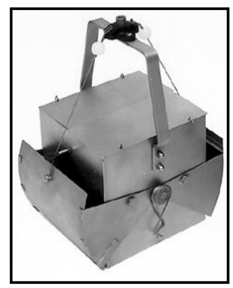


***Figure 18**: Ekman Grab Source:Rickly Hydrological Co*

***Figure 19**: Ponar Grab Source: Rickly Hydrological Co*

Similar to the Ekman grab, the Ponar grab (Figure 19) is used to collect benthos in deep waters in both hard and soft substrates. The jaws of the Ponar grab are powerful enough to crush clams and break rocks. This device is mounted on a winch in a boat. This sampler is also used to determine the abundance of benthos per unit area of substrate.

The Hester-Dendy multiple plate sampler (Figure 15) and the rock basket sampler can also beused in lentic habitats. Just as in lotic systems, these devices are used to measure the abundance of organisms which attach themselves to solid surfaces.

3.0 Carrying Capacity and Ecological Succession

Aquatic ecosystems are not “static”, they change over time. With time, wetlands and ponds may dry up giving way to grassy meadows. These changes occur through a series of steps with specific plant groups appearing and being replaced by other plants until eventually a climax community is reached.

3.1 Carrying capacity, critical habitat and limiting factors

All organisms have habitat requirements that allow them to reproduce and grow. In many cases, organisms are flexible enough to use several components of their habitats. For example, predators like dragonfly nymphs and sunfish, can switch to a planktivorous diet if insect prey are no longer available. However, most organisms at some point in their lives will have specific requirements which can only be met by particular habitats. These critical habitats usually consist of important reproductive and developmental sites; their presence determines the survival and abundance of a species.

The abundance of species within habitats is also determined by a variety of other factors including amount of food, presence of predators and limiting factors. Limiting factors are components in the ecosystem which are in short supply and affect the abundance of organisms.Phosphorous is an example of a limiting nutrient in an aquatic ecosystem. It is usually in scarce amounts and therefore limits the growth of aquatic plants. All of these factors together determine the total population of organisms that can be supported by an ecosystem, that is, the carryingcapacity of a habitat. If a species population grows above the carrying capacity of its habitat this may result in a population crash. Populations can only increase without crashing if there is a change in limiting factors. By increasing the abundance of a limiting factor, the habitat’s carrying capacity for that species also increases. Unfortunately, as seen previously with the addition of phosphorous to waterbodies, the addition of a limiting factor to an ecosystem can have negative effects by permitting species to reach unnaturally high levels.

Sometimes variations in the carrying capacity for one species can cause changes in other species. Imagine what would happen if a spawning site of large predatory fish, such as trout and pike, were destroyed. These fish would lose a critical reproductive habitat and eventually disappear. Smaller prey fish would now be free of predation pressure and increase in population. These smaller fish might eventually reach and “over-shoot” the carrying capacity of the ecosystem. The habitat would no longer have enough food to sustain the smaller fish causing them to either die out or become severely malnourished.Therefore; a decrease in the carrying capacity for predatory species has caused a severe change in prey species populations.

3.2 Ecological Succession in Aquatic Systems

In most aquatic systems we see a general progression of plant zones from deep to shallow water and finally to the shore. In each zone there are plants which are adapted to specific conditions. Aquatic ecosystems can be divided into four major plant zones: shoreline zone, emergent zone, floating-leaved zone and submerged zone.

The shoreline zone is composed of plants that require or can tolerate soil with lots of moisture. Some of these plants, including mosses, horsetails and ferns, grow at the edges of the shore since they need some surface water to reproduce. Other plants such as willows, dogwood and alders will also be found near the shoreline. Most plants found in this zone cannot endure extended periods under water.

The emergent zone is the area closest to the shoreline with the shallowest water. Plants found in this zone grow above and below the water surface. Examples of such plants include cattails, grasses, sedges, rushes, arrowheads, burreeds, calla lilies and purple loosestrife. These plants cannot survive complete submergence in water. In order to complete their lifecycle (e.g. seed production), they require that some growth occur above the water surface.

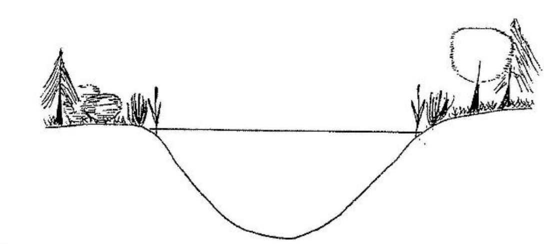
The floating-leaved zone is composed of plants which have leaves that float on the water surface. Water lilies, pondweeds, spatterdocks and water-shields are some of the common rooted plants. Duckweeds can also be found here and in deeper waters. Unlike most plants, all floating-leaved plants have stomata on the upper surface of their leaves. This adaptation allows them to obtain carbon dioxide directly from the air. Rooted plants will be found in areas that are shallow enough to permit their leaves to reach the water surface.

The submerged zone is the deepest area in basin that allows rooted plant growth. Plants found here, such as coontails, watermilfoils, stoneworts, bladderworts and common waterweeds, are completely submerged under water. Some of these plants (eg. bladderworts and watermilfoils) may have some structures growing above the water surface.

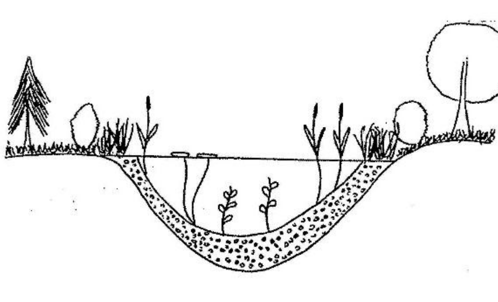
Although there are no rooted plants growing on the deep substrates of lakes, we can find phytoplankton growing in the water column. Phytoplankton generally makes up an important part of the plant community in deep basins.

3.2.1 Ecological Succession of a Pond

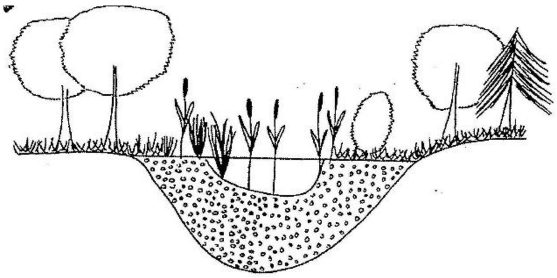
Aquatic systems change over time with the accumulation of silt and organic matter in their basins. For example, oligotrophic lakes can slowly change to a more productive eutrophic system. In some circumstances, the aquatic habitat disappears and is replaced by a terrestrial community. The following is an example of ecological **succession** seen in some ponds:



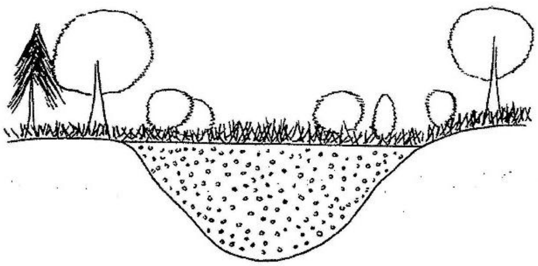
The basin is mostly composed of open water with very little silt or organic matter accumulated in the basin. Plants like mosses, sedges, greases and woody plants are found growing near or on the banks. Phytoplankton may be found in open water.



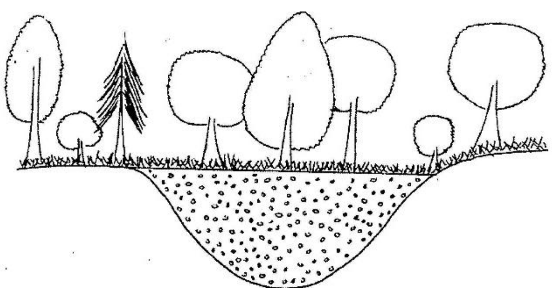
Plants are slowly invading the shallow regions of the basin and are growing out from the edges. Silt and organic material from aquatic and terrestrial sources is accumulating on the bottom. The depth of the basin slowly decreases eventually forming marsh-like conditions.



As more silt and organic matter accumulates, more plants can grow out from the edges. Eventually, submerged and float-leaved plants are replaced by emergent, shoreline plants creating a fen-like habitat. Bushes are slowly starting to invade the basin.



The basin is completely filled with organic matter and silt. Most plants growing in the basin are grasses and bushes, giving the basin a meadow-like appearance. Eventually, these plants will be replaced by fast growing trees such as aspen and birch.



Fast growing trees are replaced with longer lived species such as maple, beech and hemlock. As this point succession stops and the basin has a relatively stable climax community. Keep in mind that the animal community also changes during the process of succession.

3.2.2 Ecological Succession of a Lake

Eutrophication, the progress of a lake toward a eutrophic condition, is often discussed in terms of lake history. A typical lake is said to age from a young, oligotrophic lake to an older, eutrophic lake. Geological events, such as glaciation, created lakes in uneven land surfaces and depressions. The landscapes surrounding lakes were often infertile, and thus many lakes were oligotrophic. Eventually some of the shoreline and shallow areas supported colonizing organisms that decomposed unconsolidated materials into reasonably fertile sediments.Active biological communities developed and lake basins became shallower and more eutrophic as decaying plant and animal material accumulated on the bottom. Shallow lakes tend to be more productive than deep lakes, in part because they do not stratify, thereby allowing nutrients to remain in circulation and accessible to plants. They also tend to have a smaller lake volume, so **nutrient loading** from their watershed has a larger impact. There are undoubtedly exceptions to this typical progression from oligotrophy to eutrophywhere geology, topography, and lake morphology caused eutrophic conditions from the start.

This concept of lake aging has unfortunately been interpreted by some as an inevitable and irreversible process whereby a lake “dies”. In fact, many oligotrophic lakes have persisted as such since the last glaciation and some ultra-oligotrophic lakes, such as Lake Tahoe may have been unproductive for millions of years. Furthermore, research in paleolimnology has provided evidence that contradicts the idealized version of a lake becoming more and more eutrophic as it ages. Studies of sediment cores have suggested that the algal productivity of Minnesota lakes actually may have fluctuated a great deal during the past 12-14,000 years (the period since the last glaciation). Changes in climate and watershed vegetation seem to have both increased and decreased.Some lakes probably experienced high rates of photosynthesis fairly soon after glacial retreat and then became less productive until recent times. It is also possible that water sources for some lakes have changed over the past thousands of years through diversions of stream flow. In such cases water supplies to a lake (and therefore nutrient supplies) could have changed, leading to changes in the lake's productivity.

However, lakes may be culturally eutrophied by accelerating their natural rate of nutrient inflow. This occurs through poor management of the watershed and introduction of human wastes through failing septic systems. Such changes may occur over periods of only decades and are reversible if anthropogenic nutrient loading can be controlled. In the 1960s this was a serious issue, exemplified by the hyper-eutrophic condition of Lake Erie. Although it was pronounced "dead," it eventually returned to less eutrophic conditions, when major point sources of phosphorus were controlled in the early 1970s.

In North America many of the problems associated with the direct discharge of domestic wastewater have been successfully mitigated. Now the regulatory focus is on the much more difficult problem of controlling non-point sources (NPS) of nutrient pollution such as agricultural drainage, stormwater runoff, and inadequate on-site septic systems. NPS pollution is particularly difficult to address because it is diffuse, not attributable to a small number of polluters, and associated with fundamental changes in the landscape, such as agriculture, urbanization and shoreline development.Water quality impacts associated with eutrophication include:

- Noxious algae (scums, blue-greens, taste and odor, visual)
- Excessive macrophyte growth (loss of open water)
- Loss of clarity (secchi depth goes down)
- Possible loss of macrophytes (via light limitation by algae and periphyton)
- Low dissolved oxygen (loss of habitat for fish and fish food)
- Excessive organic matter production (smothering eggs and bugs)
- Blue-green algae inedible by some zooplankton (reduced food chain efficiency)
- "Toxic" gases (ammonia, H_2S) in bottom water (more loss of fish habitat)
- Possible toxins from some species of blue-green algae
- Drinking water degradation from treatment disinfection by-products
- Carcinogens, such as chloroform (from increased organic matter reacting with disinfectants like chlorine)

4.0 Preserving Aquatic Biodiversity

Biodiversity is defined as the sum of all bacterial, fungal, plant and animal species found within a given habitat. In other words, it is the number of different species found in a certain area. Tropical rainforests have the highest levels of biodiversity on the planet. 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, streams 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. **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. The level of biodiversity within a habitat is a good measure of the health of an ecosystem. Generally, healthy ecosystems will have a greater variety of organisms. You can imagine that a polluted ecosystem will have lower biodiversity; pollution tolerant organisms may be found in great numbers but the total number of different species in a polluted habitat will be lower than a clean, healthy ecosystem. Therefore, a drop in biodiversity is a good indication that negative factors are influencing an ecosystem.

4.1 Importance of Biodiversity

Biodiversity has some important implications for both humans and the natural world. 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, building materials, 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. With a loss of species diversity in Ontario there will be a corresponding loss of economic gain and recreational enjoyment.

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 the same or similar vital functions in an ecosystem. 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 bya 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.

4.2 Dangers to 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 effect 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. 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.

Biodiversity as a whole, as well as individual species are dependent on healthy ecosystems for survival. The activities described above can have devastating effects on local aquatic biodiversity and can eventually result in species becoming extirpated from an 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. The following are some of the major causes of current extinction:

4.2.1 Habitat destruction

The destruction of habitats is perhaps one of the major reasons why species populations have been dramatically decreasing. Species are adapted to a particular habitat and need them to fulfill all of their needs. About 70% of southern Ontario's original wetlands have been destroyed. Since many of these wetlands harbour most of our species in Ontario, their destruction has brought a corresponding decline in biodiversity.

4.2.2 Overhunting, overfishing and overharvesting

The killing and harvesting of organisms has led to declines in population and even extinction. Overharvesting of peat has led to the destruction of many of our bogs. Overfishing of lake trout in the Great Lakes has led to the collapse of the fish population and consequently the collapse of the fishing industry. Overhunting has almost caused the extinction of several of our waterfowl species.

In most cases, overhunting and overfishing do not remove or kill all members of a species. However, populations may be so low that the species may never recover. Other factors, such as low reproductive rates, natural predators, habitat destruction and pollution, may act upon these small populations and drive the species to extinction.

4.2.3 Pollution

The release of pollutants into our environment has had negative effects on most communities. Acid rain caused by fossil fuel emissions has decreased the pH of many aquatic systems resulting in fish kills and "death" of lakes. Toxic pollutants not only kill organisms immediately but in many cases remain in the environment and affect future generations. In aquatic systems, pollutants like mercury and PBCs (Polychlorinated biphenyls), accumulate in the sediments and are released slowly over time into the ecosystem which means the effects of pollution can be felt over long periods.

Many pollutants bioaccumulate in the ecosystem, with top predators having the highest concentrations of pollutants. Although low concentrations of some pollutants may not affect organisms, their accumulation within living tissues can have serious consequences. High pollutant concentrations can cause i) body deformations, ii) behavioural abnormalities, iii) motor and neural dysfunctions, iv) reproductive failure and v) death. All of these factors depress a species ability to function properly within an ecosystem.

4.2.4 Invasive species

Invasive species are organisms which have been brought intentionally or accidentally from another continent into our Canadian ecosystem. In many cases, these invasive species have no natural predators in Canada. Free from predation pressure, invasive species can proliferate and overrun the habitat. They change the ecosystem by either directly killing or out-competing native species for space and food. Native species can eventually die out if invasive species are not controlled.

The zebra mussel (*Dreissena polymorpha*) is an example of an invasive species which has invaded many of Ontario's waterways (Figure 20). Larvae of this organism were transported in ballast waters of ships from Asia and released into the Great Lakes. Since very few of our native animals eat zebra mussels, bivalve populations exploded.They colonized hard surfaces and soon clogged up drain pipes. Their ecological effects were quite dramatic. By attaching themselves to the surfaces of organisms, they would suffocate and kill aquatic plants and native clams; native clam species (Unionidae) in the St. Lawrence River have practically disappeared with the arrival of the exotic mussel species. Zebra mussels have also blanketed the bottom of basins making it difficult for fish, amphibians and waterfowl to find and eat benthic invertebrates. Being efficient filter feeders, zebra mussels out-competed many of our native plankton feeders. Many of our aquatic ecosystems have changed as a result of zebra mussels; the decrease in plankton abundance has caused a reduction in numbers of plankton feeders which in turn has reduced predator numbers.

Figure 20: *Zebra mussels*
Source: Ontario Invading Species

For a complete list of invasive species in Ontario, visit Ontario's Invading Species Awareness Program at http://www.invadingspecies.com.

4.2.5 Climate Change

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.

Keep in mind that usually a combination of the above negative factors causes a drop in population numbers. Marshes are a good example of this. Many marshes in Ontario have been filled or drained to make way for human development. Overhunting of waterfowl and overfishing has reduced the abundance of native species. Marshes collect much of the runoff and associated pollutants from surrounding lands. These pollutants accumulate in the habitat causingdeleterious effects on organisms. Exotic species such as Purple loosestrife (*Lythrum salicaria*) and the carp (*Cyprinus carpio*) are negatively changing marsh habitat ecosystems. It is the combination of these effects that has brought about a dramatic decrease in the population of our native marsh species.

4.3 Measuring Aquatic Biodiversity

As the state of aquatic biodiversity becomes one of increasing concern it is important to find ways to monitor and measure biodiversity.This is done so that scientists can communicate their findings with other scientists, politicians and the general public. 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 biodiversity of that area can be monitored. This is how changes in biodiversity over time are detected. For examples on various ways in which diversity is measured in aquatics ecosystems, refer to section 2.

5.0 Wetlands

Wetlands are unique in that they represent habitats “in-between” that of terrestrial and aquatic ecosystems. Wetlands are important habitats for many terrestrial and aquatic organisms and in Canada these ecosystems harbour high levels of biodiversity. In rivers, streams, and most lakes the constant flow of water washes away many of these nutrients.But in marshes, and other wetlands, nutrients tend to remain and accumulate. In northern regions, where water levels are relatively stable, nutrients often become trapped in the bottom sediments; but in southern regions they are released each year during spring flooding. This is one of the reasons why wetlands in southern regions are so productive and why they attract so many forms of wildlife. Wetlands also provide necessary and valuable services to humans. The main characteristics of wetlands include:

- They are rich in nutrients and teeming with life
- May be ponds, marshes, swamps, or peatbogs; each of which has its own characteristics
- Act like sponges, soaking up rain and snowmelt and slowly releasing water reducing flooding and easing the worst effects of drought
- Home for at least some part of the year to many fish, birds, and other animals. Without wetlands, some wildlife species would disappear
- Are being destroyed across the country by industry, commerce, agriculture etc.

5.1 Definition of a Wetland

Wetlands include areas that are seasonally or permanently covered by shallow water and areas where the water table is close to, or at, the surface. Usually soils are water saturated and water-tolerant and water-loving plants are common. Wetlands sometimes form an ecotone or transitional zone between deep water and terrestrial systems.

Wetlands comprise an incredible array of landscapes.They can be found near the banks of rivers and streams, along the edges of lakes and ponds, or in open fields and wooded areas where the water table is near the surface. Some of these wetlands may be ephemeral (temporary) and can be very small or thousands of hectares in size. Particularly near cities and towns, wetlands may be the only remaining “wild” spaces.Saltwater wetlands are usually caused by ocean tides. Some are flooded and dry up twice each day. Others are flooded only by particularly high tides that occur at less regular intervals.

Throughout the world many different names are used to describe wetland areas. Ephemeral wetlands, marshes, swamps, bogs and fens are the types of wetlands found in Ontario.

5.1.1 Marshes

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. Non-woody plants such as sedges, cattails, reeds and water lilies make up the majority of the plant community. Most marshes have some open water which may contain aquatic plants such as pondweed and duckweed. Shrubs like red-osier dogwood might be found growing in drier areas around the marsh. 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.

5.1.2 Swamps

Swamps are essentially wooded marshes, a waterlogged area supporting trees, tall shrubs, herbs, and mosses that can be periodically flooded with snow melt and spring rains and can become dry towards the end of the summer. Woody plants such as white cedar, tamarack, black spruce, black ash, silver and black maple make up the majority of plants in the community. Shrubs like willow, dogwood and alder can also be present. Since some swamps can dry out, they usually lack “true” aquatic plants.

We usually find a combination of aquatic and terrestrial animals in swamps. Some marsh insects, amphibians, waterfowl and mammals can use this habitat provided that it remains wet long enough to allow the proper development of young. A variety of song birds will nest in swamps since it provides an abundance of nesting cavities and food in the form of insects, nuts and berries.

5.1.3 Bogs

Bogs are found in northern regions and are permanently flooded. Bogs are depressions which fill up with rainwater or snow melt and have poor drainage. The most predominant vegetation growing in bogs is sphagnum moss. Sedges, sundew, pitcher plants and black spruce can also be found in this type of wetland. Since bogs have no outflows, dead plant material accumulates and forms a type of soil known as peat. Peat soils act like sponges in that they retain excess runoff and slowly release water to surrounding lands. Bogs do not support much animal life because they are quite acidic.

5.1.4 Fens

Fens are found in northern regions and are also permanently flooded. Fens obtain their water from rainwater, snow melt and underground springs. They are similar to bogs but have better drainage and less peat accumulation. Sedges are predominant but mosses, grasses, reeds, shrubs, sundews, pitcher plants, bladderworts, cedar and tamarack can also grow in fens. Increased drainage in fens results in lower acidity and in many cases this habitat is alkaline. Fens can support plants and animals found in marshes but generally fen animal biodiversity is lower. This habitat supports a variety of rare plants specifically adapted to fens. In northern Canada, a large expanse of bog or fen is called muskeg.

5.1.5 Ephemeral wetlands

Ephemeral wetlands are temporary wetlands which become flooded with rainwater and snow melt and dry out in late summer. They can be found in meadows or prairies. Usually only sedges and grasses grow in these wetlands. Plant matter accumulation is minimal.Ephemeral wetlands can be important resting areas for migrating waterfowl. Some animals such as fairy shrimp (Anostraca) will only be found in these habitats. Many mosquito species use ephemeral pools extensively for growth and reproduction; in many pools these insects comprise the majority of the invertebrate community.

5.2 Ecological Functions and Benefits of Wetlands

Wetlands are essential to the health of our lakes, rivers and streams. The survival of hundreds of plant and animals species depends on the unique and specialized habitats found only in wetlands. Wetlands play a critical role in the maintenance of our water supply, in cleaning up polluted waters and in flood damage control. Beneficial functions of wetlands include:

- Providing important habitat for a wide variety of wildlife species, including insects, amphibians, reptiles, migratory birds, waterfowl and mammals. They also provide spawning and nursery areas for fish
- Providing essential habitats to some of our rarest plant and animals such as the Small White Lady's Slipper Orchid (*Cypripedium calceolus*), Least Bittern (*Lxobrychus exilis*) and Prothonotary Warbler (*Protonotaria citrea*).
- Acting as a buffer zone between terrestrial and aquatic ecosystems. Wetlands trap moderate amounts of soils before entering lakes and streams. They protect shorelines from erosion caused by flowing water and wave action.
- Absorbing large quantities of water, thereby reducing flood damage. Wetlands also renew groundwater supplies when surrounding lands become drier.
- Maintaining and improving water quality by filtering contaminants and excessive nutrients.
- Providing a source of economically valuable products such as fuel wood, timber, wild rice, cranberries and commercial fish. Some of the smaller mammals, such as beaver and muskrat that live in wetlands, are important to the fur trade and the millions of game birds and fish reared in and around our wetlands support a growing recreation and tourist industry.

5.3 Threats to Wetlands

There are many factors which threaten wetlands and the biodiversity associated with them. The major threats include the following:

5.3.1 Drainage for conversion to alternative uses

This represents one of the major reasons why wetlands are disappearing in Ontario. Many wetlands have been drained or filled to create agricultural lands and for urban development. In many cases, once wetlands have been modified in this way they cannot be restored.

5.3.2 Contaminants

Although wetlands act as filters by removing contaminants from runoffs and surrounding waters, an overabundance of toxic compounds will destroy them.Contaminants such as pesticides, fertilizers, cleaning products, motor oils and hydraulic fluids can find their way in wetlands and kill plants and animals. Some contaminants may even bioaccumulate in the food chain causing health problems to many animals. For example, a pesticide known as DDT (Dichloro-diphenyl-trichloro-ethane) was applied by Ontario farmers in the 1950s and 1960s on their crops to kill insect pests.This insecticide would eventually runoff into wetlands where it was consumed by insects. These insects would then be eaten by songbirds which in turn where eaten by raptors, such as falcons and hawks. The DDT accumulated in the fatty tissues of these organisms and therefore top predators had the highest pesticide concentrations within their bodies. These toxic concentrations inhibited proper calcification of egg shells and eggs laid by female raptors would be crushed under the parent's weight. Raptor populations dramatically decreased during this time since they could not successfully reproduce. Once scientists discovered this, DDT use was banned in Canada and United States and raptor populations slowly increased.

5.3.3 Forestry and economic operations

Some forestry practices such as logging and controlling water levels have negatively affected wetlands by upsetting the natural flood cycle. Commercial harvesting of peat has destroyed many of our bogs. Overhunting and overfishing has also contributed to the decreasing biodiversity of our wetlands.

5.3.4 Introduction of Invasive species

Animal and plants species from other continents brought here by humans have caused much damage to our wetlands. In many cases, these exotic species have established themselves in our wetlands and are proliferating greatly since no natural herbivores or predators are present to control them. These exotic species can use up resources and displace native wildlife. A good example of this is a plant known as Purple loosestrife (*Lythrum salicaria*).

5.4 Approaches to Protect, Enhance and Restore Wetlands

There are many ways to protect, enhance or restore wetlands:

- If the wetland is unaffected by human activity, leave it alone! Protect the habitat from any future human activities.
- Restore native vegetation by planting a mixture of native grasses, wildflowers and shrubs around the wetland. This will create a diverse long-lasting plant community that will provide food, cover and nesting habitats for a wide range of animal species.
- Create buffer strips which are zones around wetland areas which provide buffering from surrounding land uses. This is done in order to protect both wetland and uplands. Encourage the growth of grasses, shrubs and trees in these buffer zones.
- Restore natural hydrological functions of wetlands by restoring the natural patterns of seasonal flooding and drying.
- Introduce nesting structures where there is an absence of nesting opportunities for certain species, such as Wood duck (*Aix sponsa*) boxes, Osprey (*Pandion halioetus*) platforms or floating mats of vegetation for Black terns (*Chlidonias nigra*).
- Control livestock access to wetlands by putting up fences.
- Control exotic species by removing them or preventing their establishment in the wetland.

Case Study – Purple Loosestrife in Ontario's Wetlands

Purple loosestrife is a tall, vibrant flowering wetland plant (Figure 21).This European plant grows quite well in wetlands and outcompetes native plants for water, minerals and space. Within a few growing seasons, Purple loosestrife can overrun an entire wetland. This causes a disruption in the wetland ecosystem since very few of our native herbivores can eat this exotic plant. Purple loosestrife eventually displaces native plant and animal species.

Figure 21: *Purple Loosestrife*
Source: Ontario Invading Species

It was introduced into Ontario and North America at the beginning of the 19th century 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, native 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 affect plant populations but wildlife populations as well, putting the overall biodiversity of the ecosystem in jeopardy. 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 and 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 22: *Galerucella sp. beetle and eggs on Purple Loosestrife*
Source:
http://www.edmonton.ca/city_government/environmental_stewardship/weed-biocontrol.aspx

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 (Figure 22). 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 which reduces growth and spread of the plant. 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.

6.0 Why Study Benthic Macroinvertebrates?

Benthic macroinvertebrates are an important part of aquatic food chains. In most streams, the energy stored by plants is available to animal life either in the form of leaves that fall in the water or in the form of algae that grows on the stream bottom. The algae and leaves are eaten by macroinvertebrates. The macroinvertebrates are in turn a source of energy for larger animals such as fish which are preyed upon by birds, raccoons, water snakes and even fishermen.

Some benthic macroinvertebrates cannot survive in polluted water. Others can survive or even thrive in polluted water(See Table 2 below for specific species tolerance to pollution). In a healthy stream, the benthic community will include a variety of pollution-sensitive macroinvertebrates. In an unhealthy stream, there may be only a few types of nonsensitive macroinvertebrates present.

Table 2: Pollution tolerance levels of the major benthic macroinvertebrate groups found in Ontario

Pollution Sensitive	Somewhat Pollution Sensitive	Pollution Tolerant
Caddisfly	Beetle larvae	Aquatic Worms
Mayfly	Clams	Blackfly
Riffle Beetle (Adults)	Cranefly	Leeches
Stonefly	Crayfish	Midges
Water penny (Larvae)	Damselfly	
	Dragonfly	
	Scuds	
	Sowbugs	
	Fishfly/Alderfly	

It may be difficult to identify overall stream pollution with water analyses, which can only provide information for the time of sampling. Even the presence of fish may not provide information about a pollution problem because fish can move away to avoid polluted water and return when conditions improve. However, most benthic macroinvertebrates cannot move to avoid pollution. A macroinvertebrate sample may thus provide information about pollution that is not present at the time of sample collection.

Useful benthic macroinvertebrate data are easy to collect without expensive equipment. The data obtained by macroinvertebrate sampling can serve to indicate the need for additional data collection, possibly including water analysis and fish sampling.

6.1 Benthic Macroinvertebrate Sample Collection Techniques

The most common method for collecting benthic macroinvertebrates is to use a kick seine (also known as a kick net).

A simple kick seine can be constructed from the following materials:

- 3.5' x 4' nylon screening or netting (1/16" mesh)
- 2 broom handles or wooden dowels (5-6' long) for handles
- heavy tacks and hammer or heavy staples and staple gun

Instructions:

1. Make a hem along the 4' sides of the netting by folding over and sewing the edges, leaving a 3' x 4' section of net. (If the netting is too difficult to sew, a hem can be constructed using a strip of canvas or cloth).
2. Spread the netting out flat and place the handles along the unhemmed 3' edges.
3. Roll 6" of netting around each handle, leaving a 3'x 3' section of net between the handles. Then nail or staple the net to the handles.

An alternate approach is to fold over and sew the 3' edges of the net to form sleeves for the handles. In any case, the final size of the net should be 3' x 3'.

6.1.1 Selecting a site for sampling:

Find a riffle that is typical of the stream. A good riffle for sampling will have cobble-sized stones, fast-moving water, and a depth of 3 to 12 inches. Select a 3-foot by 3-foot area within the riffle for sampling.

NOTE: If the site is to be used for long-term monitoring it will be easier to locate it if there are nearby landmarks that can be used to identify the site.

6.1.2 Positioning the kick seine:

Have one person hold the net upright facing the flow at the downstream edge of the sampling area. The net should be stretched out to its full 3-foot width with the bottom edge lying firmly against the stream bed. No water should wash under or over the net. If needed, small rocks can be used to weigh down the bottom edge of the net.

NOTE: To avoid losing macroinvertebrates that should be part of the sample, do not stand in or disturb the sampling area before the kick seine is in place. To avoid capturing macroinvertebrates that should not be part of the sample, do not stand in or disturb the stream bed above the sample area.

6.1.3 Collecting the sample

All macroinvertebrates in the 3-foot by 3-foot sample area are to be washed into the kick seine. While one person holds the net, a second person first brushes all the cobbles in the sampling area to dislodge the attached macroinvertebrates. As each cobble is brushed, it can be placed outside the sampling area. When all the cobbles are brushed, stir up the entire sampling area with hands and feet to dislodge any burrowing macroinvertebrates. Finally, for at least sixty seconds, kick the stream bed with a sideways shuffling motion towards the net. The object is to thoroughly work up the stream bed to a depth of several inches.

6.1.4 Removing the kick seine from the water

When Step 3 is completed, lift the kick seine out of the water with a forward scooping motion. The object is to avoid losing any macroinvertebrate specimens while the seine is lifted. This will be easier if one person holds the top of the kick seine handles while the other person holds the bottom of the handles.

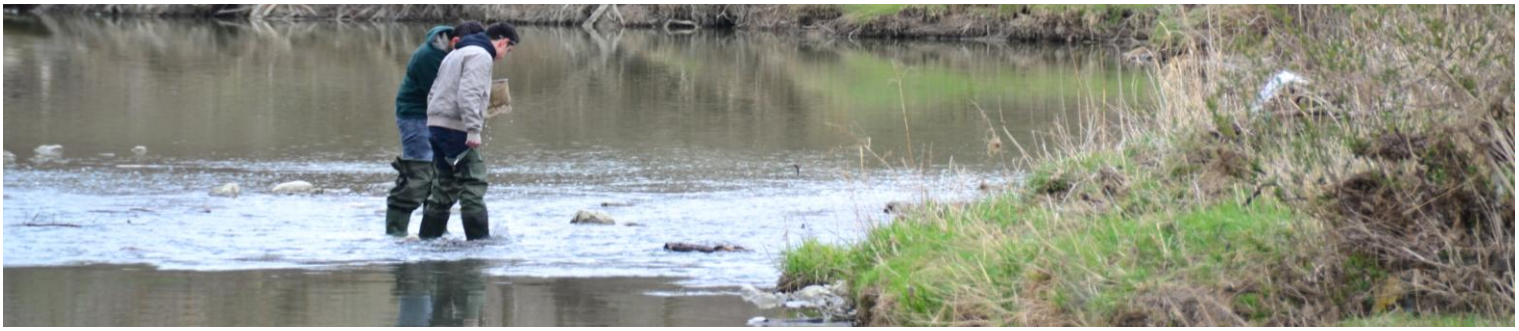
6.1.5 Removing the sample from the kick seine

Carry the kick seine to the stream bank and spread it out flat. Carefully examine the net and the collected debris for macroinvertebrates. Look carefully as many specimens will be small and hard to see. Using tweezers or fingers, place all the specimens in white containers filled with stream water. Sort them into different types as you remove them from the net, and place each type in a separate container.

NOTE: If your plan is to transport the sample back to your "lab" before sorting and identification, you can place the contents of the kick seine (including the debris) into a bucket that is partly filled with stream water. If you put a lid on the bucket (recommended), you should leave some air space above the water in the bucket to allow mixing of oxygen.

6.1.6 Identification

Once the macroinvertebrates are collected and sorted, they can be identified in the field using the identification key provided in Appendix B.



7.0 Indigenous Peoples & Aquatic Resources

Native people have lived in North America for thousands of years, using both terrestrial and aquatic resources to sustain themselves. The arrival of European settlers disrupted the lives of Aboriginal people; conflicts arose over the use of land and waterways. In an attempt to resolve these conflicts the federal, provincial and Aboriginal governments set up treaties to define Native people's rights to natural resources.

Aboriginal people have lived in North America since time immemorial as distinct nations with established governments, cultures, languages, traditions, customs, and territories. Aboriginal people migrated throughout the continent in response to changing climate conditions. They depended on the land and natural resources for their sustenance and had a spiritual connection with the natural world. Fishing, for example, is of such cultural importance that religious ceremonies are done before and after fishing to ensure that proper respect is paid to the fish harvested. Other traditional activities of Aboriginal people include hunting, trapping, gathering, agriculture, wild rice production, and trading.

Aboriginal communities engaged in commercial activities through trade and barter among community members, with other First Nations, and eventually with European settlers and traders. The arrival of Europeans to North America, beginning in the 1500's, brought significant changes to the lives of Aboriginal people. The fur trade was established by the Europeans with Aboriginal people who taught the new arrivals the ways of the land; otherwise, they would have not survived. However, with the arrival of Europeans, Aboriginal people were exposed to diseases, alcohol, and European religious teachings which devastated great numbers of people. In addition, the steady growth of European settlements put increasing pressure on neighbouring Aboriginal communities in terms of available land and natural resources (e.g. hunting, fishing, logging, mining, and agriculture).

The Royal Proclamation of 1763 set out a system of government, in what is now Canada, after the Treaty of Paris, which ended the conflict between the British and French in North America.The Royal Proclamation provided a policy that all lands in "British North America" that were unceded to the Crown in 1763 were reserved to the Indians and that the Indians could surrender their lands only to the Crown at a public meeting with proper representation of the Crown and the Indians.

As Europeans attempted to gain control and ownership of the new lands, Aboriginal people were faced with protecting a significant part of their traditional economic base, hunting and fishing. The right to continue hunting and fishing, which were integral to the economic survival of Aboriginal people was often an important principle in subsequent 19th century treaty negotiations. Through these treaties, the Crown obtained surrenders of vast tracts of land. Some treaties and historical documents provide evidence that the traditional fishing grounds were specifically excluded from the land surrenders.

Throughout the treaty-making process, there were many problems and misunderstandings. Subsequent federal and provincial laws and regulations consistently restricted First Nation peoples in pursuing their fishing activities over their traditional fishing grounds. Aboriginal people continued to fish and asserted that Indian signatories to the treaties were not fluent in the language of the written treaty and that they had no intention of surrendering their land and water but rather intended to share their land and water, and its resources, with the Crown and live in harmony with the new settlers.

This difference of views about the interpretation of treaties and the rights of Aboriginal people to fish in their traditional territories has led to a number of cases going to court. The courts, in turn, have written decisions clarifying the nature of the rights of Aboriginal people and the responsibilities of government in dealing with them.

The Ontario Court of Appeal, in R.v. Taylor and Williams, 1979, ruled that if a promise was made by the Crown at the time of signing of a treaty, then the promise shall be treated as if it was in fact the written version of the treaty. That case, as well as other cases tried since, has stated that the words used in a treaty should be given their widest meaning in favour of Aboriginal people; that any ambiguity is to be resolved in favour of Aboriginal people; and that treaties should be interpreted so as to avoid bringing dishonour to the government and Crown.

The *Constitution Act, 1982* recognizes and affirms the existing Aboriginal and treaty rights of all Aboriginal people in Canada. The Constitution is the supreme law of Canada and any law that is inconsistent with the provisions of the Constitution is, to the extent of the inconsistency, of no force or effect. The Constitution dictates that a new approach be taken by government to ensure that its policies meet the constitutional requirements of s. 35(1) which states that “the existing Aboriginal and treaty rights of the Aboriginal peoples of Canada are hereby recognized and affirmed.” S. 35(2) states that “In the Act, Aboriginal peoples of Canada include the Indian, Inuit and Métis peoples of Canada.”

In 1990, the Supreme Court of Canada ruled in R v. Sparrow that fisheries regulations cannot interfere with an Aboriginal right to fish for food unless the government can justify the interference on the basis of specific legislative objectives, such as conservation or public safety. The Supreme Court ruled that the first priority of allocation of the fisheries resource is for conservation of the resource itself, the second priority is for the Aboriginal food fishery, and the third priority is for other users of the resource.

In subsequent court cases (R. v. Bombay, R.v. Agawa, R. v Jones and Nadjiwon, R. v King et. al.), the courts have considered evidence supporting a historical tradition of fishing for commercial purposes and have found that where such evidence exists, there is a right to fish commercially, and that the government continues to have the responsibility to negotiate with First Nations about their allocation of fish and to ensure that the fisheries resources are properly regulated.

7.1 How is the Government of Ontario working with First Nations to resolve the fishing issues?

In many cases, as in the Sparrow decision (which recognized an Aboriginal right to fish for food, social, and ceremonial purposes), Aboriginal and treaty rights override federal and provincial laws. As a result, Ontario has implemented an Interim Enforcement Policy (IEP) to minimize the number of instances where Aboriginal people are in conflict with the application of fisheries and wildlife legislation. This policy is subject to conservation and public safety objectives. The interim policy will remain in effect until new arrangements are negotiated with First Nations.

Ontario’s challenge is to ensure a priority allocation of fish for First Nations for food, social, and ceremonial purposes and to negotiate appropriate arrangements for First Nations that can demonstrate an Aboriginal or treaty right to fish commercially. The process and criteria used to determine the order of priority must be fair and equitable for both Aboriginal and non-Aboriginal people.

Ontario and the Union of Ontario Indians (UOI) have signed the Ontario-Anishinabek Conservation and Fishing Agreement (1993). It is a framework of guiding principles and key elements of future conservation and fishing agreements with UOI member First Nations. The principles of this agreement are summarized as follows:

- Conservation of the fisheries resource is of paramount importance.
- Conservation takes precedence over all other allocations.
- Allocations are based on sustainable yield principles.
- Shared responsibility to preserve, protect and enhance the environment.
- Existing Aboriginal and treaty rights (and inherent self-government rights) are recognized.
- Priority allocation is accorded to Aboriginal and treaty rights
- The government-to-government relationship is recognized.

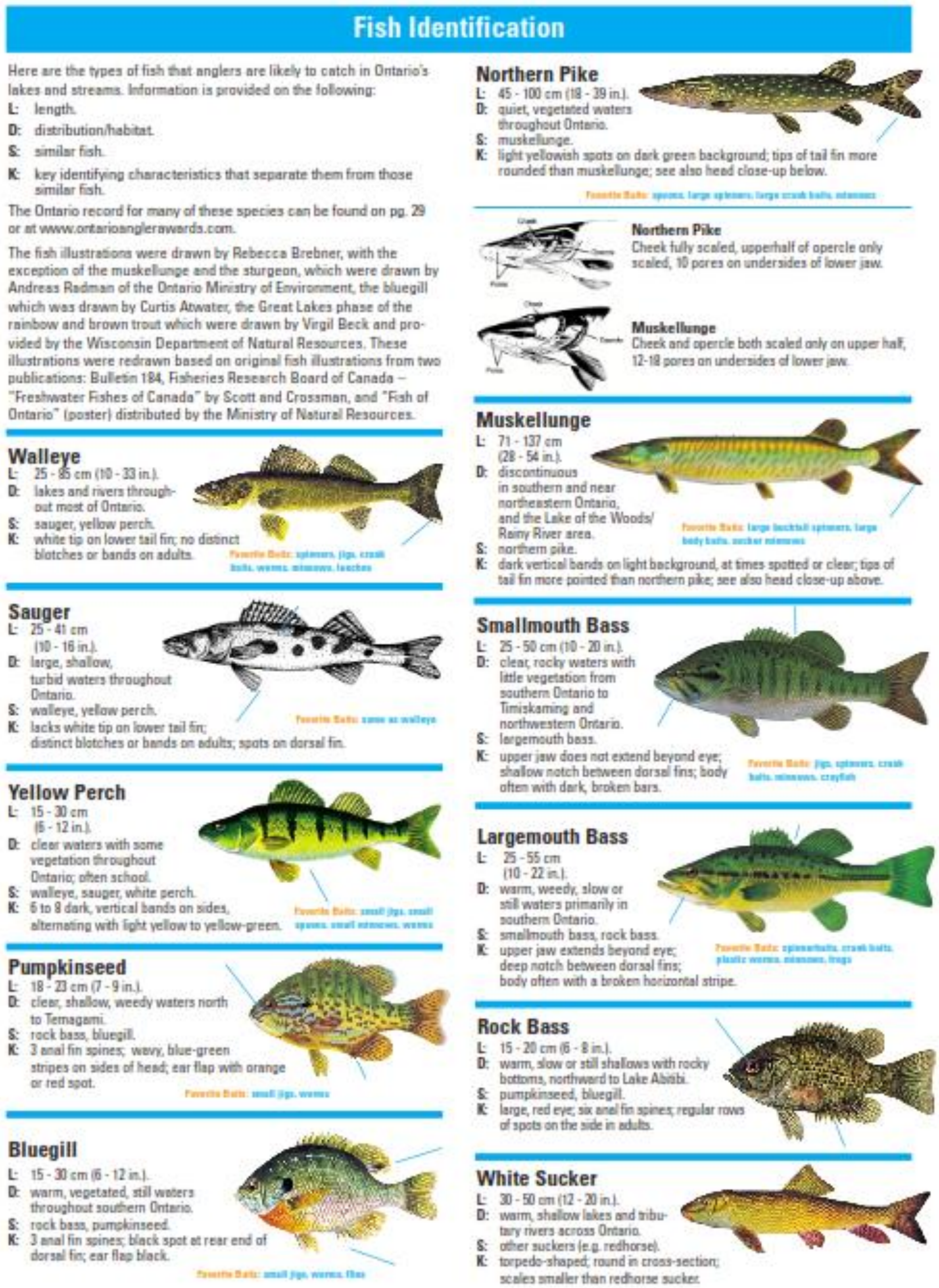
First Nations aspirations include achieving self –government and economic stability. With respect to resource management in relation to aquatic resources, aquaculture is a good economic development activity for First Nations that might be interested in pursuing it, and a number of First Nations are involved in aquaculture.

From early colonization to the present time, sustaining the fisheries resources has been challenging due to over harvesting and poaching of species, industrial and other global pollution, and habitat degradation. In order to rehabilitate the land, water, and air, we cannot limit our concern just to the fisheries but rather we must look deeper into examining aquatic resources as a whole and recognizing the integral importance of aquatic ecosystems to the entire biosphere.

Our challenge is to begin a new era, one built on mutual respect, equity, and empowerment through understanding and co-operation of people working together to solve common problems. Recognizing that information and research is critical to sustaining aquatic ecosystems as part of the biosphere, we must begin to use all of the information and technical resources available to us to ensure our own survival; in other words, we should be looking towards Aboriginal traditional ecological knowledge in addition to modern science. We must continue to develop our relationships with each other, learn about and understand the natural world, and continue to work together in partnership to protect our natural world for the benefit of all future generations.

Appendix A

Source: http://files.ontario.ca/environment-and-energy/fishing/198234.pdf



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. 29 or at www.ontarioanglerawards.com.

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.

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

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

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.

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.

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

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.

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.

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

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.

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

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

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.

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.

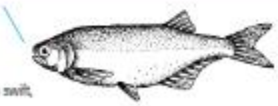
Favorite Baits: small jigs, small minnows, worms

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.

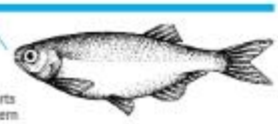
Favorite Baits: small jigs, small minnows, worms

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)

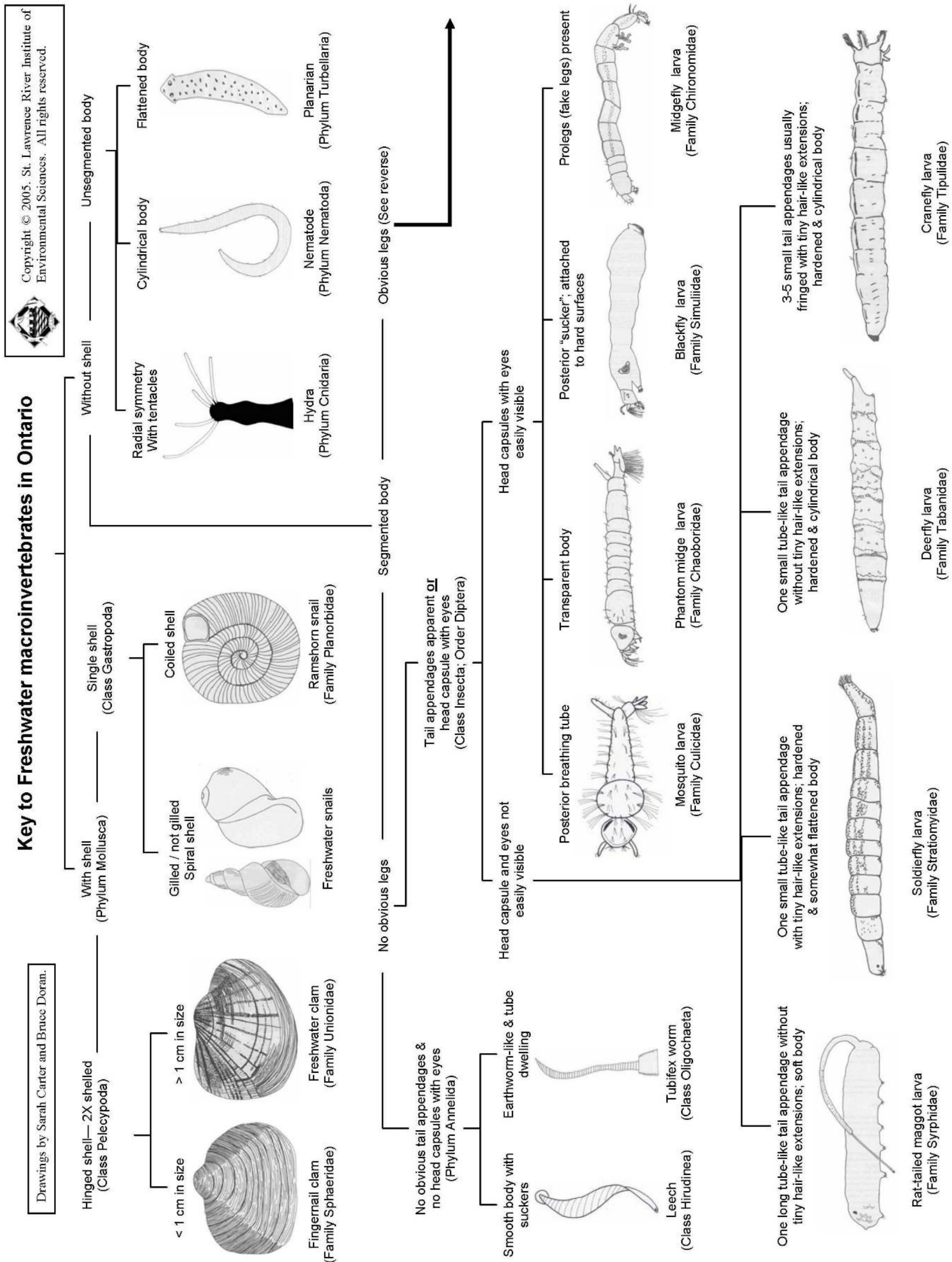
L: to 38 cm (15 in.).
D: cool waters of lakes and rivers throughout Ontario.
S: bowfin.
K: single "whisker" on tip of chin; long, thin anal fin.

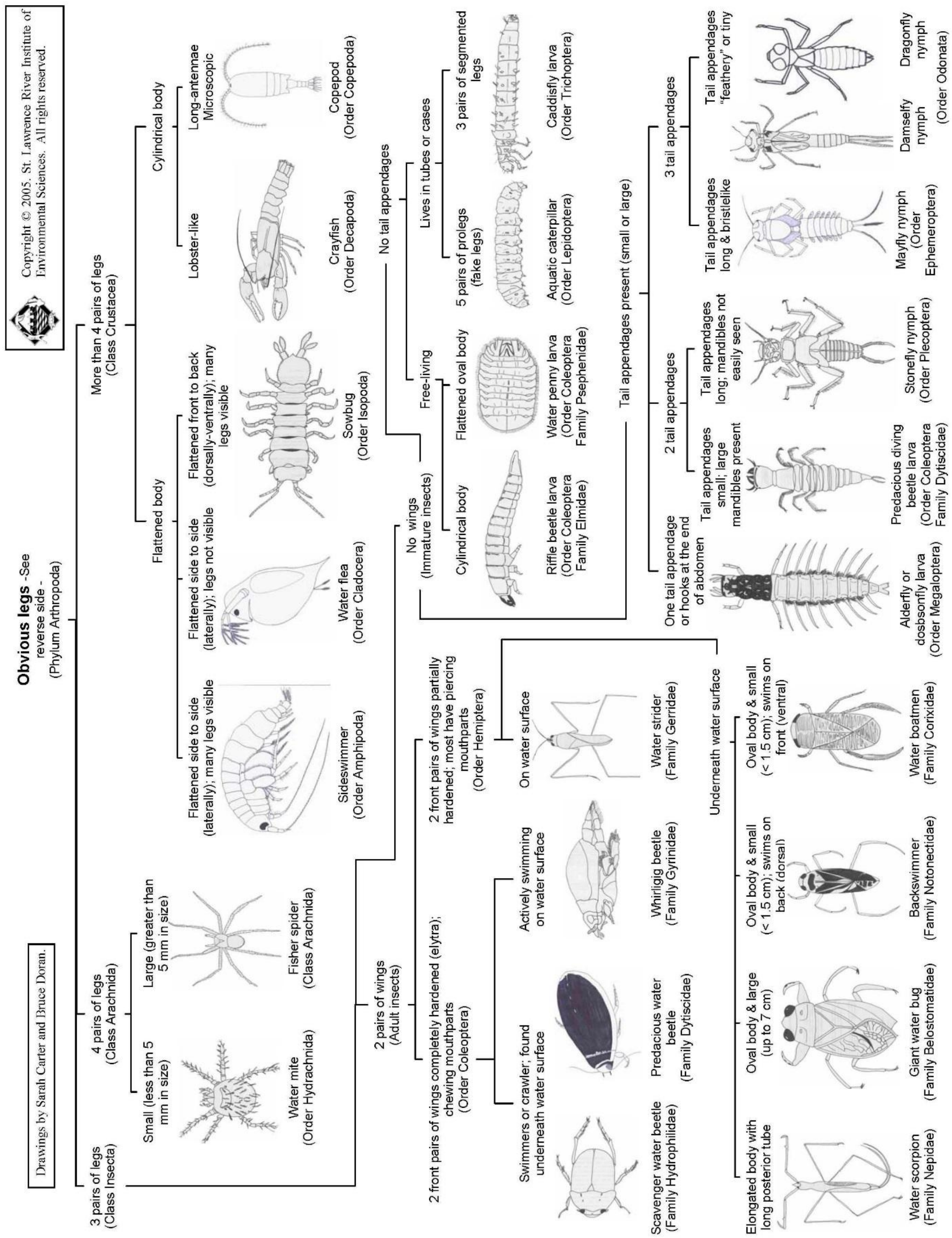
Bowfin

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.

Appendix B

Source: The St. Lawrence River Institute





Drawings by Sarah Carter and Bruce Doran.
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Obvious legs - See reverse side - (Phylum Arthropoda)
3 pairs of legs (Class Insecta)
4 pairs of legs (Class Arachnida)
More than 4 pairs of legs (Class Crustacea)
Small (less than 5 mm in size)
Water mite (Order Hydrachnida)
Large (greater than 5 mm in size)
Fisher spider (Class Arachnida)
Flattened body
Cylindrical body
Flattened side to side (laterally); many legs visible
Sideswimmer (Order Amphipoda)
Flattened side to side (laterally); legs not visible
Water flea (Order Cladocera)
Flattened front to back (dorsally-ventrally); many legs visible
Sowbug (Order Isopoda)
Lobster-like
Crayfish (Order Decapoda)
Long-antennae Microscopic
Copepod (Order Copepoda)
2 pairs of wings (Adult insects)
No wings (Immature insects)
2 front pairs of wings completely hardened (elytra); chewing mouthparts (Order Coleoptera)
2 front pairs of wings partially hardened; most have piercing mouthparts (Order Hemiptera)
Swimmers or crawler; found underneath water surface
Scavenger water beetle (Family Hydrophilidae)
Predacious water beetle (Family Dytiscidae)
Actively swimming on water surface
Whirligig beetle (Family Gyrinidae)
On water surface
Water strider (Family Gerridae)
Underneath water surface
Elongated body with long posterior tube
Water scorpion (Family Nepidae)
Oval body & large (up to 7 cm)
Giant water bug (Family Belostomatidae)
Oval body & small (< 1.5 cm); swims on back (dorsal)
Backswimmer (Family Notonectidae)
Oval body & small (< 1.5 cm); swims on front (ventral)
Water boatmen (Family Corixidae)
No tail appendages
Free-living
Cylindrical body
Riffle beetle larva (Order Coleoptera Family Elmidae)
Flattened oval body
Water penny larva (Order Coleoptera Family Psephenidae)
Lives in tubes or cases
5 pairs of prolegs (fake legs)
Aquatic caterpillar (Order Lepidoptera)
3 pairs of segmented legs
Caddisfly larva (Order Trichoptera)
Tail appendages present (small or large)
One tail appendage or hooks at the end of abdomen
Alderfly or dosbsonfly larva (Order Megaloptera)
2 tail appendages
Tail appendages small; large mandibles present
Predacious diving beetle larva (Order Coleoptera Family Dytiscidae)
Tail appendages long; mandibles not easily seen
Stonefly nymph (Order Plecoptera)
3 tail appendages
Tail appendages long & bristlelike
Mayfly nymph (Order Ephemeroptera)
Tail appendages "feathery" or tiny
Damselfy nymph
Dragonfly nymph
(Order Odonata)

Glossary

Algae: simple nonflowering plants of a large group that includes the seaweeds and many single-celled forms. Algae contain chlorophyll but lack true stems, roots, leaves, and vascular tissue.

Aquatic biodiversity: the variety of life and the ecosystems that make up the freshwater, tidal, and marine regions of the world and their interactions.

Aquatic organism: an animal, either vertebrate or invertebrate, which lives in water for most or all of its life.

Benthic: of, relating to, or occurring at the bottom of a body of water.

Bioaccumulation: the accumulation of a substance, such as a toxic chemical, in various tissues of a living organism.

Biological availability: the degree and rate at which a substance is absorbed into a living system or is made available at the site of physiological activity.

Bog: an area of wet, spongy ground consisting mainly of decayed or decaying peat moss (sphagnum) and other vegetation.

Bonded: a mutual attraction between two atoms resulting from a redistribution of their outer electrons.

Carbon: the chemical element of atomic number 6, a non-metal that has two main forms (diamond and graphite) and that also occurs in impure form in charcoal, soot, and coal.

Carbon dioxide: a colorless, odorless gas produced by burning carbon and organic compounds and by respiration. It is naturally present in air and is absorbed by plants in photosynthesis.

Clarity: the state or quality of being clear or transparent to the eye.

Density: the degree of compactness of a substance.

Detritus: waste or debris of any kind such as gravel, sand, silt, or other material produced by erosion and organic matter produced by the decomposition of organisms.

Dissolved oxygen (DO): the amount of oxygen dissolved in a body of water as an indication of the degree of health of the water and its ability to support a balanced aquatic ecosystem.

Eutrophication: the process by which a body of water becomes enriched in dissolved nutrients (ie. phosphates) that stimulate the growth of aquatic plant life usually resulting in the depletion of dissolved oxygen.

Eutrophic lakes: lakes characterized by an abundant accumulation of nutrients that support a dense growth of algae, the decay of which depletes shallow water of oxygen in summer.

Epilimnion: the upper layer of water in a stratified lake.

Fen: a low and marshy or frequently flooded area of land.

Hardness: (water) a measure of the amount of calcium and magnesium salts in water. Calcium and magnesium enter water mainly through the weathering of rocks. The more calcium and magnesium in water, the harder the water.

Hydrogen: a colorless, odorless, flammable gas that combines chemically with oxygen to form water.

Hypolimnion: the lower layer of water in a stratified lake, typically cooler than the water above and relatively stagnant.

Invasive species: an organism (plant, animal, fungus, or bacterium) that is not native and has negative effects on our economy, our environment, or our health.

Ion balance: a state of equilibrium that exists when acidic and basic ions in solution neutralize each other.

Marsh: a tract of low wet land, often treeless and periodically inundated, generally characterized by a growth of grasses, sedges, cattails, and rushes.

Medium: an intervening substance, as water, through which a force acts or an effectis produced.

Mesotrophic Lakes: lakes with an intermediate level of productivity between the oligotrophic and eutrophic stages.

Nitrogen fixation: the chemical processes by which atmospheric nitrogen is assimilated into organic compounds, especially by certain microorganisms as part of the nitrogen cycle.

Nutrient loading: quantity of nutrients such as nitrogen or phosphorus entering an ecosystem in a given period of time.

Oligotrophic lakes: lakes characterized by a low accumulation of dissolved nutrient salts, supporting a sparse growth of algae and other organisms, and having a high oxygen content owing to the low organic content.

Oxygen: a colorless, odorless reactive gas, the chemical element of atomic number 8 and the life-supporting component of the air.

Particulate matter: also known as particle pollution or PM, is a complex mixture of extremely small particles and liquid droplets. Particle pollution is made up of a number of components, including acids (such as nitrates and sulfates), organic chemicals, metals, and soil or dust particles.

pH: a measure of the acidity or alkalinity of a solution, numerically equal to 7 for neutral solutions, increasing with increasing alkalinity and decreasing with increasing acidity. The pH scale ranges from 0 to 14.

Poikilothermic: (applies to all animals except birds and mammals) having a body temperature that varies with the temperature of the surroundings

Polar compound: a compound in which the electric charge is not symmetrically distributed, so that there is a separation of charge or partial charge and formation of definite positive and negative poles, i.e.H_2O.

Polarity: the property or characteristic that produces unequal physical effects at different points in a body or system.

Precipitation: rain, snow, sleet, or hail that falls to the ground.

Secchi disk: an opaque disk, typically white, used to gauge the transparency of water by measuring the depth (*Secchi depth*) at which the disk ceases to be visible from the surface.

Sedimentation:the natural process in which material (such as stones and sand) is carried to the bottom of a body of water and forms a solid layer.

Silt: fine sand, clay, or other material carried by running water and deposited as a sediment, especially in a channel or harbour.

Solubility: the amount of a substance that will dissolve in a given amount of another substance (solvent).

Solvent: a substance in which another substance is dissolved, forming a solution.

Specific heat: the amount of heat needed to raise the temperature of one gram of a substance by one degree Celsius, or to raise the temperature of one pound of a substance by one degree Fahrenheit.

Stormwater runoff: water from rain or melting snow that flows across the land instead of seeping into the ground.

Stream flow: the water that flows in a specific stream site, especially its volume and rate of flow.

Succession: (ecology) the gradual and orderly process of change in an ecosystem brought about by the progressive replacement of one community by another until a stable climax is established.

Surface tension: the elastic-like force existing in the surface of a body, especially a liquid, tending to minimize the area of the surface, caused by asymmetries in the intermolecular forces between surface molecules.

Swamp: an area of low-lying, uncultivated ground where water collects.

Thermal stratification: the formation of layers of different temperatures in a lake or reservoir.

Turbidity: the cloudiness or haziness of a fluid caused by large numbers of individual particles such as stirred up sediment.

Volume: the amount of space, measured in cubic units, that an object orsubstance occupies.

Watershed: the area of land where all of the water that is underneath it or drains off of it goes into the same place.

Wetlands: an area of land (such as a marsh or swamp) that is covered with shallow water.