2023
NCF-ENVIROTHON NEW BRUNSWICK

AQUATIC ECOLOGY STUDY RESOURCES

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2023 NCF-Envirothon New Brunswick

Aquatic Ecology Study Resources

Key Topic #1: Hydrology and Aquatic Environments

1. Identify the physical and chemical characteristics of water and explain how those characteristics affect aquatic ecosystems.
2. Diagram the water cycle and describe the water cycle's role in weather and climate.
3. Describe the importance, functions, and characteristics of watersheds/catchment areas.
4. Identify the biotic and abiotic components of aquatic ecosystems and describe the processes by which these interact.
5. Differentiate the types of wetlands and describe their characteristics, including dominant species found in each.
6. Compare and contrast the physical characteristics of lakes and streams.
7. Determine the order of a stream and describe what the order indicates.
8. Describe the natural aging process of lakes and ponds.

Study Resources

Resource Title	Located on
Watersheds	Pages 4-10
The Water Cycle	Pages 11-12
Physical and Chemical Properties of Water	Pages 13-14
Aquatic Environments	Pages 15-22

Information for this section was compiled from the following sources*:

- Wetland Classification System Field Guide – *Ducks Unlimited Canada, 2021*
- The Wetland Care Guide- Atlantic Wetland Care Program – *Ducks Unlimited Canada, 2011*
- Manual for Wetland Ecosystem Services Protocol for Atlantic Canada: Non-tidal Wetlands – *Adamus, P., 2018*
- Canadian Environmental Quality Guidelines- *The Canadian Council of Ministers of the Environment, 2023*
- Presence and Levels of Priority Pesticides in Selected Canadian Aquatic Ecosystems- *Water Science and Technology Directorate Environment Canada, 2011*
- National Recommended Water Quality Criteria- Aquatic Life Criteria Table- *EPA, 2023*

* Please Note: The information within this document is the ***official*** 2023 NCF-Envirothon Aquatic Ecology Study Resource and should be used by the teams to study for the Aquatic Ecology station tests. Additional information found in the sources cited above are not required.

<u>Study Resources begin on the next page!</u> ➡

Watersheds

A watershed (Figure 1) is an area of land bordered by ridges in which all water falling within that area, or basin, drains to a common destination, analogous to a funnel. Any rain falling within this boundary will make its way to the mouth of the river by following the slope of the landscape. A portion of precipitation falling within this boundary is also stored as groundwater water beneath the land surface, which is an essential resource to the communities.

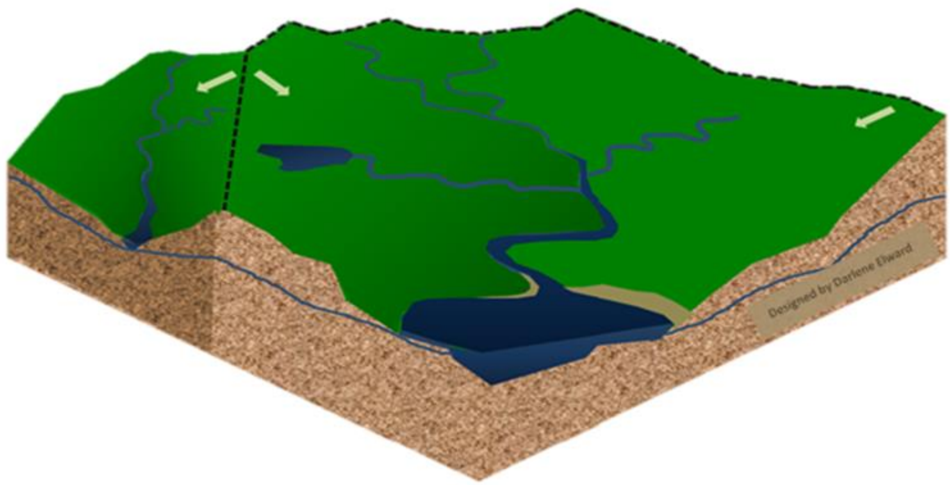


Figure 1: Watershed layout

Drainage Pattern

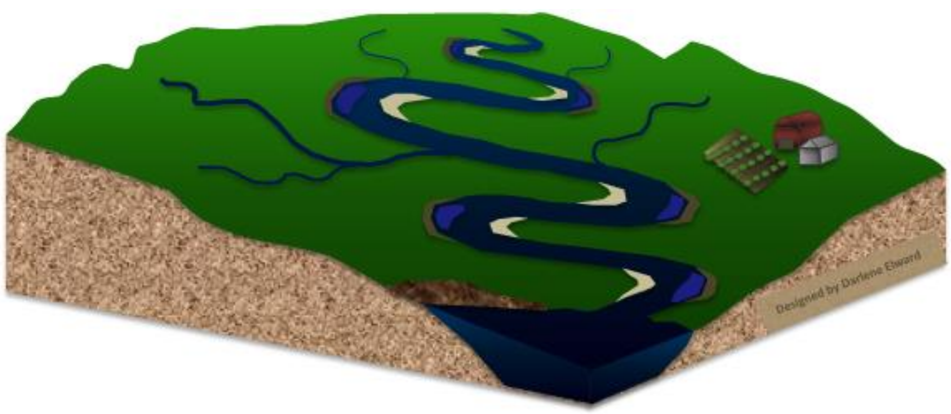


Figure 2: Meandering drainage pattern in watershed

Streams, rivers, and lakes form characteristic drainage patterns within their watersheds. These patterns are governed by underlying topography of the land, whether a region is underlain by hard or soft rocks, and by the slope of the landscape. The majority of New Brunswick's terrain is considerably flat with presence of some more prominent slopes in certain areas of the province. Due to the low sloping landscape in New Brunswick, dendritic drainage patterns with meandering watercourses are the most common (Figure 2). These patterns comprise winding and looping watercourses that transport water and sediment laterally as well as downslope (Figure 2). Depending on the position of a watercourse within a watershed, natural waterways can take many forms, but can generally be described as straight, meandering, braided, or anastomosing as illustrated in Figure 3. These systems are also formed of many smaller contributing streams. They have a main watercourse joined by several tributaries, medium to small streams, comparable to the twigs and branches joining the trunk of a tree. Larger river systems have a series of meanders which flow and merge in U-shaped floodplains.

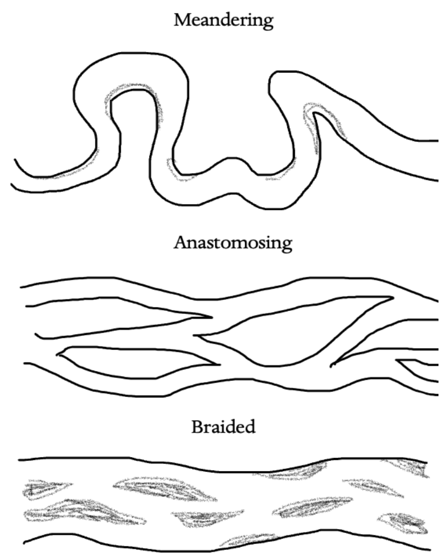


Figure 3: Other drainage patterns

Fluvial Processes

Fluvial processes (Figure 4) are the changes a river undergoes including the movements of sediments by erosion or deposition on the riverbed. Water dynamically changes the river systems and is able to carry soil, rocks, sand and fine particles along its drainage path leading towards the ocean. Waterways are capable of transporting sediment discharge coming from eroding lands and riverbanks (e.g., bank erosion, landslides and runoffs).

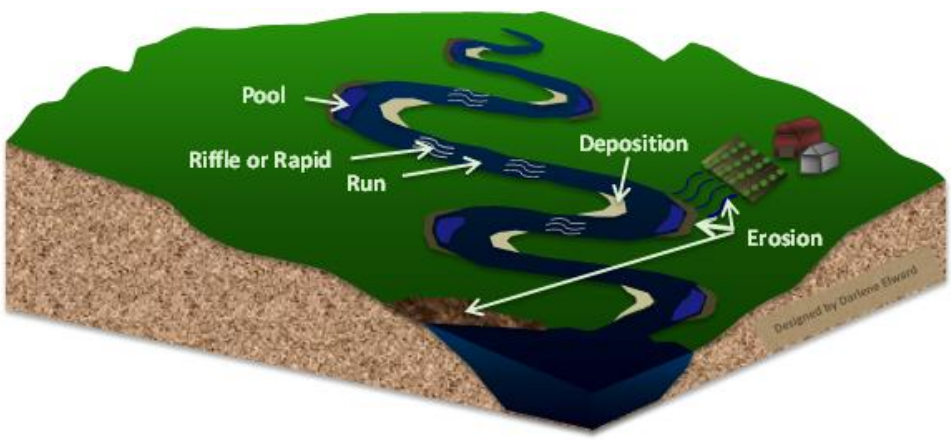


Figure 4: Fluvial processes

Stream Order

Stream order is a method of classification to help determine the amount of branching a watershed exhibits. It takes two streams of the same order joining together to increase the order downstream. For example, two first-order streams joining together create a second-order stream. Two second-order streams joining together create a third-order stream, and so on. However, streams of unequal orders joining together will result in no increase of order downstream. Instead, the highest order between the two streams joining together will be the same order downstream. In other words, a second-order stream joining with a first-order stream will simply continue to be a second-order stream below where they have joined together.

All headwater tributaries start as first-order streams. At Point “A”, two of these first-order streams join together to create a second-order stream. At Point “B”, we see that another first-order stream joins together with our second-order stream. However, because the two streams are of different order, the stream after Point “B” remains a second-order stream. At Point “C”, on the other hand, we see that another second-order stream is joining together with the second-order stream we have been following. Therefore, the resulting combination is a third-order stream. Along the way downstream, we see Points “D”, “E”, and “F”, which all have orders lower than three. As a result, our third-order stream remains a third-order stream even after all of these points. When it reaches Point “G”, it is met with another third-order river, creating a fourth-order river below. One final first-order stream joins together with our fourth-order stream at Point “H”. But like Points “D”, “E”, and “F”, this lesser-order stream does not change the order of our main watercourse.

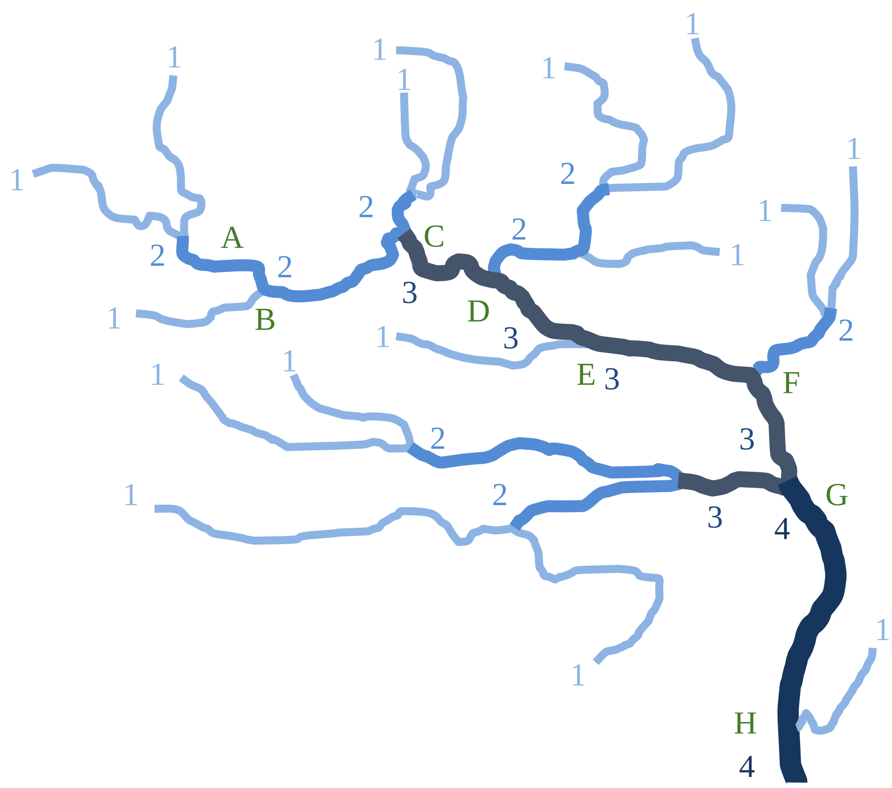


Figure 5: Stream order example up to 4th order stream

Delineating a Watershed's Boundaries

Watershed delineation is an important tool used to determine the total area of land that influences a certain watercourse. Every watershed can be broken up into sub-watersheds for each tributary a river possesses.

In this topographic map, the lines represent contours of equal elevation. The circular areas represent sites of highest relative elevation, e.g., peaks of hills or mountains. The distance between contours indicates the magnitude of the slope: the closer together the lines, the steeper the slope. Conversely, the farther apart the lines, the flatter the ground.

The watershed being delineated in this example surrounds the watercourse marked by the yellow arrow.

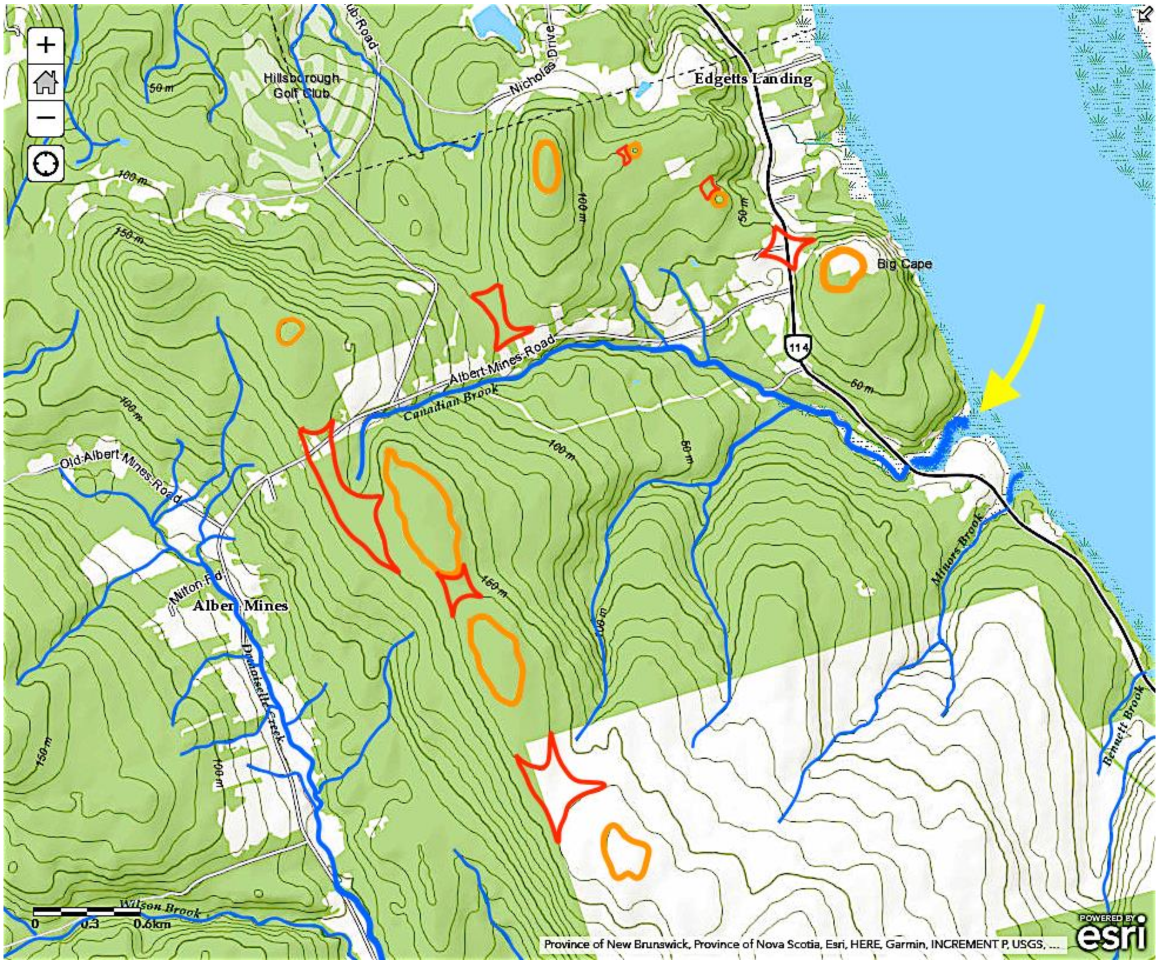
To delineate the watershed:

Begin at the river mouth and cross each line perpendicularly as you travel upslope. Use the ridges as a guide but be sure not to cross a river. Make sure to include all the branches connected to your main watercourse but be sure not to include branches from other watercourses not directly connected to it.

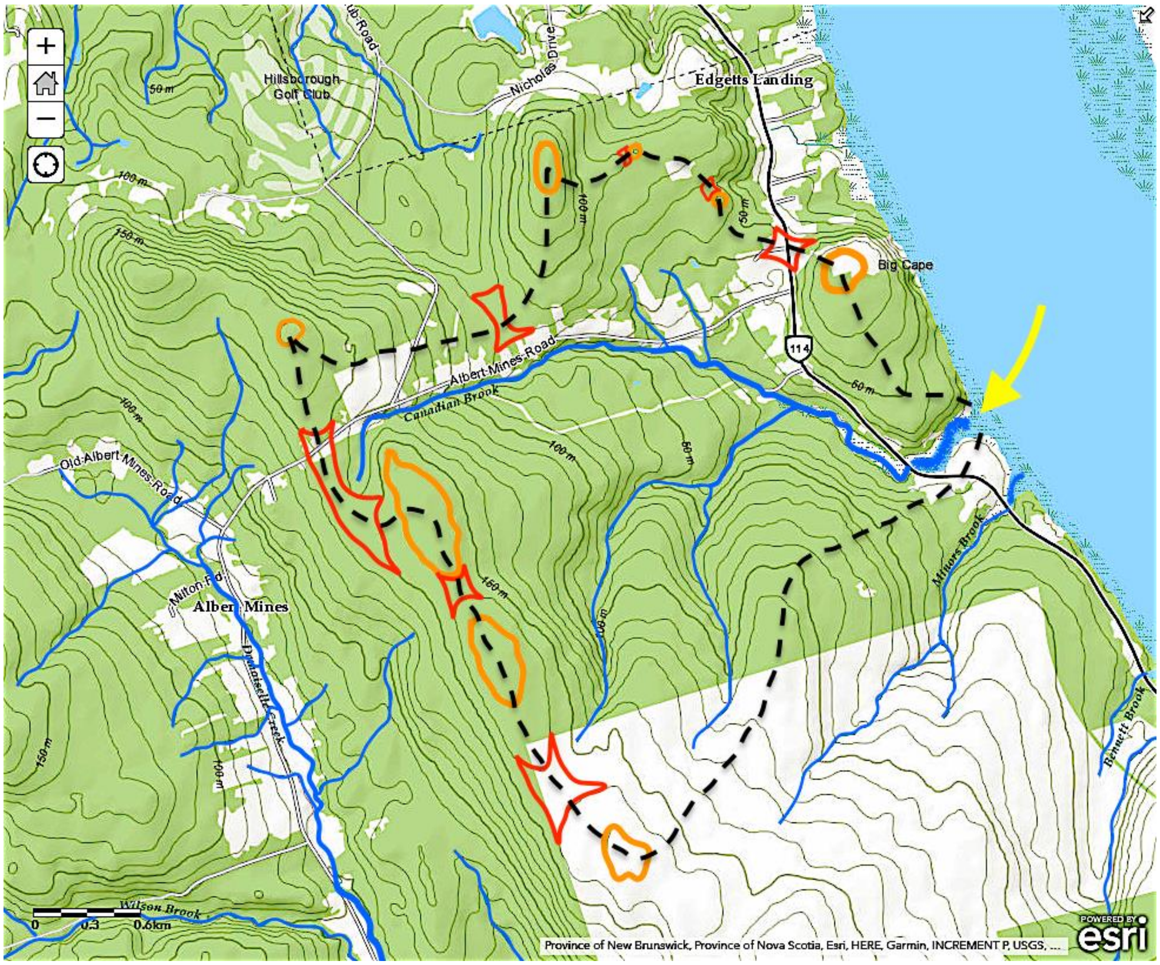
1. Find all the circles, or peaks, in the immediate area around the watercourse.

2. Find the saddles!

Saddles indicate the lowest area between two neighboring peaks, and the path water will travel as it flows down them. If you're walking down one peak toward another, the saddle is where you start going back up again. There is always a saddle between each peak.



3. To further delineate the area, connect the peaks and saddles!



We've just delineated the Canadian Brook sub-watershed! Any rain that falls within this boundary will make its way to the mouth of the river.

The Water Cycle

Water is in constant circulation, powered by the energy from sunlight and gravity in a natural process called the hydrologic cycle. Water evaporates from the ocean and land surfaces, is held temporarily as vapour in the atmosphere, and falls back to Earth's surface as precipitation. Surface water is the residue of precipitation and melted snow. When the average rate of precipitation exceeds the rate at which surface water seeps into the soil, evaporates, or is absorbed by vegetation, bodies of surface water such as streams, rivers, and lakes are formed.

It's important to protect water quality and quantity resources as it is a foundation for a healthy ecosystem.

Figure 6: Example water cycle

Evaporation

Evaporation is the process by which water changes from a liquid to a gas. It is the primary pathway by which surface water is transferred from a liquid state into the atmosphere as vapor to form clouds.

Transpiration

Transpiration is the process of water movement through a plant from where it enters it via the roots to its evaporation from aerial parts at the top of the plant, such as leaves, stems, and flowers. Water is necessary for plants but only a small amount of water taken up by the roots is used for growth and metabolism. The remaining 97–99.5% is lost by transpiration and guttation (the process in which water moves up through plants in the night through higher water pressure in the plant roots).

Precipitation

Precipitation is water released from clouds in the form of rain, freezing rain, sleet, snow, or hail. It is the delivery mechanism of atmospheric water to the Earth's surface.

Surface Water

Surface water is water present on the land surface and includes rivers, lakes, and wetlands.

Infiltration

Infiltration is the entry of water below the ground surface into the soil via pore spaces between soil particles during or after precipitation. Infiltration is affected by variables such as the permeability of the land surface, vegetation cover, biodiversity of plant species and root systems, type of soil, and human activities.

Percolation

Rainfall seeps through the ground via a process called percolation, whereby water travels through pores between rock and soil particles. Percolation is influenced by the type of subsurface material (rock or soil), its composition, structure, and texture, as well as vegetation and human activities.

Ground Water

Groundwater water subsurface water contained within rocks. There are many sources the contribute to the supply of groundwater, including rain and snow that soak into the ground. Groundwater tends to inherent some of the mineral composition of it host rock. Additional information on groundwater is on page 22.

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.

Molecular Composition of Water

Water is composed of two hydrogen atoms both bonded to one atom of oxygen (H20). 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 7).

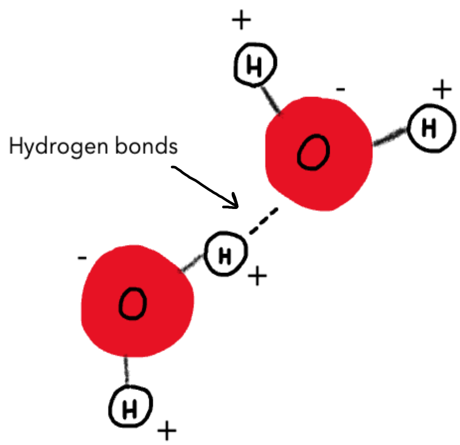


Figure 7: Water particle bond example

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. 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, bringing about 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 New Brunswick, aquatic organisms are subjected to much narrower temperature ranges (4°C to 27° C) as compared to terrestrial organisms which must cope with annual temperatures that can range between -40° C to +35° C. 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.

Density of Water

As with all other liquids, freshwater density increases as it cools. It attains its maximum density at 3.98°C 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 meters 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.

Aquatic Environments

Lake

A lake is a localized water basin surrounded mostly by land and may have a river or stream feeding into it or draining from it. Apart from a pond, a lake is usually bigger and deeper as there is presence of an aphotic zone. This zone is the bottom portion of a lake where little or no sunlight reaches this depth; less than 1% of sunlight penetrates. Natural lakes can often form following receding glaciers from the last Ice Age. Over time, they slowly fill in with sediments to become ponds, wetlands and eventually forested lands.

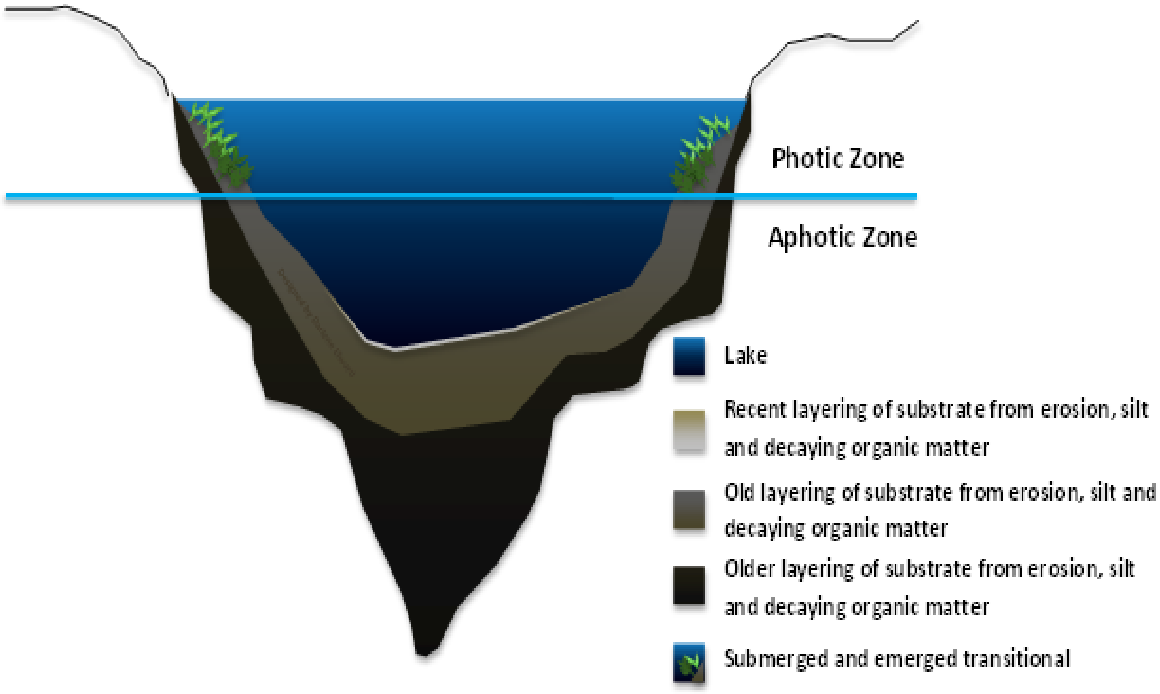


Figure 8: Lake cross-section

Pond

A pond is a smaller localized water basin surrounded by land that is naturally found in floodplains as part of a river system. A pond usually covers a smaller surface area than a lake, has shallower water levels in its depression and the aphotic zone is absent. Sunlight can easily reach the bottom of a pond; more than 1% of sunlight penetrates. Life found in a pond habitat can be quite different from a lake depending on certain conditions such as depth, water level, nutrients, shade, presence or absence of stream inlets and outlets, and periods of drought. Ponds can naturally help filter stormwater runoffs as they capture sediments and other particles before reaching the rivers.

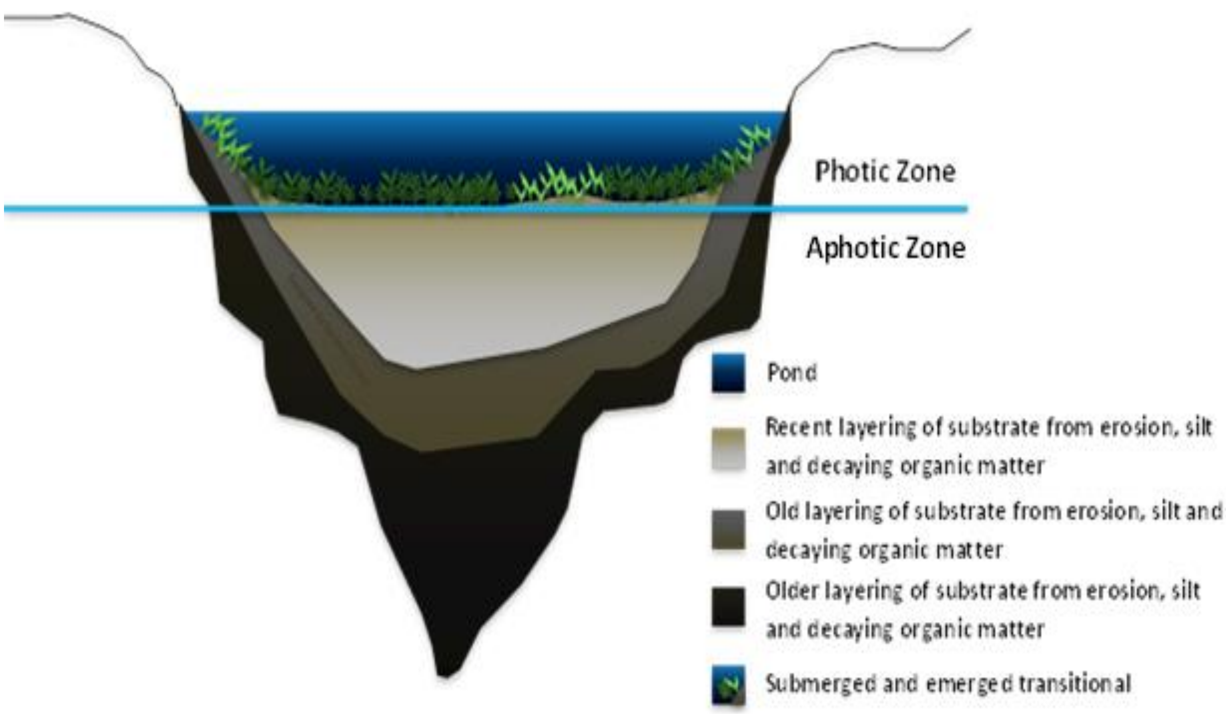


Figure 9: Pond cross-section

Wetland

Wetlands are ecosystems transitioning between land and water. Wetland soils are typically a mixture of organic matter and sediments permanently or seasonally saturated by water. The soil conditions are therefore anaerobic, meaning they lack oxygen. Wetlands are like sponges that can store a lot of water, salt, brackish or freshwater. Wetlands are also covered with plants adapted to their unique conditions such as saturated soils. They provide important habitat to a wide range of wildlife and help improve water quality, and can reduce the intensity of flooding and drought in the environment. There are many types of wetlands with different characteristics depending on their location and hydrology. Here are a few examples:

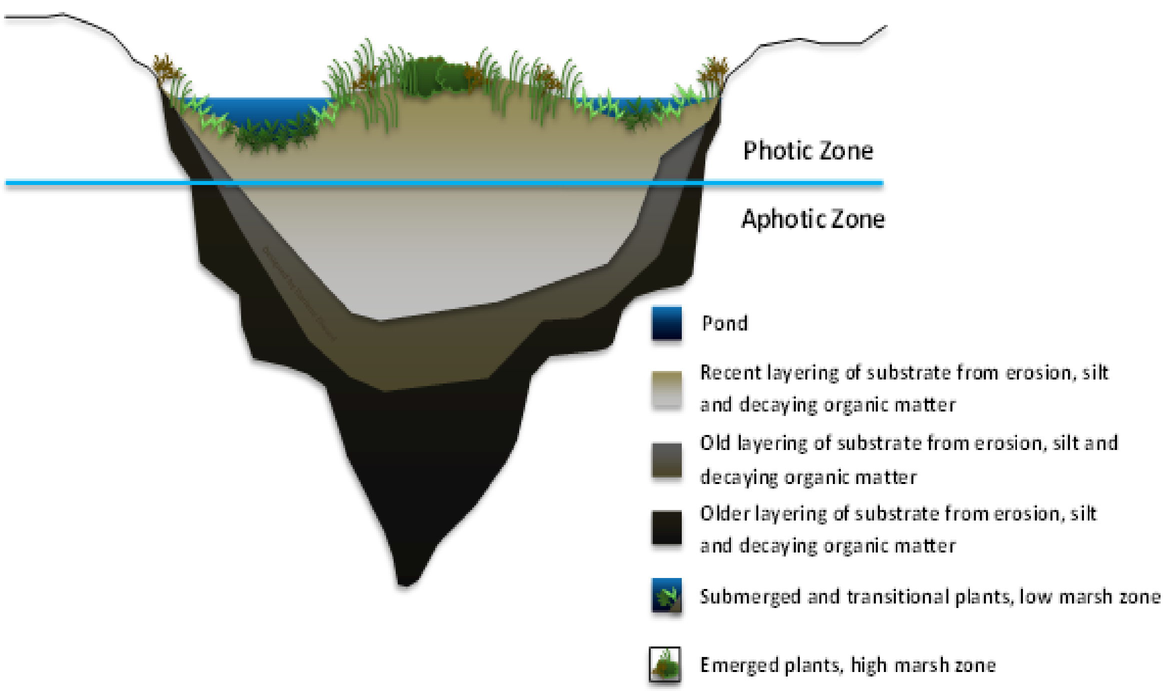


Figure 10: Wetland cross-section

Figure 11: Bog

Bogs

Bogs are shallow depressions composed of peat. The main water source that feeds into bogs is from rain. It has little or no input from groundwater, creating an acidic and poor nutrient environment. Bogs provide habitat for a variety of animals and hydric plant species such as sundew and pitcher plants. An indicator for determining a bog from other wetlands is often the presence of acid-tolerant plant species.

Vernal Pools

Located in the floodplains, vernal pools are small wetlands that are periodically filled with shallow water from winter to spring and usually dry out by the summer. They are mostly fed by snow melt, rain, runoff, and the occasional flooding, which provides most of the nutrients to these systems. These are important breeding areas for salamanders, insects, and frogs, and they can seasonally provide food to wildlife.

Figure 12: Fen

Fens

Fens are similar to bogs as they also are composed of peat moss. The main water sources that feed into fens are from mineral-rich groundwater and rain, making them less acidic and richer in nutrients than bogs. Fens provide a diverse ecosystem including hydric plant species such as grass meadows, sedges, and wildflowers.

Figure 13: A swamp

Swamps

Located in different landscapes, swamps have water flowing within them that varies seasonally. The main water sources that feed into swamps are from streams, groundwater, and rain. Nutrient composition can range from poor to rich depending on water inputs. Swamps provide habitats to hydric plant species that are mainly trees and shrubs.

Figure 14: A freshwater marsh

Marshes

Marshes are formed in shallow depressions associated with shallow water. They have a wide variety of water sources (stream, groundwater, and rain) that feed into them that provides a nutrient-rich environment. Marshes provide habitat to a broad range of animals as well as food and nesting areas to waterfowl. They are also dominated by aquatic plants such as cattails, sedges, and grasses. Depending on the proximity to the coast or tidally influenced river, marshes can be freshwater or saltwater.

Figure 15: A shallow water wetland

Shallow Water Wetland

Shallow water open wetlands, in adjacent to ponds, are generally less than 2 metres in depth. They have a variety of water sources (stream, groundwater and rain), either standing or flowing, that provides them with a nutrient-rich environment. Shallow water wetlands are mostly vegetated of duckweed and waterlilies.

Figure 16: A meadow

Meadows

Wetland meadows are located by streams where water levels fluctuate on a continuous basis. They are mainly fed by stream water, groundwater, rain, and runoff. Meadows have nutrient-rich environments. They are mostly vegetated by hydric plants including sedges (i.e., species of Carex) or grasses.

Figure 17: A forested wetland

Forested Wetlands

Forested wetlands are located in dense forests in the floodplains adjacent to waterways. They are mostly fed by rain, runoff, and the occasional flooding, which provides most of the nutrients to these systems. These forested wetlands provide habitat to many animals as well as food, nesting areas and important corridor passages to birds. Vegetation found here are mostly large trees such as red maple, oak, or ash.

Figure 18: A coastal wetland on the Memramcook River

Coastal Wetlands

Coastal wetlands include salt marshes, estuaries and mudflats. They are mainly influenced by salt-brackish water typically located between land and sea. Their main water sources are from storm surges, tides, and the occasional direct access from the ocean. Coastal wetlands have very productive ecosystems with both terrestrial and aquatic characteristics. They provide habitats for early fish life stages, food resources, and help in flood control and erosion prevention.

Rivers

A river is a natural flowing fresh waterbody, fed by rain and groundwater. If the river terminates at the ocean then it will be influenced by brackish water and tides at its estuary interface. Rivers drain into other waterbodies including other rivers, lakes, or the ocean while changing the morphology of the landscape along its path. The water of a river flows through a channel. The deepest point of this channel is called the thalweg, defined as the lowest points along the entire length of a riverbed. When measuring the width of a river, there are two widths to consider: the wetted width, the current width of the river where the water touches the banks; and the bankfull width, the high-water mark where the stream completely fills the channel during the highest flow period of the year. During flooding, the river may breach its banks and enter the floodplain, defined as the area of land adjacent to a river that stretches beyond the channel banks to the base of valley walls.

Figure 19: The Petitcodiac River

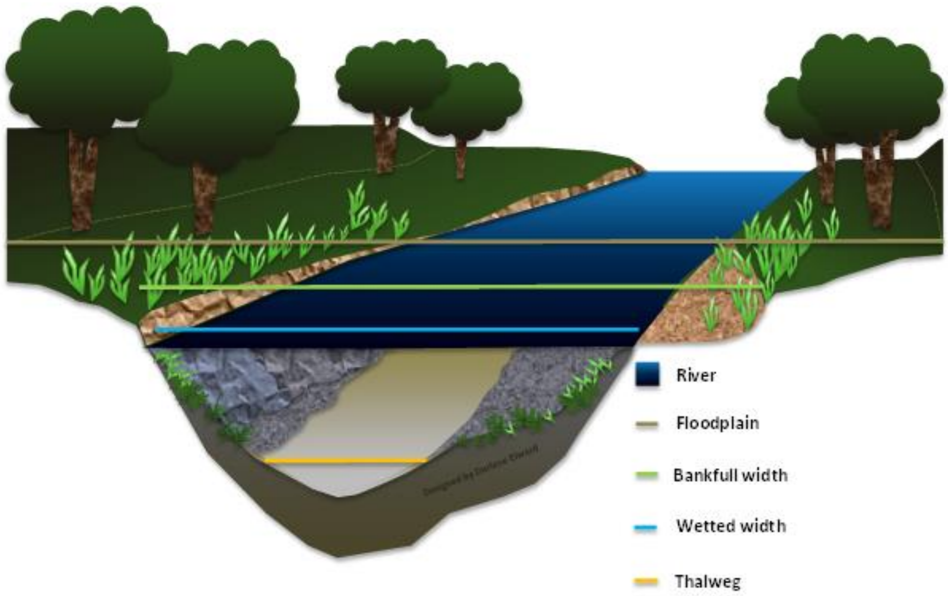


Figure 20: A river cross-section

Riparian Zones

The riparian zone is the transitional zone between aquatic and terrestrial ecosystems where a mixture of water-loving and terrestrial species is found. It includes the floodplain and the flood influenced zones (first and second terraces in the diagram).

The Watercourse Wetland Alteration Technical Guidelines 2012 for the Province of New Brunswick indicates that a riparian buffer should be a minimum of 30 meters from the riverbank or designated wetland to any alterations from riverfront landowners on residentially-zoned properties.

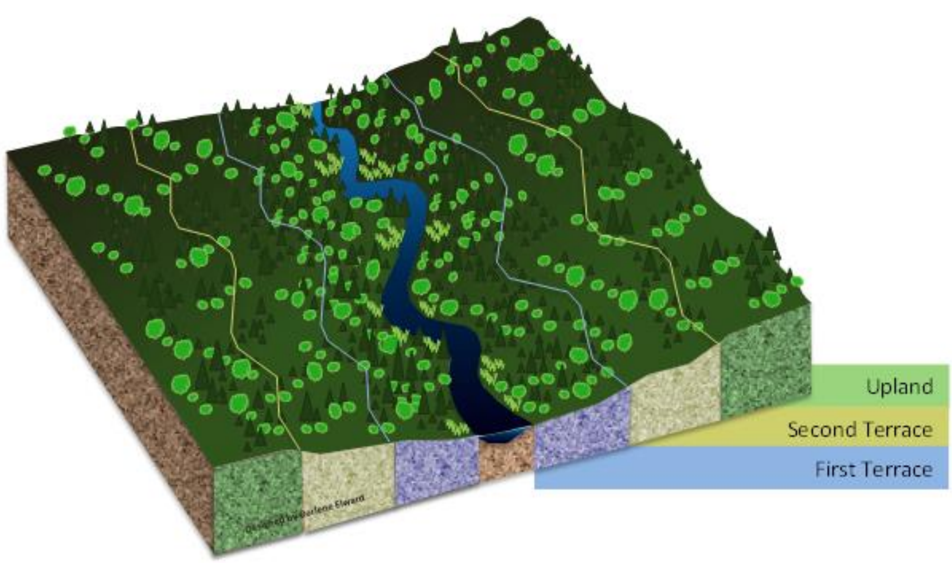


Figure 21: Riparian zones and transitional zones

Groundwater

Water is stored underground. After rain events and snow melts, surface water will infiltrate the soil and percolate through the pores of permeable soil and through interstices and fractures of rock formations to groundwater, also known as ground water recharge. In areas where communities rely on well water, this is how such water is collected and stored. The top layer of soil is considered the unsaturated zone: where pores in the soil are filled with both air and water. Beneath the top layer is the saturated zone; the depth at which only water and no free-air is present in soil pores and rock interstices and fractures. The boundary between unsaturated and saturated zones is known as the water table. A rock formation that stores groundwater is called an aquifer, of which there are two types: unconfined and confined. The unconfined aquifer, typically the shallowest, is located at the top in unconsolidated (loosely arranged) soil. The confined aquifer is located above the bedrock and overlain by an impermeable layer, often made up of clay.

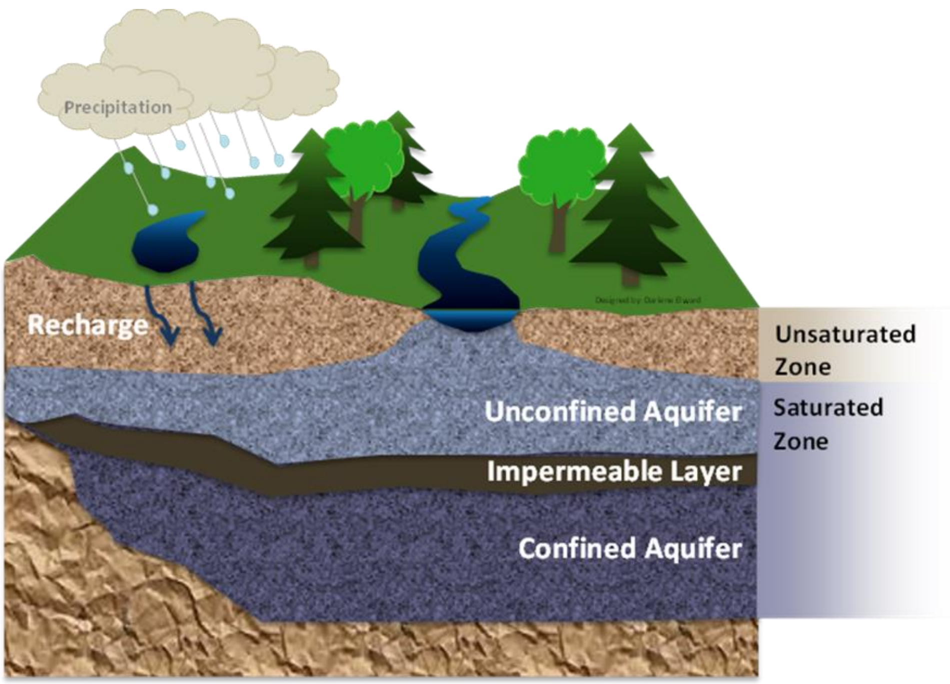


Figure 22: Groundwater cross-section

2023 NCF-Envirothon New Brunswick

Aquatic Ecology Study Resources

Key Topic #2: Aquatic Organisms and Ecosystem Dynamics

9. Describe the different adaptations of aquatic organisms to lake and stream environments.
10. Define habitat requirements for a variety of aquatic plant and animal species and illustrate with specific examples.
11. Diagram an aquatic food web and describe the flow of energy within it.
12. Explain the role of aquatic ecosystems in biogeochemical cycles, such as the carbon, nitrogen, and phosphorus cycles.
13. Describe aquatic ecosystems are affect by seasonal changes in temperature, water level, flow rate, nutrient sources and availability, and surface runoff.
14. Explain the importance of biodiversity in aquatic ecosystems.

Study Resources

Resource Title	Located on
Balanced Ecosystem	Pages 24-25
Food Webs	Pages 26
Species at Risk Statuses	Page 27

Information for this section was compiled from the following sources*:

- Food chains & Food webs – *Khan Academy, 2023*
- The End of the Line – *Documentary, 2009*
- Cyanobacteria – *NB DELG, 2023*
- *The Atlas of Common Freshwater Macroinvertebrates of Eastern North America, 2023*
- Species at Risk Act Registry – *Government of Canada, 2023*
- Freshwater Mussel Habitat Stewardship in the Petitcodiac Watershed through Monitoring, Outreach, and Habitat Improvement **-** *Darlene Elward, The Petitcodiac Watershed Alliance, 2023*

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Study Resources begin on the next page! ➡

Balanced Ecosystem

An environment can only support a certain amount of life with the number of available resources needed to survive. It's also known as the carrying capacity of an ecosystem. Ecosystems provide a limited amount of food, water, oxygen, and space in order to have a healthy and diverse environment.

Figure 23: Example of a balancing ecosystem

An example of carrying capacity can be imagined through a fishbowl. A population of fish will reproduce and use the resources available in an ecosystem to live and compete with other species until the carrying capacity can no longer support them. Their population reduces until their numbers balance out with the limitations in this environment. The important takeaway is that ecosystems provide a limited amount of food, water, oxygen and space in order to have a healthy and diverse environment.

Biological Indicators

Water quality provides a snapshot of water health and biological indicators can give long-term information. Some species are sensitive to pollutants. For example, the Canadian Aquatic Biomonitoring Network (CABIN) uses aquatic invertebrates as an indicator of water quality.

Benthic Macroinvertebrates

- They are an important part of aquatic food chains.
- They feed on aquatic plants, smaller macroinvertebrates, and other organic matter.
- They provide a source of energy for larger animals such as fish, which are preyed upon by birds, raccoons, water snakes, and fishermen.
- Some benthic macroinvertebrates cannot survive in polluted water while others can thrive in polluted water.

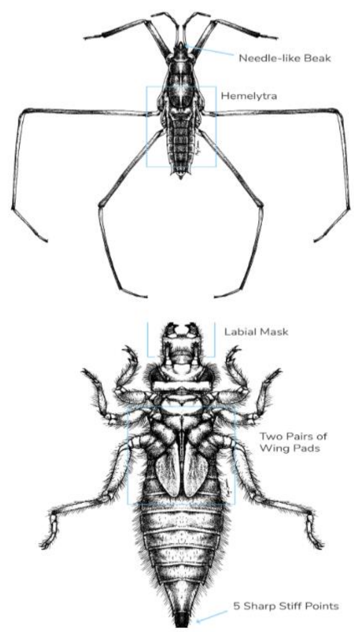


Figure 24: Image of a *Hemiptera* (True Bugs) sample and a *Odonata* (Dragonfly) larvae from *macroinvertebrates.org*

How to Identify Macroinvertebrates:

STEP 1: Determine the site you want to study and what samples you will be identifying.

STEP 2: Look at a dichotomous key to identify visual characteristics of the sample. Follow the identification key categories, starting at the top, making your way down to determine what category the sample falls into and identify the species.

STEP 3: Look at what category of sensitivity your sample species falls into.

1. A **healthy river system** will have an abundance of pollution-sensitive benthic macroinvertebrates.
2. An **unhealthy stream** will mainly have more pollution-tolerant benthic macroinvertebrates.

For more information and resources on using identification keys and benthic macroinvertebrates, visit www.macroinvertebrates.org for access to high quality images and instructions. *(This is a supplemental resource that is not required reading.)*

Freshwater Mussel Identification

Another method of macroinvertebrate survey that may help assess the environmental integrity of an aquatic ecosystem are freshwater mussel surveys focused on local mollusk species that have their own respective tolerance of pollution and are biological indicators.

Nearly 75% of freshwater mussel species in North America are considered at risk or in a concerning situation (*Nedeau, E.J., Victoria, J. 2003*). Rivers and streams in New Brunswick hold important habitats to as many as eleven native freshwater mussel species as indicated in the New Brunswick Museum's field flashcard guide (*McAlpine, D. F., Sollows, M. C., Madill, J. B., Martel, A. L. 2018*) from which an excerpt can be found in Key Topic #4.

Freshwater mussel populations have been declining for more than 50 years largely due to poor land management practices and urban expansion. Road infrastructure that affects river systems (such as causeways that pose as barriers to fish passage for anadromous fish species that may serve as hosts to some freshwater mussel species) have great impacts on aquatic ecosystems (*D. Elward, 2023*). More information on freshwater mussels can be found in Key Topic #4.

Food Webs

A food chain and food web represent the flow of energy and matter. Everything that is alive finds energy to survive and thrive in different ways. While a chain can be helpful in determining a piece of the biotic puzzle, a web is a more complex understanding of how the biotic world interacts with each other.

Within a traditional food chain from the **bottom-up** perspective you have primary producers > primary consumers > secondary consumers > tertiary consumers > quaternary consumers > apex consumers.

In an aquatic ecosystem this can be demonstrated in Figure 25, starting with an aquatic plant species at the bottom left.

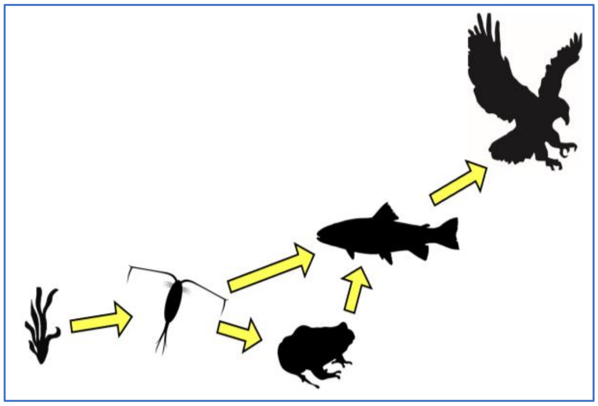


Figure 25: Image of an example food chain

The aquatic plant species in the example featured in Figure 25 would be the primary producer, eaten by these shrimp and macroinvertebrate species or primary consumers. The secondary consumers then would be the frog and fish species, with the chain top being the apex consumer or raptor species.

But what happens when there are changes to the habitat that the species in this chain relies on? If for example, there was a pollutant dumped that the macroinvertebrate was sensitive to, the dynamics would change quickly. The frog that relies heavily on this one source of nutrient would decline. The fish species, though an opportunistic feeder who gains nutrients from a diverse diet, would also decline with some of its food sources impacted. However, while the higher trophic levels suffer, the primary consumer may thrive without a stable predator, and begin a steady population growth. However, this rise cannot be sustained with limited resources. This is when a chain would begin to collapse.

There are benefits to thinking of prey and predator as a **chain**, to link the order of who's eating whom from bottom to top. But when you dive deeper, into the complex dynamics and diversity of diets, a food **web** is a more accurate analogy. True to the inspiration of a spider's web, if one part of the web is impacted, it is felt by the whole. These impacts can often be attributed to human sources. A great example of this can be found in the documentary "The End of The Line" (*2009*) which describes the reality of overfishing impacts to the aquatic food web. Climate change adds stress to all trophic levels and is a great factor in the decline of biodiversity and mass extinction worldwide. While making changes to live and eat more sustainably, conservation and monitoring strategies targeting species-at-risk are also important moving forward.

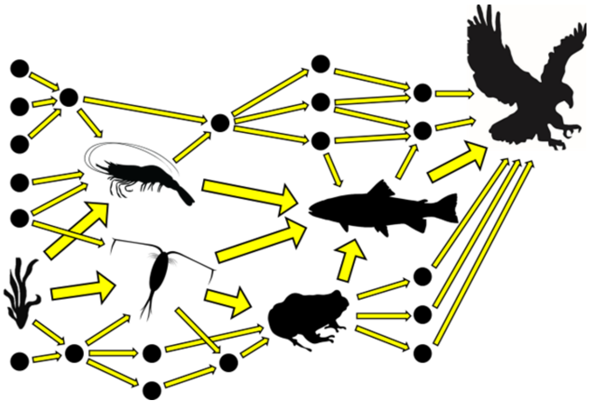


Figure 26: Image of an example food web – Circles are representative of other species, with producers in the far left column and consumers to the right, illustrating the complexity of interspecies dynamics

Species at Risk Statuses

Conservation work and biodiversity monitoring is very complex, but important for us to understand the biotic world and the many impacts to it. To help us monitor and protect these species we work with a global classification system in Species-At-Risk Act (SARA), and in Canada we also have the Committee on the Status of Endangered Wildlife in Canada (COSEWIC), an independent advisory panel to the Minister of Environment and Climate Change Canada that assesses the status of wildlife species at risk of extinction.

The statuses are as follows:

1. Extinct
2. Extirpated
3. Endangered
4. Threatened
5. Special Concern
6. Not at Risk

These designations help prioritize efforts to protect these species and address the stressors leading to their decline. Designations begin at Special Concern, and range in severity to extirpated (extinct regionally but exist elsewhere in the world) and extinction. The *Dwarf Wedgemussel* is an example of a species of mollusc and freshwater mussel that is extirpated from its historic habitat in New Brunswick but exists elsewhere in the United States.

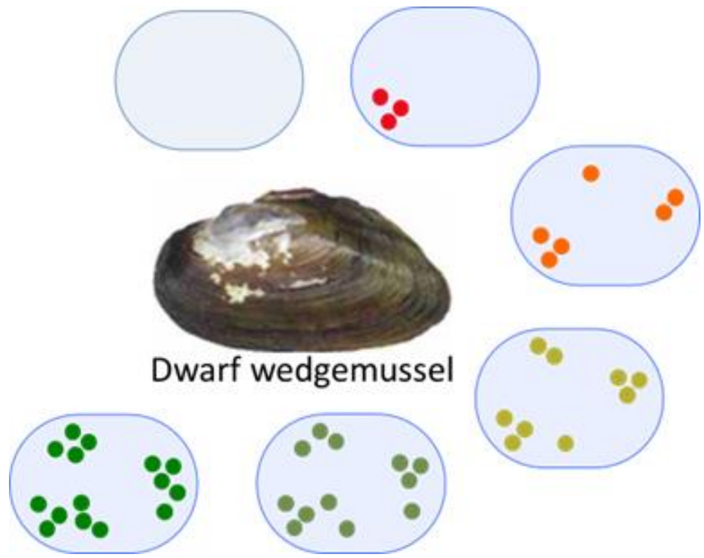


Figure 27: Image of a *Dwarf Wedgemussel* and an example distribution of species at risk

2023 NCF-Envirothon New Brunswick

Aquatic Ecology Study Resources

Key Topic #3: Human Impacts and Watershed Monitoring

15. Describe the features of a healthy watershed and identify the negative impacts human activities can have on watersheds.
16. Explain the differences between point-source and nonpoint source pollution and describe the impacts of each.
17. Describe the impacts of non-native and invasive species on aquatic ecosystems.
18. Evaluate methods of management and control for invasive aquatic species and describe their challenges and successes.
19. Demonstrate how current water use practices affect aquatic resources using examples from New Brunswick.
20. Explain how aquatic organisms and water quality are affected by the physical, chemical and biological conditions of the water.
21. Describe the role of cyanobacteria in aquatic ecosystems and their role in harmful algal blooms.

Study Resources

Resource Title	Located on
Water Quality	Pages 30-43
Alien and Invasive Species • REQUIRED VIDEO: New Brunswick Invasive Species Council Spring 2022 Awareness Video	Page 44
Cyanobacteria	Page 45
Anthropogenic Impacts and Watershed Monitoring • REQUIRED VIDEO: Excerpt from Groundwater Protection	Pages 46-48 (Page 48)
Indigenous Traditional Ecological Knowledge • REQUIRED VIDEO: Reconciliation and Stewardship Through Land Conservation • REQUIRED VIDEO: Npisun (Medicine) in the Wabanaki Forest	Pages 49-50 (Page 49) (Page 50)
Climate Change • REQUIRED VIDEO: Excerpt from Marsh Magic	Pages 51-52 (Page 52)

Information for this section was compiled from the following sources*:

- Water – From: Climate Change 2022: Impacts, Adaptation and Vulnerability. Contribution of Working Group II to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change – *Caretta, M.A et al., 2022*
- Climate Change Adaptation – *EOS Eco-Energy, 2013*
- Water Quality Monitoring Report– *Brittany Cormier, The Petitcodiac Watershed Alliance (PWA), 2022*
- Freshwater Mussel Habitat Stewardship in the Petitcodiac Watershed through Monitoring, Outreach and Habitat Improvement a summary of 2021– *Darlene Elward, Petitcodiac Watershed Alliance (PWA), 2022*
- Improving Habitat for Inner Bay of Fundy Atlantic Salmon Through the continual Refining of Remediation Techniques– *Petitcodiac Watershed Alliance (PWA)*
- Native Land Digital Online Map and Territory Acknowledgement Guide Resource–*Native Land, 2023*
- Sa'qewi-ilnuwey Awti IPCA - Reconciliation and stewardship through land conservation– *Native American Ethnobotany database, 2022*
- "Npisun (Medicine) in the Wabanaki Forest" (2022) Community Forests International – *Cecelia Brooks & Anthony Bardwell, 2022*
- Adaptation through bricolage: Indigenous responses to long-term social-ecological change in the Saskathewan River Delta, Canada– *Abu, R., & Reed, M. G., 2018*
- Climate Change and Land: an IPCC special report on climate change, desertification, land degradation, sustainable land management, food security, and greenhouse gas fluxes in terrestrial ecosystems– *IPCC, 2019*
- Salt Marshes for Climate Risk Reduction Presentation– *Dr. Danika van Proosdij, 2022*

* Please Note: The information within this document is the ***official*** 2023 NCF-Envirothon Aquatic Ecology Study Resource and should be used by the teams to study for the Aquatic Ecology station tests. Additional information found in the sources cited above are not required.

<u>Study Resources begin on the next page!</u> ➡

Water Quality

Figure 28: Image of Humphrey's Brook in the Petitcodiac Watershed

Water Quality Parameters to Gauge Ecosystem Health

A parameter is a measurable characteristic of a system that can help define the condition of the system. It is a factor of an ecosystem that can help gauge the overall ecosystem health. Parameters can be measured by testing the water in a watershed. Most often, the type of water being tested determines what *parameters* that scientific monitoring projects look for. These properties can be physical, chemical or biological factors (*Kemker, 2014*). The following are explanations of the parameters used to monitor water quality, where they come from and how they are important factors in gauging the health of the ecosystem for aquatic species, other wildlife and recreational safety for humans.

Water Temperature

This is a measurement of the intensity of heat stored in a volume of water (*Kemker, 2014*). Temperature can be influenced by a number of factors such as sun exposure and streamside shading, size and depth of the water, elevation, water velocity, groundwater inputs, agricultural and wastewater runoff, anthropogenic impact from recreational activities (*United States Geological Survey, 2014*), and stormwater runoff from heated surfaces such as parking lots, rooftops and roads (*United States Environmental Protection Agency, 2012*).

Another obvious reason for temperature change 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.

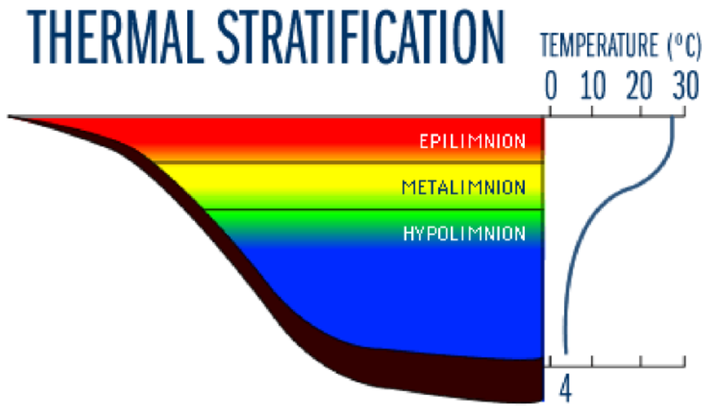


Figure 29: Example of thermal stratification of lakes during summer months

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. 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 decreases 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 stormwater enters the lake.

Water temperature is an important factor influencing many river processes and other parameters of water quality. It affects the solubility of many chemical compounds and can therefore influence the effect of pollutants on aquatic life. Water Temperature and dissolved oxygen (DO) are directly related to each other. As water temperature increases, DO decreases, thus cold water holds more oxygen than warm water.

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. Increased temperatures elevate the metabolic oxygen demand, which in conjunction with reduced oxygen solubility (*Kemker, 2014*), can affect metabolic processes in most fishes and determine their ability to survive in a certain environment (*Claireaux, 2000*). It determines which organisms are able to survive and live in a certain environment, as every species has a critical upper and lower thermal limit. These temperature limits can be of a wide or narrow range and can vary both within and among species in order for them to thrive (*Ministry of Environment BC, 2001*) which influences the composition of aquatic communities (*Bain & Stevenson, 1999*).

Fish found in several New Brunswick watersheds that are sensitive to temperature include brook trout (*Salvelinus fontinalis*) and Atlantic salmon (*Salmo salar*). Cold water fish species can only survive and thrive within a limited temperature range. Brook trout for example, require cooler temperatures (i.e., ideally 13–18 °C), but are able to survive in water temperatures of up to 22 °C. However, at this temperature, these cold-water fish must be able to find thermal refuges or regions within a river where water temperatures are cooler, or they will die (*Bain and Stevenson, 1999*). Prolonged exposure to temperatures greater than 24°C is lethal for trout and salmon species (*MacMillan et al., 2005*), and can put fish at a competitive disadvantage in the wild due to physiological stress (*Department of Fisheries and Oceans, 2012*).

Dissolved Oxygen

Dissolved oxygen (DO) is a commonly used parameter for measuring water quality (*Sánchez et al., 2007*). It is influenced by a collection of physical, chemical and biological characteristics such as temperature, salinity, wave action, and current (*Spanou and Chen, 1999; Cox, 2003; Mulholland et al., 2005; Quinn et al., 2005, USGS, 2014*). DO is one of the most fundamental parameters in water for all aquatic life. Low concentrations directly affect fish and alter a healthy ecological balance. Because DO is affected by many other water quality parameters, it is a sensitive indicator of the health of the aquatic system (*CCME, 1999*). A dissolved oxygen level that is too high or too low can affect water quality and harm aquatic life. The amount of dissolved oxygen needed is species-specific and can vary within a species based on their life stage (*Breitburg, 1994; CCME, 1999*). If a watercourse does not have adequate levels of dissolved oxygen, aquatic organisms will be unable to inhabit them. The CCME guidelines for aquatic life set the guideline as variable, based on the species of concern and should not fall below 9.5mg/L for early life stages or below 6.5mg/L for other life stages (Table 1, page 40).

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 O2/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.

The top water layer is known as epilimnion, and the deep cool layer is known as hypolimnion (see Figure 7). The DO concentration in the epilimnion remains 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).

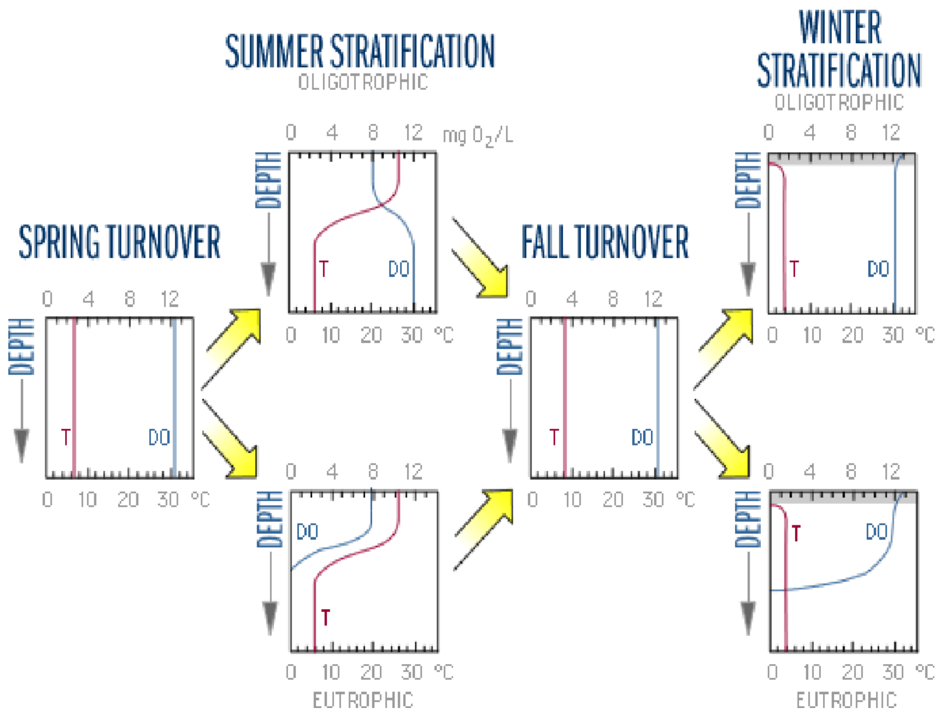


Figure 30: Typical seasonal changes in dissolved oxygen and temperature (adapted from Figure 8-1 in Wetzel, R.G. 1975. Limnology. W.B.Saunders Company)

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 O2/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.

pH

The pH is the logarithmic measurement of free hydrogen ions in solution. 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. At a 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. This will determine whether the solution in question is acidic, basic, or neutral from a scale of 0 to 14. Substances with pH of less than 7 are acidic; substances with pH greater than 7 are basic (Figure 31), and a value of 7 is neutral. CCME indicates that healthy surface water should have a pH that falls between 6.5 and 9.0 (Table 1, page 40). The U.S. Environmental Protection Agency (USEPA) classifies water that is suitable for biota as having a pH that is within the range of 6.5 - 9 (*USEPA, 2013*). Severe stress to aquatic life can be evident at pH levels below 4 units (*EPA, 2012*).

Factors affecting the pH of surface water include acid rain, surficial geology of the area surrounding the water, and wastewater runoff. Low pH levels cause chronic stress that may not kill individual fish but can lead to lower body weight and smaller size and makes fish less able to compete for food and habitat (*USEPA, 2012*). In high pH environments the effects on fish can include death, damage to gills, eyes, and skin, and an inability to dispose of metabolic waste (Locke, 2008). Buffering capacity is water's ability to resist changes in pH and it is critical to the survival of aquatic life (*Petrin, Englund, & Malmqvist, 2008*). According to Petrin et al (*2008*), low or high pH values can occur naturally due to the presence of humic acid emanating from wetlands (peatbogs in particular). Anthropogenic changes in pH can also be caused by acid rain, accidental spills, agricultural runoff and sewer overflows.

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.

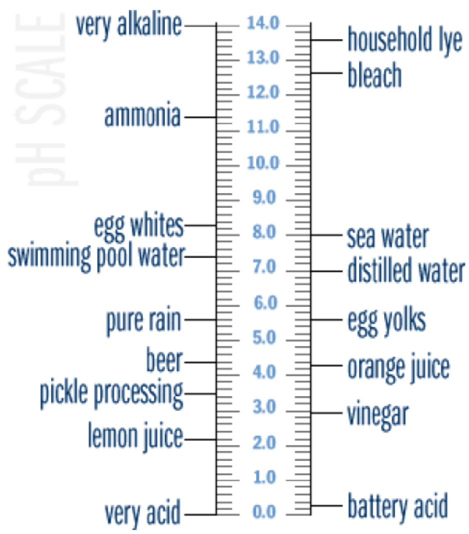


Figure 31: pH scale and examples

Specific Conductivity

Specific conductivity is a measure of the water's ability to carry an electrical current and is recorded in microSiemens per centimeter (μs/cm) (*USEPA, 2012*). Conductivity is influenced by the presence of inorganic dissolved solids such as chloride, nitrate, sulfate, phosphate, sodium, magnesium, iron, and aluminum (*USEPA, 2012*). Conductivity is also affected by water temperature: as the water temperature increases so does conductivity. For this reason, all conductivity is reported as specific conductivity (conductivity at 25°C) (*USEPA, 2012*).

There is no set range of values that are deemed necessary for a healthy aquatic ecosystem. Most streams have conductivity that fluctuates within a certain range which can serve as a background for long-term monitoring. If measurements are recorded outside of the typical range it can be an indication of a change in the stream chemistry due to increased dissolved solids in the water from discharge or point pollution (*USEPA, 2012*).

Conductivity in streams is generally determined by geology. Streams that run through granite bedrock tend to have lower conductivities than those that run through clay soils. Discharges into streams can affect the conductivity of a stream. Failing sewage systems can raise conductivity because of the presence of chloride, phosphates and nitrates but an oil spill would lower conductivity (*USEPA, 2012*).

Most rivers will naturally have a conductivity range between 50 µS and 1500 µS/cm. Conductivity measurements of 150 µS/cm to 500 µS/cm are the desired range for fish habitat (Table 1, page 40). Conductivity outside of this range is an indication that the watercourse sampled may not be a suitable habitat for some species of fish or macroinvertebrates (*Behar, 1997*).

Salinity

Salt is a natural component of our landscape (*Environment, 2001*). It has been deposited from a variety of sources over millions of years. Salt can enter our waterways from groundwater, weathering rocks and the atmosphere. In Canada, de-icing salt is an increasing concern as a source of anthropogenic salt that enters our rivers and streams. Increased salt concentrations have contributed to a loss in soil stability, which in turn increases soil erosion. The salt used during winter for road maintenance can have a negative effect on aquatic ecosystems. Recent studies have shown that salt concentrations in surface waters are frequently at levels that can negatively affect the biota (*Salt Institute, 2011*). High salt concentrations are causing damage to vegetation and shifting plant community structure as well as provoking effects on fish communities that cannot adapt to the elevated salt concentrations. Salinity decreases dissolved oxygen and increases conductivity and total dissolved solids. Most aquatic organisms prefer either freshwater or saltwater. Few species traverse between salinity gradients, and fewer still tolerate daily salinity fluctuations (*Kemker, 2014b*).

Longer-term toxicity occurs at concentrations as low as 210 mg/L; these concentrations have been observed in numerous urban creeks and streams (*Environment Canada, 2010*). Freshwater streams generally have a salinity level close to 0 – 0.5 ppt, there are a few freshwater streams such as the North River that runs through the Petitcodiac watershed in southeastern New Brunswick that runs through natural salt deposits and carry a slightly higher salinity load.

Total Dissolved Solids

Total dissolved solids (TDS) is the measure of dissolved inorganic material in water that is less than two micrometers (µm) in diameter and is measured in milligrams per litre (mg/L) (*Weber-Scannell and Duffy. 2007*). Water with total dissolved solids concentrations greater than 1000 mg/L is brackish (*Weber-Scannell and Duffy, 2007*) (Table 1, page 40). Like conductivity there is no set range of values deemed acceptable, however, with enough background data, a normal range can be determined. If this range is set and TDS does fluctuate outside of background norms it can serve as an indication that something is being introduced into the water system. Wastewater runoff, pollution, agriculture and geography are all factors in contributing to TDS measurements (*Weber-Scannell and Duffy, 2007*). The most commonly occurring cation in fresh water is calcium. It is recommended that different limits for individual ions, rather than TDS, be used for salmonid species. These limits should be based on the effect of the ion on fertilization and egg development (*Weber-Scannell & Duffy, 2007*).

Turbidity

Turbidity is the measure of relative clarity of a liquid. It is an optical characteristic of water and is an expression of the amount of light that is scattered by material in the water when a light is shined through the water sample (*CCME, 2023*). The higher the intensity of scattered light, the higher the turbidity will be. Materials that cause water to be turbid include clay, silt, finely divided inorganic and organic matter, algae, soluble colored organic compounds, and plankton and other microscopic organisms. During periods of low flow (base flow), many rivers are transparent with varying colour, and turbidity values are low, usually less than 10 Nephelometric Turbidity unit (NTU), which is a measurement of the cloudiness (*nephlo* is Greek for cloudy) of the sample by the presence of suspended solids (*Minnesota Pollution Control Agency, 2008*). During a rainstorm, particles from the surrounding land are washed into the river making the water a muddy brown color, indicating water that has higher turbidity values. Also, during high flows, water velocities are faster and water volumes are higher, which can more easily stir up and suspend material from the stream bed, causing higher turbidity values (*CCME, 2023*) (Table 1, page 40).

High concentrations of particulate matter affect light penetration and productivity, recreational values, and habitat quality, and cause lakes to fill in faster. In streams, increased sedimentation and siltation can occur, which can result in harm to habitat areas for fish and other aquatic life. Turbidity can affect hatching success in fish by clogging gills and smothering eggs which reduces the fish's efficiency of absorbing dissolved oxygen in the water (*CCME, 2023*). Turbidity can also decrease visibility within the water column which can affect foraging efficiency in species at risk, such as the Eastern painted turtle (*Chyrsemys picta*; *Grosse et al., 2010*), interactions between fish and dragonflies (*van de Meutter et al., 2005*) and feeding on species of zooplankton (*Helenius et al., 2013*). Aquatic plants are important as they create oxygen within the water column. Turbidity can limit light penetration, causing plants to die. Aerobic bacteria then begin the process of decomposition which uses up more oxygen, leading to lower dissolved oxygen content in water for aquatic life. Particles also provide attachment places for other pollutants, notably metals and bacteria. For this reason, turbidity readings can be used as an indicator of potential pollution in a water body (*CCME 2002*).

Total Suspended Solids

Suspended solids refer to the solid particles that are suspended in the water. According to the Canadian Council of Ministers of the Environment (CCME), these particles may be from soil, organic or inorganic materials, plankton or other organisms. They may also be sourced from runoffs, bank and bedrock erosion, which are carried out by the currents. Sediment can be detrimental to fish, fish eggs and invertebrates. The sediment covering the riverbed can reduce spawning substrate. Nutrients and toxins can often enter the water along with the eroded particles, which can impact the water quality and food chain.

Suspended solids can be filtered through a piece of paper from a water sample and is measure in mg/L. The CCME guidelines (Table 1, page 40) for aquatic life set the guideline at 25 mg/L for short-term exposure during a clear water flow; and 5 mg/L, for long term exposure. During a high water flow period, suspended solids levels are between 25 mg/L and 250 mg/L and the increase should be less than 25 mg/L. If levels of suspended solids are over 250 mg/L, increases should be less than 10%.

Nitrate

Nitrate (NO_3^-) is a form of nitrogen found naturally in terrestrial and aquatic environments. Nitrogen occurs in natural waters as nitrate (NO_3), nitrite (NO_2), ammonia (NH_3), and organically bound nitrogen. Of these, nitrate is usually the most important to consider when determining water quality. Normally only small amounts are found naturally, such as those formed when aquatic plants and animals die: bacteria break down large protein molecules containing nitrogen into ammonia. Ammonia is then oxidized by specialized bacteria to form nitrites and nitrates. An increase in nitrate levels can come from numerous man-made sources such as septic systems, fertilizer runoff and improperly treated wastewater. Nitrates are plant nutrients and cause an increase in plant and algae growth in aquatic ecosystems. This can be a problem when the plant or algae material subsequently dies and decomposes; dissolved oxygen levels often decrease as a result (*Chambers, et al., 2001*).

According to Reyes (2008) industrial emissions, raw sewage and sewage treatment plants that do not employ tertiary levels of treatment to remove nutrients are also contributing excessive levels of nitrogen to streams and oceans. While nutrient loading in our streams may not be having an observable impact upon our own biodiversity, it is having an impact on the Bay of Fundy and the Atlantic Ocean, and we have the responsibility to manage our effluents at the watershed level. The Bay of Fundy has a long history of algal blooms, which are linked to excessive nutrient loading (*CCME Working Group on Biodiversity, 2012*).

The water quality guidelines in Canada state that in order to protect freshwater life, levels of nitrates should be of 13 mg/L or below (*Chambers, et al., 2001*) (Table 1, page 40).

Phosphates

Phosphate (PO_4^{3-}) is also a naturally occurring nutrient in terrestrial and aquatic environments, usually present in the form of orthophosphate. Pure phosphorus (P) is rare and acts as a limiting factor in plant growth. In nature, phosphorus usually exists as part of a phosphate molecule. Phosphorus in aquatic systems occurs as organic phosphate and inorganic phosphate. Organic phosphate consists of a phosphate molecule associated with a carbon-based molecule, as in plant or animal tissue. Inorganic phosphorus is the form required by plants and is known as orthophosphate (*Chambers, et al., 2001*). Plants require orthophosphate for photosynthesis, making orthophosphate a limiting factor in aquatic plant growth (*North Carolina Water Quality Information Extension, n.a*). Since phosphorus is a nutrient which is normally in short supply in most fresh waters, even a modest increase in phosphorus can, under the right conditions, set off a whole chain of undesirable events in a stream including accelerated plant growth, algae blooms, low dissolved oxygen, and the death of certain fish, invertebrates, and other aquatic animals (*Chambers, et al., 2001*).

Orthophosphate forms of phosphorus are produced naturally but can also be introduced in streams by man-influenced sources such as: partially treated and untreated sewage, runoff from agricultural sites, and application of lawn fertilizers (*North Carolina Water Quality Information Extension, n.a*). Orthophosphates applied to agricultural or residential lands as fertilizers are carried into the surface water during storm events or snow melts (*Chambers, et al., 2001*). Algal blooms result in a net decrease in diversity, food supply and habitat destruction because it blocks light penetration, resulting in the death of plants and algae. Bacteria then decompose the organic waste, consuming all dissolved oxygen in the water, releasing even more phosphate in the process. The decrease in dissolved oxygen can create hypoxic or even anoxic conditions that are a threat to aquatic organisms. The pond, stream, or lake may gradually fill in with decaying and partially decomposed plant materials becoming a swamp, which is part of the natural aging process (*Chambers, et al., 2001*). However, excess nutrient inputs caused by humans can accelerate this natural aging process from oligotrophic to eutrophic, in a process called cultural eutrophication.

According to the CCME (Table 1, page 40), phosphorus levels should not exceed .05 mg/l if streams discharge into lakes or reservoirs, .025 mg/l within a lake or reservoir, and .1 mg/l in streams or flowing waters not discharging into lakes or reservoirs to control algal growth. Surface waters that are maintained at .01 to .03 mg/l of total phosphorus tend to remain uncontaminated by algal blooms. Currently there are no regulated limits to phosphorus levels monitored in Canadian water bodies, but there are recommended levels for drinking water.

Total Coliforms

Total coliform counts are used to assess the microbiological quality of water. Coliform bacteria are a commonly used biological indicator of water quality (*Griffin et al., 2001; Noble et al., 2003*). Coliforms are commonly found in the environment in soils and vegetation. The contamination in water is often highest immediately following a storm because of the runoff a storm generates (*CCME 1999*). Total Coliform (TC) counts reflect the presence of non-faecal bacteria, which occur naturally in water, derived from the decomposing organic matter of water weeds, floating vegetation and aquatic organisms. These bacteria do not normally cause illnesses, but they will give the water an unpleasant odour and taste. If an inordinately high TC count increases each year and cannot be explained by natural causes, it is likely the result of a "man-made" nutrient-overload, either caused using fertilizers or possibly high phosphate washing products introduced into septic systems (*CCME*, *1999*). The CCME environmental quality guidelines dictate a recreational guideline of 200 MPN/100 mL for coliforms (Table 1, page 40).

Escherichia coli

E. coli is a class of bacteria found only in human or animal faecal waste. The major sources of *E. coli* are municipal sewage discharges or runoff from failing septic systems, animal feed operations, farms and faeces deposited in woodlands from warm blooded animals (*USA Water Quality, 2008*). While all coliforms do not cause illness, their presence indicates that a watercourse may be susceptible to contamination by other microorganisms (*Nova Scotia Environment, 2009*). Once shed from a human/animal host, faecal bacteria are not expected to survive for long periods in the aquatic environment (*Winfield and Groisman, 2003*). It has been concluded, based on all of the existing evidence, that *E. coli* remains the most suitable indicator of faecal contamination in fresh recreational waters.

Studies have shown that certain illnesses, such as gastroenteritis, eye infections, skin rashes, ear, nose and throat infections and respiratory illnesses can result from exposure to certain faecal bacteria as measured by the presence of *E. coli* (*CCME, 1999*). The presence of *E. coli* in water indicates recent fecal contamination and may indicate the possible presence of disease-causing pathogens, such as bacteria, viruses, and parasites. Although most strains of coliform bacteria are harmless, certain strains, such as *E. coli* 0157:H7, may cause illness. The recreational guideline for freshwater (*Health Canada*) is as follows (Table 1, page 40):

- Geometric mean concentration (minimum of five samples without exceeding 30 days): ≤ 250 *E. coli*/100 mL
- Single-sample maximum concentration: ≤ 400 *E. coli*/100 mL

These values represent risk management decisions that have been based on a thorough assessment of the potential risks for the recreational water user (*Health Canada, 2014*). If levels of *E. coli* in surface waters are found to be greater than guideline levels, it is probable that pathogenic organisms are also present. The combination of routine *E. coli* monitoring alongside actions, procedures and tools to collectively reduce the risk of exposure to faecal contamination in the recreational water environment represents the most effective approach to protecting the health of recreational water users.

Metals

Metals, also referred to as trace metals, can be organized into various groups including transition metals, heavy metals, metalloids, lanthanides, and actinides (*Mason, 2013*). Metals exist naturally in the environment and many major metals constitute the earth's crust, such as: Iron, Aluminum, Zinc, Chromium, Copper, and Nickel (*van der Voet, et al, 2013*). Metals are distributed throughout the environment through natural processes, such as the weathering and erosion of rocks, surface deposition from volcanic activity, and gas and liquid escaping from fractures in the Earth's crust. Metals are naturally cycled through the environment by various biotic and abiotic processes (Garrett, 2000), are critical to all living organisms (*van der Voet, et al, 2013*), and are the basis of many important biochemicals (Mason, 2013).

Often playing a dual role, metals can be toxic and have adverse effects on the environment and human health if in limited or excess amounts. Humans have increased, and decreased, the inputs of metals into the environment through various activities, including: mining activity (extraction and processing), coal and hydrocarbon products (extraction and consumption), landscape alterations, and farming and forestry practices (fertilizers and pesticides). Anthropogenic activities have also heightened the discharge of metals through several natural processes, such as the erosion of earth's surface materials, through surface and groundwater runoff, and atmospheric depositions (*Mason, 2013*).

The toxic effects of metals in the environment can impact the health of humans and aquatic organisms through biomagnification, bioconcentration, and inhalation (*Solomon, 2008*). Biomagnification occurs through diet and the increased concentration of metals moving through higher levels of trophic organisms. Bioconcentration occurs in the aqueous medium in which an organism lives, through the uptake of metals through the surrounding water (*Fisk, et al, 2003*). Some notable metals can be very toxic to humans and aquatic organisms when found at unsuitable concentrations in the environment, including mercury, chromium, and lead. Mercury is biomagnified in the environment and the rate of biomagnification can be altered by water temperature, pH, and hardness. It can cause a decrease in fish, waterfowl, and bird egg hatching rates, and can cause structural damage to the human brain. Chromium undergoes bioconcentration in the environment and can become more toxic at various temperatures and pH. It can inhibit the growth of plants and organisms and cause kidney disease, low white blood cell counts, and mouth ulcers in humans. Lead has been used by humans for 5000+ years and can cause anemia in humans from the reduction of oxygen transport to cells within the body. Lead bioconcentrates in the kidneys, bones, liver, and skin of fish, and can inhibit the photosynthetic properties of algae (*Solomon, 2008*).

Pesticides

Pesticides are categorized on the basis of their pesticidal actions, including herbicides, fungicides, insecticides, nematicides, plant growth regulators, and others (*McKnight, et al, 2015*). Pesticides are the second largest group of chemicals used world-wide, with almost 20,000 pesticide products registered since 1947, and approximately 1 to 2.5 million metric tons used per year. They are used in several different sectors, including forestry, turf and landscaping, structural and fumigation, mosquito, and agriculture (i.e., agriculture being the largest; *Wins-Purdy, 2010*). Pesticides, including their metabolites, are considered prevalent and well-documented in the environment and can be found in ground and surface water, stream bed sediment, soils, and in rainwater (*McKnight, et al, 2015*). Precipitation and irrigation govern waterborne movement of pesticides into aquatic ecosystems, and pesticide spraying can lead to atmospheric deposition miles from the application site (*Schäfer, et al, 2011*).

Environment Canada published a report in 2001 titled “Threats to Sources of Drinking Water and Aquatic Ecosystem Health in Canada”, identifying pesticides as one of the 15 primary threats to water in Canada. This report helped prompt the need for pesticide monitoring in Canadian waters, and between the years of 2003 and 2005 Environment Canada conducted its first nation-wide pesticide program. There are 30 different pesticides that can cause ecological impacts listed in the Canadian Water Quality Guidelines for the Protection of Aquatic Life, and 7 of those listed were detected in New Brunswick water between 2003 and 2005 (*Environment Canada, 2011*).

Pesticides can have direct and indirect effects on freshwater organisms (plants, microorganisms, fish, amphibians, and invertebrates). Direct effects generally depend upon concentration levels, however there are other factors that can magnify them, such as the life stage in which the organism was exposed, the duration of exposure, the density of the organisms’ population, and biomagnification effects. Direct effects on freshwater organisms occur at various levels of organization and can include changes in enzyme activity and reduced respiration, changes in behaviour and reduced reproduction, changes in growth and mortality rate, and changes in community composition and ecosystem processes. Indirect or secondary effects, are the result of direct alterations to an organisms’ relationship with its environment, causing species to be affected indirectly. Ecological relationships that can be indirectly affected by pesticides include predation, competition, mutualism, and species-habitat relations (*Schäfer, et al, 2011*).

Guidelines for Assessing Water Quality Parameter Data

Canadian Council of Ministers of the Environment (CCME) guidelines for aquatic life are featured in Table 1 below. The Environmental Protection Agency (EPA) features guidelines on water quality for aquatic life, but is variable across 14 distinct eco-regions of the US.

Table 1: Summary of water quality parameters and guidelines for the protection of aquatic life.

Chemical Name	Canadian Source	Canadian Limit or Range
Water temperature	CCME (2023) (1)	(1) Salmonids: **18-19°C maximum weekly average** for adults and juveniles.
	MacMillan *et al*., (2005) (2)	(2) Long-term lethal limit: **24°C**
		(1) Human activity should not induce temperature changes of **±1°C from natural levels**
Dissolved oxygen	CCME (2023)	Variable; Should not fall below **9.5mg/L** for early life stages or below **6.5mg/L** for other life stages.
pH	CCME (2023)	6.5 – 9.0 on pH scale
Specific conductivity	Kemker (2014b) (1)	(1) Natural Freshwater: **50 – 1500 μs/cm**
	Behar (1997) (2)	(2) Desired range for fish habitat: **150 μS/cm** to **500 μS/cm**
Total dissolved solids (TDS)	Weber-Scannell and Duffy, (2007)	Freshwater: **< 1000 mg/L**
Turbidity	CCME (2023)	Clear flow - Maximum increase of **8 NTUs** from background levels for a short-term exposure (e.g., 24-hours period). Maximum average increase of **2 NTUs** from background levels for a longer-term exposure (e.g., 30-days period).
		High flow or turbid waters - Should not increase more than **10%** of background levels when background is **>80 NTUs** deposited
Total suspended solids (TSS)	CCME (2023)	Clear flow – Should not exceed a maximum increase of **25 mg/L** from background levels for any short-term exposure (e.g., 24-h period) and maximum

		average increase of **5 mg/L** from background levels for longer term exposures (e.g., inputs lasting between 24 h and 30 d).
		High flow – Should not exceed a maximum increase of **25 mg/L** from background levels at any time when background levels are between **25 and 250 mg/L**. Should not increase more than **10%** of background levels when background is **≥ 250 mg/L**.
Nitrate	CCME (2023)	< **3mg/L N**
Phosphate	New Brunswick Ministry of Environment's guideline	Levels should not exceed:
		Total phosphorus of **0.03 mg/L** for surface water
Escherichia coli	*Health Canada Recreational Guidelines*	Single-sample maximum concentration: ≤ **235 *E. coli*/100 mL**

Alien and Invasive Species

Species that are not native to an area are commonly called alien or introduced. Some of these introduced species adapt to a different climate, habitat, and nutrients so well that they outcompete native biota; these species are called invasive and can be harmful to reducing biodiversity across an entire ecosystem if left unmanaged.

How can invasive species be introduced? The NB Invasive Species Council introduction to invasive species and best management practices to prevent the spread of invasive species in aquatic environments provides a great overview of how we contribute to the problem and what we can do to prevent the spread:

REQUIRED VIDEO: ***NB Invasive Species Council, "NBISC Spring 2022 Awareness Video" (2022):***

https://youtu.be/8qdCg1Diumk

Southeastern New Brunswick is particularly vulnerable to the invasive plant species *Phragmites australis spp. australis* that has spread from transportation pathways from community to community. These species are particularly aggressive in its spread by growing through roots via rhizomes, seed dispersal, and stolon fragments. They have been a devastating issue in Ontario with thick stands creating a monoculture across lakeshores and wetlands. This can be dangerous for terrestrial species such as turtles that can experience habitat fragmentation, unable to access historic migration routes through the thick stands of these reeds.

Figure 32: Petitcodiac Watershed Alliance staff during invasive Phragmites australis spp. australis survey

Invasive species vary per region you are in the world; therefore, it is best practice to be familiar with indigenous species, introduced species, and invasive species of your local area.

Cyanobacteria

Figure 33:Picture of cyanobacteria surface bloom (NB DELG)

Cyanobacteria have been a living part of aquatic ecosystems for billions of years as one of the earliest life forms on this planet. Often referred to as blue-green algae, cyanobacteria may resemble algae but are in fact photosynthetic bacteria that are found in streams, rivers, lakes, and the ocean.

Cyanobacteria are not normally visible, but with the right conditions of temperature, sunlight, flow, and nutrients, populations can grow quickly and clump together to form what is called a bloom. These can be identified in two forms, by taking the shape of a mat, or a thin layer of blue-green film over a waterbody.

Cyanobacteria grow from nutrients in decaying organic matter that can be brought to streams, rivers, and lakes in runoff from the land, and in sediments at the bottom of the water. Many human activities can cause an increase in nutrients entering our lakes and rivers. These activities include:

- runoff (both soil and nutrients) from lawns, agricultural land, and forestry operations
- faulty or improperly functioning septic systems
- excess use of lawn and garden fertilizers
- use of household and industrial cleaners that contain phosphate

Cyanobacteria blooms typically occur in warmer months starting in late spring to early summer. However, cyanobacteria are present year-round, and blooms or mats are possible at any time. Some surface blooms can produce ***microcystin*** which is known to cause skin irritation, gastrointestinal illness, and can cause more severe illness if ingested.

Some cyanobacteria can create neurotoxins called ***anatoxins***. Human poisoning is very unlikely as most people will not ingest mat material. These toxins can cause skin irritation, gastrointestinal issues and/or numbness or tingling of fingertips and around the mouth if ingested (*NB DELG, 2023*)

Anthropogenic Impacts and Watershed Monitoring

Human impacts to the environment, also known as anthropogenic impacts, are devastating the world of aquatics faster and greater than any natural process. Anthropogenic land-use, hazardous materials, improper waste management, and the introduction of plastics products in modern society are sources of pollution to aquatic ecosystems and threats to biodiversity. Climate change, also attributed to by human activities of collective greenhouse gas emissions, is also rapidly changing aquatic abiotic processes and global biodiversity. Scientific monitoring to understand the impacts and trends is our best approach to making informed decisions on mitigation and adaptation.

Water Quality and Quantity Impacts

The impact of anthropogenic climate change is most evident by its influence on water quantity and quality, and can be tied to climate change, land-use, and hazardous materials. Droughts and flooding are two great impacts worldwide that are changing the suitability of some regions to human habitation.

Anthropogenic impacts to water quality are often attributed to stormwater runoff which carries urban pollutants over impermeable surfaces to aquatic habitats and flushes rural pollutants into groundwater and aquatic habitats. Urban, and industrial land-use and development can also exacerbate water quality impacts by increasing the sedimentation into aquatic habitats that can be damaging to biota such as molluscs or fish that rely on visual predation.

The following are examples sources of anthropogenic impacts to water quality:

- Agriculture and farming (e.g., pesticides and fertilizers)
- Cutting vegetation in riparian zones (e.g., grasses and trees)
- All-Terrain Vehicle (ATV) river crossings causing sedimentation
- Improper waste management, litter, and landfills
- Water treatment facilities can be sources of impacts to water quality unless they are equipped for catchment and treatment of all contaminants such as microfibers (microplastics from clothing) and ammonia
- House septic system leaching into groundwater unless properly disposed of
- Culverts obstructing fish passage that can pose as either a partial or a full barrier to fish passage for migratory fish species travelling to upstream habitat

These impacts can be mitigated by collective and individual actions, and we can work to adapt and enhance aquatic habitats to increase their resiliency.

Plastics

Since the 1970s plastic products have been mainstreamed into daily human activities and lifestyles through household products, clothing, furniture, dining, and medical applications. It is believed that all plastic products created still remain today, as many plastic products will take upwards of 100+ years to decompose and are breaking down into smaller more harmful microplastics under processes of photodegradation (sunlight), natural erosion (waves), and/or combustion (fire).

Plastics have been found in a new shape called the plastiglomerate, a product of a process that combines rock, sediment, plastic debris, and organic materials into a molded unit that has become an early indicator of the Anthropocene, a human-influenced and driven epoch on this Earth. Microplastics, the 5mm or smaller plastic fragments broken down from plastics products are also causing widespread impacts to marine and inland ecosystems alike, alongside adverse effects and impacts to health from ingestion and exposure that we are only beginning to understand.

Droughts

Figure 34:Photo of drought in Saskatchewan during which Saskatechewan Agriculture said estimated yields were expected to be well below average as heat, lack of moisture impacts crop conditions ***(Global News, 2021)***

Droughts are a prolonged period of abnormally low rainfall that leads to a shortage of water. Climate change and the rise in average global temperatures are playing a large role in record droughts worldwide. Droughts can be also influenced by water usage for human activities such as crop irrigation, industrial processes, and households. A dry season is when annual precipitation is low, and a drought could be brought on by these activities. Coastal areas are also susceptible to salt intrusion, which is when an aquifer/ household well drawing freshwater will have saltwater intrude into the available water.

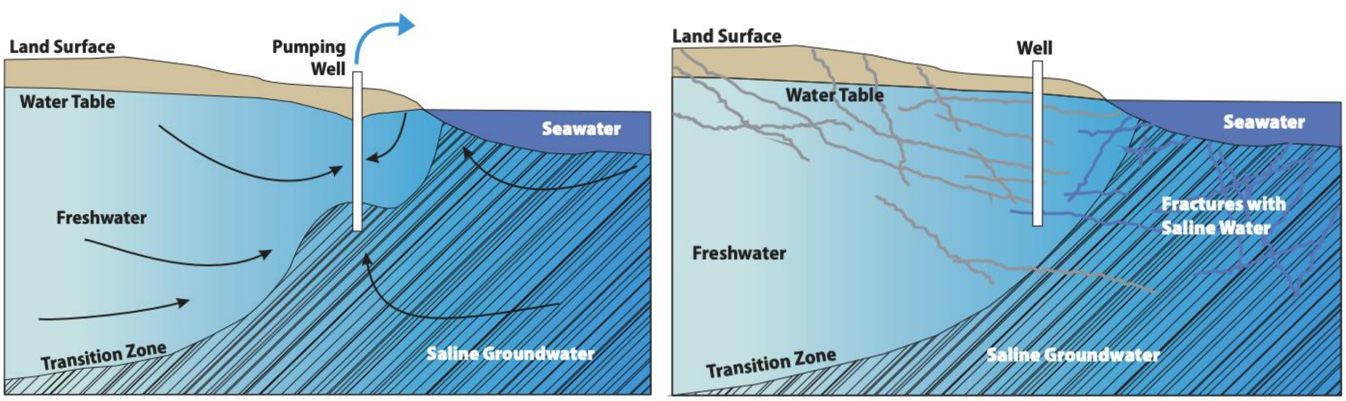


Figure 35: Image to the left demonstrates saltwater intrusion to a freshwater well actively pumping water, while Image to the left demonstrates how a single fracture in bedrock can deliver saltwater to a fractured bedrock aquifer (Government of British Columbia, 2016)

REQUIRED VIDEO: "Groundwater Protection Webinar" Presentation by Dr. Justin Lieske hosted by EOS Eco-Energy (2022):

https://youtu.be/j07p_nicMdE?t=2223
(Only the clip from 37:03 – 50:52 is required viewing)

Solutions include taking individual and collective actions. We can be mindful of water conservation and make our community less vulnerable to these risks; anything from quick showers, fixing leaky faucets, high-efficiency appliances can help along with irrigating early or late in the day, incorporating rain barrels and rainwater tanks, using permeable pavement as an alternative to asphalt, and planting rain gardens can make a difference.

Flooding

Figure 36:Photo of a house washing away from Port-aux-Basques, Newfoundland off the Atlantic Canadian coast after Hurricane Fiona in 2022 (CBC News)

Flooding is an incredulous amount of water that overflows its normal confines, whether it's in-land flooding from extreme rainfall or snowmelt or tidal flooding from sea-level rise and storm surges. Floods occur globally and can vary in severity depending on factors such as data collection, communications, and emergency planning.

In-land flooding can often be attributed to stormwater runoff, which is precipitation from rain, snow and/or ice melt that travels over saturated land and impermeable surfaces. Stormwater runoff is exacerbated by impermeable pavement such as roads, parking lots, and rooftops that are made of materials that rain cannot infiltrate. This prevents rainfall from replenishing groundwater and increases the vulnerability of communities to flooding. Due to climate change, coastal communities are impacted by not only in-land flooding, but also sea-level rise, making them more vulnerable to coastal flooding and storm surges in extreme weather events.

Ways we can mitigate and adapt to flooding are actions to protect, conserve and improve wetlands, riparian zones and forested areas and incorporate more green infrastructures with development plans to better manage stormwater runoff and flooding. Structures built in floodplains should look at retreating and building back better elsewhere.

Indigenous Traditional Ecological Knowledge

Two-Eyed Seeing (E*tuaptmumk* in Mi'kmaw) embraces "learning to see from one eye with the strengths of Indigenous knowledges and ways of knowing, and from the other eye with the strengths of mainstream knowledges and ways of knowing, and to use both these eyes together, for the benefit of all," as envisaged by Elder Dr. Albert Marshall (*Andrea J. Reid et. Al, 2020*). Indigenous traditional ecological knowledge can be woven with environmental science to obtain a deeper understanding of environmental concepts, processes, and how culture has been shaped by relationships with land.

Engaging with the indigenous history of the land you inhabit is integral in understanding it. An online map and Territory Acknowledgement Guide resource (https://native-land.ca/) featuring traditional unceded territories, languages, and treaties across the world gathered and presented by the Native Land Digital, creates and fosters conversations about the history of colonialism, Indigenous ways of knowing, and settler-Indigenous relations (*Native Land Digital*, *2023*). The resource creates spaces where non-Indigenous people are invited and challenged to learn more about the lands they inhabit, the history of those lands, and how to actively be part of a better future going forward together.

Indigenous Traditional Ecological Knowledge is rooted in storytelling. The following video shares a story on reconciliation and stewardship through land conservation in Mi'gmaq traditional territory of Fort Folly First Nation and the UNESCO Fundy Biosphere Reserve, featuring Fort Folly Habitat Recovery, an indigenous-led environmental group actively working to conserve and restore Atlantic salmon and American eel (local species-at-risk) populations through fish monitoring and restoration techniques:

REQUIRED VIDEO: Sa'qewi-ilnuwey Awti IPCA - Reconciliation and stewardship through land conservation:

https://youtu.be/O5X16k2dLtE

Ethnobotany is the study of cultural use of indigenous plants in a region, to provide food, medicine, shelter, oils, dyes, and many other manners of survival, practical, or artisanal uses. Indigenous traditional ecological knowledge of indigenous plants and their uses help us understand ecosystems more deeply, and the scope of species that were present before colonial impacts of invasive species and land-uses. Beginning in the mid-1970s the University of Michigan compiled an early set of data that become the Native American Ethnobotany database, which can be browsed at the following link: http://naeb.brit.org/

Aquatic environments such as wetlands are rich in biodiversity and are often abundant in species sought after for traditional medicine harvest. Listen to Cecelia Brooks and Anthony Bardwell in the following video as they share their story of finding npisun (mi'kmaw for medicine), the challenge of accessing lands, and a hopeful encounter with one settler landowner. On Turtle Island (also known as North and Central America), we are all treaty people. This is often overlooked in land disputes between settlers and indigenous communities.

REQUIRED VIDEO: "Npisun (Medicine) in the Wabanaki Forest" (2022)
Community Forests International – Cecelia Brooks & Anthony Bardwell.
Npisun (Medicine) in the Wabanaki Forest:

https://youtu.be/_nzY1hZsXwc

Climate Change

New Brunswick falls within the temperate broad-leaved forest category but is situated far enough north to have several boreal elements, including the prominence of balsam fir, jack pine, tamarack, and spruce species. Since the immediate post-glacial period, the Appalachian Mountains have remained above sea level and thus have served as an effective north–south migration corridor. This has resulted in a blending of northern and southern floral and faunal elements in the Atlantic region. The unique mixture of forested and non-forested ecosystems in the Maritimes has been recognized by Canadian and North American classification frameworks as a definable forest region called the Acadian Forest (also known as the *Wabanaki* forest in Mi'kmaw), and more recently, the Atlantic Maritime Ecozone. In New Brunswick, the climatic gradients characteristically are determined by a combination of elevation above sea level and proximity to the ocean (*NB Ecosystem Classification Working Group, 2007*).

The Government of New Brunswick is expecting climate change impacts related to temperature and precipitation. The climate models of the Fifth Assessment Report by the International Panel on Climate Change predict mean global temperatures will rise from 1 to 6°C by the year 2100 (*IPCC, 2014*). Any increase in mean global temperatures risks longer and more intense storm surges. The frequency of winter thaws and intensity of precipitation events have increased in New Brunswick, with snowpack in southern New Brunswick showing a decrease by 50% due to temperature fluctuations (*DELG*). There are also expected increases in the Bay of Fundy tidal range (*R.J. Daigle Enviro, 2017*). The climate projections for the province following four GHG emission scenarios show a substantial increase in mean temperature over all seasons over time horizons studies over the next six decades at least, with an increase expected for very hot days (maximum temperature higher than 30 °C) for continental cities such as Moncton of +10 to +35 hot days annually by 2080 and expected growing season length extended by +29 to +61 days (*Roy & Huard, 2016*). All these possible impacts culminate into a future of climate uncertainty that needs to be matched with adaptation at the local level to increase climate resiliency.

New Brunswick is projected to experience the worst impacts of climate change through increased flooding, extreme storm events, and increase in rainfall runoff and spring melt runoff. The province encounters water pollution from nonpoint sources due to runoff from agricultural, forestry, and residential, and urban activities (*DELG, 2019*). Climate change destabilizes water quality and quantity in the area and requires a multifaceted approach to successful adaptation. Community involvement from the general public, other non-profit organizations, and businesses is imperative to increasing the resiliency of the community.

Coastal communities are particularly vulnerable to climate change impacts such as storm surges and sea-level rise. Erosion from tidal activity is exacerbated by climate change, causing landowners and communities to armour coastlines to prevent further loss of land. Armouring practices and sea walls can be damaging to aquatic ecosystems and are a costly endeavour to maintain. Saltmarsh restoration is one technique that provides a natural buffer and carbon sequestering capacity that moves forward in climate change adaptation and mitigation. For coastal communities, having access to resources and information to increase literacy on natural solutions to climate change is a key in moving forward in climate resiliency. Resources such as the Coastal Adaptation Toolkit released by CLIMAtlantic helps provide open access to landowners and decision-makers in coastal communities and increase our collective resiliency.

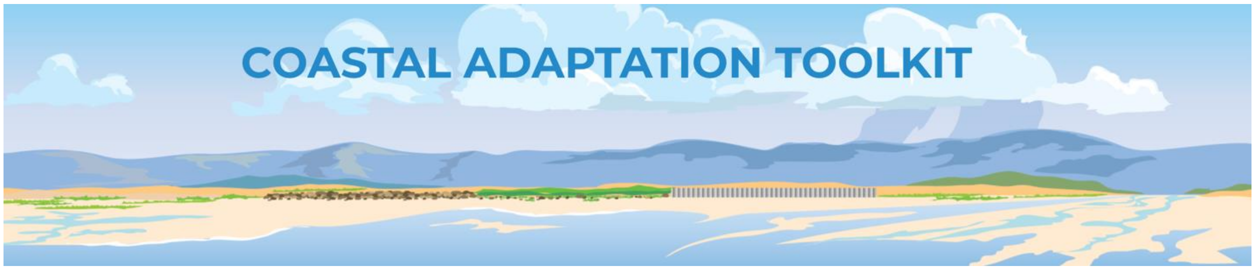


Figure 37: Header for the Coastal Adaptation Toolkit released by CLIMAtlantic

REQUIRED VIDEO: Dr. Jeff Ollerhead "Marsh Magic" Webinar hosted by EOS Eco-Energy (2023):

https://youtu.be/PNE6dm8Vqkg?t=846
(Only the clip from 14:06 – 20:06 is required viewing)

Bad land management practices can accelerate climate change impacts. Deforestation by urban development and cities expanding into natural wetlands can decrease the capacity of a region to absorb carbon emissions, deflect solar radiation, and prevent major flooding. Nature-based infrastructure can be integrated into an urban area to regain these lost benefits that help protect communities from the urban heat island effect, GreenHouse Gas (GHG) emissions like carbon dioxide, and extreme rainfall/ snowmelt events. Urban expansion is also understood to impact food security through the loss of cropland; however, these impacts can be reduced by green infrastructure. Through providing unique locations for growing food (e.g., green roofs, rain gardens, green wall), urban green infrastructure can be beneficial to food security as well as increase climate resiliency (*IPCC, 2019*).

Green infrastructure can be defined as a natural or nature-based area that provides ecological services of water management. With a focus on green infrastructure, urban and rural communities can better manage stormwater and mitigate climate change impacts within a watershed. Rain gardens are a nature-based solution to climate change impacts by providing flood mitigation and stormwater management using native water-loving plants that absorb and purify rainfall runoff from nearby impermeable surfaces like pavement and rooftops. Green roofs are shallow or deeper vegetation planted atop a building or household with waterproofing membrane that supports the soil and prevents infrastructural water damage. The Government of Canada acknowledges green roofs and urban vegetation as a key measure to reduce the urban heat island and improve the health of urban communities (*Health Canada, 2015*). There are many ways that we are building against nature, but building with nature and valuing our natural resources can be our way to a resilient future.

2023 NCF-Envirothon New Brunswick

Aquatic Ecology Study Resources

Key Topic #4: Field Skills

22. Classify different types of wetlands based on their characteristics.
23. Identify plants and animals commonly found in New Brunswick wetlands using a field guide or dichotomous key.
24. Assess water quality by using field tools to measure parameters such as temperature, dissolved oxygen, nutrient levels, turbidity, and pH.
25. Analyze the impact of different water quality parameters on aquatic organisms.
26. Apply best management practices to aquatic resource scenarios.
27. Create a water resource management plan based on different management goals.

Study Resources

Resource Title	Located on
Watershed Management Monitoring	Page 55
Water Quality Field Sampling	Pages 56-58
Benthic Macroinvertebrate Monitoring	Page 59
Freshwater Mussel Monitoring	Pages 60-61
Fish Monitoring	Pages 62-64
Aquatic Macroinvertebrate Order Level Dichotomous Key	Page 65
Benthic Freshwater Sensitivities	Page 66
Freshwater Mussels of Maritime Canada	Page 67-72
A Few Native Fish Species of New Brunswick	Page 73-74

Information for this section was compiled from the following sources*:

- Water Quality Monitoring Report– *The Petitcodiac Watershed Alliance (PWA), 2022*
- Freshwater Mussel Habitat Stewardship in the Petitcodiac Watershed through Monitoring, Outreach and Habitat Improvement a summary of 2021– *Darlene Elward, The Petitcodiac Watershed Alliance (PWA), 2022*
- Improving Habitat for Inner Bay of Fundy Atlantic Salmon Through the continual Refining of Remediation Techniques– *The Petitcodiac Watershed Alliance (PWA), 2023*
- Aquatic Macroinvertebrate Order Level Dichotomous Key and Benthic Freshwater Sensitivities **-** *Atlas of Common Freshwater Macroinvertebrates of Eastern North America, 2023*
- Freshwater Mussels of Maritime Canada: A Flashcard Guide – *McAlpine, D. F., Sollows, M. C., Madill, J. B., Martel, A. L., the New Brunswick Museum, 2018*
- A Few Native Fish Species of New Brunswick – *series compiled by Darlene Elward, adapted from University of New Brunswick resources, 2019*

* Please Note: The information within this document is the ***official*** 2023 NCF-Envirothon Aquatic Ecology Study Resource and should be used by the teams to study for the Aquatic Ecology station tests. Additional information found in the sources cited above are not required.

<u>Study Resources begin on the next page!</u> ➡

Watershed Management Monitoring

Watershed management is an approach of looking at environmental management of natural resources, abiotic and biotic factors, anthropogenic impacts, and social considerations under a watershed lens. Legislative borders between states or regional municipalities are often arbitrary and don't wholly encompass ecosystems and water systems that are intricately connected. Watershed management offers an alternative perspective by suggesting environmental monitoring and restorative actions should and can be accomplished on a watershed level.

Water quality and quantity affect aquatic food webs intricately and are important to monitor through various methods. The general characteristics to have for healthy river ecosystems are:

- Cold water
- Clear water
- Highly oxygenated
- Minimal nutrient input
- Deep and shallow sections
- Vegetated and uncut buffer zones

Environmental monitoring is described as the processes of observation and data collection to assess the quality of the environment. It's a useful scientific practice that helps environmental groups plan, execute and analyse environmental impact assessments. It helps them detect any harmful impacts from human activities and find ways to minimize them by working with important stakeholders.

Water Quality Field Sampling

There are standard operating procedures on how water quality field sampling is conducted and how water samples are tested in the laboratory. It's always important to follow the protocol and procedures of any monitoring to obtain the most accurate and comparable data. Therefore, this information can be taken into consideration when analysing environmental conditions in long-term comparison. Consistency and regular site visits (monthly or weekly) are also key factors in obtaining good comparison. Water quality sampling consists of collecting water samples for microbiological and nutrient testing purposes, sampling with a multi-meter device to measure physical parameters and recording site observations.

Figure 38: The YSI Professional Plus series (YSI ProPlus) multi-meter.

Field Observation

Variables present at the time of sampling that can be essential to record for examples are: date, time, weather, bank conditions, air temperature, and land use.

Field Sampling: Physical Parameters

Physical parameters such as temperature, dissolved oxygen (DO), pH, specific conductivity, salinity, and total dissolved solids (TDS) are examples of measurable parameters that can be taken with a YSI Professional Plus series (YSI ProPlus) multi-meter (Figure 38). This device is one of the models equipped with three different probes: one measures the pH; a second measures DO and temperature; and a third measures specific conductivity, TDS and salinity. The probes are all mounted on one end of the instrument's cord. Another device that some environmental groups use to monitor is a Palintest portable turbimeter to measure turbidity.

Field Sampling: Bacteria and Nutrients

Water samples should be taken using sterilized re-usable water sampling bottles to avoid contamination to sample. Samples should be taken about halfway the water column facing upstream against the current, the bottles labelled with the site name. They should then be stored on ice in a cooler at approximately 4 °C (39.2 °F) until they are brought to a laboratory and tested for water quality parameters such as nutrients (e.g. nitrates and phosphates) and bacteria (e.g. total coliform and E-coli).

Quality Assurance/ Quality Control

Monitoring groups and microbiology laboratories will use quality assurance measures to ensure data remains useful. This is especially important to the typical staff turnover. Quality Assurance (QA) generally refers to a broad plan for maintaining quality in all aspects of a program. This can include Standard Operating Procedures (SOPs), and a Quality Management System document. Quality control (QC) consists of steps you take to determine the validity of specific sampling and analytical procedures. An example is a field duplicate, which is an extra sample taken at a regular monitoring site that is testing alongside the regular samples. Another example is a field blank sample, which is a sample of distilled water stored with field samples and transported for the duration of field activities and tested alongside the regular samples. Others include negative plates, lab replicates, and calibration blanks.

Figure 39: The sterilized re-usable water sampling bottles.

Nitrates and Phosphates

Nitrates and phosphates can be analyzed using a YSI EcoSense 9500 Photometer and Palintest reagents within 8 hours of sampling (Figure 40). A 10mL sample of the stream water is poured into a cuvette and then placed into the photometer to act as a blank, calibrating the machine to compare the change in colour of the sample after the reagents are added. After the blank sample is evaluated by the machine, the test sample with reagents added is placed in the photometer after the appropriate time needed for the reaction to occur. Using light, the photometer can then measure the change in colour from the blank sample and can give a reading of the water sample's nutrient value measured in mg/L.

Figure 40: The YSI Photometer 9500 10mL samples

Bacteria - Total Coliforms and E. coli

Total coliforms and *E. coli* samples can be measured using the Quanti-tray® procedure from IDEXX Laboratories Inc. This procedure begins with a 100-mL water sample which has been stored in the refrigerator that is mixed with Colilert® bacterial growth agent and is then poured into a Quanti-tray. The tray is then placed onto the rubber tray carrier and sealed by passing through the Quanti-tray sealer. The sample trays are then placed in the incubator at the same time and incubated at a temperature of 35°C ± 0.5°C for a 24-hour period.

After the incubation period, the large and small wells located on the tray (Figure) have turned yellow in colour are marked and counted, indicating the number of wells corresponding to the value of Total Coliforms. A long wave ultra-violet light of 366 nm is then shone on the trays, being held 5 inches above the trays (Figure 50). The wells that fluoresce blue are reacting with an enzyme secreted by only *E. coli* bacteria. These wells, which are marked and counted, correspond to the value of *E. coli* in the sample. The IDEXX Quanti-Tray MPN table is then used to determine the most probable number (MPN) for total coliform and *E. coli*, ranging from 0 to >2419.6 MPN.

Figure 41: After the incubation period, the Quanti-tray wells turn yellow, which indicates the total coliform concentration (left). Under a ultra-violet light, the fluorescent blue well indicates the concentration of E. coli (right).

Benthic Macroinvertebrate Monitoring

Benthic macroinvertebrates are the building blocks of aquatic life, and incredible indicators of healthy ecosystems or of harmful pollutants. Through monitoring the biodiversity of benthic macroinvertebrates, environmental scientists can capture a glance of a healthy ecosystem or an unstable habitat. Benthic macroinvertebrates are a source of energy for many aquatic species such as fish. In many aquatic ecosystems, energy is stored by plants in the riparian zone or aquatic plants such as algae that grows in the water. Leaves from riparian vegetation fall into the water, and algae that grows in the water are eaten by macroinvertebrates which transfer the energy to predators such as fish, birds, raccoons, eels, and even anglers.

In Canada, the Canadian Aquatic Biomonitoring Network (CABIN) measures freshwater ecosystem health with standardized methods, databases, activities maps, and training. The CABIN methods and tools are developed on rigorous science and evolve with current research. They are maintained and tested by a team of people within Environment and Climate Change Canada and external experts (ECCC, 2019).

CABIN is used extensively by scientists within federal, provincial and territorial governments as an important part of their water monitoring programs. CABIN is also used by First Nations, academia, industry, and non-government organizations to monitor benthic macroinvertebrates in a shared network and database.

To perform CABIN surveys, field technicians need to be familiar with following an identification key, and which species found are tolerant or intolerant to pollution. For more information on this process, refer to the Macroinvertebrate Order Level Key and Freshwater Sensitivities documents later in Key Topic #4.

Freshwater Mussel Monitoring

Introduction to freshwater mussels

Freshwater mussels are located in rivers and streams of a watershed. They are mostly sedentary bivalve organisms that are vulnerable to habitat changes, which make them great bio-indicators on habitat condition, pollutants, and sedimentation (Elward, D., Thongboonmee, N. 2021).

Nearly 75% of freshwater mussel species in North America are considered at risk or in a concerning situation (Nedeau, E.J., Victoria, J. 2003 and). Rivers and streams in New Brunswick hold important habitats to as many as eleven native freshwater mussel species according to New Brunswick Museum's newest field flashcard guide (McAlpine, D. F., Sollows M. C., Madill, J. B., Martel, A. L. 2018), but many other species exist across the world. Freshwater mussel populations have been declining for more than 50 years due to poor management practices (Hanson, J.M., Locke, A. 2001), which can include disturbances from infrastructures (e.g. dams and culverts), residential developments, agriculture practices, forestry practices, recreational activities and undesignated river crossings.

Figure 42: An underwater photo of four Brook Floater (Alasmidonta varicosa) mussels filtering the water located at Little River, Petitcodiac Watershed.

Freshwater mussels have a commensalism relationship with fish as their host to carry their larvae in the watercourses (Elward, D., Thongboonmee, N. 2021) – an association between these two organisms in which the mussel benefits from the fish, but the fish is neither harmed nor benefited directly from the mussel. However, fish will benefit from the presence of mussels filtering the water in the ecosystem, improving its quality.

Mussels have an important role in the ecosystem. They help clean freshwater by filtration, between 2-5L/hour per individual, while feeding on small particles including algae and bacteria. Mussels can be a food source to other animals such as muskrats, raccoons and otters that live around watercourses. Muskrats, for example, will leave small shell piles also known as middens on the side of the rivers once they have feasted on their meal (Beaudet, A., Tremblay, E., Martel, A. 2002). These heaps of shells can be helpful to researchers when identifying species during a mussel monitoring.

Monitoring

To conduct scientific monitoring, watershed groups need to obtain a scientific license to conduct the work and to handle species at risk. There are different methods to monitoring freshwater mussels to obtain quantitative or qualitative results, all depending on the research goal. Some methods include timed search on defined or undefined areas to help determine presence or absence of mussel species and to obtain current data; or excavation, to help determine presence or absence of juveniles to give insight on mussel reproduction.

During the freshwater mussel monitoring, it’s important to make observations on potential threats that could impact the surrounding freshwater habitat. From the observations, watershed organizations can make recommendations on the best improvement approach and partner with landowners to engage in habitat improvement work. These improvement activities often include revegetation of riparian zones to reduce surface water runoff or stabilization of eroded riparian zones to reduce sedimentation.

Fish Monitoring

To conduct scientific monitoring, watershed groups need to obtain a scientific license to conduct the work and to handle species at risk. Fish monitoring can be done using various methods that will depend on your purpose and regional circumstances. Monitoring fish populations is often carried out to monitor fish stocks for harvesting and angling, to ensure sustainable practices and populations are maintained. Environmental non-profits such as the Petitcodiac Watershed Alliance may carry out fish monitoring to survey population abundance and biodiversity of fish species in various locations of a watershed for conservation purposes, and for habitat restoration projects. Some techniques for monitoring fish can include **seine fishing**, **electrofishing**, **trap net** and **smolt wheel.**

Seine Fishing Monitoring

Seine fishing is accomplished through the use of a net called a seine that is deployed into a stream, river, or the ocean from a riparian zone, beachfront, or a boat. This method of fish identification accomplishes a study sample of fish that are captured and identified before release. This method is deemed less effective than electrofishing, but useful if the survey site is known to have existing stressors to the fish such as parasites that might be vulnerable to additional impacts from an electrofishing event.

Figure 43 Seine fishing survey

Electrofishing Monitoring

Backpack electrofishing is a method to survey the distribution and abundance of fish populations including salmonid populations. It’s a common fish sampling practice used by inland fish research worldwide. This fishing technique uses direct electricity current running through a submerged cathode and anode. This attracts nearby fish in the site surveyed to swim toward the anode, where they can be stunned and caught with dip nets. The fish are placed in a well circulated bucket of water to recover. The fish collected are identified, measured, and sometimes sampled for scale and tissue before being released back into the river. Only certified professionals in electrofishing may use this method who have experience with the equipment, safety protocols, and site-specific information.

Figure 44: Electrofishing survey

While electrofishing can be a more accurate assessment method of the abundance and biodiversity, the other methods can be better suited to local fish populations. Site specific information such as any diseases and parasites affecting fish species that would be collected for the study sample should be considered in choosing the best method for surveying. Electrofishing is the preferred method in most cases due to the benefits of time efficiency and ease in measuring specimens stunned by the equipment. In cases where site specific stressors exist to the fish species that will be collected, the feasibility of other methods should be considered to ensure all precautions are taken not to add stressors to aquatic life.

Figure 45: Measuring fish species in survey

The following video on electrofishing by ACAP Saint John offers a glimpse into the process of this method of fish monitoring on a New Brunswick stream (*watching is not required, information is supplemental*): Electrofishing by ACAP Saint John

Trap Net Monitoring

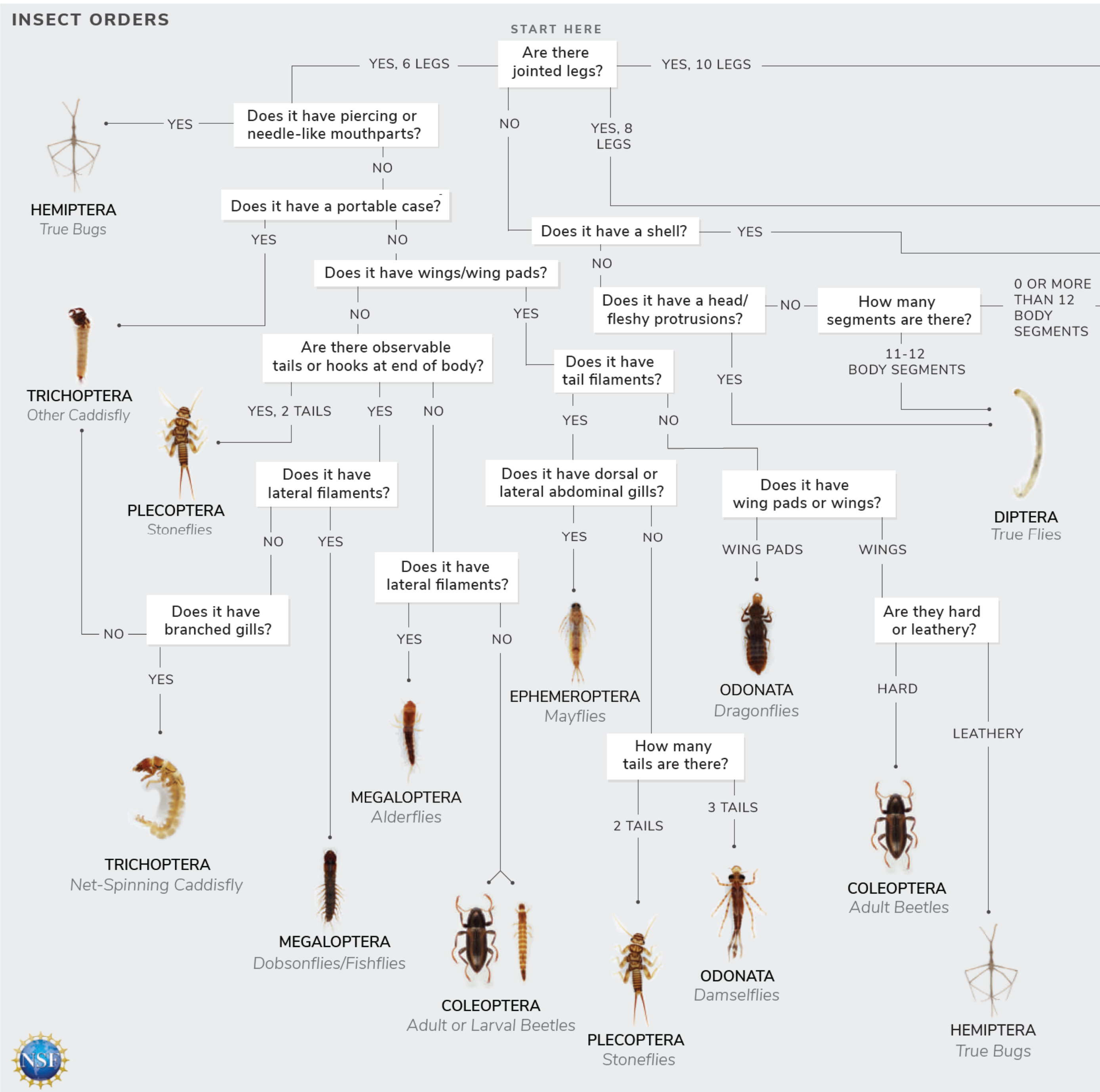
Trap net monitoring is a method of fish surveying where a structure is established that will span the width of the river or stream subject to study, in such a way that the fish will be guided into a trap net that will be retrieved, identified, and released to resume its migratory path. The above image is a structure set by the Fort Folly Habitat Recovery team in the Petitcodiac watershed.

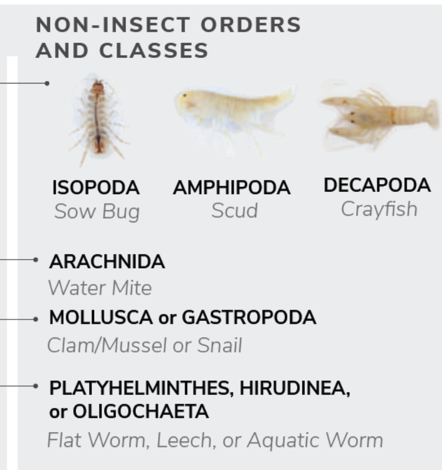
Figure 46: Fort Folly Habitat Recovery group trap net

Smolt Wheel Monitoring

A smolt wheel, also known as a Rotary Screw Trap, is designed to catch a portion of juvenile Inner Bay of Fundy Atlantic salmon migrating out to the sea in the Spring (Fort Folly Habitat Recovery, 2016-2021). The salmon is unharmed and released after collecting the necessary data: tagging, scale and tissue sampling, and length and weight measuring. A number of those salmon are safely transported to a Live Gene Bank (LGB) where representation of their species is being maintained as part of the recovery program.

Aquatic Macroinvertebrate Order Level Key





GLOSSARY

abdominal gills Gills located on the third and most posterior major body region.

branched gills Gills that have divisions or an offshoot off the main axis; branching.

lateral filaments Slender and thin appendages off the sides of the body.

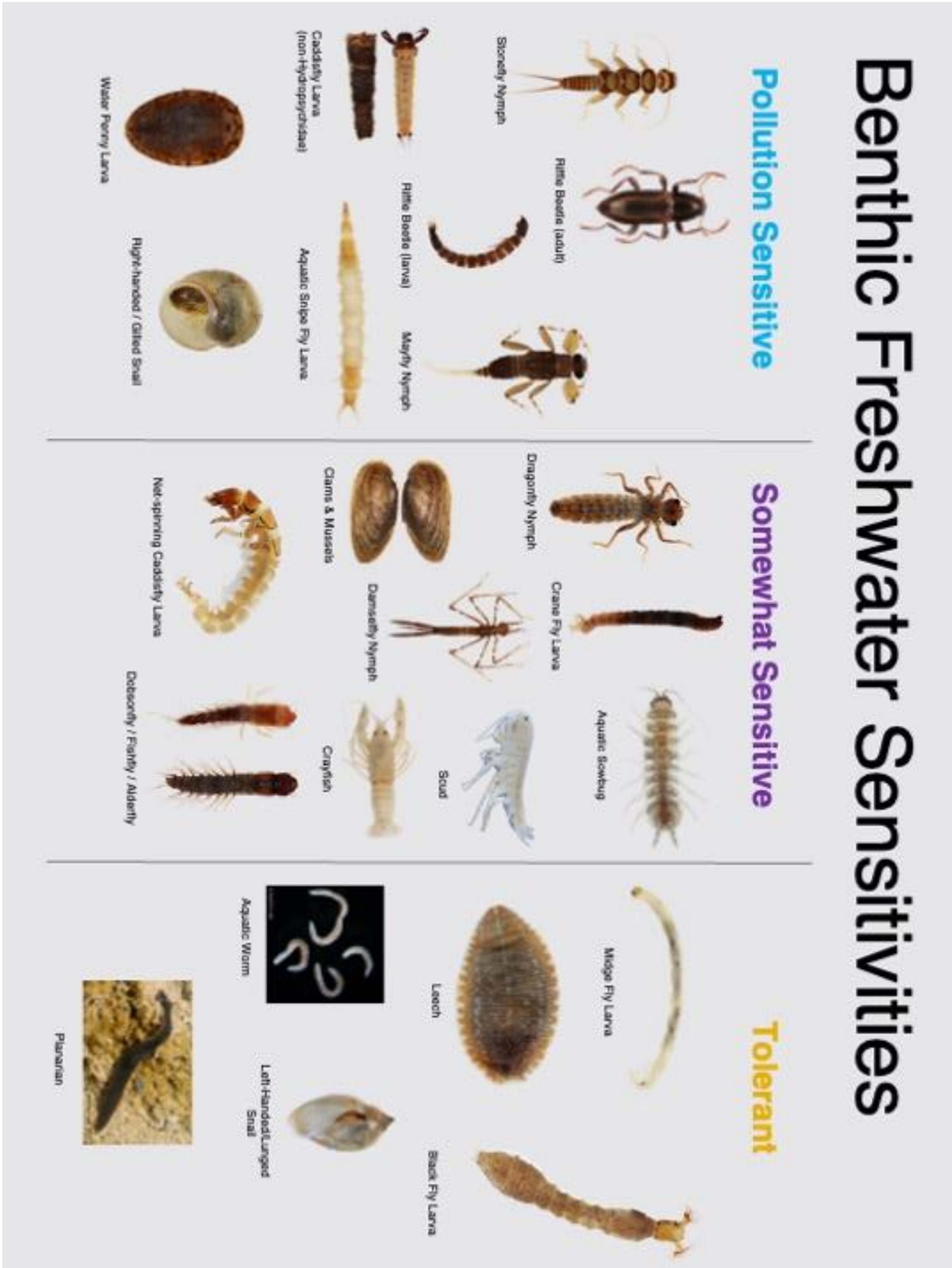
piercing mouthparts Sharp or needle-like mouthparts for sucking nutrients such as blood or plant fluids

portable cases Protective retreats made from leaves, twigs, or sand that some caddisfly and midge larvae carry with them.

tail filaments An appendage located on the abdomen; used often for navigation and respiration.

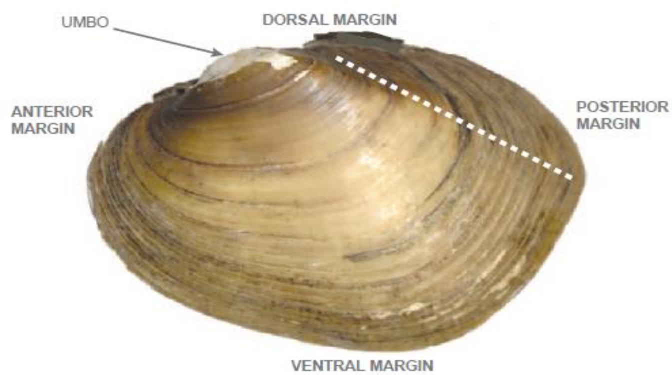
wing pads Developing wings or the sheath of a developing wing.

Atlas of Common Freshwater www.Macroinvertebrates.org of Eastern North America


Benthic Freshwater Sensitivities
Pollution Sensitive
Stonefly Nymph
Riffle Beetle (adult)
Mayfly Nymph
Caddisfly Larva (non-Hydropsychidae)
Riffle Beetle (larva)
Aquatic Snipe Fly Larva
Water Penny Larva
Right-handed / Gilled Snail
Somewhat Sensitive
Dragonfly Nymph
Crane Fly Larva
Aquatic Sowbug
Clams & Mussels
Damselfly Nymph
Scud
Crayfish
Net-spinning Caddisfly Larva
Dobsonfly / Fishfly / Alderfly
Tolerant
Midge Fly Larva
Leech
Black Fly Larva
Aquatic Worm
Left-Handed/Lunged Snail
Planarian

Freshwater Mussels of Maritime Canada: A Flashcard Guide

In Wolastoqey, Mi'kmaw, French and English



NEW BRUNSWICK MUSEUM MUSÉE DU NOUVEAU-BRUNSWICK

Canadian Museum of Nature / Musée canadien de la nature

Donald F. McAlpine, Mary C. Sollows, Jacqueline B. Madill and André L. Martel

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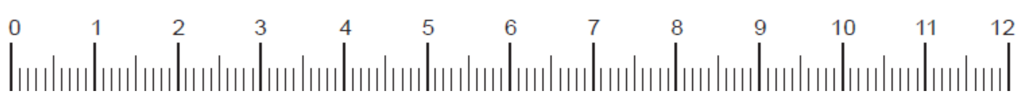
Citation: McAlpine, D.F., M.C. Sollows, J. B. Madill, and A. L. Martel. 2018. Freshwater Mussels of Maritime Canada: A Flashcard Guide in Wolastoqey, Mi'kmaw, French and English. New Brunswick Museum, Saint John, New Brunswick, and Canadian Museum of Nature, Ottawa, Canada.

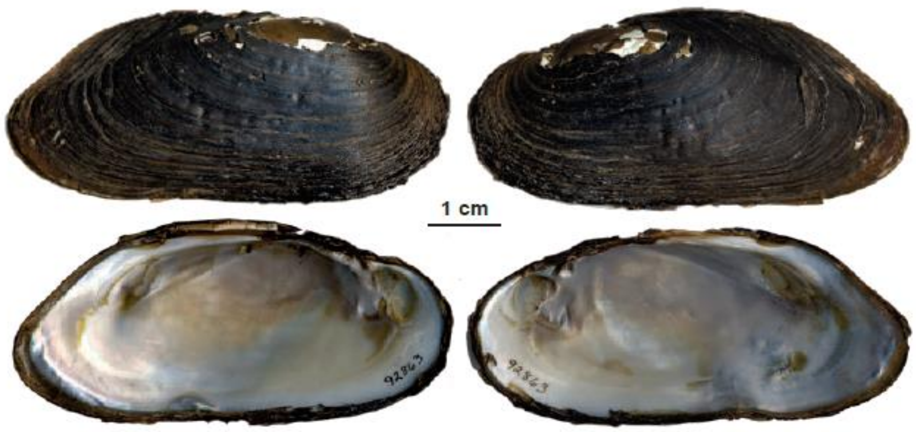
Use in conjunction with

Martel, A. L.,D.F. McAlpine, J. Madill, D. Sabine, A. Paquet, M. Pulsifer and M. Elderkin. 2010. Pp. 551-598. Freshwater Mussels (Bivalvia: Margaritiferidae, Unionidae) of the Atlantic Maritime Ecozone. In D.F. McAlpine and I.M. Smith (eds.). Assessment of Species Diversity in the Atlantic Maritime Ecozone. NRC Research Press, National Research Council of Canada, Ottawa, ON. 785 pp.

Nedeau, E.J., M.A. McCollough, and B.I. Swartz. 2000. Freshwater Mussels of Maine. Maine Department of Inland Fisheries and Wildlife, Augusta, ME, 118 pp.



Eastern Pearlshell *(Margaritifera margaritifera)*



1 - 1A

NEW BRUNSWICK MUSEUM MUSÉE DU NOUVEAU-BRUNSWICK

Canadian Museum of Musée canadien de la NATURE

Eastern Pearlshell *(Margaritifera margaritifera)*

Size: Medium – large; to 150 mm

Shell: Thick, laterally compressed, curved ventral margin

Periostracum: Brown, black, rays absent

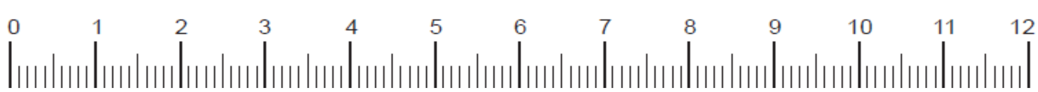
Nacre: White, distinctive pits with tails

Soft Parts: Mantle margin dark grey, purple or black; mantle edges entire, siphonal openings not separated

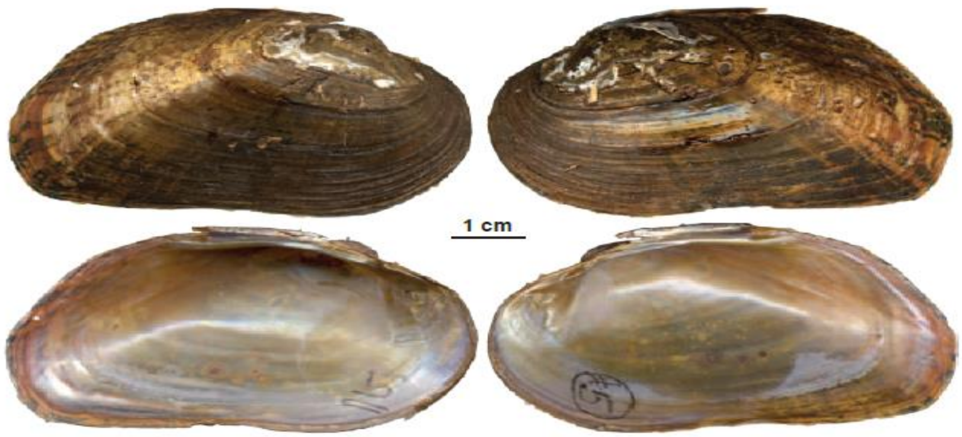
Canadian Conservation Status: Secure

Hinge Teeth *Margaritifera margaritifera*			
Left Valve		Right Valve	
Pseudocardinal	Lateral	Pseudocardinal	Lateral
2	0	1	0

2 - 1B



Brook Floater *(Alasmidonta varicosa)*



5 - 3A

NEW BRUNSWICK MUSEUM MUSÉE DU NOUVEAU-BRUNSWICK

Canadian Museum of Musée canadien de la NATURE

Brook Floater *(Alasmidonta varicosa)*

Size: Small – medium; to 70 mm

Shell: Ridges or wrinkles on dorsal posterior slope perpendicular to growth lines, indented or flat ventral margin, moderately inflated laterally

Periostracum: Brown, black, green rays frequent

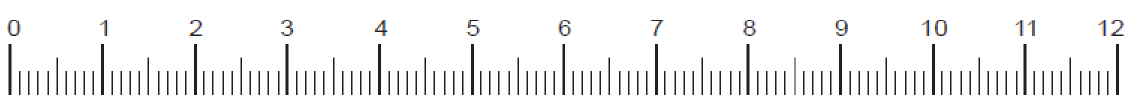
Nacre: Blue-white, pale pink, orange

Soft Parts: Foot orange

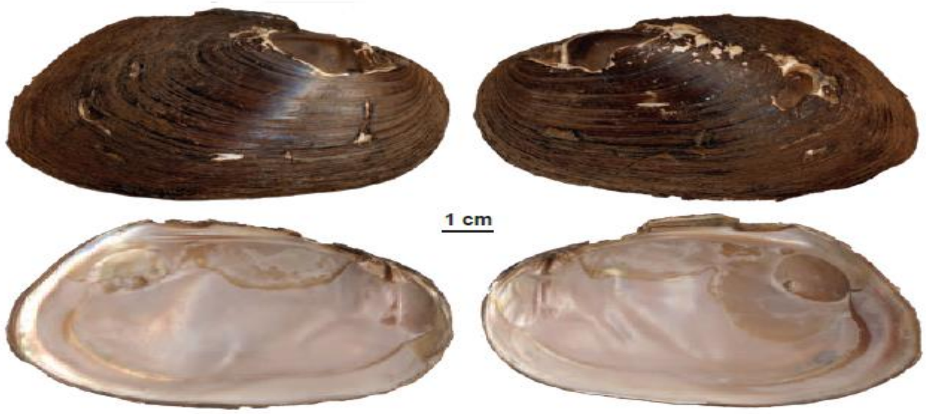
Canadian Conservation Status: Special Concern (SARA)

Hinge Teeth *Alasmidonta varicosa*			
Left Valve		Right Valve	
Pseudocardinal	Lateral	Pseudocardinal	Lateral
1 small bump	0	1 small bump	0

6 - 3B



Eastern Elliptio *(Elliptio complanata)*



11 - 6A

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Eastern Elliptio *(Elliptio complanata)*

Size: Medium – large; to 120 mm

Shell: Thick, rectangular but variable, laterally compressed with posterior ridge, umbo not prominent

Periostracum: Brown to black

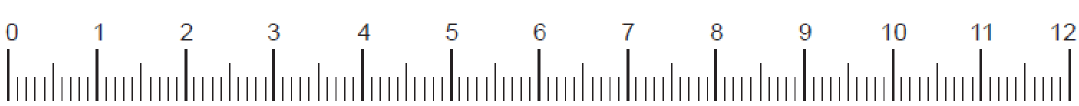
Nacre: White, pink, purple

Soft Parts: Mantle margin greyish or black without pattern

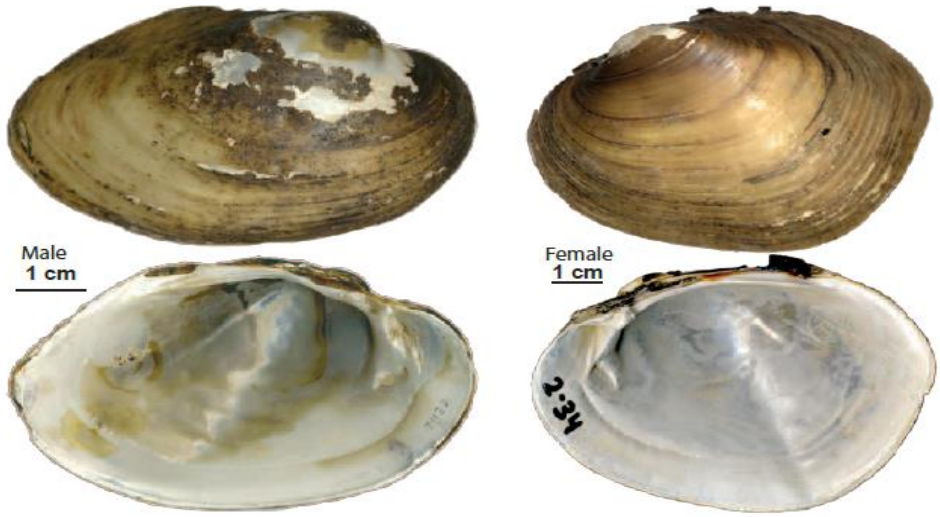
Canadian Conservation Status: Secure

Hinge Teeth *Elliptio complanata*			
Left Valve		Right Valve	
Pseudocardinal	Lateral	Pseudocardinal	Lateral
2	2	1	1

12 - 6B



Yellow Lampmussel *(Lampsilis cariosa)*



13 - 7A

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Yellow Lampmussel *(Lampsilis cariosa)*

Size: Medium – large; to 115 mm

Shell: Thick, oval, laterally inflated, ventral margin rounded, pseudocardinal teeth almost directly under umbo, umbo prominent

Periostracum: Glossy yellow or yellowish brown

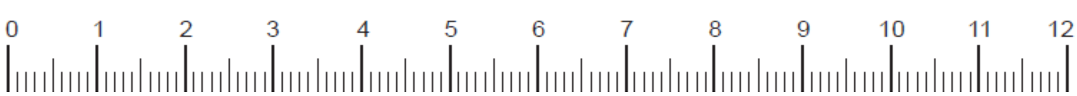
Nacre: White or bluish white

Soft Parts: Mantle margin smooth, patterned with grey, ochre and cream; ventro-posterior edge of mantle with flap-like extension with dark eyespot in mature females

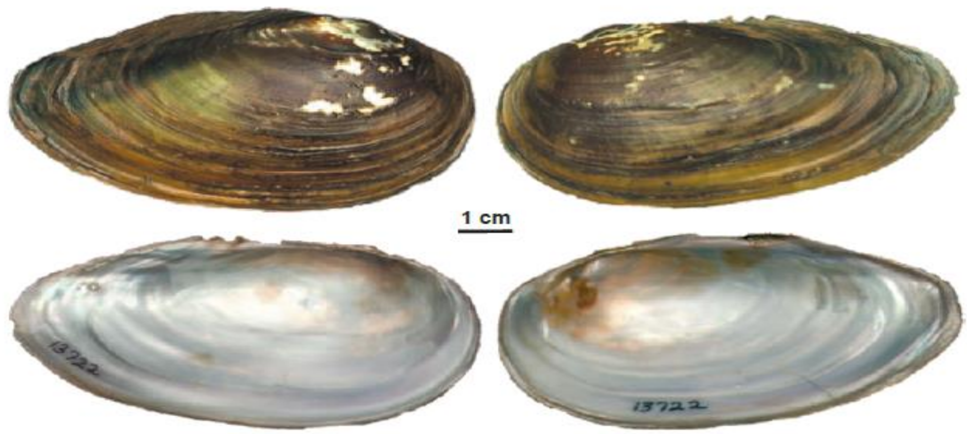
Canadian Conservation Status: Special Concern (SARA)

Hinge Teeth *Lampsilis cariosa*			
Left Valve		Right Valve	
Pseudocardinal	Lateral	Pseudocardinal	Lateral
2 stout with distinct striations	2	2 or 3 stout with distinct striations	1

14 - 7B



Eastern Floater *(Pyganodon cataracta)*



19 - 10A

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Eastern Floater *(Pyganodon cataracta)*

Size: Medium – large; to 180 mm

Shell: Thin, elongate, laterally inflated, prominent growth lines ventral margin uniformly thin, umbo inflated

Periostracum: Smooth yellow, green, brown or black

Nacre: Silvery white, often iridescent or metallic, sometimes with a yellow tinge

Soft Parts: Pale orange foot, tan gills

Canadian Conservation Status: Secure

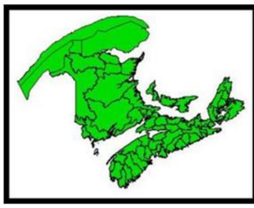
Hinge Teeth *Pyganodon cataracta*			
Left Valve		Right Valve	
Pseudocardinal	Lateral	Pseudocardinal	Lateral
0	0	0	0

20 - 10B

0 1 2 3 4 5 6 7 8 9 10 11 12

A Few Native Fish Species of New Brunswick

American Eel - Anguille d'amérique – Anguilla rostrata



Description: 100cm (39 inches)

The body shape is elongate

Its colour, depending on the life stage, is typically dark green to brown with lighter green to yellow sides, and a lighter belly

Long dorsal and anal fins that are continuous with a rounded caudal

Atlantic Salmon – Saumon Atlantique – Salmo Salar

Description: 85cm (33 inches)

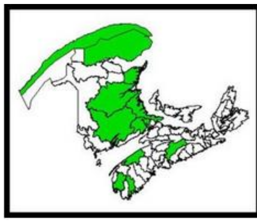
Maxillary to below centre of eye in 6-inch fish, seldom far behind eye (except in large males)

Gill cover with 2 or 3 large spots only

Dorsal fin rays usually 11

Vomerine teeth usually not well developed:

Striped Bass – Bar rayé – Morone saxatilis



Description: 100cm (39 inches)

Dorsal fins entirely separated at base

soft anal rays 9-11

Anal spines more slender, longest spine less than one-half height of fin, fine teeth at base of tongue

Brook Trout – Omble de fontaine – Salvelinus Fontinalis

Description: 10-20cm (4-8 inches)

Caudal fin square or nearly

Dorsal and caudal fins with distinct, dark, wavy lines or blotches

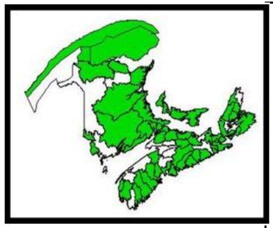
Lower fins with pure white leading edges usually followed by black

Back usually with wavy lines

Sides with pink or red spots, many of which have blue borders

Young have 8-10 regularly arranged parr marks on sides

Atlantic Tomcod – Poulamon atlantique – Microgadus tomcod



Description: 15-25cm (6-10 inches)

Colour is patchy brown to olive with yellow or green shades, lightening to greyish or white belly

The lateral line is generally white and curves over the pectoral fins

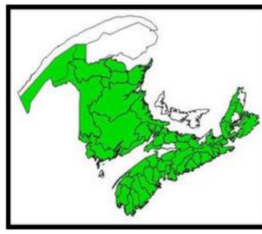
Three dorsal fins, bases of near equal length

2 anal fins, caudal is rounded

The second ray of pectoral fins is twice the length of the other rays

Tomcod have a single barbel at the tip of the lower jaw

White Sucker –Meunier noir – Catostomus commersoni



Description: 50cm (20 inches)

Scales larger, usually fewer than 90 in lateral line

Lower lip much wider than its height

Oblique rows of scales from lateral line to dorsal origin 8-10; dorsal fin rays 10-12

Least caudal peduncle depth more than one-half length of dorsal fin base

No membranous connection

White Perch – Baret – Morone americana

Description: 50cm (20 inches)

Laterally compressed deep body

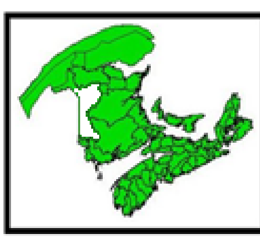
It has an olive to dark grayish back, silvery to grayish sides, lightening to a white belly

The first dorsal fins are spined and the second dorsal and pelvic fins have one spine and the anal fin has three

The lateral line has 46 - 51 scales along its length

No lateral stripes

Sea Lamprey – Lamproie marine – Petromyzon marinus



Description: 50-100cm

The body shape is elongate

Its scaleless body ranges in colour from olive to brown with dark patches in larger individuals

It lacks pectoral and pelvic fins, has two dorsal fins which the largest continuous with the anal fin

It has seven gills slits

Absence of a true jaw, it has a circular oral disc and tongue that are heavily toothed