Woodlands and Waterways EcoWatch

Aquatic Monitoring Protocol Manual

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Executive Summary

The purpose of this protocol is to assess aquatic ecosystem conditions following a modified Ontario Benthos Biomonitoring Network (OBBN) protocol. Benthic macroinvertebrates (benthos) can be used as indicators of water and habitat quality in lakes and near shore environments. This document outlines recommended sampling, processing and analytical procedures used by the Woodlands and Waterways EcoWatch (WWEW) program in benthos biomonitoring.

In developing a long-term biomonitoring plan, each associated lake must collect a benthos baseline inventory over a 5-year span. This data will provide a baseline that covers natural changes in climate, weather, and other variances. Long-term assessments can be compared to this initial baseline to track changes in benthic composition and water and habitat quality over time. Since benthos community composition is determined by environmental attributes, such as substrate type and vegetation, appropriate reference (minimally impacted) sites will be sampled alongside other potentially impacted sites.

This protocol details sampling and processing methods for lake environments. We discuss sampling methods, define sampling units, and specify sampling effort, replication, and collection procedures. These standardizations allow for comparisons between sites and times and sharing among other organizations.

The condition of sample sites are summarized using a set of indices (e.g. community composition, percent *Ephemeroptera, Odonata, Plecoptera*). These index values can be compared to their normal range in lake sites found in Haliburton County and the surrounding areas to determine how unusual the sample sites are.

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1 Introduction

1.1 Woodlands and Waterways EcoWatch (WWEW)

Woodlands & Waterways EcoWatch is a community based environmental monitoring program coordinated by the U-Links Centre for Community Based research in conjunction with a number of volunteer and not-for-profit organizations in the Haliburton Region. The program utilizes the resources and knowledge of Trent University and Sir Sandford Fleming College in order to assist community organizations monitor the long-term health of the forests and lakes of Haliburton County and the surrounding region.

In 2019 U-Links participated in a pilot project involving six lakes within Haliburton County in order to determine the potential of a benthos biomonitoring program. All six projects were successful and it was determined in early 2020 that the program would continue and expand to more lakes throughout the Haliburton region. WWEW currently works with 14 lake, cottage, and property owners' associations in the Haliburton and Kawartha Lakes region sampling 76 sites on 25 lakes. WWEW's biomonitoring efforts focus on benthic macroinvertebrate monitoring following the Ontario Benthos Biomonitoring Network protocol.

1.2 Ontario Benthos Biomonitoring Network (OBBN)

The Ontario Benthos Biomonitoring Network, coordinated by the Ministry of Environment, Conservation, and Parks, is an aquatic macroinvertebrate biomonitoring network for Ontario's Steams, lakes, and wetlands. It is designed with a data sharing and standardization approach to allow for data comparison and coordination between organizations. Several government, not-for-profit, and volunteer groups currently use OBBN across Ontario.

Biomonitoring is an essential part of water management and sustaining current water uses so they do not negate future uses of aquatic ecosystems. OBBN can be used to determine ecosystem health to aid in management programs. It can also be used to determine the effectiveness of environmental management and if they are progressing towards sustainability.

2 Site Selection Guidelines

2.1 Study Site Selection

Study sites (sample sites) can be selected based on the interests of the organization. Many Lake Associations ask, is my lake healthy? Are conditions changing over time? Based on the question of interest, there are multiple approaches to site selection. The following 3 study design options are provided to guide site selection.

1. *Stratified Shoreline Segments*:
   Lakes may have participated in shoreline assessments that provide data on shoreline habitats, and can therefore inform site selection on individual lakes. Stratified sampling

sites reflect the overall shoreline condition (i.e. if 50% of the lake is developed, 25% is manicured, and 25% is undeveloped, 2 sites would be in developed areas, 1 in a manicured site, and 1 on undeveloped shores). The overall design will help to ensure that representative samples are reflective of the condition of the lake over time.

2. *Impact/Control*:
   Another study design is to track known lake impacts. Sample sites would be divided to represent 1 impacted site and 1 control site where both sites have similar substrates. Similarly, sites could be chosen that are developed, undisturbed, and one in between. Note that there are very few pre-identified control/reference sites within the OBBN in Haliburton area, so control sites would be based on visual and ecological knowledge of the lake. Sites used in this design should have similar dominant substrates to allow for direct comparisons to be made. This reduces the variables in the study and allows for comparisons within the lake.

3. Reference/Random:
   Based on background survey work, one site on the lake may be used as a "reference" site. This site should be one that will remain unimpacted over the long term (crown land, unused shoreline away from cottages or other impacts). This reference site would be sampled every year providing an opportunity to monitor change over time. Additional sites could be sampled each year, selected from a random pool of available sites.

2.2 Field Site Selection

Once a study approach has been decided, site locations are picked. No matter what approach is chosen, sites should only be compared if they have similar dominant substrates. Priority should be given to habitats that contain a mix of substrate types, as they would maximize the chances of similarity of habitats, and therefore the ability to make reasonable comparisons across the lake. Canadian shield lakes often contain a mix of sand, gravel, silt, and organics.

Sampling areas to avoid:

- Pure sandy beaches (limited benthos diversity)
- Highly organic, wetland sites (poor sites for benthos)
- Large boulder sites (unsafe)
- Pure bedrock sites, (unsafe, limited benthos)

2.3 Replication

In order to ensure in-site variation, replicates are taken at each sampling site. A minimum of 2 replicates is recommended, while 3 is better if field capacity and time permits. Replicates are taken perpendicular to the shoreline, roughly 3-5 metres apart.

3 Modified Ontario Benthos Biomonitoring Network (OBBN) Protocol

The Woodlands and Waterways EcoWatch (WWEW) follows a modified Ontario Benthos Biomonitoring Network (OBBN) protocol for the benthic biomonitoring portion of the program. All guidelines and procedures are derived from OBBN and modified slightly to meet the vision and goals of WWEW.

3.1 Health and Safety

Health and safety is a priority when working in and around water. Proper personal protective equipment should be worn at all times, including: chest waders with an effective belt and an appropriate sized personal floatation device (life jacket). It is good practice to always bring a first aid kit out into the field with your team.

3.2 Sampling Procedure

Each lake participating in WWEW benthic biomonitoring contains a number of sample site locations (Figure 1), as described in Section 2, Site Selection Guidelines**.** The following data is collected and recorded on a digital (Appendix A.) or physical field sheet (Appendix B.) at each sample site: **sample site features**, **water chemistry**, and **sampling data**. Sample site features, and water chemistry data are collected prior to sampling when possible, this allows the water to remain undisturbed while collecting information. Sampling data is collected as sampling is conducted using the **kick and sweep method**. Below is a list of equipment required to complete sampling.

- First aid kit
- Health and Safety Binder
- SPOT device
- Waders
- Life jacket
- GPS unit
- 1L jar with lid
- duct tape
- Sharpie
- Field sheet (digital or physical with clipboard and pencil)
- YSI multimeter
- OAKTON multimeter
- A d-net, with 500micron mesh
- 30m measuring tape
- A bin/basin/bucket
- A squirt bottle
- A 500 micron sieve

All equipment should be sanitized after use. Multimeters, tablets, GPS units, and meter tapes should be sanitized with alcohol by dabbing or spraying alcohol onto a clean cloth and wiping down equipment. Waders, d-net, squirt bottles, and plastic bins should be sanitized with bleach solution by applying bleach solution to surfaces and allowing them to stand for 5-10 minutes.

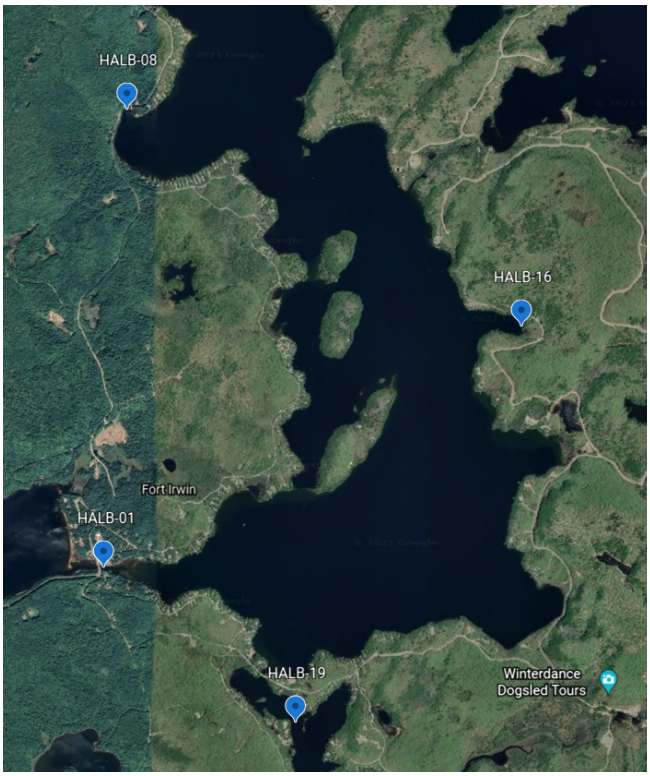

Figure 1: Example site map of the four Haliburton Lake 2021 benthic biomonitoring sample sites.

3.2.1 Sample Site Features

Recording the features of a sampling site allows for characterization of the site's habitat. Habitat type may affect which benthos are present, and can be used when comparing sites. Some sample site features are collected per site, and some are collected at each replicate within a site. Table 1. lists, and explains the method of collection for each site feature. Table 2. Explains how to record data for site features that are collected based on their presence/absence. For site features that are collected based on theirRefer to Appendix C. for site feature reference photos.

Table 1: Sample Site Features

Site Feature	Method of Collection
Site Code Collected per replicate	The Site Code is what identifies and differentiates one site from another. Site codes are as follows: **4 letter code - site # - replicate #**

	Example: **GULL-01-R1** or **GULL-01-R2**
Site Description Collected per site or replicate when relevant	The site description should include location (N/S/E/W) of relevant features otherwise not recorded in the sample site features section. The site description may also help to identify the site in succeeding years. Examples: 1. Located west of a dam 2. Located within south bay, on the east side
Site Location (Latitude and Longitude) Collected per site	The site location is the general location of the site, collected using a GPS or GIS software on a phone/tablet. Can be collected in degrees, minutes, seconds, or decimal.
Sampling Event Date Collected per site	DD/MM/YYYY Example: 01/10/2021
Time of Day Collected per replicate, at the start of each kick and sweep event	24 hour time: HH:MM Example: 13:30
Riparian 1.5m-10m Collected per site	The riparian zone is the vegetation community present adjacent to the shoreline of your sample site. Riparian 1.5-10m is the dominant vegetation community present from 1.5m to 10m. It can be classified as one of the following: 1. None: no vegetation (ex. lake, road, building) 2. Lawn: manicured grass (ex. lawn, golf course) 3. Cropland: agricultural field 4. Meadow: grasses, flowers, non-woody, herbaceous plants 5. Scrubland: shrubs and woody plants with a height of less than 10m 6. Forest: trees with a height of 10m or more 7. Wetland: wetland plants **Note: There may be more than one riparian type present, select the type that is dominate Ex. shrubs (approx 40% of area) and trees (approx 60% of area). This

	would be classified as a forest
Riparian 10-30m Collected per site	See the column above for description. Riparian 10-30m is the dominant vegetation community present from 10m to 30m. It is classified as one of the riparian types listed in the column above. **Note: for riparian 10-30m and riparian 30-100m (below column) it can often be difficult to see the dominant riparian type if there are tall trees blocking the way. When in the field you can assume classification type, but it is a good idea to check google earth aerial photos to confirm your assumption later.
Riparian 30-100m Collected per site	See "Riparian 1.5-10m" for description. Riparian 30-100m is the dominant vegetation community present from 30m to 100m. It is classified as one of the riparian types listed in "Riparian 1.5-10m" methods.
Sample Location (Latitude and Longitude) Collected per replicate	The sample location is the specific location of each replicate within a sample site. It should be taken on the shoreline directly in front of the kick and sweep transect. Collected using a GPS or GIS software on a phone/tablet. Can be collected in degrees, minutes, seconds, or decimal.
Dominant Mineral Substrate Collected per site	The dominant mineral substrate is exactly what it sounds like: the most dominant mineral substrate present in the water at your sample site. For fine substrate types it is helpful to pick up a dime size of the substrate and rub it between your thumb and index finger to determine the texture. For the larger substrate types the best way to identify is by size. The mineral substrate may be classified as one of the following: 1. Clay: fine and sticky texture 2. Silt: fine and slimy texture (< 0.06 mm diameter) 3. Sand: gritty and coarse texture (0.06-2mm) 4. Gravel: can pick up with your fingers (2-65mm) 5. Cobble: can pick up with one hand (65-250mm) 6. Boulder: can maybe pick up with two hands (>250mm) 7. Bedrock: solid rock
2nd Dominant Mineral Substrate Collected per site	The 2nd dominant mineral substrate is also exactly what it sounds like: the 2nd most dominant mineral substrate present in the water at your sample site. Therefore, it cannot be the same at the dominant mineral substrate. It may be classified as one of the substrate types listed in the column

	above.
Woody Debris Collected per site	Woody debris is any woody material found at the bottom of the water at your sample site. Example: sticks, twigs, logs Recorded based on presence/absence (Table 2.)
Detritus Collected per site	Detritus is any plant material present at the bottom of the water at your sample site. Usually it is beginning to decompose. Example: leaves, needles, dead aquatic plants Recorded based on presence/absence (Table 2.)
Macrophytes - Emergent Collected per site	Emergent macrophytes are any aquatic plants present in the water at your sample site, where their leaves, stem, and flowers are above the water's surface. Example: arrowhead, pickerel weed, cattails Recorded based on presence/absence (Table 2.)
Macrophytes - Rooted Floating Collected per site	Rooted floating macrophytes are any aquatic plants present in the water at your sample site that are rooted in the substrate and floating on the water's surface. Example: white or yellow water lily, watershield Recorded based on presence/absence (Table 2.)
Macrophytes - Submergent Collected per site	Submergent macrophytes are any aquatic plants present in the water at your sample site that are completely submerged under the water's surface. Sometimes the tops of the flowers may emerge from the water. Example: water milfoil, pond weeds, tape grass Recorded based on presence/absence (Table 2.)
Macrophytes - Floating Collected per site	Floating Macrophytes are any aquatic plants present in the water at your sample site that are free floating on the surface of the water and not rooted in the substrate. Example: duckweed, bladderwort Recorded based on presence/absence (Table 2.)
Algae - Floating Collected per site	Floating algae is algae - an aquatic plant with no flowers or leaves, often resembling a green or brownish mass - that is floating on the surface or within the water column.

	Recorded based on presence/absence (Table 2.)
Algae - Filamentous Collected per site	Filamentous algae is algae - an aquatic plant with no flowers or leaves, often resembling a green or brownish mass - that has non-branching filaments or hair like chains. Recorded based on presence/absence (Table 2.)
Algae - Attached Collected per site	Attached algae is algae - an aquatic plant with no flowers or leaves, often resembling a green or brownish mass - that is attached to an object in the water, such as a rock or log. Recorded based on presence/absence (Table 2.)
Comments Collected per site or per replicate when relevant	The comments area is there for any additional information that is relevant to the sample site and may impact benthos present. Example: 1. A lot of garbage present at site 2. A lot of xyz species present at site

Table 2: How to record presence/absence of site features

Site features	Recorded As		
Woody Debris, Detritus, Macrophytes, and Algaes	0 - absent none present at site	1 - present at least one present, but not taking up more than 50%	2 - abundant site feature taking up greater than 50% of the sample area

3.2.2 Water Quality

Four water parameters are measured per WWEW's Modified OBBN Protocol. Water temperature, dissolved oxygen, conductivity, and pH measurements are collected and recorded at each sample site to determine the overall water quality at each site.

Water temperature is measured in celsius and varies across the seasons the same as air temperature. Water temperature can affect other water quality parameters such as dissolved oxygen (USGS, 2018).

Dissolved oxygen is measured in milligrams per litre (mg/L) and is an important parameter to measure because it is essential for aquatic organisms to breathe or respire underwater (Boyd, 2016).

Conductivity is measured in microsiemens per centimeter (µs/cm) and measures the ability of an electrical current to run through a sample. Samples with higher amounts of dissolved ions will have a higher conductivity. Conductivity is therefore a good indicator for the amount of minerals in a sample (Boyd, 2016).

pH is a measure of the acidity or basicity of a sample on a scale from 0-14, where 0 is acidic, 14 is basic, and 7 is neutral. pH is an important parameter to measure because extremely low pH or extremely high pH can negatively affect aquatic life (Boyd, 2016).

Temperature, dissolved oxygen, conductivity, and pH are collected using calibrated field instruments, such as the YSI Multimeter, or OAKTON PCTS50 TESTER. These parameters are collected prior to disturbing the substrate at each sample site.

3.2.3 Kick and Sweep Sampling Method and Sampling Data

Benthos samples are collected using a modified OBBN Kick and Sweep method. At each sample site there are 2 replicates and 2-3 transects per replicate. A benthos sample is collected within each replicate along 2-3 transects. There are two replicates per site to ensure diversity, and 2-3 transects per replicate to ensure the required 100 organisms are collected. Samples are collected starting from a depth of 100cm and over a period of at least 6 minutes. The sampling data you will record on your field sheet includes **sampling distance (m)**, **sampling time** in minutes and seconds, and **maximum sampling depth (cm)**. The steps for conducting the modified OBBN Kick and Sweep are as follows.

Step 1: Label your sample jar with the following information: “ORGANIZATION, SITE CODE, DATE, LAKE NAME, PRESERVATIVE TYPE, JAR # / #”

Example: “U-LINKS, GULL-01-R1, 01/10/2021, GULL LAKE, ETHANOL, JAR 1/1”

Step 2: Determine where 100cm lies on your body, remember the location or mark with a piece of tape on your waders. That is the depth you will wade to to begin sampling.

Step 3: Using a 30m measuring tape wade out to the marked 100cm depth with the D-net, and pull the tape measure tight, your team member holding the other end of the tape on shore will record the **sampling distance (m) and maximum sampling depth (cm)** on the field sheet

NOTE: Occasionally your site will be too shallow to reach 100cm depth. Where this occurs, walk out 30m and record the depth you are at

Step 4: A team member on the shore will start a timer and you will begin the kick and sweep along your first transect. You should sample each transect for 3 minutes.

Facing the opposite direction of the waters flow (water → ← you), begin kicking into the substrate to a depth of 5cm, and simultaneously sweep the D-net from side to side just above

the floor of the water body. Avoid kicking substrate directly into the net, and instead kick it into the water column and sweep up the organisms there.

While kicking and sweeping make your way back to the shore along your transect, over the 3 minutes. The team member with the timer should inform you of each passing 30 seconds so that you can adjust your speed accordingly

When you are back to the shore your teammate will stop the timer and record the **sampling time** in minutes and seconds ex. Sampling time minutes: 3, Sampling time seconds: 5

Step 5: Thoroughly rinse the net in the water to remove fine particles from your sample - this will make sample processing much easier in the lab. Once the water is running clear from your net it can be transferred to your labelled jar.

Step 6: Place your labelled jar in your basin/bucket, and carefully transfer the sample from the net to the jar. Any sample that falls in the basin/bucket must be transferred to the jar. Rinse and inspect all sides of the net to ensure no benthos are hanging on to the net.

****DO NOT** overfill the jar, it should be filled no more than halfway. If it is a large sample, label a second jar with the same information listed in Step 1, and ensure the label on Jar 1 reads “JAR 1/2” and Jar 2 reads “JAR 2/2”****

Step 7: Complete **Step 3 to Step 6** again for your second transect. Make sure that you are completing your second transect a few steps away from your first transect.

Step 8: Determine whether you have collected the 100 required benthos from your first 2 transects. If you determine you have not reached 100 benthos complete a third transect.

Step 9: Complete **Step 3 to Step 8** for the second replicate at the sample site.

Step 10: Drain excess water from your sample jars using the 500 micron sieve and secure the lids.

Preservation:

If you plan to process your sample within 24 hours of collecting it in the field, preservation is not required.

If you plan to process your sample 24 hours or more after collecting it in the field, preservation is required within those 24 hours.

Preservative should be 70% Isopropyl alcohol, or 70% Ethanol Alcohol.

Fill your sample jar to the top with your preservative, secure the lid, and mix the sample to ensure it is completely saturated with preservative. Keep it in a cool dry place until processing.

4 Benthos Sample Processing Protocol

The OBBN protocol is flexible with respect to sample processing/picking. U-Links/WWEW's preferred picking method is in-lab, with preserved samples, using a teaspoon to randomly subsample, and a microscope to assist with invertebrate identification, although a marchant box may also be used.

For each sample collected, a minimum of 100 organisms are picked and identified to the OBBN minimum 27-taxa grouping, relocated to a vial of preservative for storage, and recorded on a tally sheet (Appendix D.). Prior to picking, fill out all required information on the tally sheet.

Vial labels are pre-made and contain the same information you would have recorded on your sample jars in the field (ORGANIZATION, SITE CODE, DATE, LAKE NAME, PRESERVATIVE TYPE, VIAL # / #). Have one label on the outside of the vial, and place one inside. Fill the vial 50% with ethanol and add organisms as you go. Once picking is complete fill the vial up to 90%. If a larger specimen won't fit in the provided vials, larger jars can be used.

Benthos that you pick **MUST**:

- Have a head (to prevent double counting)
- Have enough intact body parts for identification
- Inhabitants within shells/cases must be present, empty shells do not count.

4.1 The Teaspoon Method

The steps for processing/picking your benthos sample using the Teaspoon Method are listed below, and the equipment required for processing includes:

- Your sample jar
- A white basin
- Empty container for used preservative
- 500 micron sieve
- Squirt water bottle
- 70% ethanol
- Glass vial with secure lid
- 2 labels, one for outside the vial and inside
- A spoon
- A petri dish
- tweezers/droppers
- OBBN tally sheet (Appendix D.)
- Identification resources
- Pencil

Step 1: Fill out all required information on the tally sheet and label your vial.

Step 2: Using a 500 micron sieve or net, remove all the preservative from your sample and store it until you are finished picking.

Step 3: Empty your sample into a bin/bucket/tray, making sure to rinse out the jar with water to collect the entire sample.

Step 4: Add water to the bin for easy sub sampling, and using a spoon, stir the contents of the bin and randomly scoop a subsample and put it on a petri dish. Random scoops ensure no bias to larger/floating bugs when sub sampling. Add extra water to your petri dish if needed.

Step 5: Place the dish on the viewing stage of the microscope and start picking. Using tweezers or droppers, transfer identified benthos from your sub sample to the vial and record on the tally sheet as you go. Once you have collected all the benthos in a sub sample, dump it into the jar, and scoop another.

Step 6: Continue picking until you reach the required 100 benthos. You must pick the entire sub sample that contains the 100th benthic. This means your tally will likely be greater than 100.

Step 7: Once complete put the sample back into the jar, drain the water using a 500 micron sieve, and refill with preservative. U-Links staff will check your identification and pick through the sample again for additional organisms if necessary

4.2 Identification of Benthos

Benthos are categorized into 27 taxa for identification under the OBBN protocol. Using the teaspoon method and a dissecting microscope at least 100 benthos are picked and categorized into 1 of the 27 taxonomic groupings. The key identification features for each of the 27 taxonomic groupings can be found in Appendix E.

4.2.1 Benthos Look-a-Likes

There are some benthos that may be easily confused with plant matter or other organisms such as zooplankton.

Gastropod/Plant Matter: Some plant matter or seeds may look similar to gastropods with a similar spiral appearance. This plant matter will not have an opening and will contain a seed rather than an invertebrate. Figure 2. provides a comparison between a seed that resembles a gastropod and an actual gastropod specimen.

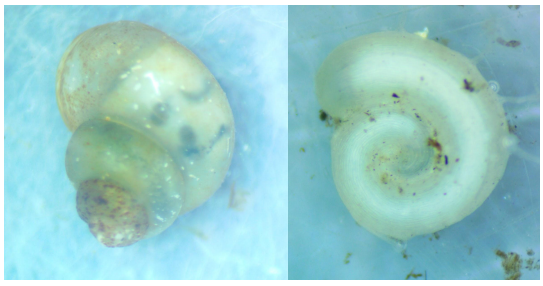

Figure 2: Gastropod (left), seed (right)

Zooplankton (Daphnia/Copepods): When picking through samples you may also come across zooplankton that may resemble benthos, particularly Copepods and Daphnia (Figure 3.). These zooplankton may be confused for Amphipods (scuds) and/or Isopods (sow bugs).

Figure 3: Daphnia specimen

5 Benthos Analysis

The benthos data that we have collected can now be used to characterize the biological condition of the sample sites, and lake as a whole. After processing the samples a series of biological indices are calculated to summarize benthos community and habitat health.

5.1 Indices

A variety of indices can be used to summarize benthos data, depending on the metrics you are interested in. Simple summaries include **Richness Measures** (total number of taxonomic groups), **Abundance Measures** (the number of organisms in a sample), **Compositional Indices** (the ratio of certain groups to the total sample), and **Diversity Indices** (incorporating both richness and abundance). Weighted summaries can also be applied, **Pollution-Tolerance Indices** combine the known pollution tolerances of taxa and are weighted to their abundance. Multivariante Summaries can be used in cluster analysis, but are not required in WWEW.

There is no limit to the number of indices that can be used for analysis, however WWEW suggests using Percent Composition, %EOT, and Simpson's Diversity Index as a starting point.

5.1.1 Percent Composition

Percent Composition breaks down the 27-group OBBN taxa into smaller groups based on their function and tolerance to pollutants and changes in water quality. Composition of each grouping can be compared to other sites within a lake or to show changes in the same site over time. The WWEW Groupings can be found in Appendix F.

To calculate Percent Composition:

$$\text{Group \%} = \frac{\#\ in\ group}{total} X\ 100$$

5.1.2 %EOT

EOT Species (*Ephemeroptera, Odonata [Anisoptera and Zygoptera], Trichoptera*) are very sensitive to pollution and changes in their habitats. As such, their abundances should be higher in healthier ecosystems with cool, oxygen-rich waters, and will typically decline when distrurbed by stressors or pollution.

WWEW has collected OBBN data from 25 lakes in Haliburton Region since 2019. To calculate a "normal range" for the area, additional data was incorporated from the Ministry of the Environment, Conservation, and Parks from 2011-2016, taken from the OBBN database. Data was used from similar Canadian Shield lake sites, roughly 30 km around Haliburton County to make a database of 39 lakes. As more samples are collected, more lakes will be added.

Calculating Normal Range:

- A random data point (site) was selected from each lake
- The average %EOT was calculated for each site
- The range was determined by characterizing the distribution of values:
    - Typical: %EOT is between the 10th and 90th percentile (resembling the majority of Haliburton Lakes
    - Atypical: %EOT is between the 5th and 10th percentile or the 90th and 95th percentile (resembling lakes slightly higher or lower than the majority of Haliburton Lakes
    - Extremely Atypical: %EOT is less than the 5th percentile or greater than the 95th percentile. (resembling lakes that are much higher or lower the %EOT

Haliburton %EOT Normal Range is:

- Typical: 4.18 - 37.12
- Atypical: 2.62 - 4.18 and 37.12 - 54.41
- Extremely Atypical: <2.62 and >54.41

Sites or Lakes with %EOT in the lower Atypical or Extremely Atypical ranges may be suffering from exposure to anthropogenic pollution sources or disturbances. Sites that fall within the upper Atypical or Extremely Atypical ranges may have healthier habitats that better suit EOT species. In both cases, more sampling should take place to look for patterns.

5.1.3 Simpson's Diversity Index

Simspon's Diversity Index is a measure of diversity which takes into account the number of species present, and the relative abundance of each of those species. Diversity will increase as species richness and evenness increase.

$$Diversity = 1 - \left(\frac{\Sigma n(n-1)}{N(N-1)}\right)$$

n = the total number of organisms of a particular species
N = the total number of organisms of all species.

The range of diversity will fall between 0 and 1, with 0 representing no diversity, and 1 representing infinite diversity. Like all ecosystems, higher diversity represents healthier environments.

6 References

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Appendices

Appendix A. Digital Field Sheet

Appendix B. Physical Field Sheet

Appendix C. Site Feature Reference Photos

Appendix D. Tally Sheet

Appendix E. Benthos Key Identification Features and ID Resources

Appendix F. Percent Composition Groupings