4/4/2023

Twelve Mile and Little Boshkung Lake Benthic Study

Prepared for the Twelve Mile and Little Boshkung Lake Association

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Introduction

In accordance with the Twelve Mile Little Boshkung Lakes Association, U-Links and the Trent Center for Community-Based Education created a benthic biomonitoring program specific to Haliburton County but can be replicated across the province. This program effectively obtains baseline lake health information to assist decision-makers in determining informed protocols and critical processes concerning lake health (Martin, 2019). Using the biological responses of indicator species' populations and communities, or "biomonitoring," allows researchers to assess anthropogenic environmental changes in ecosystems (Bae et al., 2005). Lake ecosystem biomonitoring using benthic macroinvertebrates is the most commonly used study approach in assessing water quality. Benthic macroinvertebrates' sensitivity to environmental changes is advantageous in biomonitoring as they provide a spectrum of measurements, enabling the quantitative and community analyses required for the aquatic environment they inhabit (Bae et al., 2005).

Benthic macroinvertebrates, or "benthos, " are small, spineless aquatic organisms that dwell in the bottom substrate of rivers, streams, and lakes for at least some of their lifetime (Bae et al., 2005). These organisms are essential for the health of freshwater ecosystems as they play a significant role in the aquatic food web and nutrient cycling. As among the most delicate and essential components of aquatic ecosystems, benthos are vulnerable to the adverse effects of human development and pollution (Engle et al., 2019). A study by Patang et al. found that increased human activity decreased species diversity in various freshwater streams while examining diversity in benthos (Patang et al., 2018). As a result, it can be determined that if benthic communities are in poor condition, it is probable that the body of water they inhabit lacks the services essential to support benthic macroinvertebrates and other aquatic organisms.

Though waterways can become contaminated naturally through processes like rock weathering, increased human population and urbanization can cause various problems in lakes. Nutrient enrichment from land use activities increases the risk of biodiversity loss and eutrophication. Harmful algae blooms and litter accumulation are becoming increasingly common in freshwater ecosystems, affecting shorelines, open waters, and benthic environments. In assessing water quality, many variables, including temperature,

phosphorus, nitrate, dissolved oxygen, and electrical conductivity, can be used following benthos (Bhateria & Jain, 2016). Benthos' poor mobility preventing them from escaping pollutants, comparatively long lifecycle, and their vital role in ecological activities make them a crucial resource for freshwater biomonitoring (Bae et al., 2005; Engle et al., 2019).

Lake History

The Twelve Mile Little Boshkung Lakes Association, part of the Coalition of Haliburton Property Owners Associations, represents the interests of property owners concerning safety hazards, environmental concerns, and other community issues. As their mission is to ensure the sustainability and protection of land and lakes, the TMLB Lakes Association has completed earlier water quality measures of the represented lakes (Ministry of the Environment, 2018; TMLB Lakes Association, 2023).

Twelve Mile Lake is a freshwater lake located between Minden and Carnarvon, ON, in the township of Haliburton County, with a historic Secchi depth measured between 3.3 to 6.5 m (Ministry of the Environment, 2018). The population of Haliburton County was over 18,000 in 2016. The county of Haliburton, where Twelve Mile Lake is located, is a scenic area known for tourism and cottagers. Connected to Twelve Mile Lake is Little Boshkung Lake. Little Boshkung Lake is also a freshwater body with a historical Secchi depth measurement between 4.4 to 5.8 m (Ministry of the Environment, 2018).The TMLB is fed by Boshkung Lake and feeds into Mountain Lake.

Purpose

This study aims to partner Trent University with the Twelve Mile Little Boshkung Lakes Association and U-Links Centre for Community-Based Research to determine the health of Twelve Mile and Little Boshkung Lakes. By providing baseline information to decision makers with the data they need to make meaningful changes to the health of their lakes, this project contributes to the more extensive Benthic Biomonitoring Program in Haliburton County. This project considers the specific concerns of Twelve Mile Little Boshkung Lakes Association, giving the Lakes Association a clear picture of the health and well-

being of Twelve Mile and Little Boshkung Lakes. Through biomonitoring using benthos as indicators of ecosystem health, this research aims to identify early negative trends that can help maintain the future health of the lakes and potentially aid in avoiding future issues. The project is based on the following research question: what is the baseline composition of the benthic communities of Twelve Mile and Little Boshkung Lakes? The benthic macroinvertebrate assessment for Twelve Mile and Little Boshkung Lakes will benefit residents, lake users, and fishermen. Haliburton County will benefit from efforts to assess and maintain local lake health economically and socially.

Community Concerns

Two primary concerns of the Twelve Mile Little Boshkung Lakes Association are the loss of fish stock and water quality changes. Globally, lakes and freshwater bodies are often subjected to extensive alterations through human development. Increasing populations and urbanization frequently result in freshwater disturbances, and its damaging effects reduce water quality and threaten lake species (Miserendino et al., 2008). Urbanization and development can result in eutrophication, high pollution levels, and habitat degradation, all impacting biodiversity and water quality. Harmful algae blooms and plastic pollution are of particular concern, impacting shoreline and benthic environments (Bhateria & Jain, 2016). Recreational activities, such as angling and boating, also add to the anthropogenic stress on aquatic ecosystems (Seilheimer et al., 2007). Climate change has also significantly contributed to water quality changes in Northern lakes. Oxygen depletion, dissolved organic carbon loading, and decreased nutrient supply are notably correlated with the effects of climate change. The consequences of this effect are detrimental to aquatic biota, potentially impacting fish stock (Bhateria & Jain, 2016). However, to confirm that human activity and climate change are the causes of changes in water quality or the decline of fish stocks, long-term monitoring of the TMLB Lakes is required.

Research Methods and Protocols

Samples were collected on September 27, 2022 using the standardized Ontario Benthos Biomonitoring Network Protocols. Several different site locations were selected around the lake for sample collection. To account for any natural diversity in the environment, two replicates at each sample site were collected. The kick-and-sweep method was used to unsetting the benthic macroinvertebrates from the bottom of the lake for collection. Using a 0.5 mm mesh net, the benthic macroinvertebrates were swept up and put into a container with non-toxic antifreeze for preservation and transported to Trent University.

The water chemistry measurements taken for the lake were the water temperature, conductivity, pH and DO concentrations. These measurements were taken using a multi-probe field instrument. Observations of the riparian zones, substrates, debris, macrophytes and algae were taken visually and recorded onto the field sheet.

Lab analysis of the samples from Twelve Mile Lake were conducted in February of 2023 in the Environmental Science Labs at Trent University. The OBBN protocols for benthic analysis were used. Each replicate was emptied into a large bucket and scooped into a smaller tray. Using a pipette and tweezers, each benthic invertebrate was picked out and identified using the OBBN benthic identifications. Each macroinvertebrate was placed into a small vial with ethanol and labeled with the site information. This process was repeated until there was a minimum of 100 benthic macroinvertebrates identified and then the whole scoop was completed. The remainder of the samples along with the vials were returned to U-Links to be further sorted and identified.

Data Analysis Methods

Modified Hilsenhoff Family Biotic Index (FBI)

The modified hilsenhoff family biotic index is used to identify the water quality based on the abundance of each group of invertebrates. Each group has a different tolerance level and is then rated using a rating scale. The water quality is determined based on the biotic index as seen in Table 1. The modified hilsenhoff family biotic index is calculated by finding the sum of the tolerance value of a group that has been multiplied by the total number of organisms in that group and then divided by the total number of organisms in all groups (***Equation 1***).

$$mHBI = \frac{\Sigma Tn}{N}$$

T = tolerance value of a group

n = total number of organisms in that group

N = total number of organisms in all groups

Table 1. The water quality rating determined by the biotic index found calculated by the Modified Hilsenhoff Family Biotic Index.

Biotic Index	Water Quality
0.00 – 3.50	Excellent
3.51 – 4.50	Very Good
4.51 – 5.50	Good
5.51 – 6.50	Fair
6.51 – 7.50	Fairly Poor
7.51 – 8.50	Poor
8.51 – 10.00	Very Poor

% EOT

The %EOT is used to compare the data with the "Normal Range" that was created for the Haliburton area. The results are determined by comparing them to the ratings in Table 2. The %EOT is calculated by taking the sum of the mayflies, dragonflies, damselflies and caddisflies, dividing by the total amount of benthos in the sample and then multiplying by 100 (**Equation 2**).

$$\%EOT = \frac{\#\ mayflies + \#\ dragonflies + \#\ damselflies + \#\ caddisflies}{total\ \#\ benthos} \times 100$$

Table 2. The rating of the pollution level based on the %EOT calculated.

	Typical	Atypical	Extremely Atypical
%EOT	4.18% - 37.12%	2.62% - 4.18% and 37.12% - 54.41%	<2.62% and >54.51%

Simpson's Diversity Index

The simpson's diversity index is used to determine the diversity of benthic macroinvertebrates at the sample site. If the index calculated is closer to 1, there is infinite diversity. If the index is closer to 0, there is no diversity. The simpsons diversity index is calculated by using ***Equation 3***.

$$Simpson's\ Diversity\ Index = 1 - \lambda$$

$$\lambda = \sum_{i=1}^{S} P_i^2$$

P_i = the proportion of species relative to the total number of species

% Amphipods vs % Insects

The comparison of the percentage of amphipods and insects is used to find how many of the invertebrates have a high tolerance to the pollution found at each sample site. This comparison is calculated by dividing the percentage of amphipods by the percentage of insects. The percentage of amphipods is found by dividing the sum of amphipoda by the total abundance of organisms and then multiplying by one hundred. The percentage of insects is found by dividing the sum of insects (ephemeroptera, anisoptera, zygoptera, trichoptera and chironomidae) by the total abundance of organisms then multiplying by one hundred (**Equation 4**).

$$\%\ A\ vs\ \%\ I = \left(\frac{\Sigma\ amphipoda}{total\ abundance} \times 100\right) \div \left(\frac{\Sigma\ insects}{total\ abundance} \times 100\right)$$

Results

Benthic Data

The benthic macroinvertebrates included in the percent composition group of Malacostraca (Amphipoda and Isopoda) are the most abundant benthos identified in both Little Boshkung Lake and Twelve Mile Lake as seen in Figure 1 and Figure 2. The Malacostraca group accounts for over 70% of the total percent composition followed by the Diptera group in Little Boshkung Lake (Figure 1) and the EOT group in Twelve Mile Lake (Figure 2) accounting for 17% and 4% respectively. The raw data used from the benthic sampling and for the analysis of the two lakes can be found in Appendix B (Table 4).

Figure 1. The percent composition of the benthic macroinvertebrates found and identified in Little Boshkung Lake. The %EOT consists of: Ephemeroptera (mayflies), Zygoptera (damselflies), and Trichoptera (caddisflies). The % Diptera consists of: Ceratopogonidae (no-see-ums) and Chironimade (midges). There were no worms present in the samples. The % Malacostraca consists of: Amphipoda (scuds). The % Mollusca consists of: Bivalvia (clams and mussels) and Gastropoda (snails and limpets). The % Other consists of: Hemiptera (true bugs), Hirudinea (leeches), Hydrachnidia (mites), and Lepidoptera (aquatic moths).

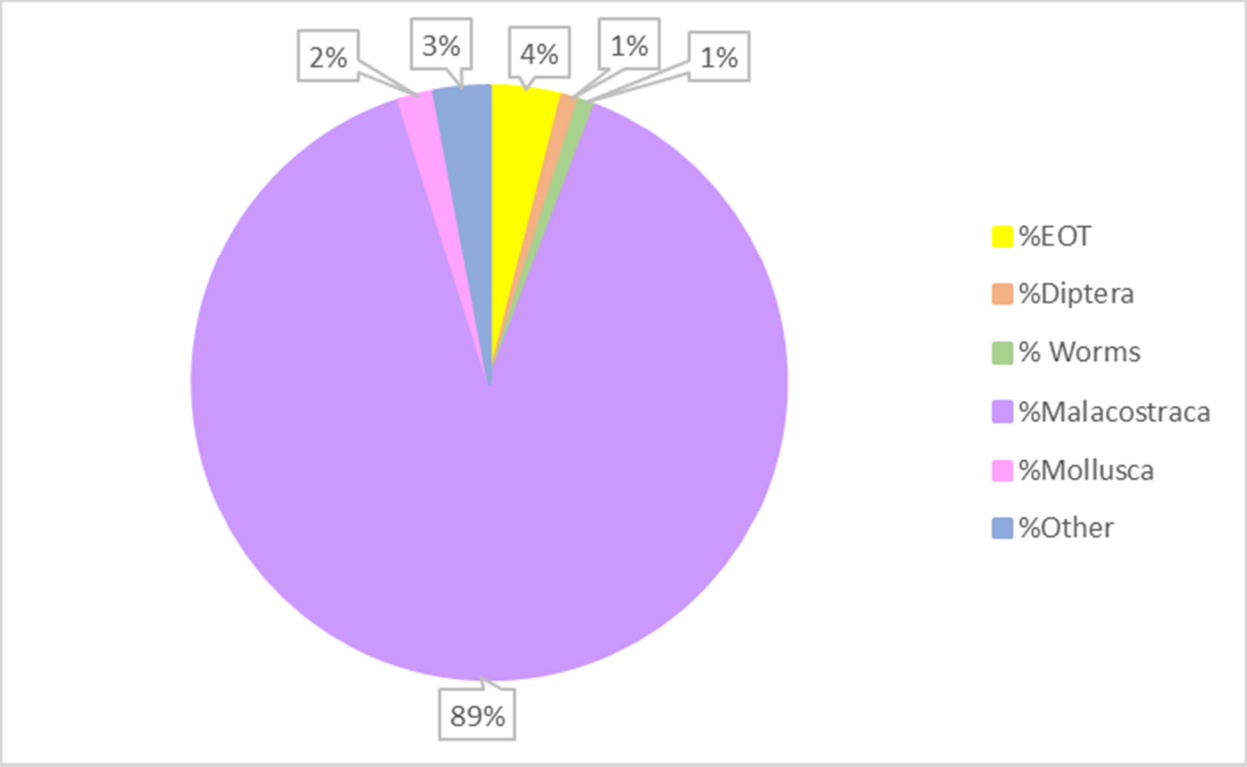

Figure 2. The percent composition of benthic macroinvertebrates found and identified in Twelve Mile Lake. The % EOT consists of: Ephemeroptera (mayflies), Anisopters (dragonflies), Zygoptera (damselflies), and Trichoptera (caddisflies). The % Diptera consists of: Chironomidae (midges), Ceratopogonidae (no-see-ums), and Simuliidae (black flies). The % Worms consists of: Oligochaeta (aquatic worms). The % Malacostraca consists of: Amphipoda (scuds) and Isopoda (sow bugs). The % Mollusca consists of: Bivalvia (clams and mussels) and Gastropoda (snails and limpets). The % Other consists of: Coleoptera (beetles),

Hirudinea (leeches), Lepidoptera (aquatic moths), Megaloptera (alderflies and dobsonflies), Nematoda (roundworms), and Plecoptera (stoneflies).

Water Chemistry and Vegetation

Sample sites TWLV-01, TWLV-02, and TWLV-04 were all located near cottages. Sites TWLV-02 and TWLV-04 both had the most dominant mineral substrate being silt. The dominant substrate for site TWLV-01 was sand. The second most dominant substrate for sites TWLV-01, TWLV-02, and TWLV-04 were silt, cobble, and gravel respectively. Any debris, detritus, and vegetation was mostly minimal to absent for these sites with the exception of TWLV-04 having an abundance of emergent macrophytes. Site LBSK-01 was located near a bridge. The most dominant and second most dominant substrates present were sand and silt. There was minimal to no debris, detritus, and vegetation present at this site. Sample site TWLV-03 was located near a public beach and had a dominant substrate of sand and a second dominant substrate of gravel. There was minimal to no debris, detritus, and vegetation with the exception of an abundance of submerged macrophytes.

The water chemistry measurements of water temperature, dissolved oxygen levels and pH had very minimal variability among all the sample sites. There was the most variability between the conductivity levels with a range between 45.4 uS/cm and 55.1 uS/cm with site TWLV-04 being the highest and LBSK-01 being the lowest, as seen in Figure 3. All raw data relating to water chemistry and vegetation can be found in Appendix B (Table 4).

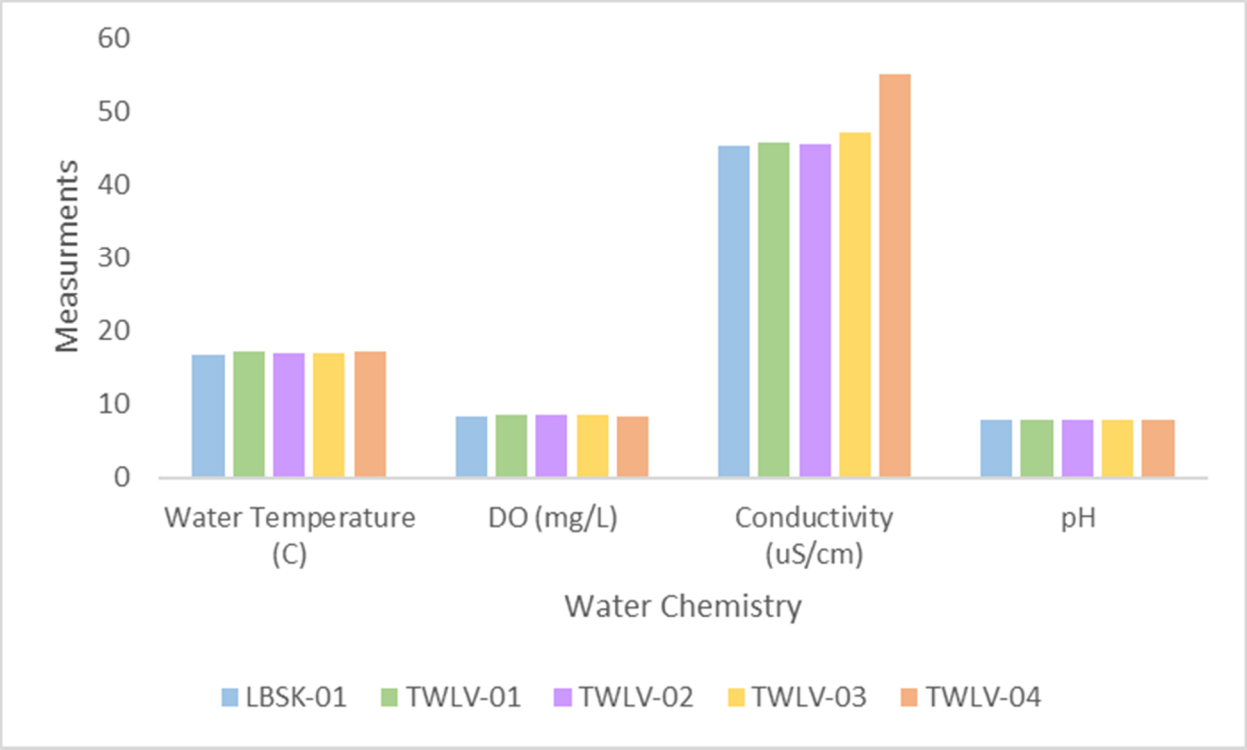

Figure 3. The water chemistry measurements taken at each sample site on September 27, 2022.

Benthic Data Indices

% EOT

The % EOT for all the sample sites are rated as being poor. The % EOT values calculated for sites LBSK-01 and TWLV-01 are typical for the Haliburton area. The % EOT values calculated for sites TWLV-02, TWLV-03, and TWLV-04 were atypical for the Haliburton area. The typical % EOT values range from 4.18% to 37.12%. Site LBSK-01 had a % EOT of 6.965% and the atypical % EOT values range from 2.62% to 4.18% and 37.12% to 54.41%. Site TWLV-01 had a % EOT of 5.341%. Site TWLV-02 had a % EOT of 4.168%. Site TWLV-03 had a % EOT of 4.020%. Site TWLV-04 had a % EOT of 3.704%. The %EOT distribution can be seen in Figure 4.

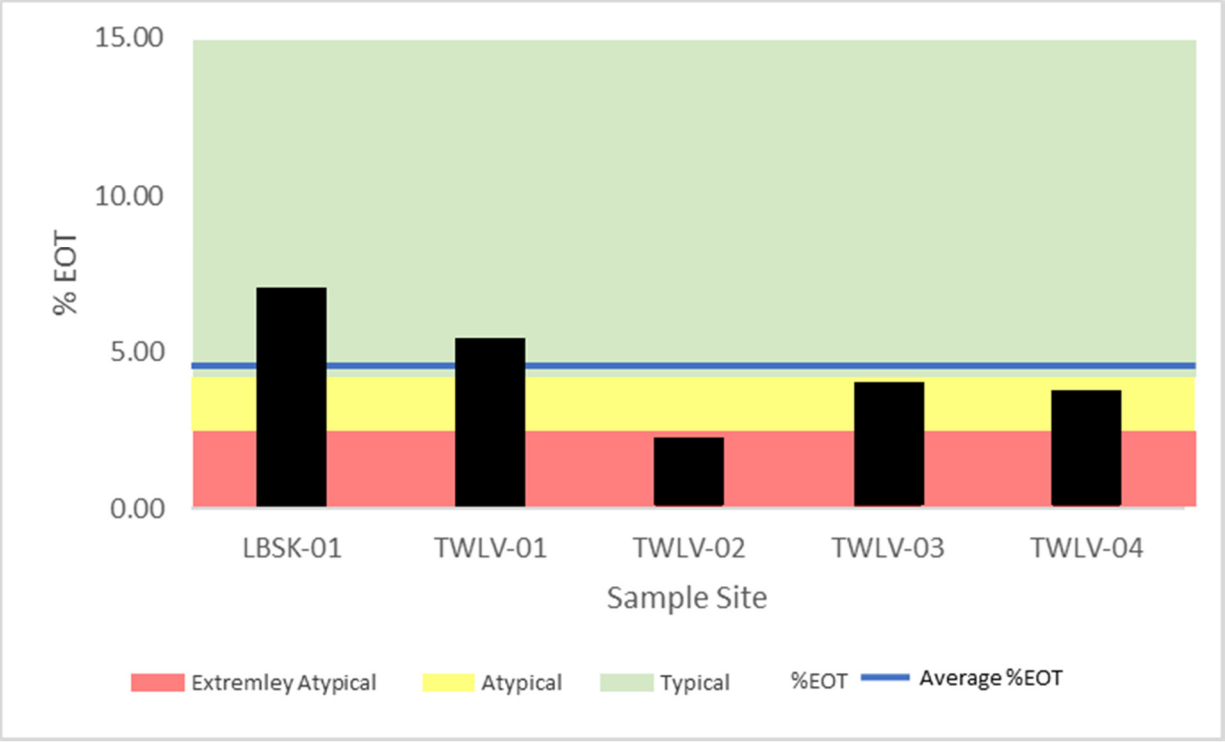

Figure 4. The %EOT calculated for each sample site in Little Boshkung and Twelve Mile Lakes in comparison to the typical, atypical, and extremely atypical ranges for the Haliburton area.

Simpson's Diversity Index

The Simpson's Diversity Index ranged from a rating of fair to good-fair across all sample sites (Table 3). Sites TWLV-01 and TWLV-02 had ratings of good-fair with indexes of 0.500 and 0.511 respectively. Sites LBSK-01, TWLV-03 and TWLV-04 had ratings of fair with indexes of 0.464, 0.301, and 0.488 respectively. The average Simpson's Diversity Index was 0.453. Sites LBSK-01 and TWLV-04 were the closest to the average index.

Table 3. The calculated Simpson's Diversity Index at all sample sites in Little Boshkung and Twelve Mile Lakes.

Lake	Little Boshkung Lake	Twelve Mile Lake				Average
Sample Site	LBSK-01	TWLV-01	TWLV-02	TWLV-03	TWLV-04	
Simpson's Diversity Index	0.464 (Fair)	0.500 (Good-Fair)	0.511 (Good-Fair)	0.301 (Fair)	0.488 (Fair)	0.453

% Amphipods vs % Insects

The % amphipods vs % insects for sites TWLV-03 and TWLV-04 are very similar with TWLV-03 having 18.44 amphipods for every insect and TWLV-04 having 18.25 amphipods for every insect. Both sites had the highest ratio of amphipods per insect. The second highest ratio is site TWLV-02 having 15.40 amphipods for every insect, followed by TWLV-01 having 10.81 amphipods for every insect. The lowest ratio is site LBSK-01 having 3.27 amphipods for every insect. The average ratio of amphipods to insects is 13.24 amphipods for every insect. This distribution can be seen in Figure 5.

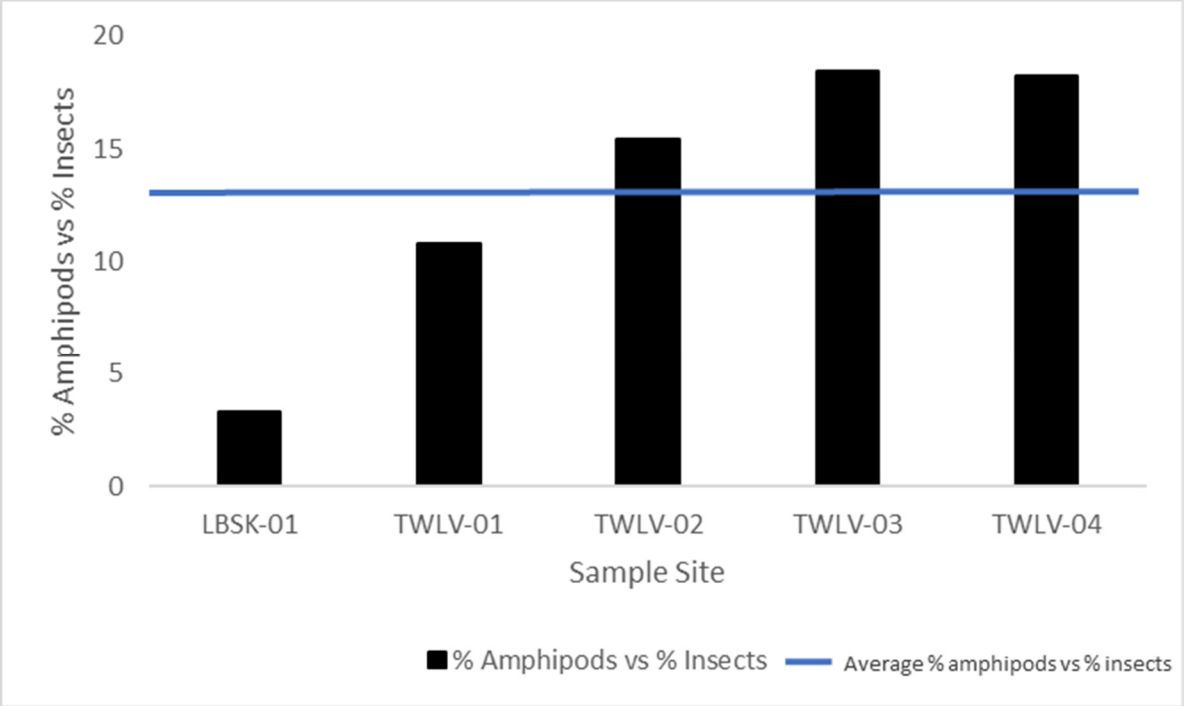

Figure 5. The ratio of amphipods present to insects present at each sample site at Little Boshkung and Twelve Mile Lakes.

Discussion

Water Chemistry and Vegetation

Of the five sites sampled, the temperature was all within 16.7 -17.2 degrees Celsius, indicating that the vegetation and chemistry have reason to be relatively the same amongst the different sites. The Twelve

Mile sites are all identical in having a riparian zone of forest cover for 30-100 m. In contrast, sites located on Little Boshkung Lake did not have a riparian buffer zone after the 10-meter mark following the sampling location. This aligns with the locations of the sample sites as the location of the lake is not heavily inhabited or populated with all-season roads other than Highway 35. When focusing on the chemistry of the water and its aquatic vegetation, there are some common trends between sites. The pH across the five sites was relatively the same, varying from 781-7.91. According to the Provincial Water Quality objective, this level is set to fall within acceptable standards for the health and productivity of an Ontario water system (MECP, 2016). Any pH range from 6.5-8.5 is acceptable. However, levels below seven are considered acidic waters, which may be too acidic for some vegetation, with a pH of 7 considered neutral, and levels above 7 are considered basic (MECP, 2016). With the range being within 7, the conditions at both lakes are normal. Thus, these results show that the potential hydrogen levels in the lakes are acceptable for their environment and not a possible threat to the biodiversity and composition of the lake.

Additionally, the conductivity across the sample sites studied aligns with the average conductivity from the 2016 Ministry of Environment, Conservation and Parks (MECP) study released in 2018, which had a value of 48.46 µs/cm and a specific value of 48 µs/cm in the spring and 50 µs/cm in the fall. Across the three sites, the conductivity ranged from 45.0-55.1 µs/cm. Conductivity relies on water temperature, with conductivity increasing as temperature increases. Therefore, comparing past years' data, the temperature increased in the 2022 data across sites. These results could explain why the conductivity varied. However, precipitation influences conductivity, with heavier precipitation decreasing conductivity.

Moreover, the conductivity of the water in Twelve Mile Lake is of no concern as this measurement fluctuates with different conditions of the environment. Other water chemistry characteristics include the lake water's dissolved oxygen (DO) content. The results of the sampling processes showed that the DO varied from 8.26 to 8.66 mg/L. The government of Ontario states that DO

levels must hit a minimum value of 6 mg/L to protect aquatic species (MECP, 2019). Twelve Mile and Little Boshkung exceed the minimum values. Therefore there is more than enough oxygen in the water to sustain aquatic life at the sites sampled.

The vegetation in Twelve Mile Lake shows little concern as it falls within acceptable and similar conditions when compared to past historical data and data at different sites that were not studied in this specific report. There was no presence of algae, free-floating and rooted floating macrophytes across all sites for this year's data, consistent with data from 2021 (Jamieson, 2022). This shows that no distinct change in the lake's health warrants the growth of unusual aquatic vegetation that was not present in the past. Other vegetation varied across sites, such as detritus sediment (build-up of decomposing vegetation suspended on the lake floor) and submergent and emergent vegetation. This is expected as different locations on shores contain different plant diversity depending on substrate type and other conditions such as sun profile. Overall, the vegetation and chemistry of the Twelve Mile Lake sampling sites do not show conditions that should be considered threatening or of any concern. These current conditions align with previously sampled data and thresholds outlined by the Ministry of the Environment.

Benthic Data Analysis

When looking at the results from the field and lab portions of this project, there are a few conclusions that can be drawn. The results show that the most dominant species found in Twelve Mile Lake/Little Boshkung Lake is Amphipoda followed by Isopoda (89% for TWML and 72% for LBSK). These two species are crustaceans among 14 other orders of species. These two species share the same family, being Malacostraca, which includes crabs, crayfish, lobsters and more. Other noticeable species that were found at the sites from Little Boshkung lake included those found within the Diptera family holding approximately 17% of the total species sampled. The more uncommon species included EOT, those of the Mollusca species and Worms. Twelve Mile Lake displayed other trends with the second highest species being EOT at 4%, and the remaining groups representing very low numbers at less than 3% for each. The low abundance of EOT,

Mollusca and Worms can be attributed to the conditions in the waters of the two lakes. Twelve Mile and Little Boshkung are slower moving lakes, being favourable habitat for species like Amphipoda and Isopoda.

%EOT

Using the results calculated from the total of Mayflies, Dragonflies, Damselflies, and Caddisflies compared to the total amount of species found at the sites, EOT values were calculated. The standard for all sites showed that EOT group populations were very low. However, for the conditions of the lakes, the low populations of EOT is not atypical. The dominant substrate type for each site varied between sand and silt with gravel/cobble being the second dominant mineral substrate. These types of substrate are not favourable for EOT taxonomic groups, as these habitats are not the most suitable for species succession. However, despite the low values of EOT for both lakes, given the substrate and conditions for each lake, the total number of EOT species warrants little concern. Naturally the conditions offered by the lake do not cater to optimal habitat, so since EOT is still being found in the lakes, the water quality still remains at a healthy level.

Simpson's Diversity Index

Simpsons' diversity index covers the overall diversity of benthic invertebrates at each sample site. The standard indicates that values summed to be closer to 1, then the diversity is undisturbed and healthy. After calculating the index, the sites indicate that the diversity sits at relatively poor to the fact that the average of all sites between both lakes is set at 0.453. This correlates to the sampling results as the majority of the species identified to be present in the lakes were of the Malacostraca family (Amphipoda and Isopoda). Therefore, the lakes show to have poor species diversity, highlighting that the competition may be leaning in favour of Malacostraca taxonomy.

% Amphipods vs % Insects

This index focuses on the ration of % Amphipods in relation to the % Insects of the sites. Beginning with The Little Boshkung site, the results show that there is a relatively low % of Amphipods per insect, with a value of 3.27% per insect. To contrast, the Twelve Mile Lake sites had results with significantly higher % Amphipods per insect. The average % of Amphipods sits at 13.24 Amphipods per Insect. This provides the potential explanation that the conditions of the lake are more favourable for Malacostraca species due to their high tolerance and not favourable for insects as their tolerance to variability tends to be lower (Jamieson, 2022).

Comparison with Literature

Benthic Data

The presence and abundance of benthic macroinvertebrates can be indicators of the overall health of the lake being assessed. Benthic macroinvertebrates are sensitive to the changes in water quality and pollution and each species group has a different tolerance level to the pollution. A decline in the abundance of the benthic macroinvertebrates that are expected or were previously found to be present in the lake, will indicate a decline in the health of the lake. Benthics are relatively easy to sample and identify leading to their use in this study.

A study done on an urban and an urbanizing area surrounding the basin of Lake Simcoe and Lake Ontario used benthic as bioindicators of the lake health (Bazinet et al., 2010). The water chemistry found around the two water basins varied based on the level of urbanization that led to more run off in more densely urbanized areas. The variation between the basin in Lake Simcoe and in Lake Ontario correlates to the level of urbanization in the areas. The benthic results found in the study conducted in Twelve Mile and Little Hawk Lakes can be used to determine the effects of the population from cottagers in the surrounding areas.

Water chemistry and vegetation:

The water chemistry variables outline that the pH, DO, conductivity and temperature all fall within acceptable ranges for lakes found within Ontario, according to the Ministry of the Environment and Parks, as discussed previously. The main concerns for this report were the decrease in fish stock and the relative overall health of the two lakes. Solely focusing on water chemistry and vegetation, the results show relatively healthy values for a lake in Haliburton County. However, the lake may be experiencing changes due to urban expansion as human populations surrounding the lakes increase slowly.

Urban expansion means developing land and structures to suit the desired needs. Therefore, anthropogenic activities and practices may be influencing the natural growth and functionality of the lakes. While the vegetation in both lakes was not revealed to be atypical for the conditions of the lakes, there are some possible explanations for the change in the lake composition in recent years and future years. In 2017, Fowler Construction took over the contract to perform routine winter maintenance on roads in Haliburton County, of which both Twelve Mile and Little Boshkung lakes fall (Fowler Construction, n.d). Highway 35 runs adjacent as well as through both lake systems. Therefore, road runoff can alter lake chemistry, such as pH and conductivity (Palmer et al., 2011). Routine winter maintenance often entails the use of ice-removing additives such as salt. As of July 22, 2020, K&S Windsor Salt Company agreed with the County of Haliburton to provide sodium chloride for winter road maintenance (County of Haliburton, 2020). The routine de-icing of roads can increase the lakes' overall conductivity during increased road runoff that carries sodium chloride into the lake system.

Road runoff and influxes of salinity can potentially diminish turnover events which can create hypolimnetic anoxic conditions (Dupis et al., 2018). These anoxic conditions can alter the conditions needed to establish diverse benthic invertebrates following winter seasons heavy with sodium chloride use, resulting in low species populations. Studies conducted on the seasonal mixing of sodium chloride found that during the fall and spring seasons, lakes often experience anoxic conditions and high levels of

methane (Dupis et al., 2018). Low oxygen concentrations and high methane concentrations make establishing benthic species complex and lake vegetation. At both lakes, the sites contained submerged vegetation. However, the abundance varied per site, with abundance in submerged macrophytes not occurring at every site. Studies conducted in Lake Erie found that spawning grounds that were once abundant with vegetation were slowly diminishing due to chemical inputs altering the water chemistry and creating harsher conditions for vegetation to reestablish (Miller et al., 2018). Concentrating on the recent increase in tourism and the year-round public in the area, road runoff can be responsible for the lack of vegetation within the lakes. The low presence of vegetation can be responsible for reducing the spawning habitat for fish species in the two lakes. The same study found increased suspended solids along the lake bottom, creating interrupted habitat for spawning and succession (Miller et al., 2018). Therefore, over the years, the fish stock has decreased due to a reduction in preferred spawning habitat (Miller et al., 2018). This phenomenon could occur in Little Boshkung Lake and Twelve Mile Lake as road runoff would alter the spring and fall water conditions which is prime timing for fish establishment.

Further explanation on the impacts of urbanization on the lakes can be explained by the presence of septic systems and their direct relationship with benthic macroinvertebrates and lake vegetation. Septic systems hold nutrient matter, which has the potential to be released into the environment in cases of poor management or lack of adequate treatment and inspection (Lapoint et al., 2017). These systems tend to leak nitrogen and phosphorus into the soils, which can migrate into water systems, increasing the total nutrient concentrations (Lapointe et al., 2017). As a result, a phenomenon known as eutrophication occurs when excessive algal blooms block sunlight penetration through the water. The lack of sunlight in an aquatic system reduces the total oxygen in the water, making it difficult for aquatic organisms with low tolerance to function (Herren et al., 2021). Additionally, vegetation with high sunlight requirements is put to compete with overachieving algal species, leading to a decrease in vegetation presence. Therefore, manufactured systems such as septic tanks should be further developed and investigated in the regions

surrounding the lakes to determine whether the lakes' low vegetation can be attributed to nutrient overloads in the water.

Overall, the lake's health meets the standards outlined by the Ministry of Environment, Conservation and Parks. However, as there is limited data available for past years as insight into water quality and benthic composition, it is difficult to grasp a complete understanding of the trends of the lake's health. While some explanations exist for the concerns expressed by the Twelve Mile and Little Boshkung Lake Association, more historical data is needed to make concrete conclusions. As a result, literature focused on lake systems exposed to road runoff and development, such as urbanization and septic systems, have shown links between these factors and water chemistry and vegetation. These factors have been shown to influence water quality through the increase in anoxic conditions following seasons of heightened salinity influx and increased methane concentrations due to low oxygen presence.

Additionally, the factors have been shown to decrease fish stock through the reduction of adequate spawning habitat, which, if recurring over the years, can explain the slight decrease in fish populations. Urban development approaches, such as septic systems, have been shown to influence nutrient overloads and be linked to vegetation loss. The loss of vegetation correlates with the decrease in fish stock through the loss of habitat for spawning and habits.

Overall, further research will aid in providing exact explanations for the fish stock decrease. For now, lake health is coherent with standards. Therefore, health has not decreased to the point of extreme concern. Thus, recommendations include mapping of spawning habitat for fish species to provide quantitative analysis of breeding success and inspection of urban systems such as roadways and their runoff, as well as septic systems and similar organic matter holding tanks.

Perceived State of the Lake

As this is TMLB Lake's second year of inclusion in the Benthic Biomonitoring Program in Haliburton County, some trends from the previous year can be analyzed. Compared to the sampling year of 2021-2022, this year's benthic composition resulted in a slight decrease in % EOT and a significant increase in % Malacostraca. However, further study and sampling of these lakes are required for conclusive results. To give an idea of trends with any certainty, five or more years of data are necessary. That said, from the findings presented in this study, TMLB Lakes appear in fair health.

Comments and Notes on the Sampling Process

The sampling process was done by a team of volunteers associated with U-Links in the fall . The samples were then sent to Trent University to be sorted in the winter. The OBBN protocols were followed during the entire sampling process. Given the samples were collected in the fall, some decomposition had taken place when the samples arrived at Trent University. Even though the samples had been preserved in antifreeze, decomposition occurred making some of the benthic macroinvertebrates unidentifiable.

Conclusion

A study of Twelve Mile and Little Boshkung Lakes' health was conducted by collecting and analyzing the presence and abundance of macroinvertebrates. This study aims to provide baseline information to decision makers with data they need to make meaningful changes to their lakes' health and contribute to the more extensive Benthic Biomonitoring Program in Haliburton County. Following the OBBN protocols, the benthic macroinvertebrates were collected at one Little Boshkung Lake sampling site and four Twelve Mile Lake sampling sites. The samples were then sorted and analyzed following the OBBN analysis protocols in a lab at Trent University and with U-Links in Haliburton. The results are inconclusive as this was only the second year of Little Boshkung and Twelve Milek Lakes being sampled. However, the TMLB Lakes appear to be in fair health. With further sampling and analysis, conclusive results and recommendations can be made on how the lake and cottage associations can maintain and improve the health of their lakes.

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Appendix/Appendices

Appendix A

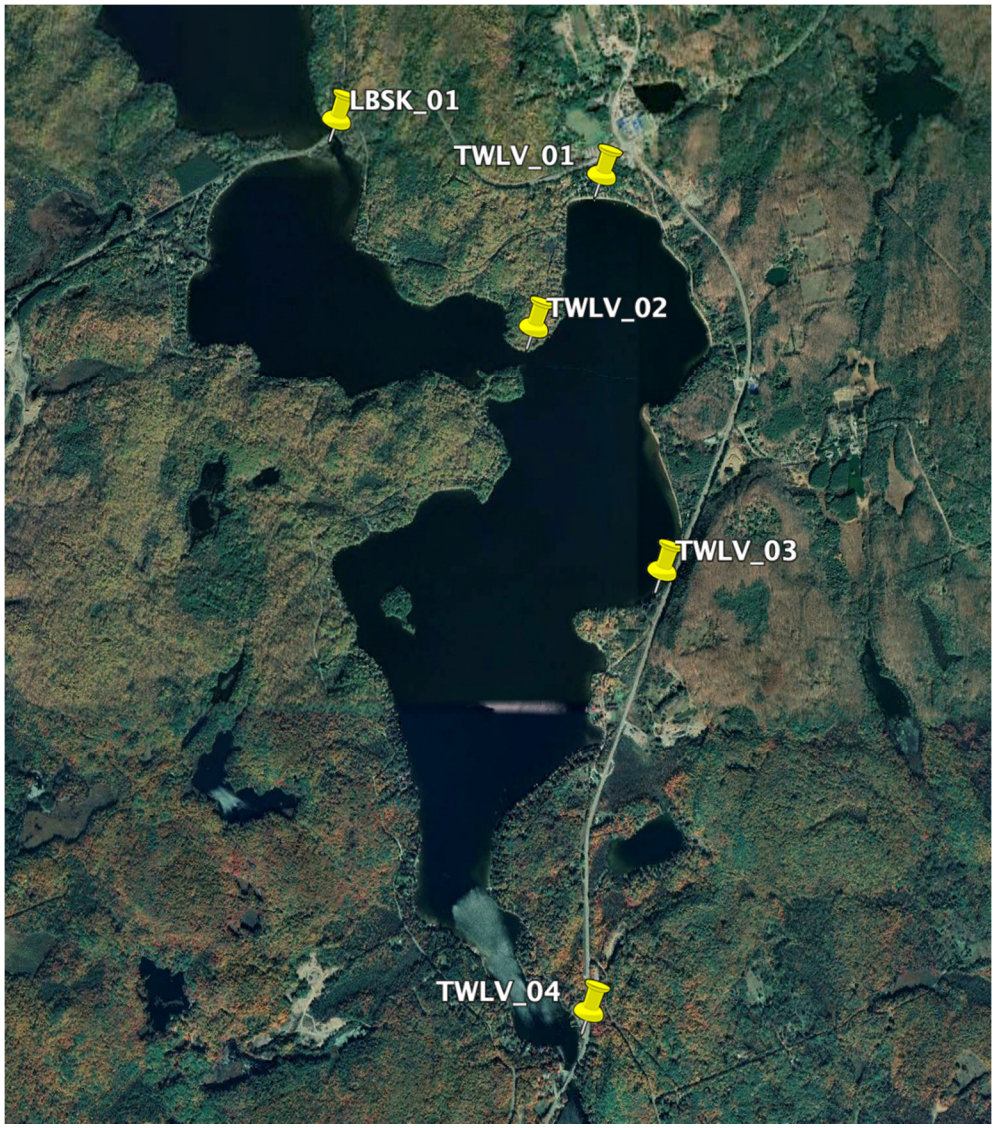

Figure 6. Map of all sampling sites on Twelve Mile and Little Boshkung Lakes.

Appendix B

Table 4. The raw data from samples collected from Little Boshkung and Twleve Mile Lakes. This data is the count of benthic macroinvertebrates found in each sample.

Lake	Little Boshkung		Twelve Mile								
Sample	LBSK-01		TWLV-01			TWLV-02		TWLV-03		TWLV-04	
Replicate	R1	R2	R1 1/2	R1 2/2	R2	R1	R2	R1	R2	R1	R2
Bivalvia (clams and mussels)	1							4	6	1	
Gastropoda (snails, limpets)	1	1		6		1					
Oligochaeta (aquatic earthworms)					3	5	4	1		1	
Hirudinea (leeches)		2	1		1	1					
Nematoda (roundworms)									1		
Hydrachnida (water mites)		1									
Amphipoda (scuds)	66	78	93	47	80	176	99	88	78	81	65
Isopoda (sow bug)			20	50	3	36	2			22	29
Ephemeroptera (mayflies)	3	3	4		6	1			2	1	2
Anisoptera (dragonflies)								2		2	
Zygoptera (damselflies)	1			1	2					2	1
Plecoptera (stoneflies)									6		
Hemiptera (true bugs)	1										
Megaloptera (fishflies, alderflies)								3	2		
Coleoptera (beetles)					2					4	4
Trichoptera (caddisflies)	5	2	2	1	4	4		1	3		
Lepidoptera (aquatic moths)		1				1					
Diptera (true flies)							1				
Chironomidae (midges)	21	9			3	3	3		1		
Ceratopogonidae (biting midges)	2	3						1			1
Simuliidae (blackflies)						1	1				
Replicate Totals	101	100	120	105	104	229	110	100	99	114	102
Site Totals	201		329			339		199		216	
Totals	1284										