Final Summary Report

An Assessment of Lake Scugog Nearshore Water Quality and Ecological Condition (2017-2019)

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Preamble

This report intentionally presents a high-level summary of findings related to the Ontario Trillium Fund Project's nearshore study. It was written to showcase results aimed at informing future lake management and stewardship activities. More detailed findings from this study will be presented in peer-reviewed journal publications that will be shared with the Scugog Lake Stewards upon publication.

Acknowledgements

This study, performed in partnership between the Scugog Lake Stewards, Kawartha Conservation, and Ontario Tech University, was funded by an Ontario Trillium Fund Grow Grant awarded to the Scugog Lake Stewards (2017-2019). The community science co-production model involved the triad of research partners where each partner had a distinct, but important role in the successful execution of this study. This study could not have come to fruition without the dedicated community scientists that volunteered to collect water samples from nearshore sites throughout the study period. Their efforts have allowed us to determine the key issues and drivers of Lake Scugog water quality, and for that, we are deeply grateful.

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Executive Summary

Lake Scugog is a large, shallow reservoir just outside the Greater Toronto Area that has been a popular recreation destination since the mid-19th century. However, it has increasingly become inundated with invasive species, periodic algal blooms, and aquatic weeds. To understand the cause and extent of these problems, the Scugog Lake Stewards in collaboration with Kawartha Conservation and Ontario Tech University, initiated a "citizen science" (now referred to as "community science") research project that aimed to monitor and examine nearshore water quality and ecological condition over three years (2017-2019). The purpose of this study was to examine the nearshore zone of Lake Scugog. The nearshore zone is an important component to the overall lake ecosystem as it provides fish spawning and nursery grounds, and habitat and food to many other lake organisms with its high plant and algae growth.

The nearshore zone was targeted not only because of its importance for fish spawning and nurseries, but also its immediate proximity to run-off from the adjacent landscape. The nearshore zone is also where people enjoy the lake, whether it is at a beach, swimming, or kayaking. It's also where the impacts from our activities on land are directly felt. Twelve sites around the lake were monitored, by trained community scientists, who collected biweekly water samples (n=253) and recorded observational data from late May to September. A total of 7 water quality parameters were examined, which included: total phosphorus, total nitrogen, chlorophyll *a*, *Escherichia coli*, total suspended solids, chloride and water temperature (Table 1).

In 2018-2019, additional field data (pH, dissolved oxygen, and conductivity) and biological samples were collected on a monthly basis (May-September), including: phytoplankton, periphyton, macroinvertebrates, and submerged aquatic plants (known as macrophytes) as part of a graduate research project (Table 2). The addition of the biological parameters aide in a better understanding of the site characterization and dynamics as the physical, chemical and biological components are interrelated. The chemical, physical, and biological parameters were examined in relation to site location and land use at the total drainage area scale and at the local scale (1 km) for each site. The following categories of land use were included: natural cover (forest, wetlands), urban developed, and agriculture (Figure 1). It is well known that agricultural and industrial land-use has negative impacts on lakes, however, this study wanted to determine how smaller-scale activities, near the shoreline, are impacting water quality as well (Arbuckle and Downing 2001, Jones et al. 2004, Fraterrigo and Downing 2008).

Table 1. Description of chemical and physical water quality parameters examined in this study.

Water Quality Indicator	**Common Land-use Source(s)**	**Significance**
Chloride (Cl)	De-icing road salt, dust suppressants, fertilizer	Indicates urban land-use, can be detrimental to certain aquatic species.
Conductivity	Erosion and release of mobile elements from the landscape (e.g., salts)	Represents total amount of dissolved ions in water; used to infer land-use activities, but hardwater lakes have naturally high conductivity due to local limestone source
Total Phosphorus (TP)	Manure, fertilizer, septic system, sewage inputs	High levels can result in excessive weed and algae growth.
Total Nitrogen (TN)	Manure, fertilizer, septic system, sewage inputs	An important nutrient for plant and algae growth.
Chlorophyll *a* (Chl *a*)	N/A	Represents the amount of algae growing in the water. High levels usually indicate high nutrient levels.
E. coli	Waterfowl, manure, septic systems	Indicator bacteria of fecal contamination and potentially harmful pathogens.
Total suspended solids (TSS)	Erosion from various land-use activities including agricultural and urban development	Sediment suspended in the water can make it difficult for fish to find their food; block light and reduce plant growth.
Water Temperature	Influenced by air temperature and stormwater run-off; run-off water warmer in urban areas	As water becomes warmer, it can limit the presence and growth of some plant and animal species, can be important for some fish life cycles (e.g. egg hatching), support blue green algae blooms.

Dominant land use in the Lake Scugog watershed is primarily composed of agricultural land-use (67%), followed by natural land cover (mostly wetlands and forests) (30%), while the remainder is composed of urban developed land-use. Although developed land-use makes up a small proportion of the total watershed land-use, it is highly concentrated along the shoreline. Overall, the results show that nearshore sites dominated by urban development at the local level (1-km buffer) have the most degraded water quality and ecological condition when compared to sites dominated by agricultural land-use or natural cover. In particular, developed sites had the highest chloride and phosphorus concentrations, and in some cases exceeded the Provincial Water Quality Objectives.

Table 2. Descriptions of the biological parameters studied.

Biological Parameter (Bioindicators)	Description	Significance
Phytoplankton	Usually microscopic-sized **floating** algae representing a diversity of species like blue-green algae, diatoms, and chlorophytes.	Interpretation of species that are present/absent and their abundance can be used to assess habitat condition and water quality status. When sensitive species are absent or weedy species are abundant, that usually indicates degraded water quality and habitat condition.
Periphyton	Usually microscopic-sized algae that grows **attached** to rocks, docks, plants. Like phytoplankton, can represent a diversity of species like blue-green algae, diatoms, and chlorophytes.	Interpretation of species that are present/absent and their abundance can be used to assess habitat condition and water quality status. When sensitive species are absent or weedy species are abundant, that usually indicates degraded water quality and habitat condition.
Macroinvertebrates	Macroscopic invertebrates (aquatic insects (bugs), crayfish, mollusks, etc).	Macroinvertebrates are valuable bioindicators due to their low motility relatively long lifespan spent in the same location. Different species have a range of tolerances to a variety of water quality parameters. Their diversity and abundance can indicate local habitat conditions.
Submerged Macrophytes	Macrophytes (aquatic plants and macroalgae) that grow mainly below the water surface.	Their abundance and community composition can indicate water quality conditions. Prevalence of weedy species usually indicates human disturbance and nutrient pollution.

When comparing levels of fecal coliforms in the nearshore zone, it was found that water samples collected after storm events had significantly higher coliform levels (Fig. 5). Higher intensity storms are expected to increase with climate change, thus suggesting that fecal pollution of the lake will only increase. With higher volumes of water flushing the landscape, more bacteria will be washed from the land into the water. This scenario is particularly exacerbated at developed sites with manicured lawns that attract Canada geese. Primary producers (phytoplankton, periphyton, aquatic plants) were generally highest at developed

sites, likely due to elevated nutrient levels. At the eight sites studied for biotic condition, developed sites continued to present as the most degraded, where all types of primary production (phytoplankton, periphyton, aquatic plants) had the highest biomass representing. This is likely due to the high levels of phosphorus measured at these sites. Generally, there was not a dominance of one type of primary producer at any given site, which can be the case in other systems (e.g., when phytoplankton biomass is low, aquatic plant biomass is high).
Macroinvertebrate diversity was lowest at sites with low aquatic vegetation and sites dominated by urban development. Pollution sensitive taxa were also in low abundance at developed sites, compared to sites dominated by agriculture or natural land-cover. The macroinvertebrate community findings illustrate the importance of nearshore habitat condition in maintaining lake biodiversity. The macroinvertebrate community was significantly more diverse at sites with high aquatic plant growth. Although aquatic plants are considered a nuisance in the nearshore to many Scugog residents, these results show that they are important in maintaining the ecological health of the lake. Macroinvertebrates play a key role in the aquatic food web, and with increased diversity, they can support the varied and specialized diets of predators, most of which are fish.

Based on the chemical water quality and bioindicator results of this study, the nearshore environment in Lake Scugog is not homogeneous or identically the same, but rather represents a spatial gradient from poor to good ecological condition. Future stewardship and mitigation activities should be focused at the most urbanized areas around the lake and the most developed shorelines to have the greatest positive impact to Lake Scugog’s health and sustainability. Continued stewardship efforts such as:

- Shoreline naturalization
- Good functioning septic systems
- Eliminating fertilizer/pesticide application
- Deterring the congregation of wild fowl (i.e. Canadian geese)
- Education and Outreach opportunities (Lake week, information sessions)
- Further studies in climate change impacts and additional environmental drivers
- Targeting 'hot spots' and
- Sharing knowledge (Indigenous Traditional and Western Science) will all aide in understanding and taking action to improve the health of Lake Scugog in the future.

Background

Lake Scugog is a large shallow reservoir (64 km^2) situated within a large watershed (529 km^2) that straddles the municipalities of the Region of Durham and City of Kawartha Lakes. Due to its close proximity to the Greater Toronto Area (GTA) and popularity with boaters and anglers, Lake Scugog is a key driver of regional tourism and economic growth. However, over the last decade, the health of Lake Scugog has been in noticeable decline. In recent years, there has been an increase in blue-green algae blooms, invasive species such as *Dreissena polymorpha* (zebra mussels), and an abundance of invasive aquatic vegetation known as macrophytes. To understand and address these issues, we must investigate the underlying causes, including sources and drivers of water quality and ecological degradation.

As part of a larger Ontario Trillium Fund project entitled: *Acquisition of community-based knowledge on walleye conservation in Lake Scugog*, the nearshore zone was targeted as a study focus because it reflected a major data and knowledge gap in understanding over-all lake health. The nearshore zone is the area of the lake with the greatest biological activity, it provides key habitat to everything from plants to macroinvertebrates, fish to waterfowl (Vadeboncoeur et al. 2011). The nearshore zone serves as spawning and nursery grounds for a large variety of fish species in the lake. The nearshore zone is also important for people, be it for swimming, fishing, or just relaxing. When there are water quality problems in the nearshore zone, such as high fecal bacteria numbers or blue-green algae blooms, they directly impact human activities, and potentially human health.

Another key consideration for focusing on the nearshore zone is that it is the first “frontline” area in a lake that receives run-off from the surrounding landscape. It is well known that agricultural and industrial land-use has negative impacts on lakes, however, we wanted to determine how smaller-scale activities, near the shoreline, affect water quality as well (Arbuckle and Downing 2001, Jones et al. 2004, Fraterrigo and Downing 2008). The Lake Scugog watershed (529km^2) is primarily composed of agricultural land-use (67%), followed by natural land cover (mostly wetlands and forests) (30%), while the remainder is composed of developed land-use (Fig. 1). Although developed land-use makes up a small proportion of the total watershed land-use, it is highly concentrated along the shoreline. The developed area of Port Perry hosts 43% of Scugog’s population and continues to expand. Therefore, it is vital to understand the potential impacts of such development on the health of the lake. In addition to the urban area of Port Perry, we also wanted to better understand how the activities in the exurban shoreline communities, such as Caesarea, Viewlake, and Washburn Island are impacting nearshore water quality and the biotic community.

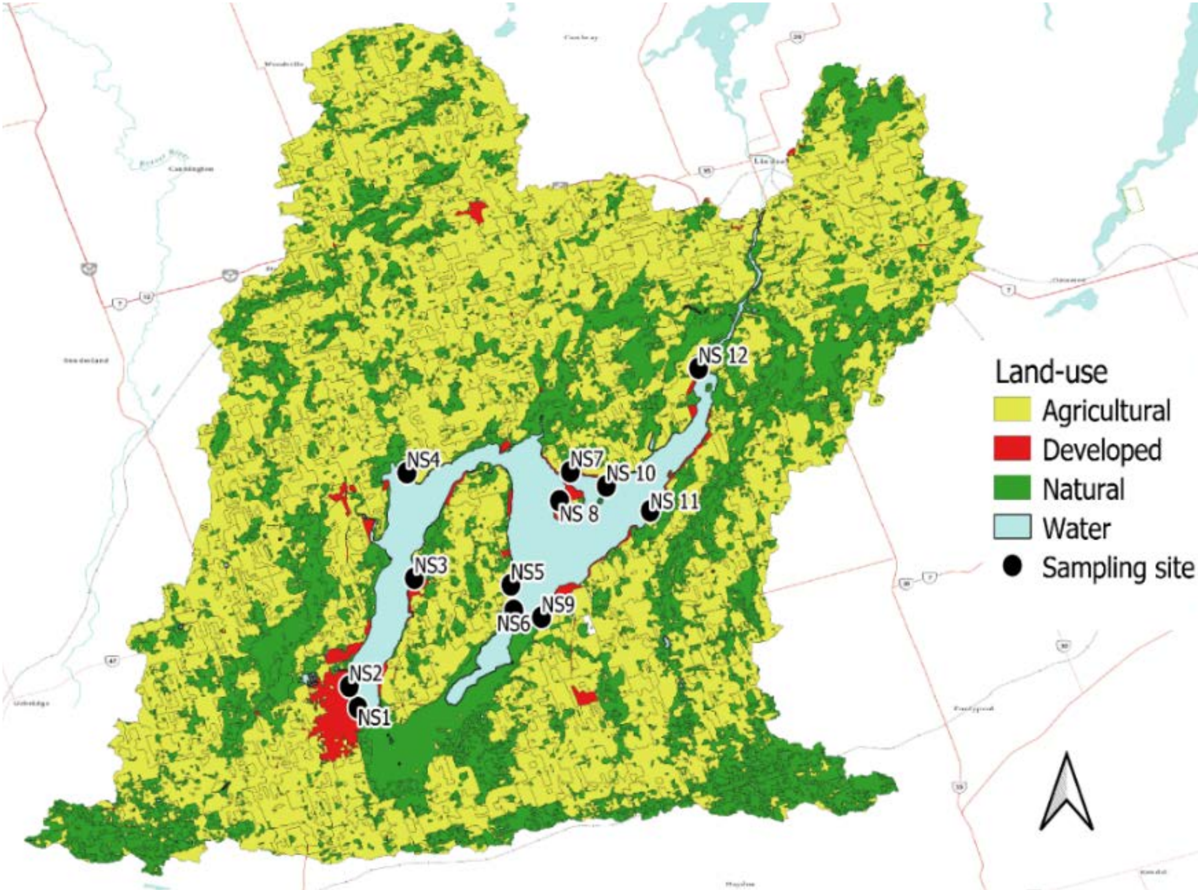

Figure 1. Map of Lake Scugog and its watershed, with land-use categorized as agricultural, developed, natural, or water. Black circles represent sampling locations.

Most of Lake Scugog's waterfront is highly developed, reflecting privately-owned shoreline. This presents difficulties with accessing the nearshore zone, as Lake Scugog is generally too shallow and weedy to access the nearshore by boat. Using a community science approach with a co- production model provided consistent access and standardized data collection in addition to value added local historical knowledge sharing. The community scientists, were integral to the nearshore study because they could easily and dependably access the nearshore from the shoreline and collect water samples and observational data. Community scientists were not just passive volunteers, but trained individuals in the scientific method and the study objectives. The community scientists played an important role as part of a larger research team within a research co-production model. The community science co-production model involved a triad of research partners including a university (Ontario Tech), watershed authority (Kawartha Conservation), and a volunteer-run stewardship group (Scugog Lake Stewards). Each partner had a distinct, but important role in the execution and delivery of the water quality monitoring program (Figure 2). Community science also allowed this project to have broad spatial coverage of the lake, without the need to hire additional lab personnel. In addition to benefitting the project, the community science method can have benefits for the volunteers, who can increase their scientific knowledge, change their environmental attitudes, and start to see themselves as Earth stewards (Brossard et al. 2005, Fernandez-Gimenez et al. 2008, Dickinson et al. 2010). Although there exists a perception that samples collected by lay people are not as accurate as those collected by professional technicians, studies have shown this is not the case, especially when volunteers have been trained, as they were in this study (Freitag et al. 2016, Scott and Frost 2017).

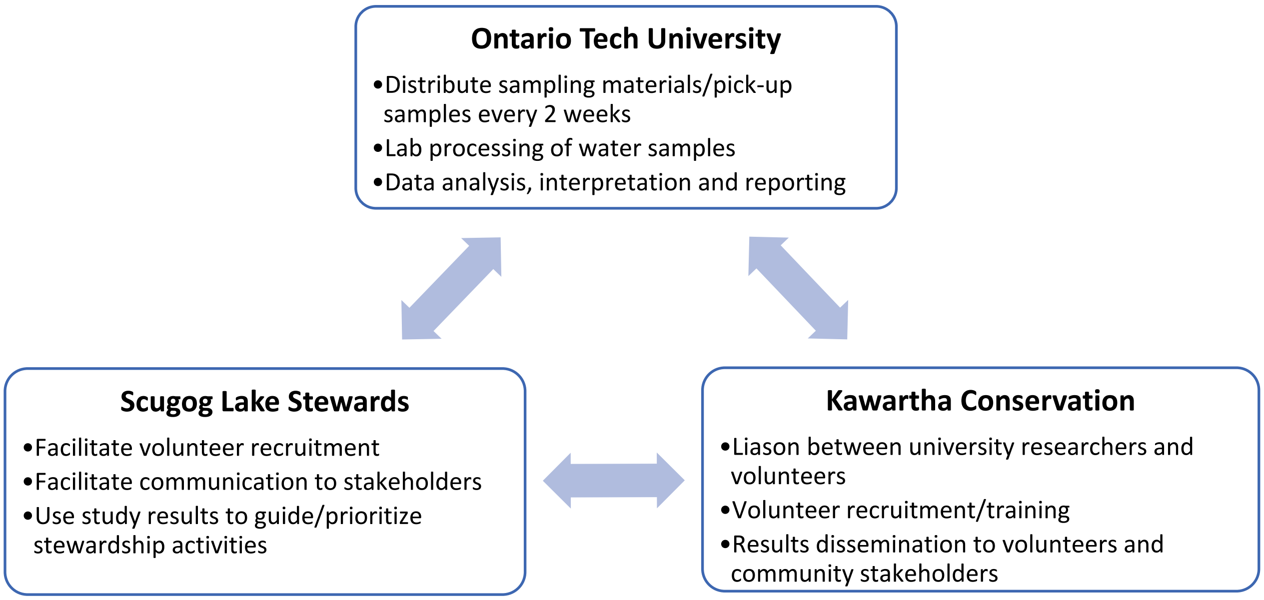

Figure 2. The community science co-production model involved a triad of research partners including a university (Ontario Tech), watershed authority (Kawartha Conservation), and a volunteer-run stewardship group (Scugog Lake Stewards). Each partner had a distinct, but important role in the execution and delivery of the water quality monitoring program.

In addition to collecting samples for water quality analysis from the community scientists, we were interested in surveying the biotic community to assess ecological condition in the nearshore zone. Specifically, the macroinvertebrate community, which are important not only due to their role in the aquatic food web, but they are also valuable bioindicators (Waters et al. 2005). Bioindicators are organisms that can provide information about the environmental conditions of an area based on their abundance and species composition. Macroinvertebrates are valuable bioindicators due to their low motility, relatively long lifespan, and range of tolerances to a variety of water quality parameters (Rawtani and Agrawal 2016). A select group of community scientists allowed access to their properties in 2018 and 2019 for the deployment of Hester-Dendy samplers at the end of their docks. Over a period of 3 weeks, local periphyton and macroinvertebrates colonized the Hester-Dendy samplers at each site. Having both water quality and biological data collected concurrently allowed for a more fulsome assessment of ecological condition in the nearshore zone of Lake Scugog.

Study Objectives

The purpose of this study was to:

1. Obtain baseline water quality data for the nearshore zone of Lake Scugog, and examine spatial and temporal patterns over three field seasons (May – September).
2. Assess the relationship between nearshore water quality and land-use in the watershed at local- and catchment-scales.
3. Document the nearshore macroinvertebrate community and evaluate the role of water quality and primary production (phytoplankton and periphyton) in community composition and abundance.

Study Approach

Community Scientist Recruitment and Training

The nearshore water quality monitoring program was advertised to residents in the Township of Scugog via Kawartha Conservation and Scugog Lake Stewards social media posts and through local committees including The Scugog Environmental Advisory Committee and the Healthy Lake Scugog Steering Committee. Upon completion of the recruitment period, 12 community scientist volunteers were available with four and eight volunteers, on the west and east sides of the lake, respectively. In the spring of 2017 training sessions were conducted individually at the volunteer’s dock, and included a briefing on the study, a background on Lake Scugog's water quality, the methodology used to collect the samples, and expected commitment. A sampling spot was selected based on a standardized depth of 1-m. Volunteers were provided with their first set sampling kit, which included two 1 L Nalgene™ bottles (water samples), one sterile specimen cup (water for *E.coli*), datasheets (observational data), disposable gloves, a cooler bag, an ice pack, and a thermometer. Full samples were left in a cooler bag with an ice pack in a designated pick up area on the community scientist's property and were exchanged for empty bottles on a bi weekly basis.

Community scientists received a courtesy reminder phone call/ email, 24 hours before each sampling event. Ongoing communication between the community scientists and research team was vital during the duration of the study, especially to relay anomalies, on the lake such, as possible blue green algal blooms. It also created additional opportunities for deeper engagement and promoted good volunteer retention. . At the end of each sampling season (3 years) volunteers received a preliminary report with results, a thank you, and plans to contact the volunteer the following year.

Water Sample Collection and Processing

Water samples and observational datasheets were collected between 08–09:00 h bi-weekly, from the end of May to early September. Samples were stored in a cooler bag with an ice pack and placed in a shaded spot in front of the volunteer's home for researchers to pick-up. During sample pick-up, two acid washed 1 L Nalgene™ bottles and one sterile specimen cup were left for the next sampling event. Once picked-up, samples were kept on ice and transported to the lab for processing. All processing was done within 24 h of collection. Water samples were processed for chloride, total suspended solids (TSS), total coliforms, *Escherichia coli*, chlorophyll a, total phosphorus (TP), total dissolved phosphorus (TDP), and nitrogen suite analyses. All water processing was performed at the Ontario Tech University lab, with the exception of the nitrogen suite analysis, which was performed by an accredited lab (SGS Canada, Lakefield, Ontario).

Frozen lake water samples were shipped to SGS for determination of ammonia/ammonium, nitrate/nitrite, and total Kjeldahl nitrogen. Total nitrogen was determined by summation of nitrogen species. Phosphorus and TSS were measured using standard protocols from the Standard Methods for the Examination of Water and Wastewater, American Water Works Association. Total coliforms and *E. coli* were measured using the high-throughput Coliplate™ system (Bluewater Sciences, Toronto, ON). The Coliplate method determines the "most probable number" of bacterial cells per 100 mL of lake water. It is similar to, though not directly comparable to, the "colony forming unit" (CFU/100 mL) approach, which requires growing coliforms on plated media.

Field Data and Biological Sample Collection

In addition to water samples collected by community scientists, we obtained permission to collect biological samples from eight of the twelve sites. At these sites in 2018 and 2019, monthly macroinvertebrate, phytoplankton, periphyton, aquatic plant, and water samples were collected, along with field measurements. Water samples were processed using the same methods as bi-weekly water samples, and field measurements included dissolved oxygen, specific conductivity, temperature, and pH. Macroinvertebrate samples were collected using Hester-Dendy artificial samplers.

The samplers were deployed for 3-week intervals and macroinvertebrate colonizers were preserved in 70% ethanol for identification under a dissecting microscope. Phytoplankton samples were collected from the water column on days when the Hester-Dendy samplers were deployed and collected. Phytoplankton samples were analyzed for chlorophyll *a*, a proxy measurement of algal biomass. Periphyton samples were collected from the Hester-Dendy samplers and analyzed for chlorophyll *a* as well. Chlorophyll *a* was extracted using 90% ethanol extraction and measured by spectrophotometer. Aquatic plants were dried and weighed for relative biomass determination.

Study Findings

Community Scientist Participation

Participation in the community science component of the project was consistently high from 2017-2019, with an average participation rate of 87%. There was even a significant increase in the participation rate from 2017 to 2019 (Fig. 3, $P < 0.05$). Community scientist participation compliance was key to the success of this project. The Scugog Lake Stewards were able to activate a committed, engaged volunteer base. Due to the strong connection between volunteers, their lake, and the lake-stewards organization, we had very high participation rates throughout the project. For comparison, many other community science projects have reported participation rates in the 20-30% range (Scott and Frost 2017).

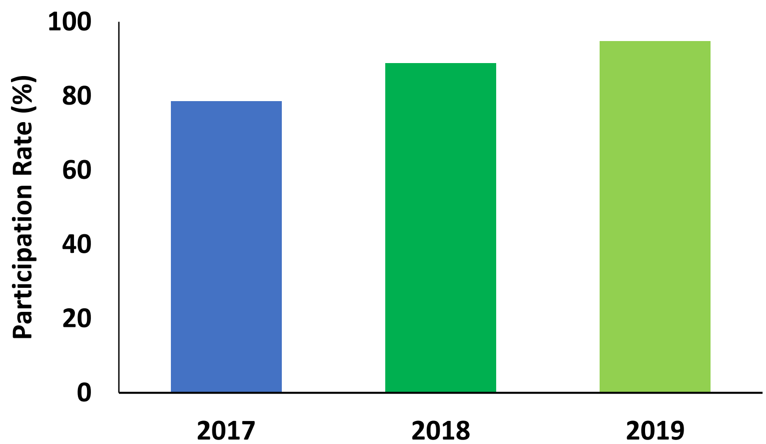

Figure 3. Average community scientist participation rate in each year of the study.

One of the keys to the success of this community science project was ongoing communication. Consistent and constant communication with volunteers, from training to final results dissemination was a key ingredient to the success of the volunteer retention. Volunteers were reminded of sampling dates in advance, provided results as soon as they were available, and contacted well in advance of sample collection each year to confirm availability. The importance of effective and consistent communication has previously been found to be essential to the success of community science projects, and cannot be underestimated in the future (Djenontin and Meadow 2018, San Llorente Capdevila et al. 2020).

Water Quality

Water samples collected by community scientists were aggregated into dominant land-use type to protect their spatial identity. Sites were classified based on dominant land-use within a 1 km radius of the sample site. When categorizing water quality data by site land-use class, notable patterns are evident (Table 3). All water quality parameters measured in the nearshore zone over the study period were highest at developed sites. In particular, developed land-use had notably higher concentrations of chloride and total phosphorus. A major source of chloride is road salt, and it is of concern because at high levels, it can be toxic to sensitive aquatic organisms and can shift aquatic communities to tolerant taxa (Elphick et al. 2011). Total phosphorus can be sourced from lawn and garden fertilizers, as well as leaky septic systems. It is the growth-limiting macronutrient for algae and aquatic plants, therefore at high levels, can support the proliferation weeds and algae blooms (Bachmann and Jones 1974). The connection between developed land-use and water quality variables at the local scale indicates the importance of reducing impervious surfaces requiring road salt application, as well as manicured lawns maintained with fertilizer. Sites in Port Perry were consistently high for both chloride and total phosphorus, and both sites had hardened shorelines. Small scale changes are having an impact on water quality in Lake Scugog, starting at the nearshore zone.

Table 3. Water quality parameters averaged over three years for each land-use category. Land-use category is based on dominant land-use within a 1 km radius of the sample site. The standard deviation (SD) for each value is indicated below. MPN = Most Probable Number. PWQO = Provincial Water Quality Objective.

	DEVELOPED	**AGRICULTURE**	**NATURAL**
TP (µg/L) PWQO – 20 µg/L	37.56 (19.66)	25.96 (16.72)	25.63 (10.62)
Chl a (mg/L)	13.56 (14.75)	10.00 (14.75)	8.69 (5.24)
TN (mg/L)	0.63 (0.37)	0.66 (0.18)	0.52 (0.18)
Total Coliforms (MPN/100 mL)	63.98 (114.07)	51.27 (78.61)	56.93 (56.16)
E. Coli (MPN/100 mL)	33.61 (84.54)	21.46 (49.96)	26.31 (23.68)
TSS (g/L)	0.061 (0.408)	0.011 (0.177)	0.010 (0.56)
Chloride (mg/L) PWQO – 120 mg/L (Chronic 28-Day)	61.25 (52.32)	10.26 (35.42)	10.03 (18.44)

Seasonal Precipitation

Precipitation varied by year and season, generally peaking in May, with a decrease throughout the season, except for 2018, which saw a peak in precipitation in August (Fig. 4). High volumes of precipitation increase surface-runoff, which can carry sediments and other contaminants into receiving waters. Due to the higher percentage of impervious surfaces, stormwater run-off in urban areas can flow across the landscape more quickly and forcefully. This is one reason why water quality is more degraded at developed sites than other sites in the lake.

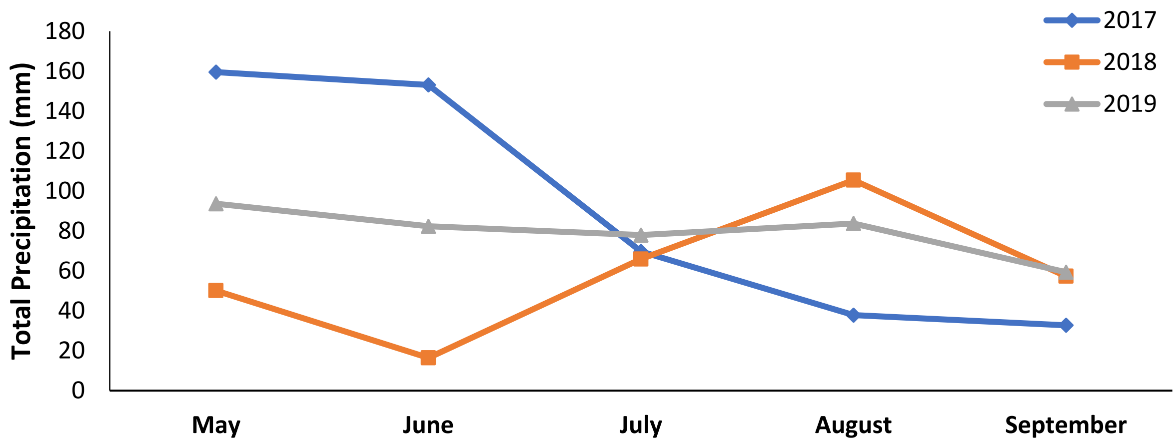

Figure 4. Total seasonal precipitation for each year of study from 2017-2019.

Storm events (> 15 mm precipitation / 24 h) were counted in each two-week interval between sampling events, and samples were classified as either following a storm event within 24 hours or not. When comparing levels of fecal coliforms in the nearshore zone, it was found that water samples collected after storm events had significantly higher coliform levels (Fig. 5). These seasonal trends indicate that climate change will have negative impacts on the health of the lake. The number of storm events in the area is expected to increase with climate change. With higher volumes of water flushing the landscape, more bacteria will be washed from the land into the water. This scenario is particularly exacerbated at developed sites with manicured lawns that attract Canada geese.

Sites dominated by development also have higher septic-system density, which poses another source pathway for coliform bacteria. Although the *E. coli* levels are not a major concern for the lake based on current water quality guidelines, they may continue to increase with climate change and shoreline development. Water temperature was also monitored throughout the three-year study period and monthly averages are presented in Figure 6. Water temperature followed seasonal trends as expected, peaking in late summer each year. There were 22 reports of water temperatures being 25˚C or higher. High water temperatures that are already occurring in the late summer favour the growth of blue-green algae. If summer temperatures continue to increase, the occurrence of blue-green algae blooms is expected to increase as well.

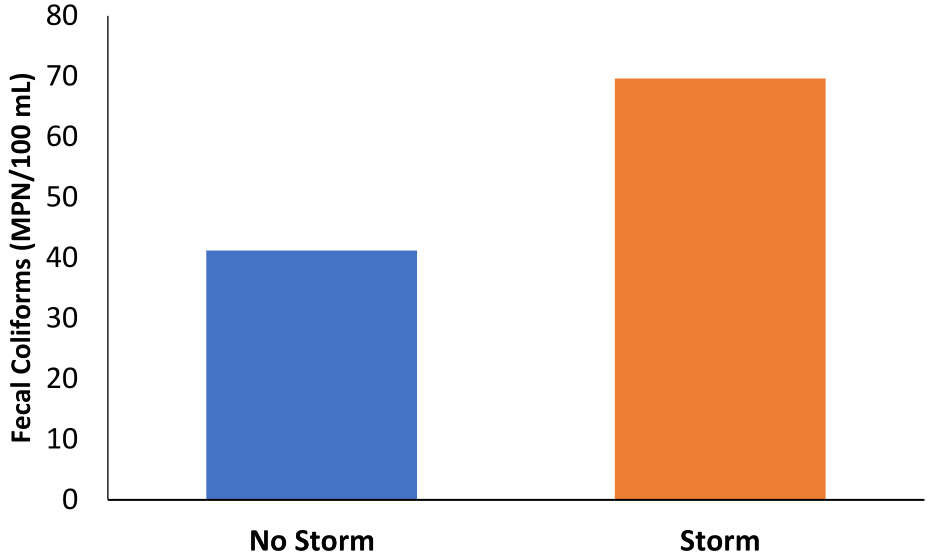

Figure 5. Average fecal coliforms in water samples from all sites without a storm event occurring > 3-days (no storm) compared to following a major storm event (> 15 mm) within 24 hours.

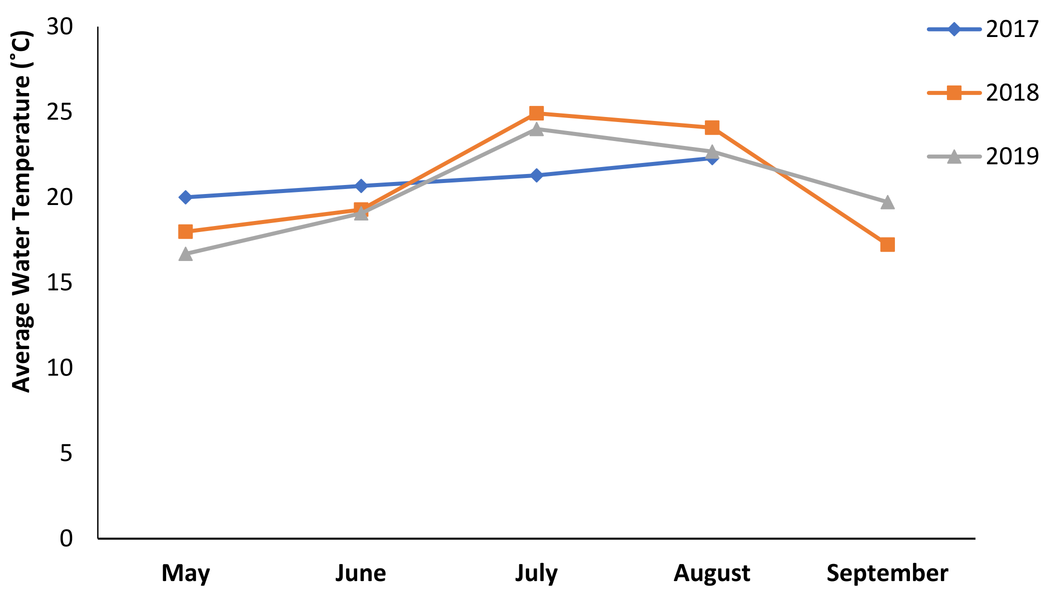

Figure 6. Seasonal water temperature from 2017-2019, each month averaged across 12 sites.

Algae and Aquatic Plants

At the eight sites studied for biotic condition, developed sites continued to present as the most degraded, where all types of primary production (phytoplankton, periphyton, aquatic plants) had the highest biomass representing eutrophic status. This is likely due to the high levels of phosphorus measured at these sites. We generally did not see the dominance of one type of primary producer at any given site, which can be the case in other systems (e.g., when phytoplankton biomass is low, aquatic plant biomass is high).

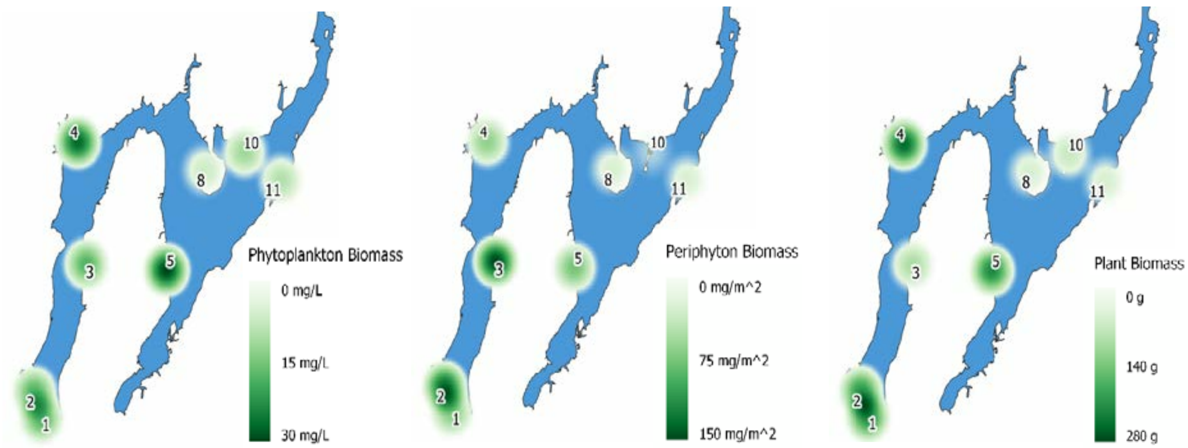

Figure 7. Heatmap visualization of average primary producer (phytoplankton, periphyton, aquatic plants) biomass at eight sites (2018-2019).

Macroinvertebrate Community

The macroinvertebrate community findings illustrate the importance of nearshore habitat condition in maintaining lake biodiversity. The macroinvertebrate community was significantly more diverse at sites with high aquatic plant growth (Fig. 8, Student's t-test $P < 0.001$). Although aquatic plants are considered a nuisance in the nearshore to many Scugog residents, they are important in maintaining the ecological health of the lake. Macroinvertebrates play a key role in the aquatic food web, and with increased diversity, they can support the varied and specialized diets of predators, most of which are fish. In addition to the role of aquatic plants in increasing macroinvertebrate diversity, another key consideration is the types of macroinvertebrate taxa present at each site. Large-bodied nymph larvae such as mayflies (Ephemeroptera), Stoneflies (Plecoptera), and Caddisflies (Trichoptera) are not only important fish food, but their sensitivity to pollution and habitat degradation make them ideal bioindicators.

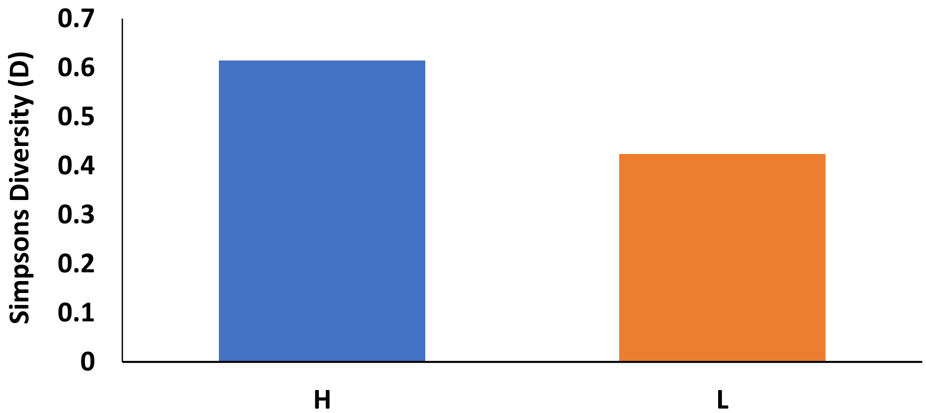

Figure 9. Average macroinvertebrate diversity (D) at sites classified as high (H) or low (L) aquatic plant abundance.

The percentage of Ephemeroptera, Plecoptera, and Trichoptera (EPT) taxa was calculated for each site over the 2-year study period (2018-2019). EPT taxa are generally more sensitive to water quality conditions, and thus tend to be found in higher abundance in less degraded environments. EPT was compared to dominant land-use in the 1-km radius, and it was found that EPT was significantly lower at developed sites compared to agricultural sites (Fig. 9, ANOVA $P < 0.05$). These results not only highlight the degraded status of developed sites, but they also show how run-off from agricultural lands may be supporting higher relative abundance of EPT taxa compared with natural sites.

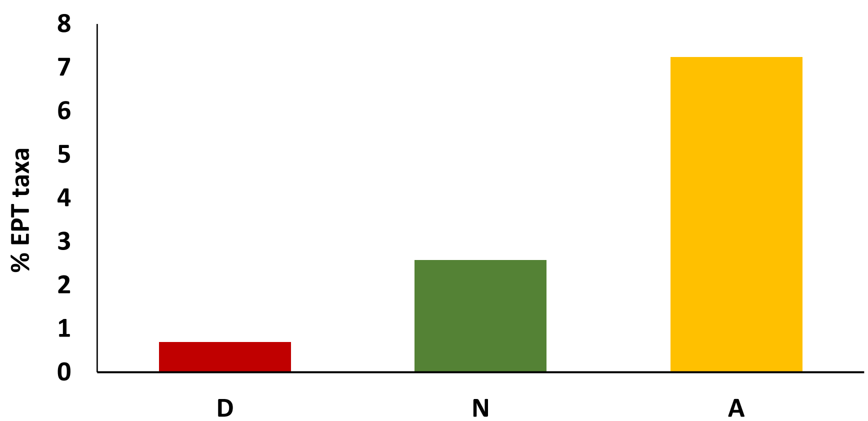

Figure 9. Average % EPT taxa for each dominant land-use type, where D = Developed, N = Natural, and A = Agriculture.

Study Conclusions

The findings of this study provide valuable information to inform the future management and stewardship of Lake Scugog. Capturing detailed water quality and biotic integrity data in the nearshore zone provides direct evidence of the state of nearshore habitats, and the influence of local land-use. The study's success was in no small part due to community scientist volunteers, who largely participated at high rates of compliance. Not only did their efforts ensure high quality data collection, but they also learned about the value of the nearshore zone in their beloved lake, and the importance of understanding the factors that influence water quality, biodiversity, and overall lake health. It is important to reiterate that the keys to the success of this community science project were effective communication and a structured sampling program. In the future, any community science projects implemented on the lake should have specific goals, continuous engagement, and a set program structure to ensure consistent volunteer participation.

Results of both the water quality and biological sampling over the course of the study clearly show the impact of local land-use in the nearshore zone. Nutrients, sediments, coliforms, chloride levels are all highest at the most developed sites. Urban development, especially near the shoreline, is the likely source of nutrients and contaminants. Developed land, particularly concentrated in the Port Perry area, is having the most severe impact on water quality and ecosystem health. This also does not bode well for future climate scenarios, where increased frequency and magnitude of storm events will drive pollutants at a higher rate into the lake. Also, elevated late summer water temperatures are conducive to supporting blue-green algae blooms; a phenomenon already witnessed in other Ontario lakes.

Without immediate mitigation measures to reduce urban runoff to the lake, Lake Scugog's health and economic value to the region will only decline. The results presented in this report also show that Lake Scugog is not a homogeneous ecosystem, but rather a lake with areas representing high and low ecological integrity. By targeting water quality hotspots (like Port Perry) for mitigation, limited resources can be targeted at sites with the biggest return on investment. Lake Scugog will always be faced with environmental stressors and challenges, but with tangible stewardship activities such as stormwater diversion and treatment, naturalization of shorelines, reduced use of fertilizers and road salt, there is reason to be hopeful for the future state of the lake.

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