School of Environmental & Natural Resource Sciences
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Attention:
Bill Napier,
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24 Charles Court,
Lakefield, ON K0L 2H0

Sara Kelly,
Faculty, Sir Sandford Fleming College
200 Albert St. S
P.O. Box 8000
Lindsay, ON K9V 5E6

Subject:

Submittal of Report on the Status of Dissolved Oxygen Levels in Pigeon, Lovesick, and Stony Lakes.

Greetings,

The following deliverables were completed in response to your request on September 10th, 2018.

Completion of the deliverables was a collaboration between a team of students from the Ecosystem Management Technology program at Fleming College and the Kawartha Lake Stewards Association.

The goal was to complete a 12-15-page report on the current DO levels, TP concentration, and benthic communities in Pigeon Lake, Lovesick Lake, and Stony Lake. The report includes an introduction providing the context for the report, a section regarding data collection methods, and a section for interpretation of the data and recommendations for future projects. This report is handed to the KLSA as a PDF and MS Word document on the USB provided, as well as a hard copy.

Background Information:
Peer literature reviews providing summative information on dissolved oxygen, temperature in lake systems, total phosphorus, benthic communities, and implications for lake ecosystems are provided to KLSA as a PDF and MS Word document.

Past studies:

Overview of past studies and current efforts to monitor DO and TP in the Kawartha Lakes are provided to KLSA as a PDF and MS Word document

Graphics:
Maps of study locations and DO levels throughout the profile of each lake and graphs depicting the DO and TP at each site are included in the report

Future Projects:
Recommendations for future studies based on data analyzed are provided to KLSA as a PDF and MS Word document

Presentation:
An introductory presentation about the project to the members of the KLSA took place October 13th, followed by a meeting sharing the results at the KLSA annual board meeting on November 26, 2018.

Included is the final product as outlined by the Kawartha Lake Stewards Association, which comprises of a report including: the dissolved oxygen and total phosphorous results, as well as recommendations for future projects. These deliverables may be used by the host organization in whole or in part for current and future purposes.

Thank you for the opportunities provided as part of this project. The professional development acquired and experience gained will be beneficial thought the duration of our careers in the environmental sector. If you have any questions or need further clarification, please do not hesitate to contact us.

Sincerely,

C. Hill C. Houston M. Van Meer C. Vieau

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Chris.Vieau@flemingcollege.ca

2018

REPORT ON THE STATUS OF DISSOLVED OXYGEN LEVELS IN PIGEON, LOVESICK, AND STONY LAKES

C. Hill, C. Houston, M. Van Meer, C. Vieau
Team STRIVE,
Kawartha Lake Stewards Association
27/11/18

Executive Summary:

The purpose of this report was to analyze the dissolved oxygen in Pigeon Lake, Lovesick Lake, and Stony Lake to identify anoxic conditions if they are occurring. pH, conductivity, and dissolved oxygen measurements were taken at 1 meter intervals from the surface to the bottom of the lake using a YSI multimeter. Total Phosphorus (TP) was determined from water samples taken one meter below the surface of the lake and one meter above the bottom using a Van Dorn, the water samples collected analyzed by the CAWT lab. A GPS was used to record sampling sites, chosen based on past projects and data available with the Kawartha Lake Stewards Association (KLSA). A Secchi disk was used to determine photic zone, while Total Phosphorus, and macroinvertebrate community indices were used to indicate the water quality and trophic state of each lake. The benthic community was sampled using an Ekman Dredge sample at each site. Key findings for Pigeon Lake include that both sample sites, PL4 and PL5 were in the range of acceptable dissolved oxygen range. PL4 ranged from F10.94-6.07 mg/L, while PL5 ranged from 11.75-6.58 mg/L. The bottom layers of the lake display low dissolved oxygen concentration, possibly a result of a lack of lake mixing. For Lovesick Lake, dissolved oxygen for both sites LS1 and LS2 are within range of acceptable dissolved oxygen measurements. LS1 ranged from 8.75 mg/L- 8.44 mg/L, while LS2 ranged from 9.27-10.23 mg/L. Stony Lake had the most consistent dissolved oxygen levels, at sites SL1, SL2, SL3. SL1 ranged from 8.88 mg/L -8.79 mg/L, while SL2 ranged from 8.69-8.03 mg/L, and SL3 ranged from 9.53-9.01 mg/L, well within the expected range. Based on past data, expected values, and the data collected, TP measurements as well as Secchi disk values indicate that the trophic level of all three lakes is meso-eutrophic or mesotrophic. pH and conductivity values were similar to expected values for lakes in this area. Further recommendations following the conclusion of this study include consistent collection of macroinvertebrates in the littoral zone with the use of Ontario Benthos Biomonitoring Network to adequately conclude communities present as an indicator for water quality. Errors found in this study may be the result of errors throughout data collection. Study sites were chosen based on past monitoring completed by the KLSA. The specific sites studied this year were based on locations sampled last year to compare result. However, lake conditions, specifically temperature, during data collection should be consistent to prior years to ensure that data is comparable. Lastly, data sampling should occur throughout the year to determine if anoxic conditions occur in the lakes studied. The threat of anoxic conditions are most eminent during winter months, when the lakes cannot mix due to ice coverage and when biological oxygen demand is high due to primary consumers working to decompose dead organic matter.

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Acknowledgements:

Team STRIVE wishes to acknowledge the support and mentorship provided Colleen Dempster, representing the Kawartha Lake Stewards Association.

We would also like to acknowledge Debbie Balika and Brett Tregunno from Kawartha Conservation for providing equipment, professional training, and devoting time to join us on our sampling campaign.

Thank you to Sara Kelly, Barbra Elliot, and Dr. Eric Sager for support with report writing and data analysis. We would also like acknowledge Jason Kerr for the facilitation of equipment.

Special thank you to Bill Napier, the chair of the Kawartha Lake Stewards Association, for his continual support, positive attitude, patience, and humour during our data collection. We couldn’t have worked the Ekman Dredge without you. This thank you extends to Lois Napier for welcoming us into your home.

1.0 Introduction

The Kawartha Lakes are a series of interconnected lakes located in Central Ontario, a part of the Trent-Severn Waterway (TSW). According to the City of Kawartha Lakes' Tourism Profile (2008), boating and fishing were ranked two of the top three activities of participation while visiting the Kawartha Lakes area. A 2005 survey of recreational fishing in Ontario (Ministry of Natural Resources, 2009) indicates that the Kawartha Lakes provide one of the largest recreational fisheries in Ontario in terms of number of days fished (Kawartha Conservation, 2016). The Kawartha Lakes have attracted significant numbers of anglers for years, because of their highly desired fish stocks (walleye, for example), and high natural productivity of the lakes. In Fisheries Management Zone 17, which includes the Kawartha Lakes region and cold water streams along Lake Ontario, it is estimated that the direct and indirect expenditures related to fishing totaled around $114 million for the year of 2005 (as cited in Kawartha Conservation, 2016).

Dissolved oxygen (DO) is an inert gas that is important for aquatic species respiration. Dissolved oxygen levels that are too high or too low can harm aquatic life and affect water quality. Dissolved oxygen is used for respiration in living organisms and microbes use dissolved oxygen for the breakdown of organic material. Eutrophication and large algal blooms can throw off the equilibrium of the lake causing dissolved oxygen levels to drop. Algae and microbes consume dissolved oxygen while breaking down algae. Large algal blooms or invasive macrophytes may therefore use large quantities of dissolved oxygen and degrade the ecosystem (Fondriest Env. Inc., 2013). Mathematical models have been created to determine the relationship between aquatic species, environmental factors, anthropogenic factors, and dissolved oxygen (Bulag and Venturino, 2017). The general dissolved oxygen results indicate that a balance is needed between TP, pH, and conductivity. Large quantities of these components can cause imbalances in these systems and can cause dissolved oxygens levels to decrease substantially. It is important therefore to strategically incorporate preventive measures to protect lakes from reaching low dissolved oxygen levels. Mean DO levels should remain near 7.5 mg/L for optimum growth and survival (EPA, 1999)l. Importantly to anglers, sensitive freshwater fish such as salmon cannot reproduce at levels below 6 mg/L (Carter, 2005). A DO level of 2 mg/L level or less is where fatalities in fish and other aquatic life will start to occur (Fondriest Env. Inc., 2013). See Appendix B15 to show potential effects at various Dissolved Oxygen concentrations.

Another indicator of lake quality is Total Phosphorus (TP).Phosphorus is considered as the primary limiting nutrient in freshwater systems (RMB Environmental Laboratories, 2018). Macrophyte biomass is heavily dependent on the amount of phosphorus present in lake ecosystems. Large inputs are deposited as a consequence of human development. Sewage treatment, erosion of soil, or agricultural runoff may contribute significantly to this amount in freshwater systems (RMB Environmental Laboratories, 2018).

Total phosphorus value incorporates the measurement of soluble reactive phosphorus (SRP), which is utilized directly by vegetation, in addition to phosphorus loaded into the system (RMB Environmental Laboratories, 2018). The biodiversity of freshwater lake ecosystems is impacted by the total phosphorus. Therefore, TP can be used as an indicator of the resilience of aquatic systems in the context of eutrophication, to determine harmful algal species dynamics, and to analyze point sources of phosphorus loading. As TP indicates how much phosphorus is in a lake ecosystem, the measurement can be used to predict a variety of factors, such as the over productivity of a system and therefore the trophic status of the lake being studied. The calculation of TP in freshwater lakes can aid in the determination of point sources of phosphorus loading in a system, and as a result is an important component of restoration in over productive systems. High levels of TP are linked to eutrophication, resulting in low Lake DO levels.

In the Kawartha Lakes continuum, there is an extensive history of DO studies that have been carried out. Many stakeholders have conducted these studies, namely Kawartha Conservation (KC), and the Kawartha Lake Stewards Association (KLSA). Kawartha Conservation has completed Lake Management Plans for many of the Kawartha Lakes, over numerous years. These include, but are not limited to, the Pigeon Lake Management Plan - DRAFT 2018, Pigeon Lake Watershed Characterization Report (2018), and Lake Scugog Environmental Management Plan. Dissolved oxygen values collected in the field by KC were used in the creation of these documents, and many discuss the threat of eutrophication of the lake through excessive nutrient and sediment inputs (Pigeon Lake Management Plan, 2018). The Kawartha Lake Stewards Association was founded in 2000, and has been producing reports annually from the time of its establishment. In terms of dissolved oxygen, the KLSA has conducted studies on the population of Eurasian watermilfoil in the spring of 2011 with the help of Fleming College Credit for Product students. This project examined excessive amounts of Eurasian watermilfoil, and how they “can reduce oxygen exchange and deplete the level of available dissolved oxygen in the water needed for a healthy lake” (Kawartha Lake Stewards Association, 2011). Furthermore, they have worked in partnership with Queens University to conduct paleolimnological data in the lakes, and also with Trent University and have conducted water quality testing since its inception, most recently with Dr. Eric Sager in the summer of 2018.

Historically, the Ontario Ministry of the Environment (MOE) has also played a role in studying DO in the Kawartha Lakes. In 1972, a Report on Water Quality in Lake Scugog was conducted. MOE revealed in this study that dissolved oxygen concentrations were uniform throughout the lakes depth. There were no serious oxygen depletions observed during any of their sampling campaigns. From 1990-1998, the Ministry also completed a report titled ‘Phosphorus Loading to Lake Simcoe, 1990-1998: Highlights and Preliminary Interpretation in Historical and Ecosystem Concepts’. In the context of dissolved oxygen, the report touches on the impacts that elevated TP levels have on DO. The report details that 2-3 centuries ago, the end-of-summer dissolved oxygen concentration was approximately 8 mg/L. This value is representative of deep, natural lakes removed from human disturbance with a significant cold-water fish population. When the report was written, DO levels had fallen to only 3 mg/L, as a result of TP levels increasing 3-fold. In more recent years, the Ministry carried out a *Water Quality in Ontario* Report, looking at Lake Simcoe as their study lake. From 1990-2008, the total P input was reduced below a target of 75 tonnes per year, and subsequently dissolved oxygen levels rose to 5 mg/L in the deep waters of the lake at the end of summer.

Independent studies have been carried out as well, by groups of ecologists, biologists, Masters Students, and other stakeholders. Some of these include studies of the Brook silverside populations in the Kawartha Lakes from 1996-2004, distribution and biotypes of

Eurasian watermilfoil in the Kawartha Lakes, and examinations of dissolved organic matter quality and effects on trace metal biogeochemistry. Although not all directly related to dissolved oxygen, these studies give more context to the health of the lakes, environmental stressors, and other variables that impact dissolved oxygen.

This study, Report on the Status of Dissolved Oxygen Levels in Pigeon, Lovesick, and Stony Lakes (2018), was conducted in association with the KLSA the Kawartha Conservation Authority and Fleming College, by Fleming College students. The research is concerned primarily with dissolved oxygen and water quality in the Kawartha Lakes system. 3 lakes; Lovesick, Stony, and Pigeon, were sampled between September and October of 2018. The data acquired in this study are compared with historical data and reputable literature in order to infer ecological implications and dissolved oxygen status in addition to the status of other variables related to dissolved oxygen and ecosystem health.

2.0 Materials and Methods

2.1 Study area

Water quality in the Kawartha Lakes Continuum has been monitored by the KLSA and MOECP in past years. Sampling locations are on the locations of past data collection to ensure comparative analysis of the samples acquired in this study is possible. Studies focused on Dissolved oxygen also have been traditionally sampled at the deepest portions of lakes to ensure elimination of seasonal variability (MOE,1996) Details of depth and GPS location are include in Appendix B1: Raw Data. With an exception of LS2 on Lovesick Lake (6m depth) all sites on each of the three lakes were chosen by the KLSA and are located among the deepest portions of each lake . Sampling at the deepest point should efficiently represent water quality variability and indicate the incorporation of nutrients at a broad scale, within the system (MOE, 1996).

Figure 1: Pigeon Lake Study Sites (PL4 & PL5)

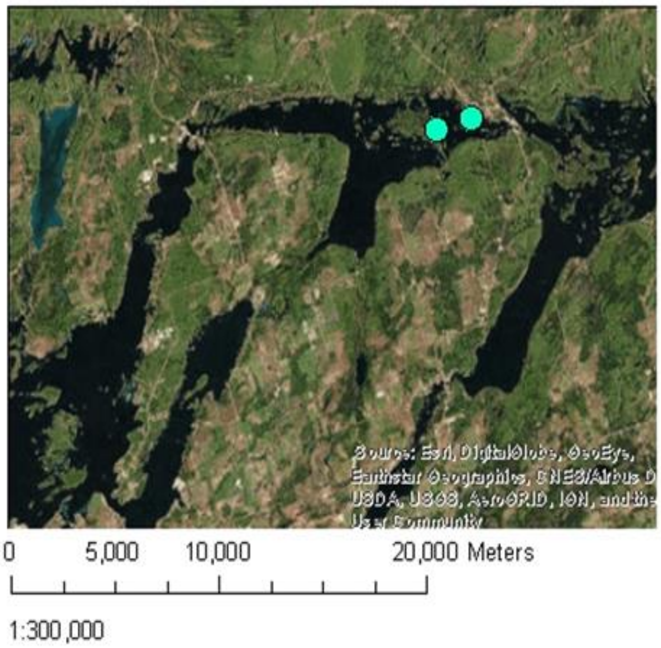

Figure 2: Lovesick Study Sites (LS1 & LS2)

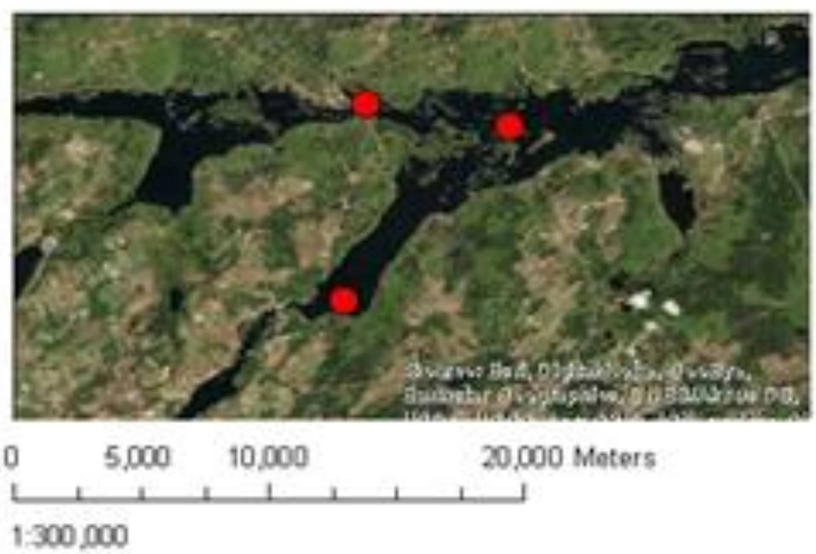

Figure 3: Stony Lake and Clear Lake Study Sites (SL1, SL2, SL3)

2.2 Study Variables

The variables measured in this study included; Secchi depth (m), Temperature, (°C) Conductivity (unit), pH (units), Dissolved Oxygen Concentration (%), Dissolved oxygen (Mg/L), and Total Phosphorus (TP). Benthic population samples were also acquired.

2.3 Materials/ Equipment

Specified GPS coordinates were located at each site, and boat position was monitored to stay in this position as sites were sampled. It was ensured that lake profile samples were acquired at locations corresponding to the deepest portions of the lake by fish-finder (depth-sensor) mounted underneath the watercraft, and a handheld depth sounder which was engaged in the water prior to lowering the other instruments (YSI meter, Ekman dredge, Van Dorn, Secchi disk). Data were acquired every meter in depth to the bottom of the lake at each location with YSI meter from the surface, to approximately 1 meter above the bottom. Data values acquired by instrument, including date, time of acquisition, and weather conditions were recorded on impervious paper. Secchi depth, Temperature, Conductivity, Van Dorn samples, and pH, were all acquired using standard Ministry of Environment Conservation and Parks (MOECP) protocol (Kawartha Conservation, 2015). The Instruments used to acquire data included; Secchi disk, YSI Professional plus meter and Van Dorn Sampler. Van Dorn Samples were stored in an ice cooler with ice pack and transported within 12 hours to the CAWT (Center for Advancement of water and Wastewater Technologies) where they were analyzed for TP. Benthic sediment samples, acquired with Ekman dredge were retrieved in accordance with the Canadian Council of Ministers of the Environment(CCME) standards (2011) and quantified using components of OBBN methodology.

2.4 Sources of Error

pH values

At one site at Stony Lake (LS3), YSI meter ran out of power at a depth of 10 m. An alternative YSI instrument was on hand, however, this instrument could only take readings from a maximum depth of 13m and also did not have pH or conductivity detection capabilities. Some data are missing on these variables below 13 m as a consequence. pH values at Pigeon Lake were markedly high relative to recent studies in the same area which have measured this variable. It is expected that this was due to a failure in instrument calibration.

Secchi depth

Secchi depth is somewhat subjective and depends on the perspective of the observer. While it is possible there was some error in these data, as Secchi depths (m) were acquired by different observers at each sampling location, KC protocol was used at each site, and this added confidence to the standardization of Secchi depth collection.

Benthic Samples

In the laboratory, live specimens were picked with a hydrostatic dropper, quantified and identified using components of OBBN methodology. Analysis diverged from OBBN protocol due to the fact that 100 specimens were not acquired in Lovesick Lake sites and Stony Lake sites. This data is considered qualitatively as a consequence. At two sites, Ekman dredge samples were lacking in substrate, and the instrument volume was not filled to 100% despite several attempts at engaging the instrument. Sampling attempts at Lovesick lake yielded little to no substrate. No Ekman dredge samples yielded a full dredge of material. A part of the instrument bearing the jaws was also damaged at Stony Lake and the instrument would not effectively close when the messenger was sent down the haul line. This may also have been a factor contributing to the sample results. Qualitative analysis of specimens collected are therefore included in the analysis.

Locational Stability

In all locations sampled, weather, and wave activity were a contributing factor to potential drift of the water craft. Because the water craft was impossible to mount perfectly, mid-lake, and positional (GPS) stability was limited to the effect of the anchor attached, depth-sounder and fish finder aided in maintaining the appropriate depth, corresponding to each known location of lake sample sites.

CAWT

The TP samples were analysed using coarse measurement and therefore the data acquired do not present values under 10 mg/L. Unfortunately these data do not allow for comparison with past data, as past TP data in the lakes have finer resolution data (<10mg/l).

3.0 Results

The following section is a collection of: the data collected for total phosphorus, dissolved oxygen graphs, and illustrations that help give further context to the study.

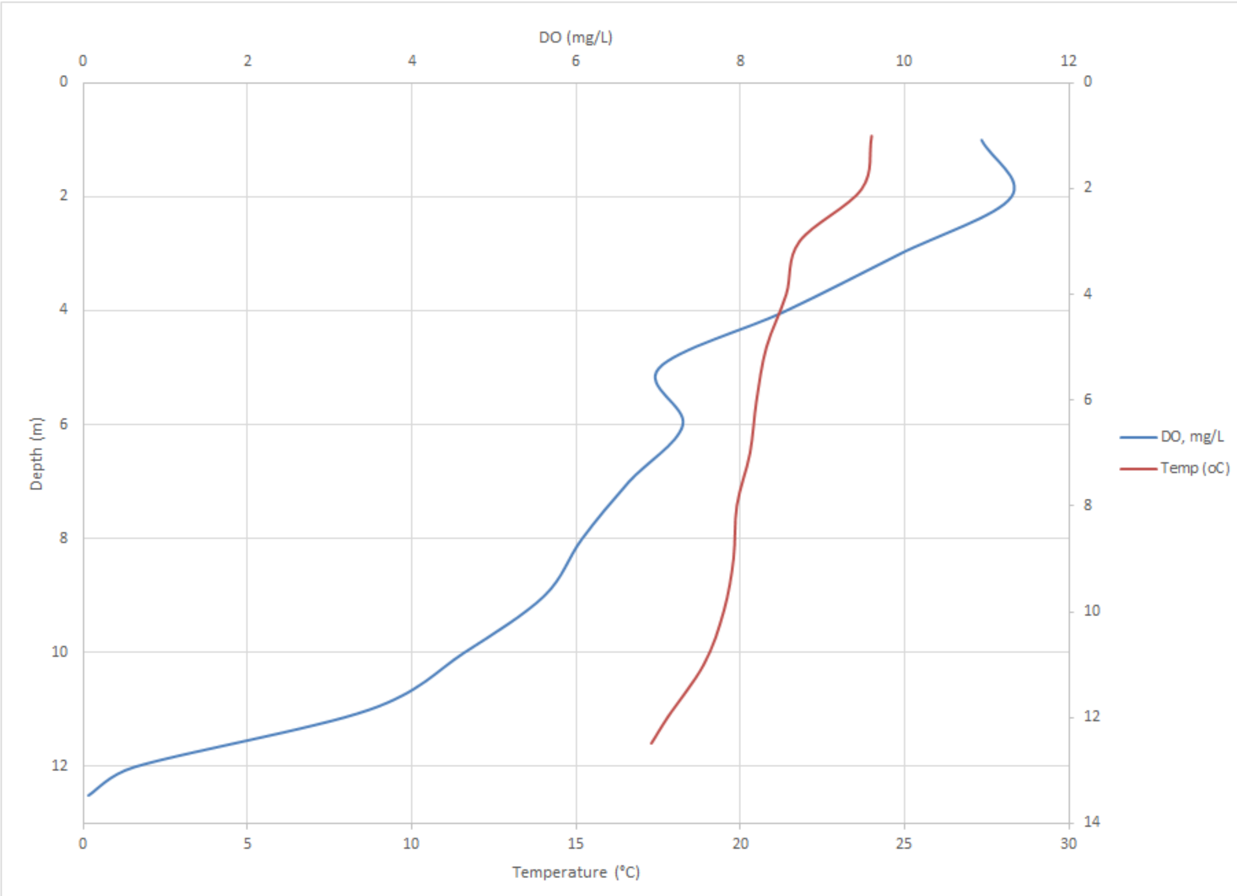

Figure 4: Graph of dissolved oxygen profile of Pigeon lake sample site 1.

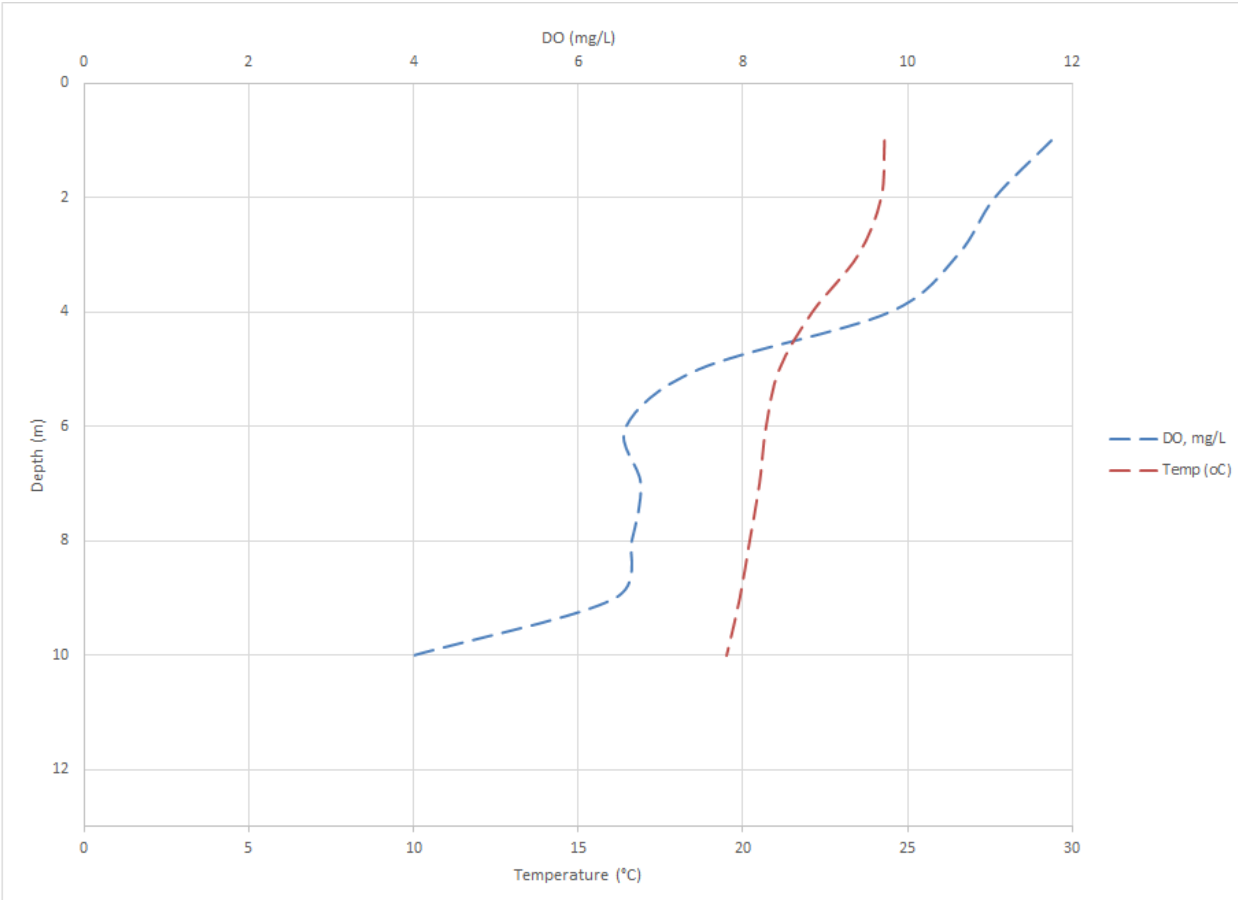

Figure 5: Graph of dissolved oxygen profile of Pigeon lake sample site 2.

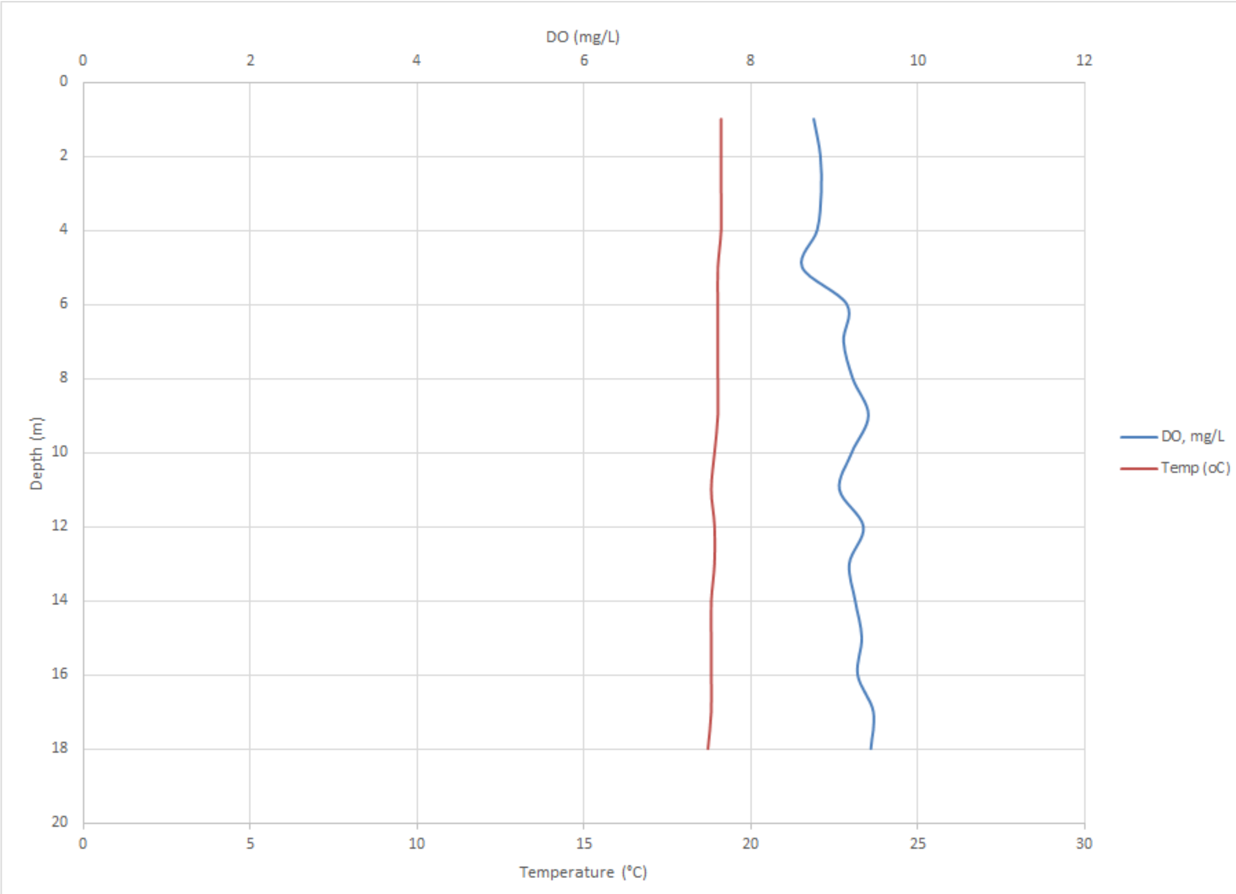

Figure 6: Graph of dissolved oxygen profile of Lovesick lake sample site 1.

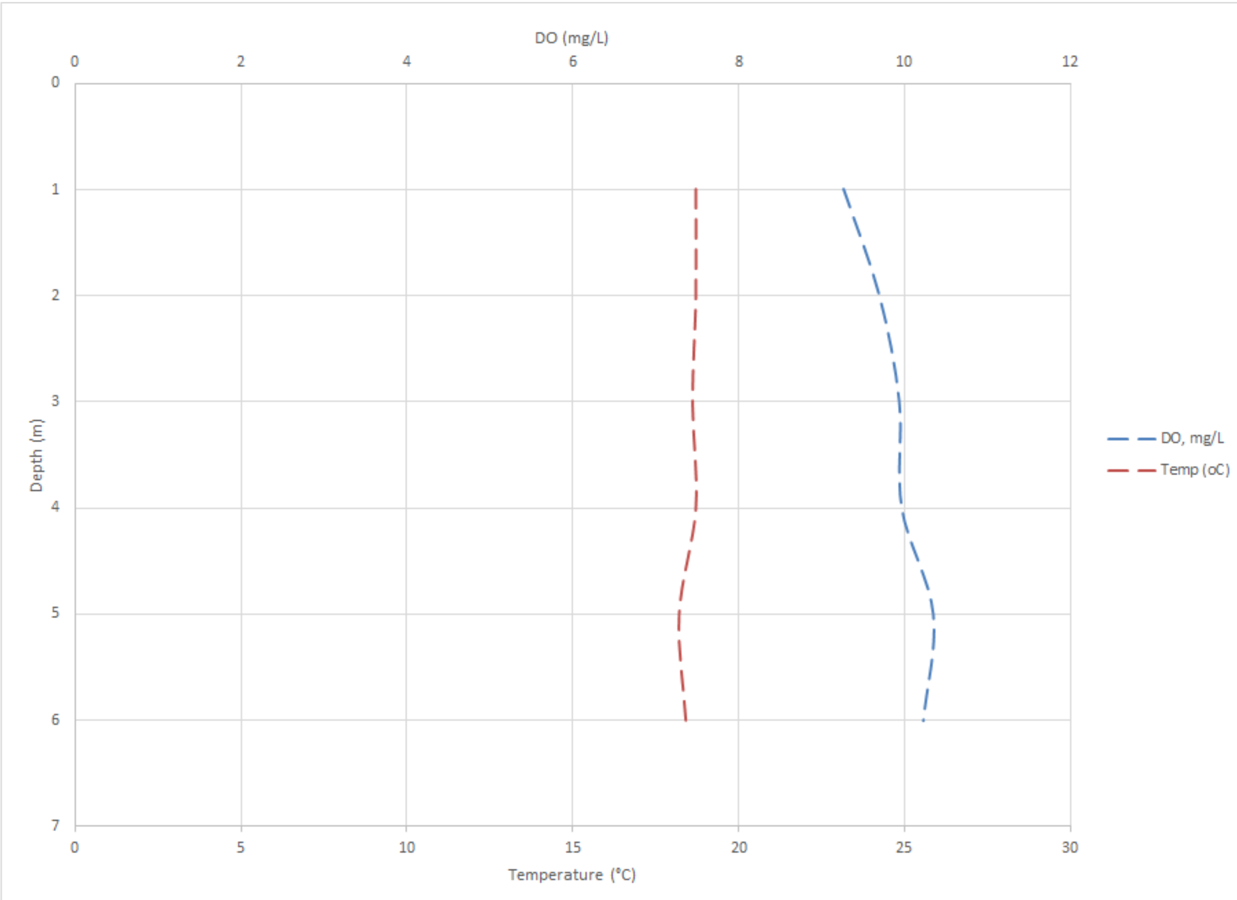

Figure 7: Graph of dissolved oxygen profile of Lovesick Lake sample site 2.

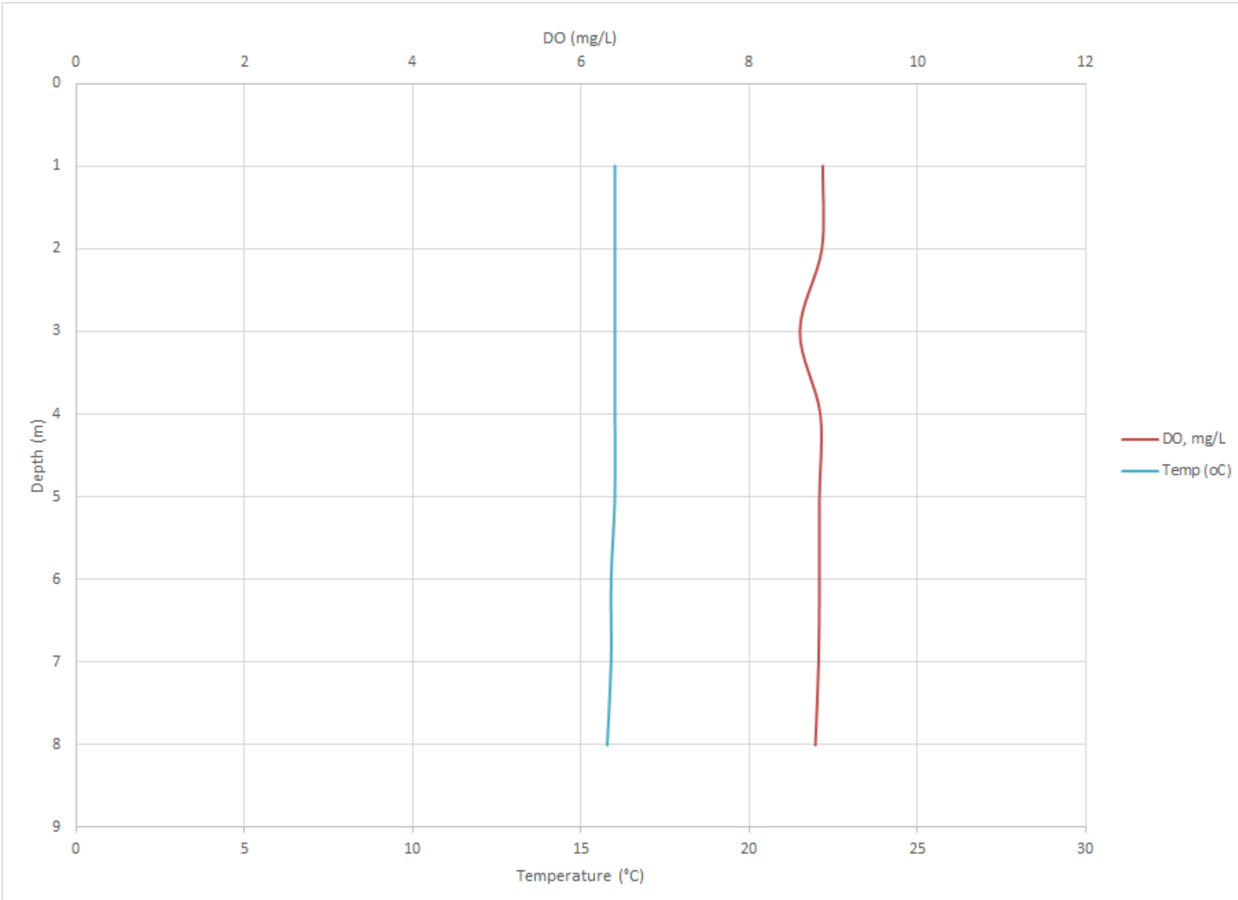

Figure 8: Graph of dissolved oxygen profile of Stony lake sample site 1.

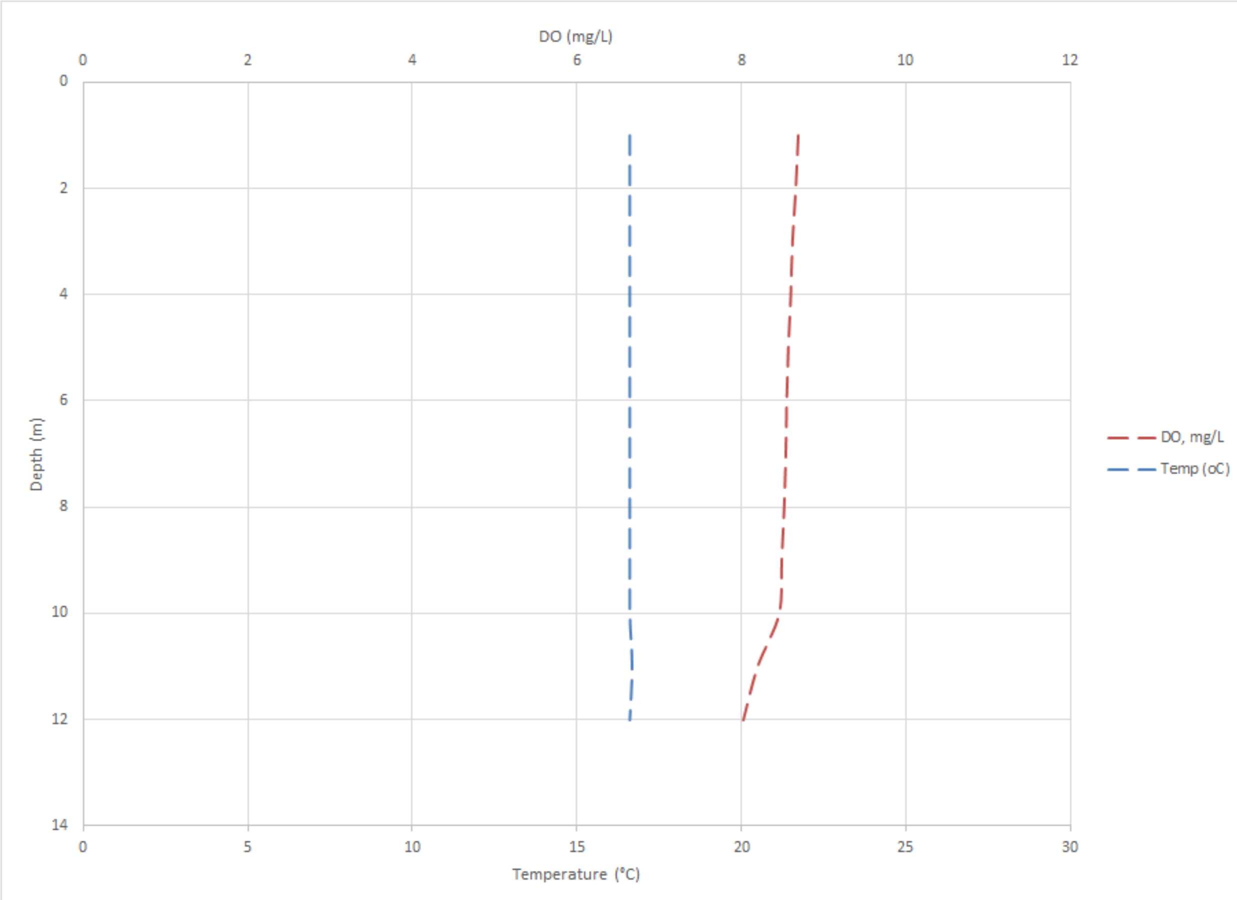

Figure 9: Graph of dissolved oxygen profile of Stony lake sample site 2.

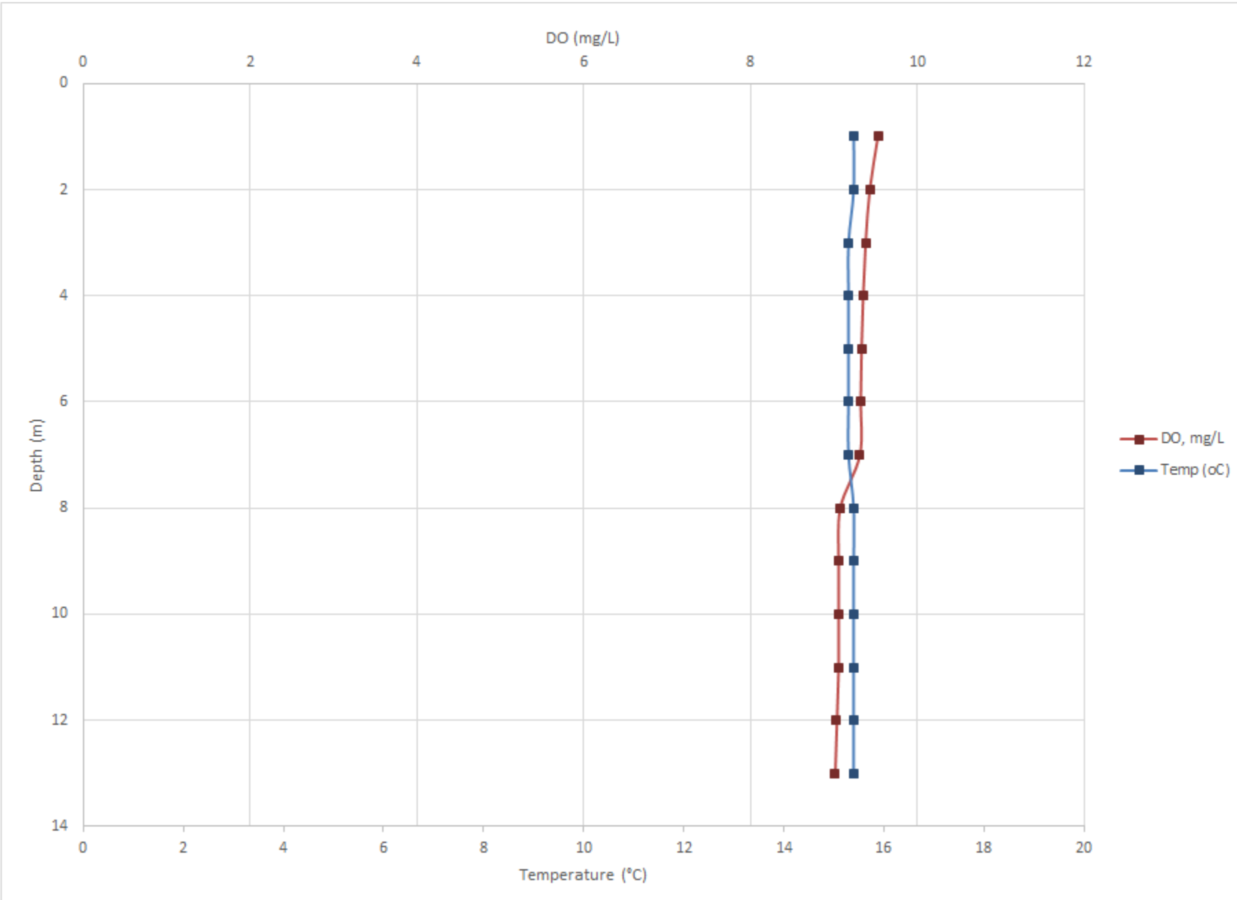

Figure 10: Graph of dissolved oxygen profile of Stony lake sample site 3.

At PL4, 100 macroinvertebrates were collected. The population distribution included 93% No-see-ums (*Ceratopogonidae*), 1% Clams (*Pelecypoda*), and 7% Aquatic Earthworms (*Oligochaeta*). At PL5, 102 macroinvertebrates were collected. The distribution of species at this site was 99% No-see-ums (*Ceratopogonidae*), and 1% Clams (*Pelecypoda*). At LS1, 5 macroinvertebrates were collected in the dredge. The distribution of this sample was 80% Midges (*Chironomidae*), and 20% Roundworms (*Nematoda*). 31 macroinvertebrates were collected at LS2. The population distribution here was 12.9% Midges (*Chironomidae*), 6.5% Roundworms (*Nematoda*), 6.5% Aquatic Earthworms (*Oligochaeta*), 16% Scuds (*Amphipoda*), 32.3% Mites (*Hydrachnida*), 22.6% Mayflies (*Ephemeroptera*), and 3.2% No-see-ums (*Ceratopogonidae*). At SL1, 3 macroinvertebrates were collected, 100% Midges (*Chironomidae*). At SL2, 81 macroinvertebrates were collected. 98% of these were No-see-ums (*Ceratopogonidae*), with 1% Midges (*Chironomidae*), and 1% Aquatic Earthworms (*Oligochaeta*). At SL3, 8 macroinvertebrates were collected. 75% of these were No-see-ums (*Ceratopogonidae*), 12.5% were Midges (*Chironomidae*), and 12.5% were Mites (*Hydrachnida*).

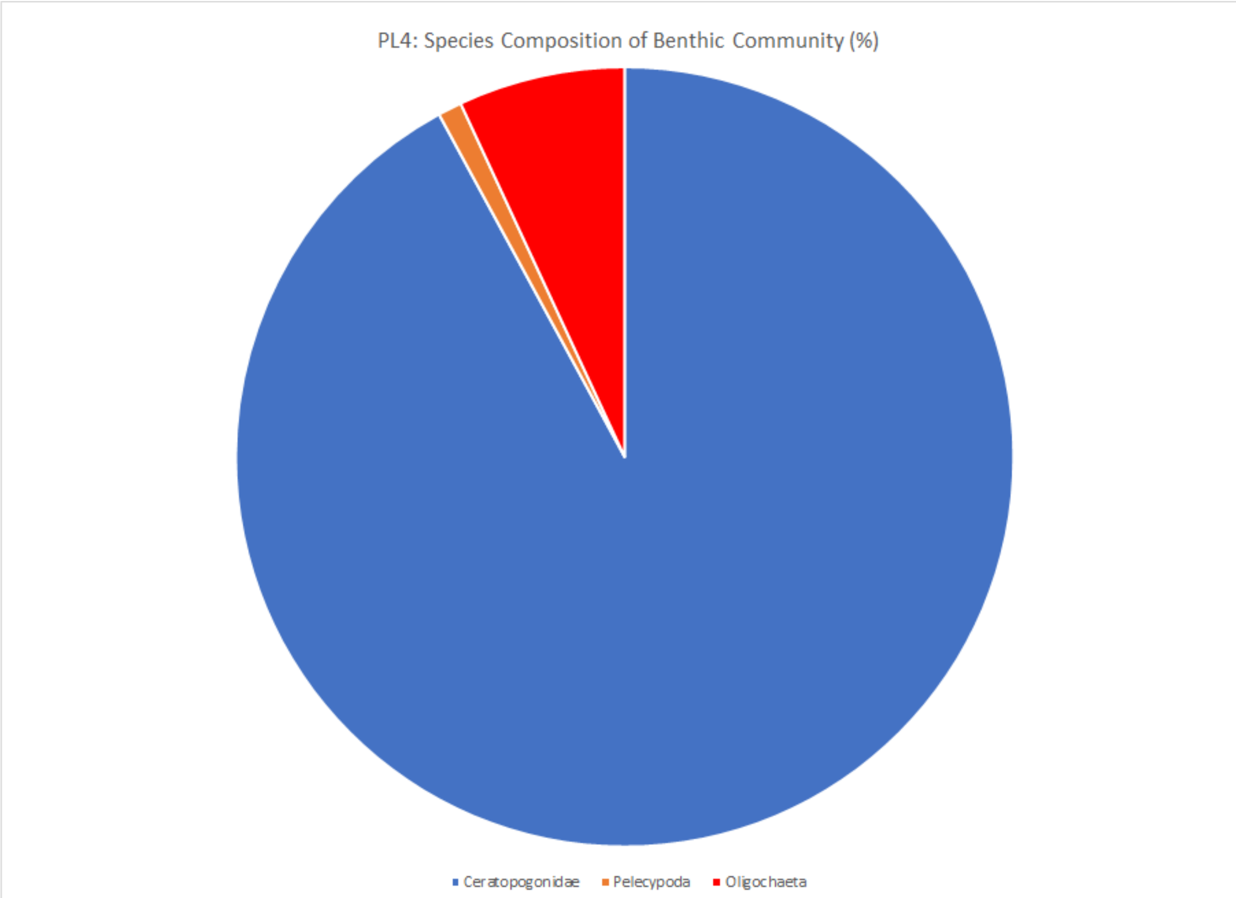

Figure 11: Benthic species composition for the first Pigeon Lake sample site (PL4).

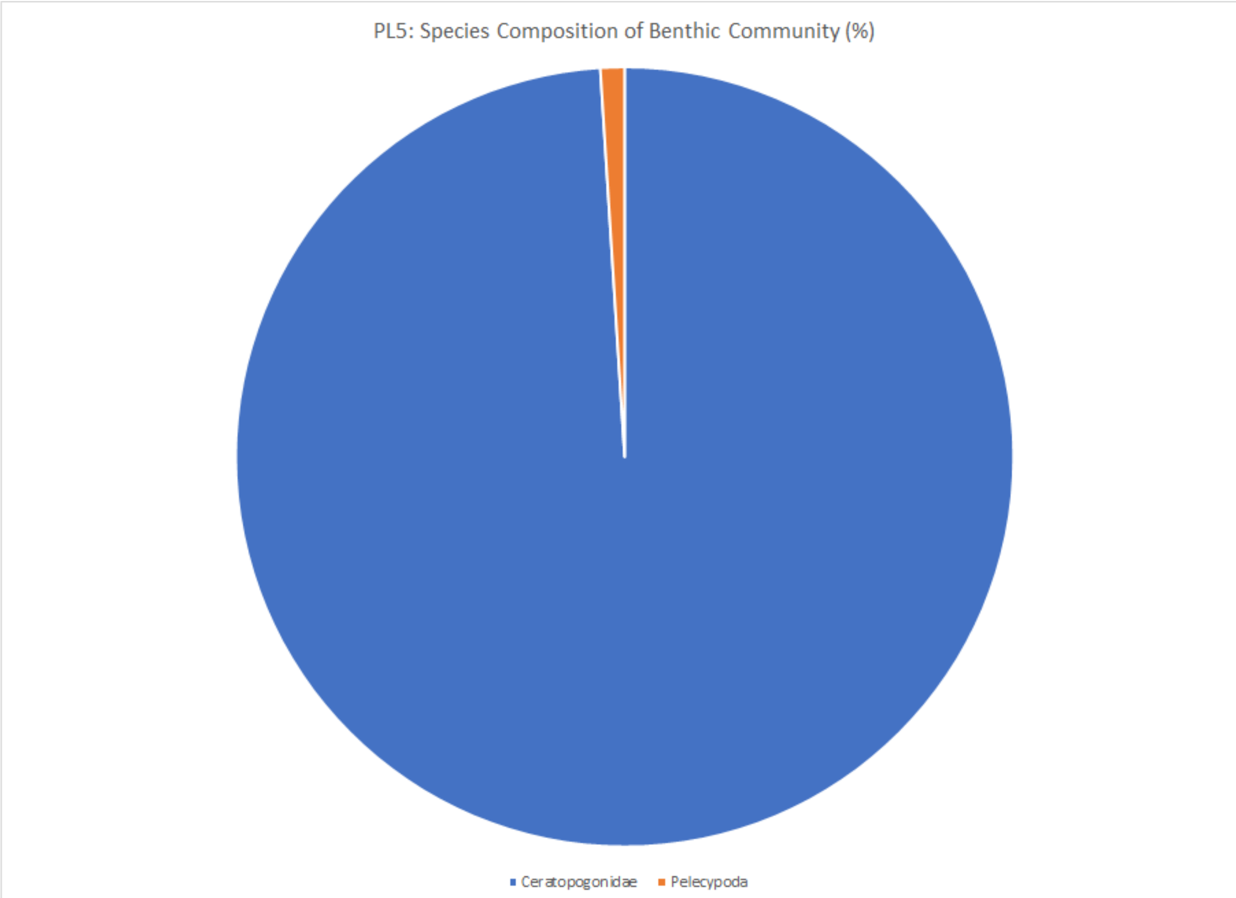

Figure 12: Benthic species composition for the second Pigeon Lake sample site (PL5).

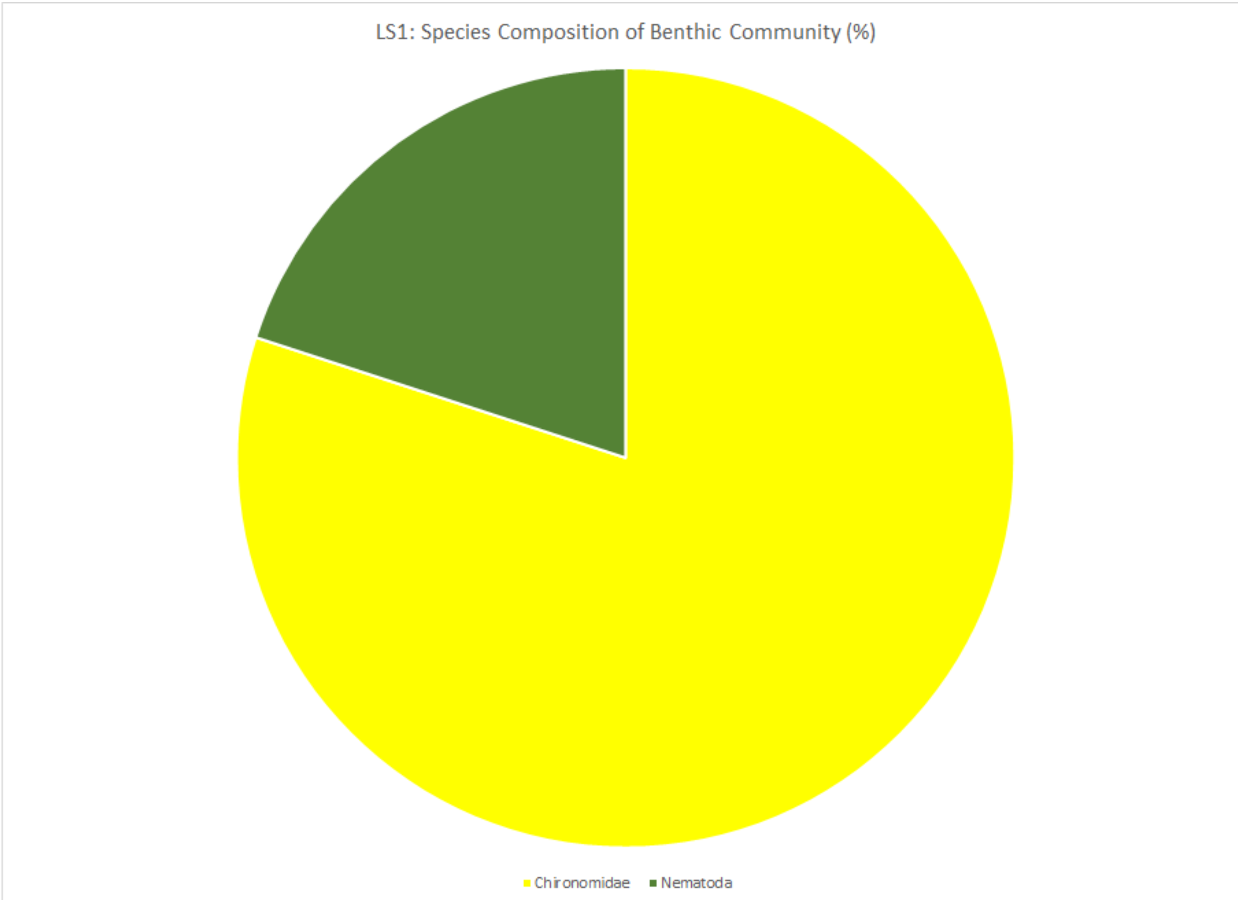

Figure 13: Benthic species composition for the first sample site at Lovesick Lake (LS1).

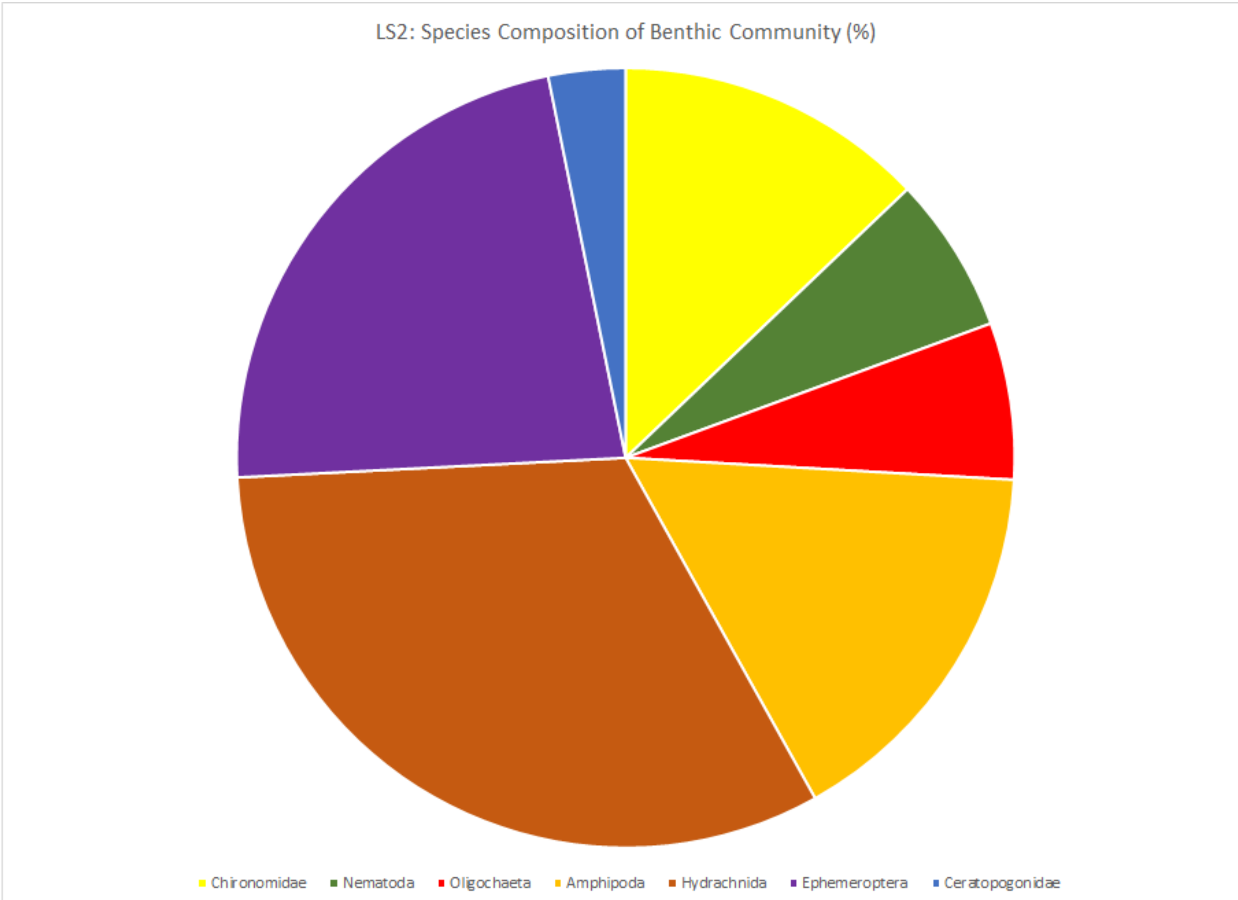

Figure 14: Benthic species composition for the second sample site at Lovesick Lake (LS2).

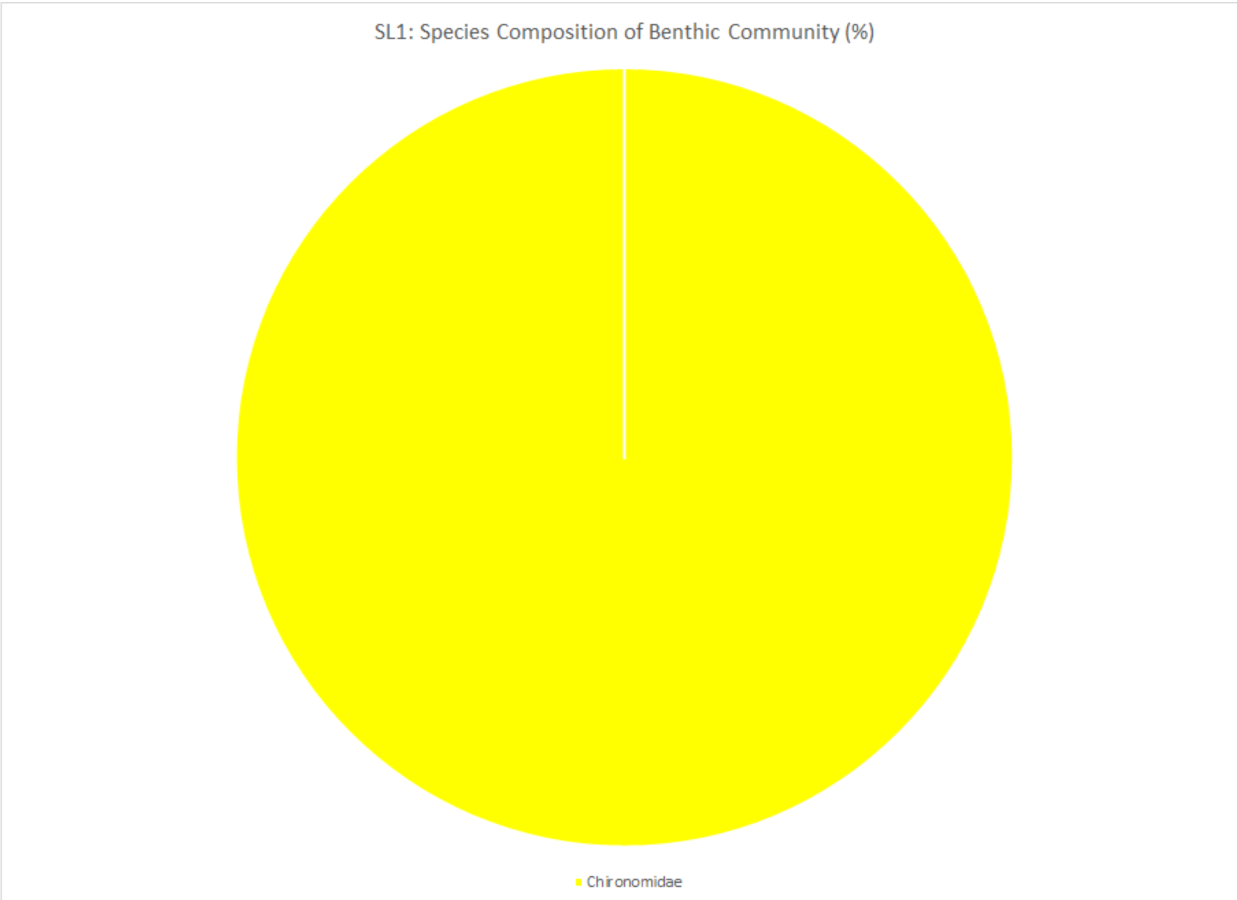

Figure 15: Benthic species composition for the first sample site at Stony Lake (SL1).

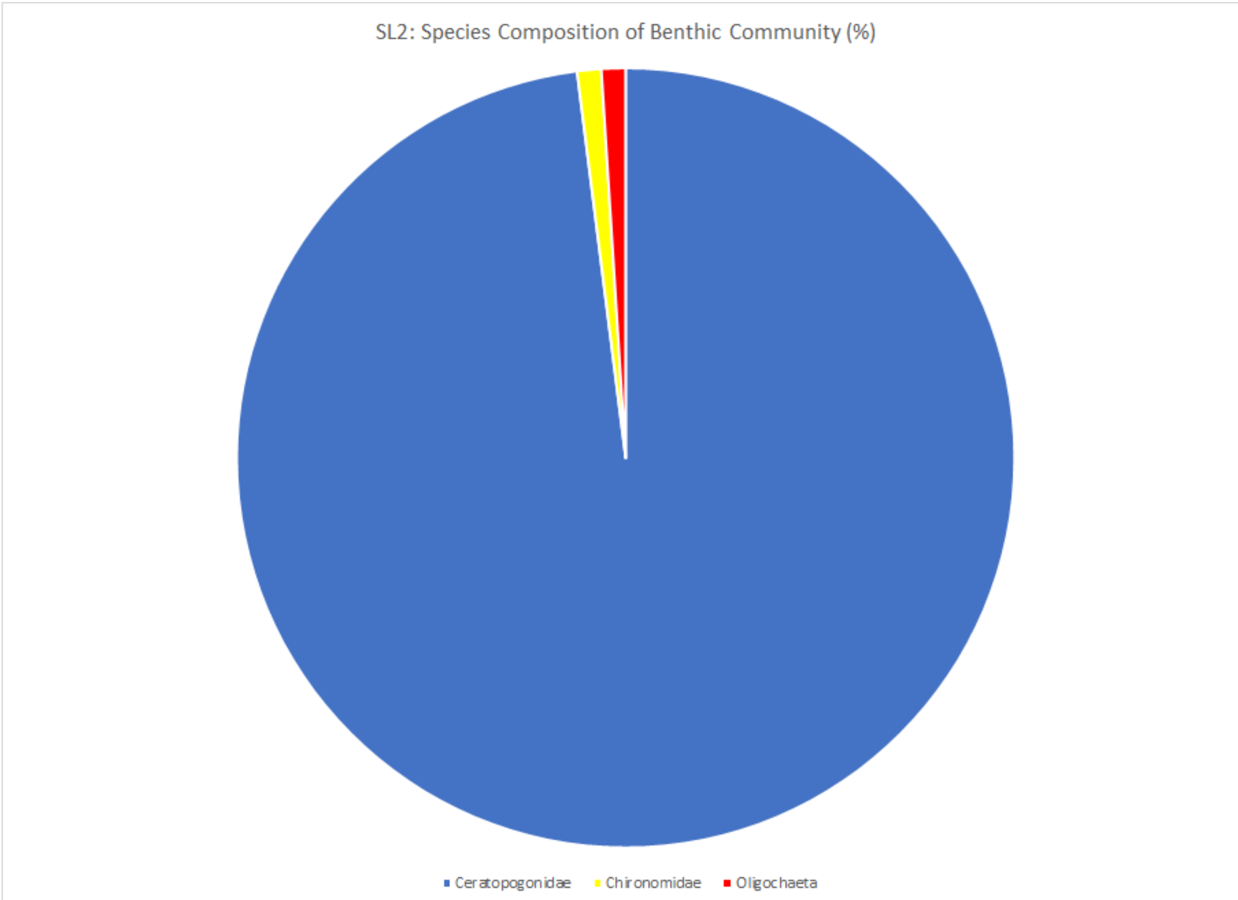

Figure 16: Benthic species composition for the second sample site at Stony Lake (SL2).

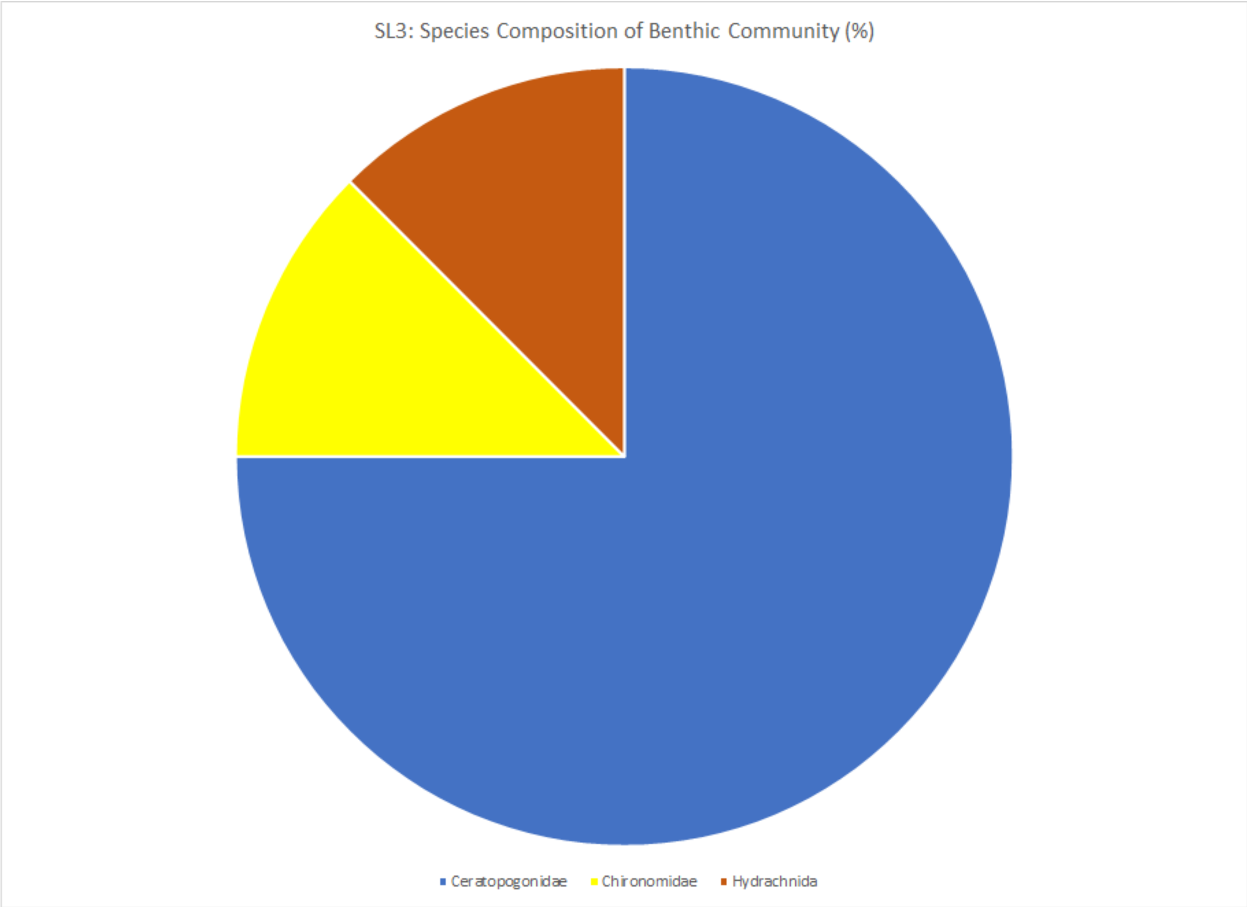

Figure 17: Benthic species composition for the third sample site at Stony Lake (SL3)

Table 1: Total Phosphorus Results

	Pigeon		Lovesick		Stony/ Clear		
	PL4	PL5	LS1	LS2	SL1	SL2	SL3
Surface (µg/L)	<10	<10	26	12	17	27	20
Bottom (µg/L)	84	<10	26	11	15	20	14

4.0 Discussion

4.1 Dissolved oxygen

Dissolved oxygen (DO) was measured using an YSI meter every meter from the surface of the water to 1 m above the bottom of the lake. The YSI meter can measure the amount of dissolved oxygen directly within the water as mg/L or as a percent dissolved oxygen (DO%). Water at lower temperatures generally have higher mg/L and higher %DO, whereas warmer, polluted water often have lower DO mg/L and %DO (Hudson & Vandergucht, 2015). According to the Canadian water quality guidelines, the lowest acceptable DO concentrations are 6 and 5.5mg/L, respectively, for the earlier and adult life stages of aquatic life in warm-water ecosystems. The acceptable DO concentrations for cold-water ecosystems are 9.5 and 6.5mg/L for the early and adult life stages of aquatic life, respectively. However, smaller organisms that dwell in the bottom layers of lakes can survive on lower dissolved oxygen levels. Factors that affect the solubility of dissolved oxygen in water are hydrostatic pressure, salinity, algae blooms, temperature, currents, upwellings, ice cover, and biological processes such as photosynthesis or respiration (CCME, 1999).

The oxygenation of a large and deep freshwater system is dependent upon proper circulation by winds, currents, and inflows that move aerated water away from the surface to deeper parts of the system. During spring turnover, DO is 100% saturated in the water column for both oligotrophic and eutrophic lakes. As the water warms during summertime, the DO concentration and solubility in the epilimnion decrease. However, in the metalimnion and hypolimnion the temperatures are lower and the level of saturation should be close to 100% with increasing depth (CCME, 1999).

Pigeon Lake is part of the Trent Severn waterway and experiences mixing events frequently due to wind, currents, and large inflows of water from the Trent Severn. The dissolved oxygen levels within the first 8m of both sampling sites (PL4 and PL5) fell below the acceptable dissolved oxygen levels (10.94-6.07mg/L) and (11.75-6.58 mg/L), respectively. The DO% saturation for PL4 and PL5 to a depth of 8m were 130.3%-67.0% and 136.2% - 71.4%, respectively (See Fig 4.). The DO% saturation for the deeper portion of the sample's sites (10-12m) were (51.1%-0.7%) and (34.6%), respectively. The dissolved oxygen concentrations near the bottom layers (10-12m) of both PL4 and PL5 are alarming (3.47-0.06 mg/L) and (3.99mg/L), respectively (See Fig 5.). However, there was little to no wind on the sampling day, thus preventing an accurate dissolved oxygen profile for the lake due to a lack of oxygenation from mixing.

Lovesick lake had a healthy dissolved oxygen profile. Both sites, (LS1 and LS2), fell within the acceptable dissolved oxygen levels for the early and adult life stages of aquatic life. The dissolved oxygen levels for LS1 ranged from 8.75mg/L at 1m depth to 9.44mg/L at 18m with a nearly linear increasing trend. The DO% saturated ranged from 94% to 101% (See Fig 6.). LS2 was a shallow site with the deepest measurement taken at 6m. The dissolved oxygen profile starting at 1m depth to 6m depth ranged from 9.27mg/L to 10.23mg/L. The DO saturation at this site was 102.2% to 109.4% (See Fig 7.). Lovesick lakes dissolved oxygen profile shows signs of “healthy” water quality and is expected to support aquatic life in all stages of their life cycle. Lovesick lake is considered to mix very well and the oxygenation profile found within our data represents this.

Stony lake had very consistent dissolved oxygen profiles at all three sites (SL1, SL2, and SL3). At SL1 the dissolved oxygen started at 8.88mg/L at a depth of 1m, to 8.79mg/L at a depth of 8m. The DO% saturation from the shallowest depth to the deepest depth ranged from 89.9% to 87.6% (See fig 8.). SL2 was a deeper site with a dissolved oxygen profile that ranged from 8.69mg/L at the shallowest measurement point (1m) to 8.03mg/L at the deepest measurement point (12m). The DO% saturation from shallowest to deepest measurement points ranged from 89.3% to 84.3% (See Fig 9.). The last site location had dissolved oxygen levels ranging from 9.53mg/L (1m) to 9.01mg/L (13m). The DO% saturation from shallowest to deepest measurement points ranged from 95.5% to 92.1% (See Fig 10.). Stony lake is another very well mixed lake. Stony lake had acceptable dissolved oxygen levels with no signs of concern for aquatic life, even at the deepest parts of the lake.

4.2 Total Phosphorus

Total phosphorus (TP) quantifies the amount of phosphorus present in particulate and dissolved phosphorus in a system (Wetzel, 2001). Particulate phosphorus encompasses all phosphorus present in organisms within the system, including phosphoproteins present in DNA, enzymes, ADP and ATP used for respiration, phosphates from rock and soil. Dissolved phosphorus includes measurements of orthophosphate as well as polyphosphates (Wetzel, 2001). In healthy lake surface systems, total phosphorus range between 10-50 µg/L, dependent on geology and land use (Wetzel, 2001). Secchi disk depth indicate the depth of the photic zone, and also an indicator of trophic state (Table 2).

Table 2: Trophic Status of Lakes based on Total Phosphorus Calculation

Trophic State: Lake Productivity	Total Phosphorus (µg/L)	Secchi Disk Reading (m)
Ultra-oligotrophic	<5	5.4-28
Oligo-mesotrophic	5-10	1.5-8.1
Meso-eutrophic	10-30	
Eutrophic	30-100	0.8-7
Hypereutrophic	>100	

Modified from (Wetzel, 2001) & (Brown & Simpson, n.d)

The Canadian Council of Ministers of Environment Phosphorus Guideline outlines a process to assess the appropriate TP concentrations for lake systems. Table 3 shows the tropic lake categories for Canadian water bodies.

Table 3: Total Phosphorus Trigger Ranges for Canadian Lakes and Rivers

Canadian Trigger Ranges Trophic Status	Total phosphorus (µg·L-1)
Ultra-oligotrophic	< 4
Oligotrophic	4 - 10
Mesotrophic	10-20
Meso-eutrophic	20-35
Eutrophic	35-100
Hyper-eutrophic	>100

(Canadian Water Quality Guidelines for the Protection of Aquatic Life, 2004).

Additionally, the Ontario government has established an interim TP guideline for evaluating lake health (Table 4).

Table 4: Total Phosphorus Interim Provincial Water Quality Objective

CAS No. 7723-14-0	Current scientific evidence is insufficient to develop a firm Objective at this time. Accordingly, the following phosphorus concentrations should be considered as general guidelines which should be supplemented by site-specific studies: ● To avoid nuisance concentrations of algae in lakes, average total phosphorus concentrations for the ice-free period should not exceed 20 µg/L; ● A high level of protection against aesthetic deterioration will be provided by a total phosphorus concentration for the ice-free period of 10 µg/L or less. This should apply to all lakes naturally below this value; ● Excessive plant growth in rivers and streams should be eliminated at a total phosphorus concentration below 30 µg/L.

(Water Management: Policies, Guidelines, Provincial Water Quality Objectives, 1994).

TP sampled from 1 meter below the water surface and 1 m above to substrate is expected between 10-30 µg/L, or 0.01-0.03 m/L (Wetzel, 2001). Total phosphorus was measured at both sites of Pigeon Lake, 1 m above the bottom and 1 m below the surface. The total phosphorus values measured for PL4 bottom is 84 µg/L, while the surface and both samples for PL5 were undetectable, >10 µg/L. This data is most likely skewed given the past results for total phosphorus in this lake, and expected values for trophic level. 84 µg/L is characteristic of a eutrophic lake, potentially indicating anoxic conditions. Overall, 84 µg/L is an outlier that can be explained via error in data collection. This high number indicates that sediment was contained in the Van Dorn during collection. Given that water was sampled <1m from the bottom of the lake, this indicated sediment was collected with the water sample (Oram, n.d). Further analysis of Pigeon Lake should be completed given the dissolved oxygen data obtained from PL4 and PL5 combined with the high Phosphorus level found. These values could indicate redox potential occurring as dissolved oxygen decreases throughout the depth of the lake (Søndergaard, 2009). The undetectable values, >10 µg/L, could be a result of data analysis at the Centre for Wastewater Treatment. Based on data from the KLSA annual reports from 2001-2005, 2007, 2013-2016, the average TP calculation for Pigeon Lake from a variety of locations during late September early October is 17 µg/L. Kawartha Conservation has measured total phosphorus data from 2012-2017 in Pigeon Lake, the average value being 21 µg/L (Kawartha Conservation, 2017). Historical TP concentrations predicted from the analysis of sediment core for the past 200 years predict an upper level of 35 µg/L (Laird & Cumming, 2018). These values seem more realistic in terms of the trophic status of the lake and water clarity. The Secchi disk measurement for PL4 was 2.24 m, 2.55 m for PL5. The clarity of the lake indicates that it is meso- eutrophic or mesotrophic (Table 2, Table 3, and Table 4) just as past TP measurements suggest.

LS1 measurements at both the surface of the lake and lake bottom are 26 µg/L. For LS2, the TP measured at the Lake Surface is 12 µg/L, while the TP measured at the lake bottom is 11 µg/L. Based on past data, the average TP value for Lovesick Lake from the 2001-2005, 2007, 2013-2016 KLSA reports is approximately 17 µg/L during late September, early October. All of these values are within the meso- eutrophic range (Table 2) or mesotrophic (Table 3) , as expected for this lake. The lower values for LS2 may be a result of the surrounding land use and phosphorus inputs into the lake, as LS1 values were slightly higher (Murphy, 2007). Further research would have to be conducted to analyze water inflow into Lovesick Lake. The Secchi Disk readings for LS1 and LS2 were 3.5 and 3 respectively, in the range of the expected measurement (Table 2).

The TP values measured for Stony/Clear Lake for all three sites range between 14- 27 µg/L. KLSA reports from 2001-2005, 2007, 2013-2016 combined have an average TP value of 15.8 µg/L, supporting accuracy of this data. The Secchi Disk readings were 4.85, 3.75, and 5.16 for SL1, SL2, and SL3, which is to be expected (Table 2). Given this information, Stony/ Clear lake are meso-eutrophic (Table 2) or mesotrophic (Table 3).

Given that Pigeon Lake, Lovesick Lake, and Stony/Clear Lake are relatively clear lakes with some productivity (Pigeon especially so), they are classified as meso-eutrophic lakes (Carlson & Simpson, 1996) or mesotrophic to meso-eutrophic (CCME 2004).

4.3 pH & Conductivity

pH should reasonably differ between lakes, especially since the Kawartha Lakes are situated over transitioning geologic deposits to different degrees, with the Canadian Shield at the northernmost portions of the lakes. The geological formation, laden with alkalis, should thus constitute varying degrees of hard water H2O as they are dissolved into the lakes. pH values in general are reflective of soil and rock weathering, atmospheric precipitation, fallout, and climate (Wetzel, 2013). pH influence important lake nutrient dynamics such as phosphate, ammonia, iron, and trace metals (Wetzel, 2001). Importantly to this study, pH influences the frequency of binding of phosphorus to iron compounds. In particular, higher pH values should constitute a decreased binding frequency for nutrients (phosphorus) loaded in bottom sediment and consequently stimulate phosphorus resuspension in water (Sondergaard, 2007). Some of the data collected were far above the range for pH values expected and it is likely that this was due to a failure in the calibration of the instrument not realized while engaged in data collection by the YSI operators.

Consultation with researchers and specialists of this system who collected data on the lakes in the past also confirmed the expectation that readings for pH were well above the values collected in the past. No recent large scale local events or land use changes should constitute drastic changes in pH from readings taken recently. Also, past research on the Kawarthas (Environment Conservation and Parks, 1964-2016) suggests that while the values expected should be relatively high, due to cultural and geologic influences, pH values should not exceed 9. Further, following Wetzel (2001) pH values below 5.5 and above 9.5 should be observably lethal to species populations, a phenomenon not recently observed in the Kawarthas.

It would have been beneficial to add reliable data for this variable, especially since pH in the Kawarthas should vary spatially and temporally given the fact that dissolved shield particles available in the system should constitute relatively high concentrations of Calcium Carbonate, a material containing dynamic ions (Wetzel, 2001). Data collected at transitional sites between lakes for this variable are available in Ontario, however the data vary in their time of acquisition, and quantity of samples taken within a year. With coarse qualitative observation of this data, it appears that within the entire Kawartha Lakes system, pH values vary roughly between 7.6 and 8.5. Further inquiry into this data could be useful as pH value is an indication of chemical activity within lake systems. Many peripheral values may therefore constitute changes in this variable. While the focus of this study is dissolved oxygen, directly related variables were chosen for depth analysis.

4.4 Benthic Analysis

Looking at the diversity of benthic macroinvertebrates in the samples allows us to extrapolate some limited information about the water quality at these sites. For example, *Chironomidae* are a very diverse family, meaning there is a large range in tolerance to stress. However, "in general, if midge larvae are very numerous and account for the majority of the community, that is an indication of poor environmental health caused by some type of pollution" (Voshell, 2002, p. 422). *Ceratopogonidae* are chiefly facultative in their stress tolerance, with others being somewhat tolerant (Voshell, 2002, p. 407). It is also worth noting that "some of the aquatic species are especially common in thick growths of algae" (Voshell, 2002, p. 407). From the samples collected in this study, it is impossible to make a conclusion about whether there is a direct relationship between the algal communities in our lakes and the population of *Ceratopogonidae*, however in future studies this could be taken into further consideration. *Amphipoda* are collectively facultative, but, again, some individual kinds are more sensitive. Some of these kinds are restricted to permanent water bodies with cool, clean, and well-oxygenated water (Voshell, 2002). Others "are sensitive to toxic heavy metals, especially copper, and pesticides" (Voshell, 2002, p. 251). The most common kinds of *Oligochaeta*, the long red worms, are very pollution tolerant. It is important to note that these kinds of worms are specifically tolerant of low dissolved oxygen conditions that result from organic waste pollution (Voshell, 2002). They can also establish "in the deepest parts of lakes that have little or no dissolved oxygen for part of the year because of natural reasons" (Voshell, 2002, p. 201). *Hydrachnida* are generally facultative as well, and again, individual species can range from being sensitive to tolerant (Voshell, 2002). Ephemeroptera are particularly useful in determining water quality, as "most species of mayflies are very sensitive to pollution" (Voshell, 2002, p. 273). When multiple kinds of mayflies are found or when mayflies make up a large proportion of the benthic sample, it is an indication that the aquatic environment is healthy (Voshell, 2002).

Again, from the samples collected at each of the sites in this study, it is difficult to make conclusions about the water quality from the diversity and abundance of various benthic invertebrates. Moving forward, it would be wise to conduct more grabs/site, to collect a larger portion of the benthic community.

4.5 Land Use

Table 5: Calculated Land Use from Shore to 200m Inland for Eleven Kawartha Lakes

Lake Name	Upper Stony	Upper Buckhorn	Sturgeon	Pigeon	Lovesick	Lower Stony	Katchanoka	Chemong	Cameron	Big Bald	Balsam
Water	25.63%	7.46%	6.90%	4.99%	13.14%	11.93%	4.51%	4.30%	9.54%	6.68%	6.28%
Freshwater marsh	0.00%	1.57%	6.75%	16.79%	0.00%	0.00%	0.00%	0.00%	7.63%	0.00%	0.86%
Deciduous swamp	8.59%	8.87%	2.96%	3.63%	19.65%	8.15%	9.89%	5.03%	3.66%	8.85%	2.12%
Conifer swamp	7.95%	2.06%	4.14%	2.04%	11.33%	4.84%	4.67%	1.39%	2.18%	7.99%	2.96%
Dense deciduous	6.52%	12.29%	6.58%	14.55%	9.54%	10.93%	5.29%	7.64%	16.66%	16.84%	16.43%
Dense coniferous	13.60%	6.90%	15.82%	9.38%	8.95%	23.09%	17.49%	9.72%	7.63%	11.18%	19.58%
Mixed forest mainly deciduous	3.56%	1.70%	2.95%	4.79%	7.63%	5.34%	0.74%	1.71%	5.06%	2.56%	8.99%
Mixed forest mainly coniferous	15.76%	5.96%	6.00%	3.61%	8.29%	15.87%	6.54%	3.86%	5.11%	8.61%	9.42%
Sparse deciduous	13.39%	18.76%	1.36%	6.91%	16.28%	14.21%	4.99%	7.88%	0.83%	33.63%	1.88%
Bedrock/sand/minetailings	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.23%	0.00%	0.00%
Pasture and abandoned fields	2.02%	5.61%	11.92%	5.27%	0.52%	0.57%	4.01%	11.26%	15.21%	0.00%	12.40%
Cropland	2.98%	28.81%	34.62%	28.04%	4.66%	5.06%	41.86%	47.21%	26.25%	3.67%	15.93%
Alvar	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	3.15%

(White, n.d.).

Land use is an important factor in monitoring the water quality of the lakes because certain types of land use can result in “high water usage, sewage and waste disposal, increased runoff from developed areas and construction sites, and runoff from the volume of lawn fertilizers and pesticides” (Alberta Environment and Parks, 2015). In Table 3, the land use types for 11 of the Kawartha Lakes are listed, including Upper Stony, Lower Stony, Lovesick, and Pigeon. The current main land use types in the Pigeon Lake “core planning area are natural areas (56%), agriculture (27%), open water (10%), and development (7%)” (Pigeon Lake Management Plan, July 2018). To the North, the land use is mostly accounted for by natural cover, especially in the Nogies Creek and Eels Creek subwatershed. Farming is a main source of income in this region, so the landscape around the Western, Eastern, and Southern parts of the lake are agriculture-based. Most of these farms produce grain and hay crops, and beef cattle is a close second (Pigeon Lake Management Plan, July 2018). Market forces have led to the conversion of land from pasture land to crop fields, resulting in the clearing of land and drainage improvements, usually tile draining. The natural areas in the North consist mainly of forest and wetland tracts, and in the South of forested areas associated with the Oak Ridges Moraine. Bobcaygeon and Omemee are the largest areas of development in the Pigeon Lake sub watershed. The population of these areas experiences an influx of cottagers in the summer. There are numerous businesses that cater to lake-related recreation and tourism in the form of lodges, golf courses, bed and breakfasts, and many others (Kawartha Conservation, 2018).

Lovesick Lake has a number of dams surrounding the lake “built between the late 1800s and early-1900s by the Trent Severn Canal Waterway” (Bridle, 2017). Burleigh Falls is a community located on the Northeast shore of the lake. There are over 2000 developed waterfront properties on Clear and Stony Lakes. At the east end of Upper Stony Lake, there is one active mining operation, and some pink and gray quartz and limestone quarrying and abandoned pits South of Stony Lake and West of Clear Lake (Kawartha Lake Stewards Association, 2008). The Fraser Estate is on the North shores of Stony, and is a natural, historical, and cultural site. It is an important wetland habitat for many different fish and turtles, but specifically for Blanding's Turtles, a 'species at risk' (Friends of the Fraser Wetlands, n.d.).

5.0 Suggestions for Future Research/Recommendations

1. Benthic Macroinvertebrate Sampling
   If benthics are to be considered more quantitatively as an indicator of water quality, OBBN protocol should be followed in the future. Reference should be made to the Ontario Benthos Biomonitoring Network: Protocol Manual (2007), in the creation of these sampling procedures and plans. It is also suggested that in the future, the project plan includes the sampling of macroinvertebrates in the tributaries to each lake. This is because "the greater part of the nutrient load enters the lake with river flow. Therefore water quality and nutrient concentrations in tributaries may largely determine the water quality and ecological state of the lake" (Kawartha Conservation, 2010, p. 30).
2. Length of Sampling Campaigns
   Part of the errors found in this study come from the availability of data on study sites and days and times of acquisition, as the variables of study are expected to change over the course of a year. To more accurately study the dissolved oxygen status in the lakes, the lakes should be studied during the same time of year relative to spring or fall turnover (MOE, 1996, p.9). One sample annually at the correct time is considered appropriate and reliable in the determination of entire lake status with regards to total phosphorus. it can be troublesome to interpolate data from one sample, when lakes show substantial chemical variability throughout a the course of a year(MOE, 1996, p.9). Long term studies with frequent sampling can be used to determine the reliability of sampling times, relative to lake turnover in future campaigns so that annual period sampling can reliably represent lake character((MOE, 1996 p.9). It would also be effective to measure other water quality variables. Although traditionally, the kawarthas measure TP as an indicator of lak productivity, the measurement of nitrogen, which is also a limiting nutrient in aquatic ecosystems, may also be useful in the determination of DO dynamics. Soluble reactive phosphorus (SRP), and particulate phosphorus (PP) could also be useful in the development of a more refined lake profile.
3. Multi-Season Sampling
   Dissolved oxygen levels can be representative of the health of the lake. Anoxic conditions are most threatening in the winter months when the lakes are covered with ice. Ice decreases reaeration, influxes of oxygen-depleted groundwater, and oxidation of organic material. A future recommendation to KLSA's project would be to sample water quality in the winter term (E. Sager, personal communication, November 6, 2018).
4. Finer Phosphorus Analysis

Total phosphorus data were acquired using coarse analysis with TP values only observable above 0.10 µg/L. Unfortunately, several readings were below 0.10µg/L and therefore while still comparable to TP data taken in past studies, yield coarse comparison. Fine data analysis for TP should be undertaken if studies are to address the same variables of interest in the future.

5. Land Use & Shoreline Development Monitoring
   As earlier stated, land use is a variable that directly impacts water bodies. To ensure continued lake health, the KLSA should monitor land use and shoreline development, to ensure that no further sources of lawn fertilizers, pesticides, development runoff, and unfiltered sewage effluent are created, or to react quickly in the creation of a mitigation plan.
6. REDOX Potential
   A future consideration is to look into redox potential and its relationship with dissolved oxygen and the overall quality of water within the lakes. A literature review focus could be on redox potential, as it relates to certain aspects of the project (Sondergaard, 2009).

In Summary, the Kawartha Lakes Continuum does not appear to have anoxic conditions. However, as previously stated, anoxic conditions are most prevalent in the winter season when the lake is covered by ice and future studies should consider a winter sampling project if possible. The low DO values found in Pigeon Lake, and high TP value found at the bottom of PL4 indicated that anoxic conditions were potentially present. Although these data points were considered anomalies, future research should be conducted to ensure the health and absence of anoxic conditions in Pigeon Lake.

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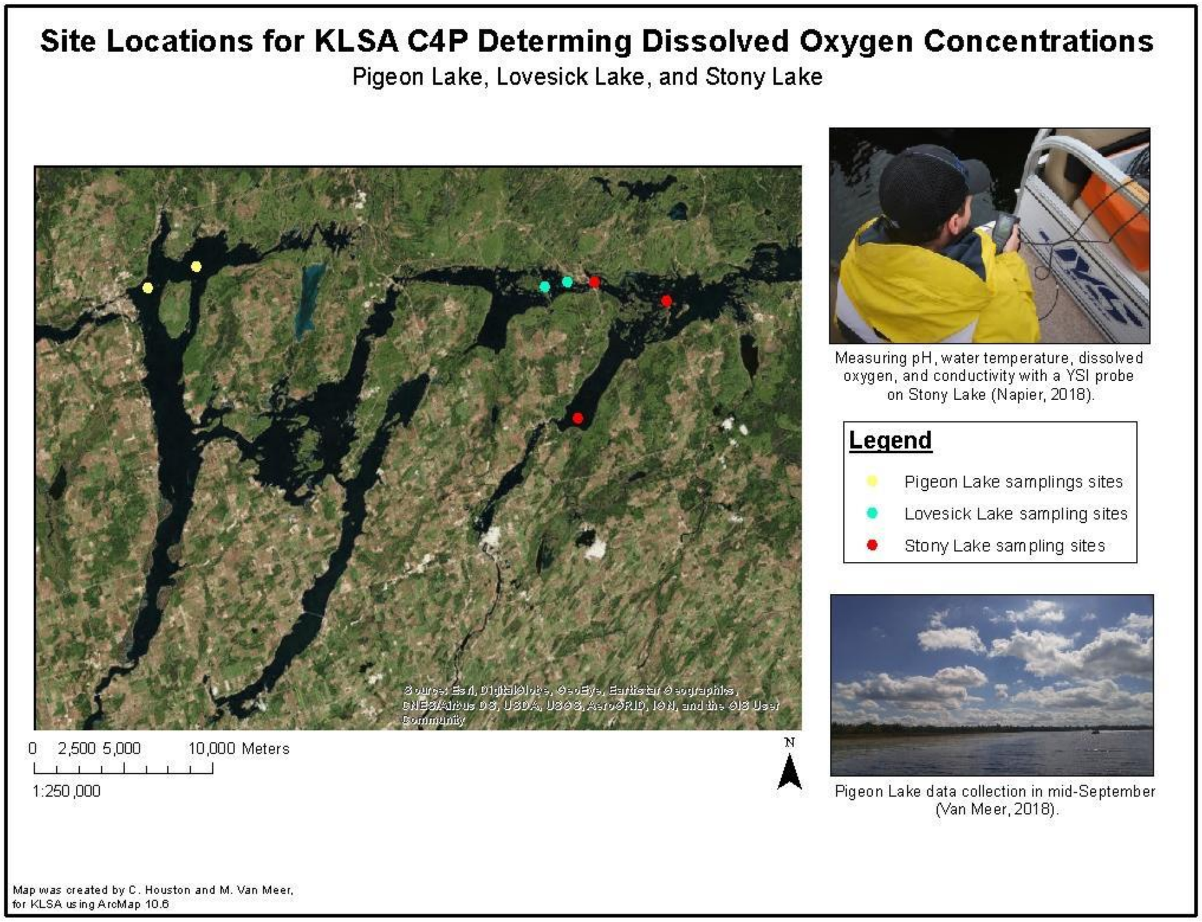
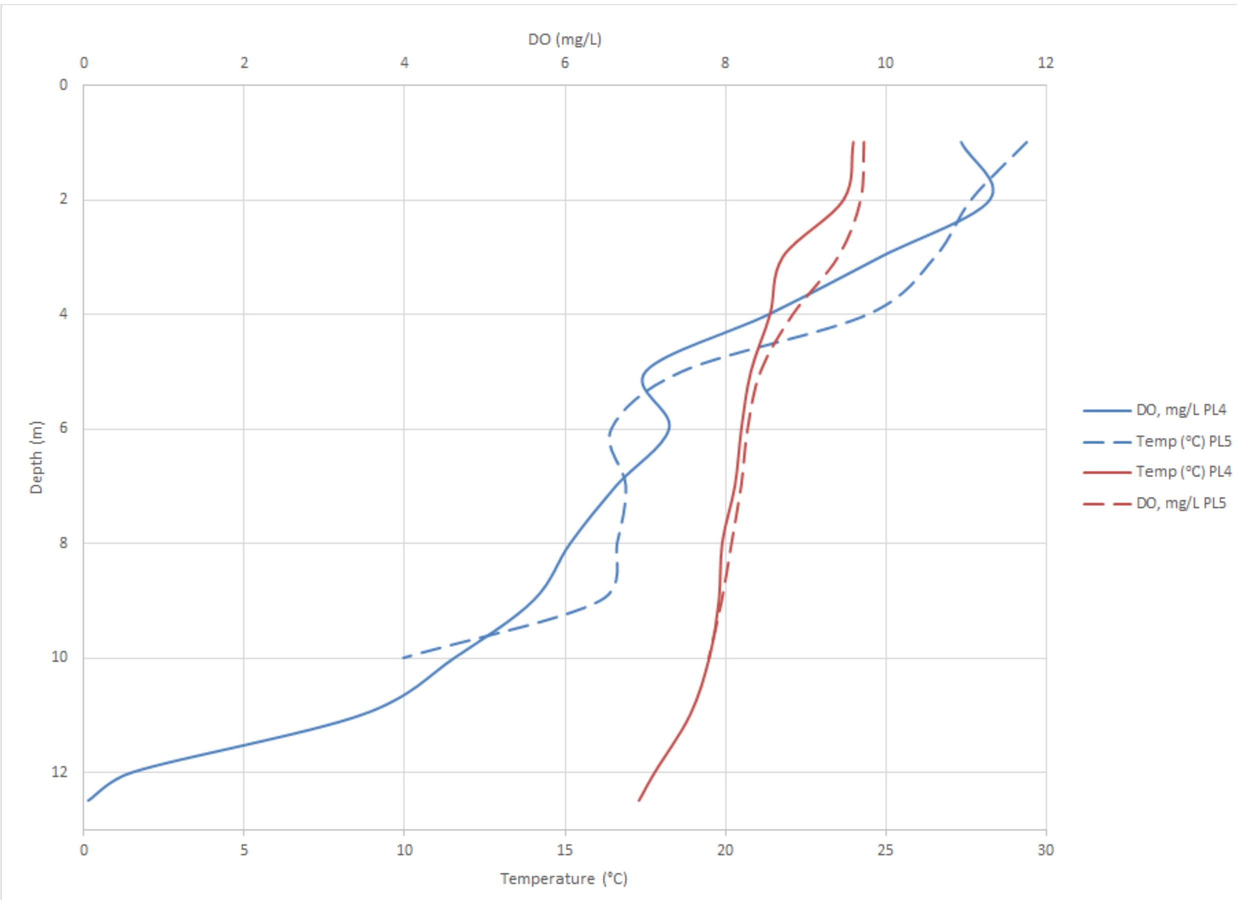
Appendix

Appendix A: Additional Data

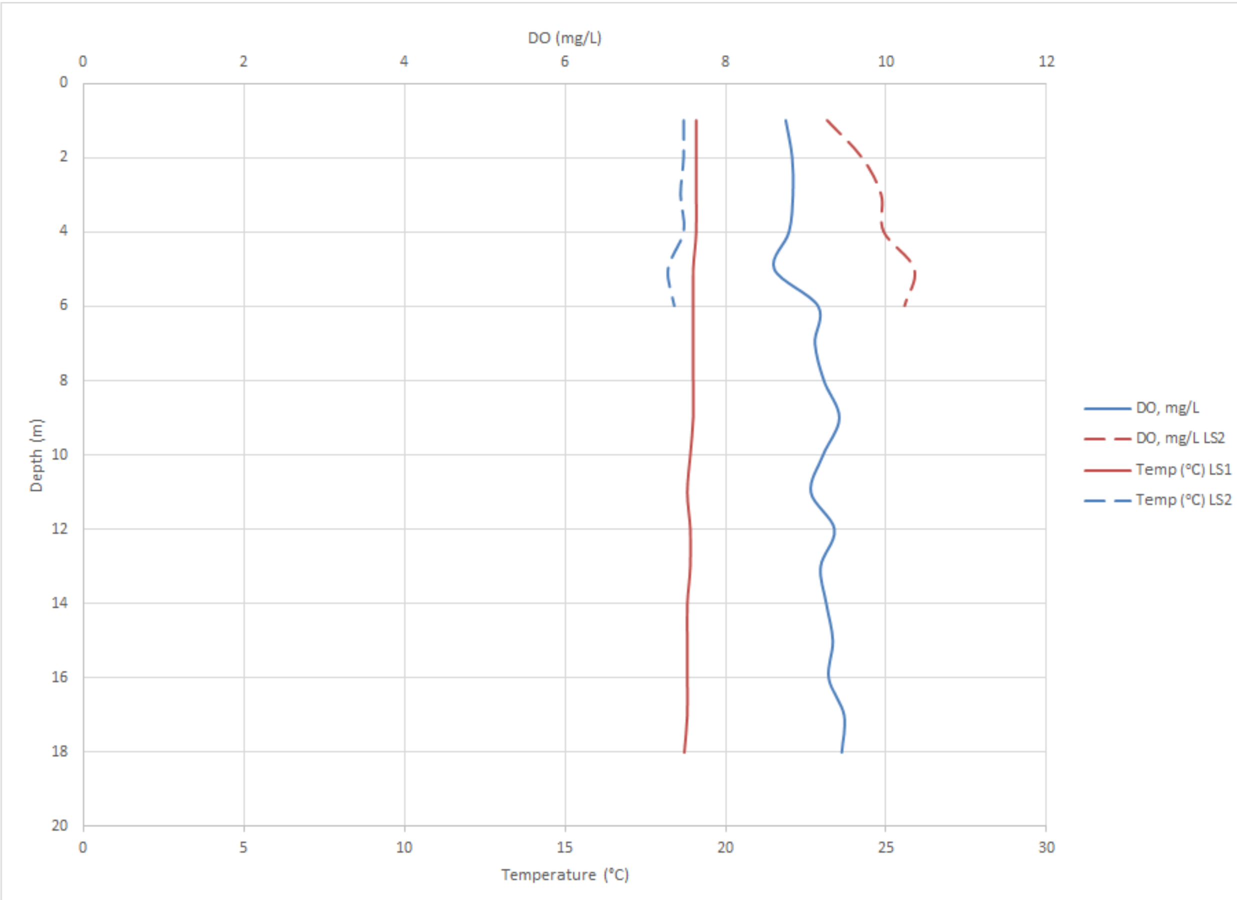


Appendix A1: Map depicting the location of all of the sampling sites, looking at all of the Kawartha Lakes.



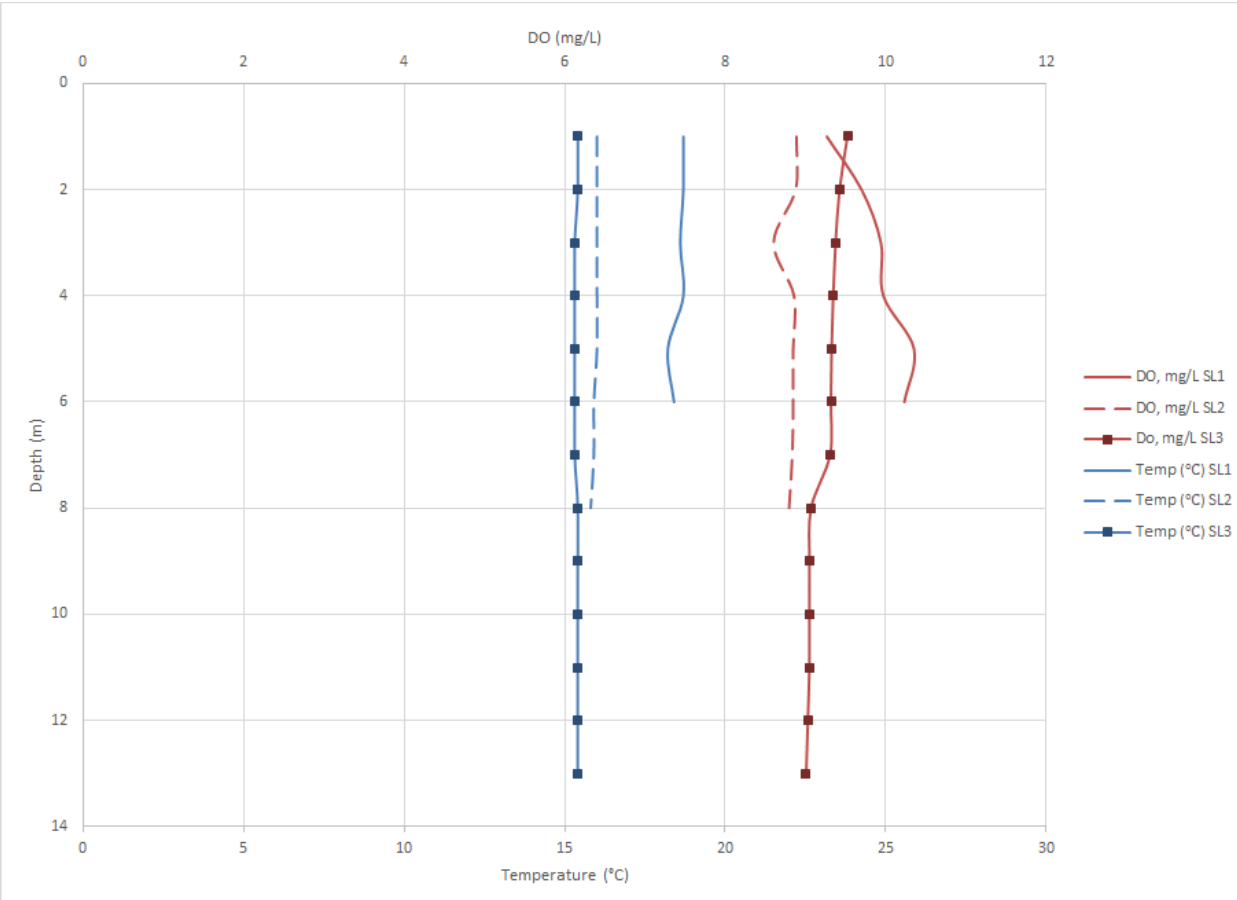
Appendix A2: Pigeon Lake Dissolved Oxygen Profile

Overall dissolved oxygen profile for Pigeon Lake for both sample sites.



Appendix A3: Lovesick Lake Dissolved Oxygen Profile

Overall dissolved oxygen profile for Lovesick Lake for both sample sites.



Appendix A4: Stony Lake Dissolved Oxygen Profile

Overall dissolved oxygen profile for Stony Lake for all sample sites.

Volunteer Temperature and Dissolved Oxygen Data Sheet

Lake Information
Lake Name: Upper Stoney Township: Douro Dummer
STN: 5178 Site ID: 6
Midlake Deep Spot (105ft.)

Volunteer Information
Name: Roz Moore Phone Number: 416-484-8328
Email: roslyn.moore@rogers.com

Depth (m)	Temperature (°C)	Dissolved Oxygen (mg/L)	Depth (m)	Temperature (°C)	Dissolved Oxygen (mg/L)
Date: Sat. May 27/2017 Time: 8:30-9 am			Date: May 27/2017 Time: 9-9:30 am		
Surface (0.1m)	15.3	9.98	21	7.9	9.45
1	15.3	9.98	22	7.6	9.26
2	15.3	9.93	23	7.1	8.85
3	15.2	9.90	24	6.8	8.85
4	14.9	9.74	25	6.5	8.60
5	14.5	9.69	26	6.3	8.44
6	14.0	9.52	27	6.2	8.34
7	13.4	9.49	28	6.0	8.14
8	12.4	9.58	29	5.8	7.76
9	11.1	9.61	30	5.7	.10
10	10.3	9.63	31	5.7	.05
11	9.6	9.59	32	5.7	.02
12	9.3	9.62	33		
13	9.1	9.63	34		
14	8.9	9.65	35		
15	8.8	9.64	36		
16	8.7	9.66	37		
17	8.6	9.65	38		
18	8.5	9.62	39		
19	8.4	9.59	40		
20	8.2	9.56	41		

Comments
Overcast, slight current, no breeze
++ rain last week & yesterday

Mail Completed Data Sheet(s) to:
Ministry of the Environment Lake Partner Program
Box 39, Dorset, ON
P0A 1E0

E-mail: anna.desellas@ontario.ca
Phone: 1-800-470-8322

Appendix A5: Upper Stony Lake Dissolved oxygen data from Roz Moore on May 27,2017.

Volunteer Temperature and Dissolved Oxygen Data Sheet

Lake Information
Lake Name: Upper Stoney Township: Douro Dummer
STN: 5178 Site ID: 6
Midlake Deep Spot (105ft.)

Volunteer Information
Name: Roz Moore Phone Number: 416-484-8328
Email: roslyn.moore@rogers.com

Date: July 19/2017 Time: 7:45–8:15 (am) / pm
Date: July 19/2017 Time: 8:15–8:45 (am) / pm

Depth (m)	Temperature (°C)	Dissolved Oxygen (mg/L)	Depth (m)	Temperature (°C)	Dissolved Oxygen (mg/L)
Surface (0.1m)	23.4	8.58	21	8.6	6.84
1	23.4	8.58	22	8.3	6.73
2	23.4	8.54	23	8.0	6.48
3	23.3	8.52	24	7.4	5.78
4	22.6	8.37	25	7.1	.03
5	22.3	8.27	26	7.1	.04
6	22.2	8.02	27	7.1	.05
7	21.4	7.03	28	7.1	.06
8	19.2	5.89	29	7.1	.06
9	16.7	5.22	30	7.1	.06
10	13.7	5.26	31	7.1	.07
11	12.1	5.68	32	7.1	.07
12	11.1	6.04	33	7.1	.07
13	10.3	6.23	34		
14	9.7	6.51	35		
15	9.4	6.54	36		
16	9.3	6.70	37		
17	9.2	6.78	38		
18	9.0	6.70	39		
19	9.0	6.73	40		
20	8.8	6.73	41		

Comments
Calm, hot sunny morning

Mail Completed Data Sheet(s) to:
Ministry of the Environment Lake Partner Program
Box 39, Dorset, ON
P0A 1E0

E-mail: anna.desellas@ontario.ca
Phone: 1-800-470-8322

Appendix A6: Upper Stony Lake Dissolved oxygen data from Roz Moore on July 19, 2017.

Volunteer Temperature and Dissolved Oxygen Data Sheet

Lake Information
Lake Name: Upper Stoney Township: Douro Dummer
STN: 5178 Site ID: 6
Midlake Deep Spot (105 ft.)

Volunteer Information
Name: Roz Moore Phone Number: 416 484-8328
Email: roslyn.moore@rogers.com

Date: Aug. 15/2017 Time: 7 – 7:30 am / pm (pm circled)			Date: Aug. 15/2017 Time: 7:30 – 8 am / pm (pm circled)		
Depth (m)	Temperature (°C)	Dissolved Oxygen (mg/L)	Depth (m)	Temperature (°C)	Dissolved Oxygen (mg/L)
Surface (0.1m)	23.6	8.73	21	8.4	5.47
1	23.6	8.70	22	8.1	5.22
2	23.6	8.69	23	7.7	4.89
3	23.5	8.68	24	7.4	4.12
4	22.5	8.30	25	7.1	3.61
5	22.1	8.11	26	6.9	3.14
6	21.7	7.29	27	6.8	2.82
7	20.9	6.54	28	6.7	2.46
8	18.7	4.39	29	6.6	1.93
9	15.5	2.95	30	6.6	1.23
10	13.2	3.59	31	6.5	.87
11	11.2	4.59	32	6.5	.26
12	10.3	4.97	33	6.5	.16
13	9.8	5.23	34	6.5	.01
14	9.5	5.16	35		
15	9.3	5.38	36		
16	9.2	5.37	37		
17	9.1	5.36	38		
18	9.0	5.55	39		
19	8.9	5.36	40		
20	8.7	5.51	41		

Comments Calm early evening

Mail Completed Data Sheet(s) to:
Ministry of the Environment Lake Partner Program
Box 39, Dorset, ON
P0A 1E0

E-mail: anna.desellas@ontario.ca
Phone: 1-800-470-8322

Appendix A7: Upper Stony Lake Dissolved oxygen data from Roz Moore on August 15, 17.

Appendix B: Raw Data

PLMP water quality sampling form - Lake

Sample Date: 17/09/18

Sampling Crew: BRETT TREGUNNO, DEBBIE BALIKA, BILL NAPIER, CHELSEA HOUSTON, CHRIS VIEAU, CONNOR HILL, MARA VANMEER

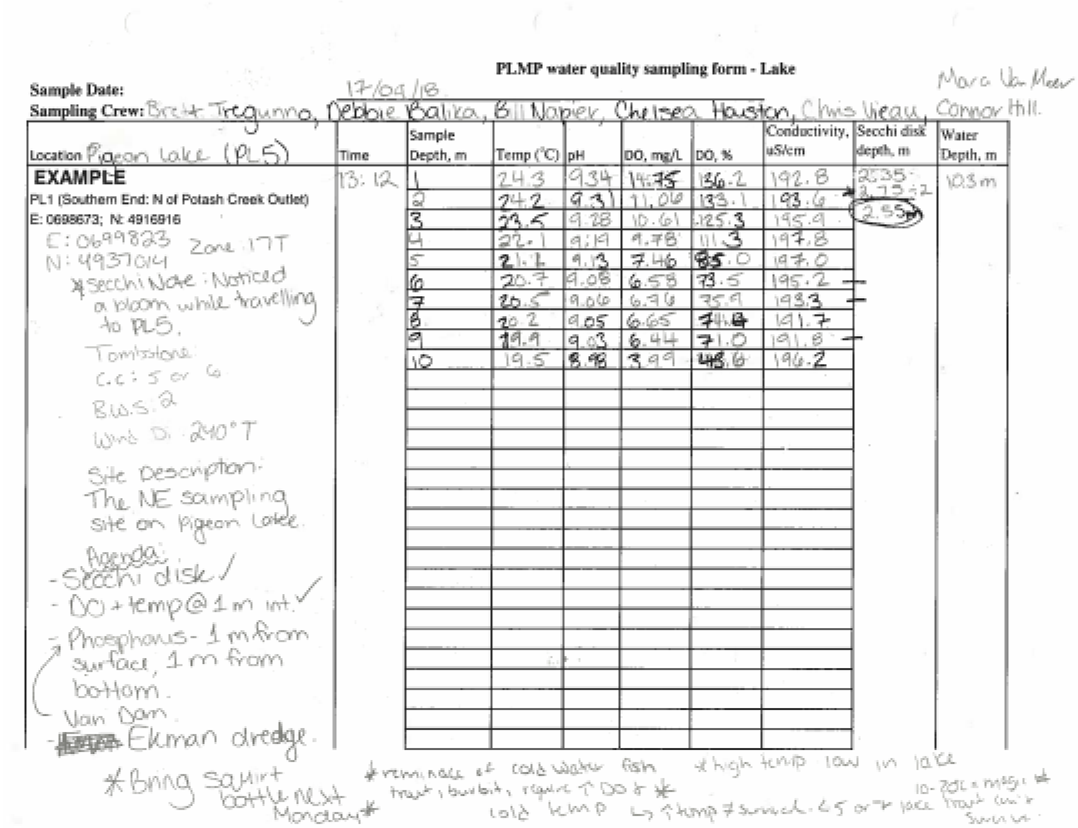
Deepest Part of Lake

Location Pigeon Lake (PL4)	Time	Sample Depth, m	Temp (°C)	pH	DO, mg/L	DO, %	Conductivity, uS/cm	Secchi disk depth, m	Water Depth, m
EXAMPLE PL1 (Southern End: N of Potash Creek Outlet) E: 0698673; N: 4916916	1457	1m	24.0	9.06	10.94	130.3	187.6	2.43	13.5
E: 0697195 N: 4935642		2m	23.7	9.22	11.3	133.5	190.8	2.04 ÷2	
C.C: 4 or 5		3m	21.8	9.15	9.94	115.1	196.6	4.47	
BWS: 2		4m	21.4	9.11	8.55	96.3	197.3	= 2.24	
Wind D: 236°T		5m	20.8	9.05	7.01	78.5	195.2		
		6m	20.5	9.04	7.3	82.0	192.8		
		7m	20.3	9.02	6.64	72.5	191.8		
		8m	19.9	8.99	6.07	67.0	191.0		
		9m	19.8	8.98	5.61	62.0	197.8		
		10m	19.5	8.95	4.63	51.1	194.8		
		11m	18.9	8.87	3.47	37.7	194.6		
		12m	17.8	8.78	0.62	10.2	191.99		
		12.5m	17.3	8.74	0.06	0.7	203.3		

DO mg/L < 7 limiting to cold water fish
< 3 limiting to warm water fish

Appendix B1: PL4 Raw Data

Raw data and field notes for sampling at Pigeon Lake site PL4.



PLMP water quality sampling form - Lake

Sample Date: 17/04/18

Sampling Crew: Brett Tregunno, Debbie Balika, Bill Napier, Chelsea Houston, Chris Vieau, Mara Van Meer, Connor Hill.

Location: Pigeon Lake (PL5)

Time	Sample Depth, m	Temp (°C)	pH	DO, mg/L	DO, %	Conductivity, uS/cm	Secchi disk depth, m	Water Depth, m
13:12	1	24.3	9.34	14.75	136.2	192.8	2.535 - 2.73 ÷ 2 → 2.55m	10.3m
	2	24.2	9.31	11.06	133.1	193.6		
	3	23.5	9.28	10.61	125.3	195.9		
	4	22.1	9.19	9.78	111.3	197.8		
	5	21.6	9.13	7.46	85.0	197.0		
	6	20.7	9.08	6.58	73.5	195.2		
	7	20.5	9.06	6.76	75.9	193.3		
	8	20.2	9.05	6.65	74.4	191.7		
	9	19.9	9.03	6.44	71.0	191.8		
	10	19.5	8.98	3.99	48.6	196.2		

EXAMPLE
PL1 (Southern End: N of Potash Creek Outlet)
E: 0698673; N: 4916916

E: 0699823 Zone 17T
N: 4937014
*Secchi Note: Noticed a bloom while travelling to PL5.
Tombstone
C.C: 5 or 6
B.W.S: 2
Wind D: 240°T

Site Description: The NE sampling site on Pigeon Lake.

Agenda:
- Secchi disk ✓
- DO + temp @ 1 m int. ✓
- Phosphorus - 1 m from surface, 1 m from bottom.
- Van Dorn
- Ekman dredge.

Bring squirt bottle next Monday

reminder of cold water fish trout, burbot, require ↑ DO & cold temp

high temp low in lake 10-20C = magic ↳ ↑ temp ≠ survival. 25 or ↑ lake trout can't survive.

Appendix B2: PL5 Raw Data

Raw data and field notes for sampling at Pigeon Lake site PL5.

PLMP water quality sampling form - Lake (Lovesick)

Sample Date: 24/09/18

Sampling Crew: CONNOR HILL, [illegible], MARA VANMEER, [illegible], CHELSEA HOUSTON

Location Lovesick Lake (LS1)-7087 (Station)	Time	Sample Depth, m	Temp (°C)	pH	DO, mg/L	DO, %	Conductivity, uS/cm	Secchi disk depth, m	Water Depth, m
EXAMPLE	11:44	1	19.1	8.74	8.73	94.3	177.2	14:13	18.7
PL1 (Southern End: N of Potash Creek Outlet)		2	19.1	8.35	8.83	95.1	177.2	?	
E: 0698673; N: 4916916		3	19.1	8.28	8.84	94.7	177.1	~3.5m	
44°33'22" N		4	19.1	8.26	8.79	95.6	177.2		
78°14'16" W		5	19.0	8.5	8.61	94.7	177		
	12:25	6	19.0	8.41	9.15	98.5	177		
Wind dir: 120°T		7	19.0	8.3	9.11	98.2	176.9		
C.C: 1/10		8	19.0	8.28	9.22	99.8	177.0		
Bus: 4		9	19.0	8.25	9.41	101.1	176.7		
VERY PRODUCTIVE LAKE		10	18.9	8.23	9.21	99.1	177.3		
Northern end of Lovesick Lake		11	18.8	8.23	9.06	98.1	177.1		
→ YSI RESULTS MAY HAVE SOME ERROR DUE TO WIND.		12	18.9	8.22	9.35	100.4	177.4		
→ EKMAN DREDGE BENTHIC SAMPLE TAKEN @ 40FT		13	18.9	8.23	9.18	99.8	177.3		
↳ 44°33'21" N		14	18.8	8.24	9.25	100.8	177.4		
↳ 78°14'19" W.		15	18.8	8.23	9.33	99.8	177.5		
		16	18.8	8.23	9.28	100.3	177.3		
		17	18.8	8.23	9.47	101.6	177.4		
		18	18.7	8.24	9.44	101.3	177.3		

Appendix B3: LS1 Raw Data

Raw data and field notes for sampling at Lovesick Lake site LS1.

PLMP water quality sampling form - Lake

Sample Date: 24/09/18

Sampling Crew: Connor Hill, Chelsea Houston, Bill Napier, Maria Vanmeter, Chris Vicana

Location Lovesick Lake (LS2)	Time	Sample Depth, m	Temp (°C)	pH	DO, mg/L	DO, %	Conductivity, uS/cm	Secchi disk depth, m	Water Depth, m
EXAMPLE	13:09	1	18.7	8.32	9.77	105.2	177.4		6m
PL1 (Southern End: N of Potash Creek Outlet)		2	18.7	8.31	9.10	102.6	177.3		
E: 0698673; N: 4916916		3	18.6	8.29	9.94	106.0	177.4	5.5m	
44°33'33" N		4	18.7	8.30	9.97	105.6	176.9	4.5m	
78°13'22" W		5	19.2	8.31	10.35	110.5	176.7	=5m	
C.C = 1		6	18.4	8.32	10.23	109.4	177.1		
W.W = 4									
Wind direction = 106°T									

Appendix B4: LS2 Raw Data

Raw data and field notes for sampling at Lovesick Lake site LS2.

PLMP water quality sampling form - Lake

Sample Date: 08/10/18

Sampling Crew: BRETT TREGUNNO, BILL NAPIER, CONNOR HILL, CHELSEA HOUSTON, MARA VAN MEER, CHRIS VIERU, ROB STANINGA

Location Stony Lake (SL1)	Time	Sample Depth, m	Temp (°C)	pH	DO, mg/L	DO, %	Conductivity, uS/cm	Secchi disk depth, m	Water Depth, m
EXAMPLE PL1 (Southern End: N of Potash Creek Outlet) E: 0698673; N: 4916916 44.55765 N (lat) 78.15200 W (long) C.C = 10 B.W.S = 0 W.D = N/A [illegible] House boat also on water	10:50	1	16	7.80	8.88	89.4	175.6	4.85 (TIME: 11:25)	8.6m
		2	16	7.77	8.87	89.9	175.6		
		3	16	7.76	8.6	88.8	175.6		
		4	16	7.75	8.85	89.7	175.7		
		5	16	7.78	8.84	87.5	175.4		
		6	15.9	7.74	8.84	89.3	174.6		
		7	15.9	7.73	8.83	89.2	174.5		
		8	15.2	7.72	8.79	87.6	174.4		

Appendix B5: SL1 Raw Data

Raw data and field notes for sampling at Stony Lake site SL1.

PLMP water quality sampling form - Lake

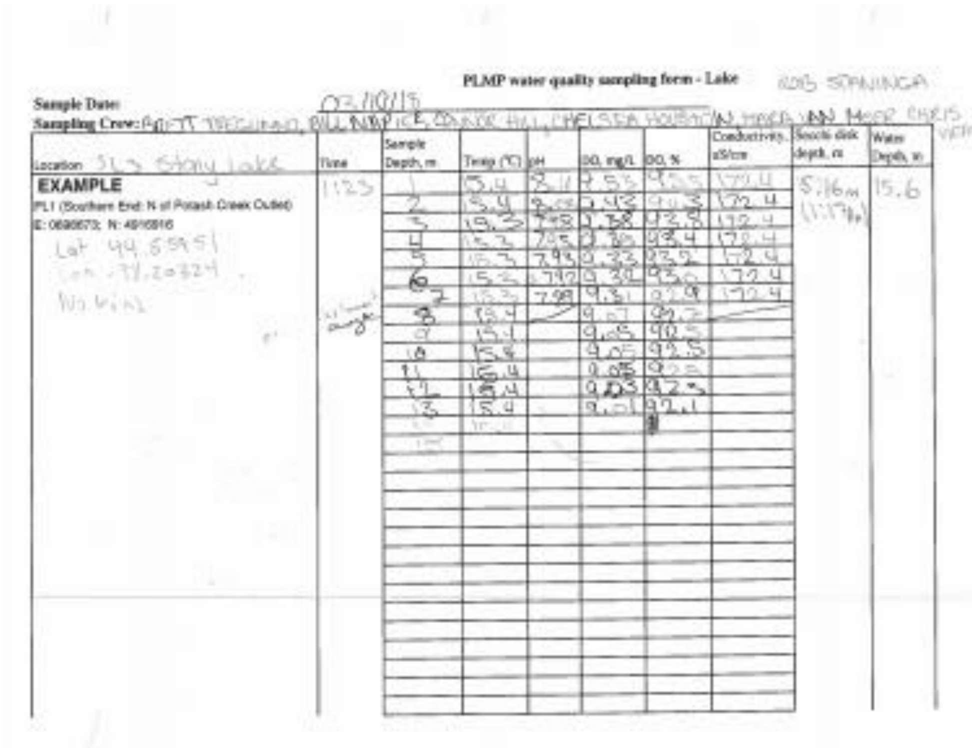
Sample Date: 08/10/18

Sampling Crew: BRETT TREGUNNO, BILL NAPIER, CONNOR HILL, CHELSEA HOUSTON, MARA VAN MEER, CHRIS VIERU, ROB STANINGA

Location SL2 Stony Lake	Time	Sample Depth, m	Temp (°C)	pH	DO, mg/L	DO, %	Conductivity, uS/cm	Secchi disk depth, m	Water Depth, m
EXAMPLE PL1 (Southern End: N of Potash Creek Outlet) E: 0698673; N: 4916916 Lat 44.49056 Lon 78.21096 No wind	12:00	1m	16.6	7.99	8.69	89.3	182.2	4m+3.5 / 2 = 3.75	13.0
		2m	16.6	7.95	8.66	88.9	182.2		
		3m	16.6	7.92	8.62	88.5	182.2		
		4m	16.6	7.91	8.60	88.5	182.2		
		5m	16.6	7.89	8.57	88.0	182.2		
		6m	16.6	7.87	8.55	87.8	182.2		
		7m	16.6	7.85	8.54	87.6	182.2		
		8m	16.6	7.84	8.52	87.5	182.2		
		9m	16.6	7.87	8.49	87.2	182.5		
		10m	16.6	7.80	8.46	86.8	182.5		
		11m	16.7		8.20	86.1			
		12m	16.6		8.03	84.3			
		12.5							

Appendix B6: SL2 Raw Data

Raw data and field notes for sampling at Stony Lake site SL2.



PLMP water quality sampling form - Lake

Sample Date: 07/10/15

Sampling Crew: [illegible], Bill [illegible], Connor Hill, Chelsea Houston, [illegible] Van Moer, Chris [illegible], Rob Staninga

Location: SL2 Stony Lake

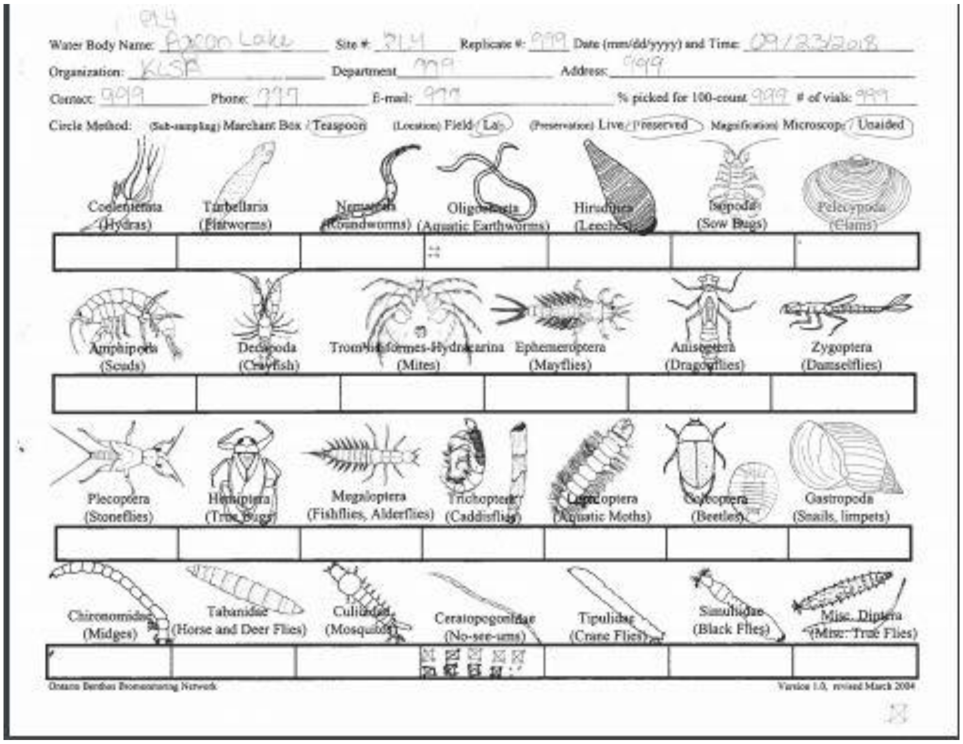
EXAMPLE
PL1 (Southern End: N of Potash Creek Outlet)
E: 0690673; N: 4916916

Lat 44.55951
Lon -78.20324
No wind

Time	Sample Depth, m	Temp (°C)	pH	DO, mg/L	DO, %	Conductivity, µS/cm	Secchi disk depth, m	Water Depth, m
11:23	1	15.4	8.11	9.53	95.5	172.4	5.16m (11:17am)	15.6
	2	15.4	8.0[illegible]	9.43	94.3	172.4		
	3	15.3	7.98	9.38	93.8	172.4		
	4	15.3	7.95	9.36	93.4	172.4		
	5	15.3	7.93	9.33	93.2	172.4		
	6	15.3	7.92	9.32	93.0	172.4		
	7	15.3	7.98	9.31	92.9	172.4		
	8	15.4		9.07	92.7			
	9	15.4		9.05	92.5			
	10	15.4		9.05	92.5			
	11	15.4		9.05	92.5			
	12	15.4		9.03	92.3			
	13	15.4		9.01	92.1			

Appendix B7: SL3 Raw Data

Raw data and field notes for sampling at Stony Lake site SL3.


Water Body Name: Pagon Lake Site #: PL4 Replicate #: 999 Date (mm/dd/yyyy) and Time: 09/23/2018
Organization: KLSA Department: 999 Address: 999
Contact: 999 Phone: 999 E-mail: 999 % picked for 100-count 999 # of vials: 999
Circle Method: (Sub-sampling) Marchant Box / Teaspoon (Location) Field / Lab (Preservation) Live / Preserved Magnification) Microscope / Unaided

Coelenterata (Hydras)	Turbellaria (Flatworms)	Nematoda (Roundworms)	Oligochaeta (Aquatic Earthworms)	Hirudinea (Leeches)	Isopoda (Sow Bugs)	Pelecypoda (Clams)

Amphipoda (Scuds)	Decapoda (Crayfish)	Trombidiformes-Hydracarina (Mites)	Ephemeroptera (Mayflies)	Anisoptera (Dragonflies)	Zygoptera (Damselflies)

Plecoptera (Stoneflies)	Hemiptera (True Bugs)	Megaloptera (Fishflies, Alderflies)	Trichoptera (Caddisflies)	Lepidoptera (Aquatic Moths)	Coleoptera (Beetles)	Gastropoda (Snails, limpets)

Chironomidae (Midges)	Tabanidae (Horse and Deer Flies)	Culicidae (Mosquitoes)	Ceratopogonidae (No-see-ums)	Tipulidae (Crane Flies)	Simuliidae (Black Flies)	Misc. Diptera (Misc. True Flies)

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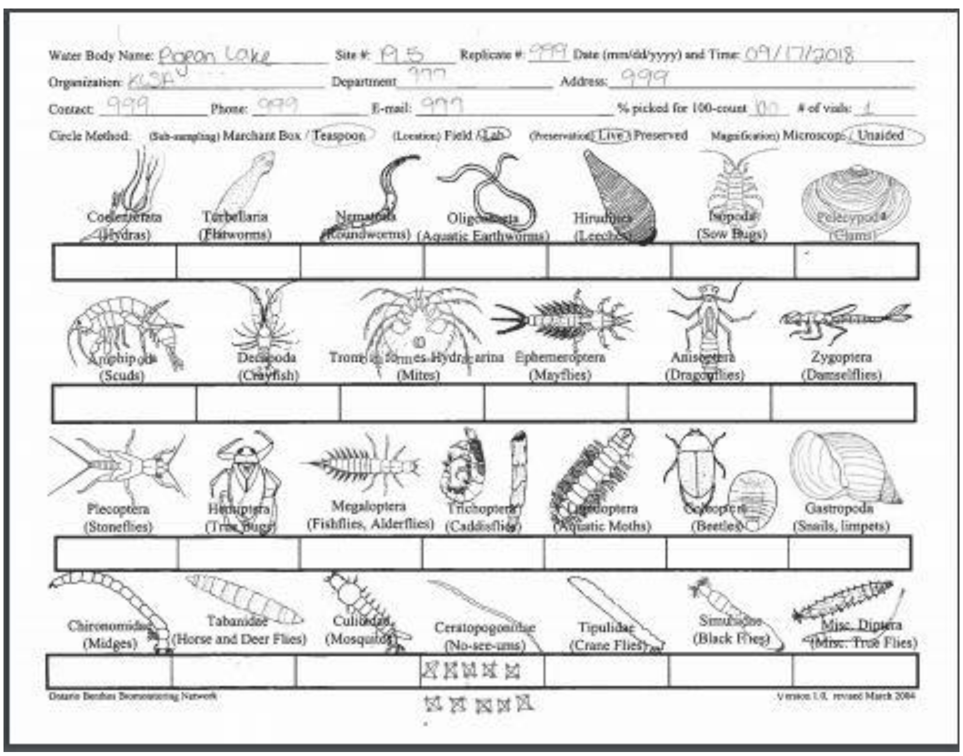
Appendix B8: Benthics for PL4


Water Body Name: Pagon Lake Site #: PL5 Replicate #: 999 Date (mm/dd/yyyy) and Time: 09/17/2018
Organization: KLSA Department: 999 Address: 999
Contact: 999 Phone: 999 E-mail: 999 % picked for 100-count 100 # of vials: 1
Circle Method: (Sub-sampling) Marchant Box / Teaspoon (Location) Field / Lab (Preservation) Live / Preserved Magnification) Microscope / Unaided

Coelenterata (Hydras)	Turbellaria (Flatworms)	Nematoda (Roundworms)	Oligochaeta (Aquatic Earthworms)	Hirudinea (Leeches)	Isopoda (Sow Bugs)	Pelecypoda (Clams)

Amphipoda (Scuds)	Decapoda (Crayfish)	Trombidiformes-Hydracarina (Mites)	Ephemeroptera (Mayflies)	Anisoptera (Dragonflies)	Zygoptera (Damselflies)

Plecoptera (Stoneflies)	Hemiptera (True Bugs)	Megaloptera (Fishflies, Alderflies)	Trichoptera (Caddisflies)	Lepidoptera (Aquatic Moths)	Coleoptera (Beetles)	Gastropoda (Snails, limpets)

Chironomidae (Midges)	Tabanidae (Horse and Deer Flies)	Culicidae (Mosquitoes)	Ceratopogonidae (No-see-ums)	Tipulidae (Crane Flies)	Simuliidae (Black Flies)	Misc. Diptera (Misc. True Flies)

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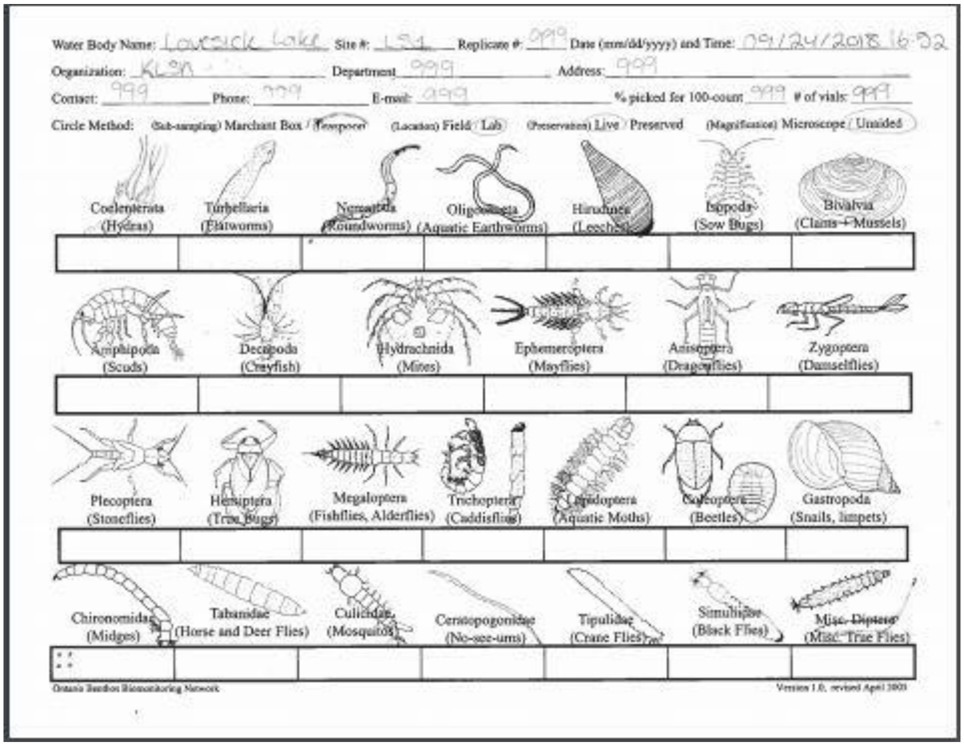
Version 1.0, revised March 2004

Appendix B9: Benthics for PL5



Water Body Name: Lovesick Lake Site #: LS1 Replicate #: 999 Date (mm/dd/yyyy) and Time: 09/24/2018 16:52
Organization: KLSA Department: 999 Address: 999
Contact: 999 Phone: 999 E-mail: 999 % picked for 100-count: 999 # of vials: 999
Circle Method: (Sub-sampling) Marchant Box / Teaspoon (Location) Field / Lab (Preservation) Live / Preserved (Magnification) Microscope / Unaided

Coelenterata (Hydras)	Turbellaria (Flatworms)	Nematoda (Roundworms)	Oligochaeta (Aquatic Earthworms)	Hirudinea (Leeches)	Isopoda (Sow Bugs)	Bivalvia (Clams + Mussels)

Amphipoda (Scuds)	Decapoda (Crayfish)	Hydrachnida (Mites)	Ephemeroptera (Mayflies)	Anisoptera (Dragonflies)	Zygoptera (Damselflies)

Plecoptera (Stoneflies)	Hemiptera (True Bugs)	Megaloptera (Fishflies, Alderflies)	Trichoptera (Caddisflies)	Lepidoptera (Aquatic Moths)	Coleoptera (Beetles)	Gastropoda (Snails, limpets)

Chironomidae (Midges)	Tabanidae (Horse and Deer Flies)	Culicidae (Mosquitos)	Ceratopogonidae (No-see-ums)	Tipulidae (Crane Flies)	Simuliidae (Black Flies)	Misc. Diptera (Misc. True Flies)
::						

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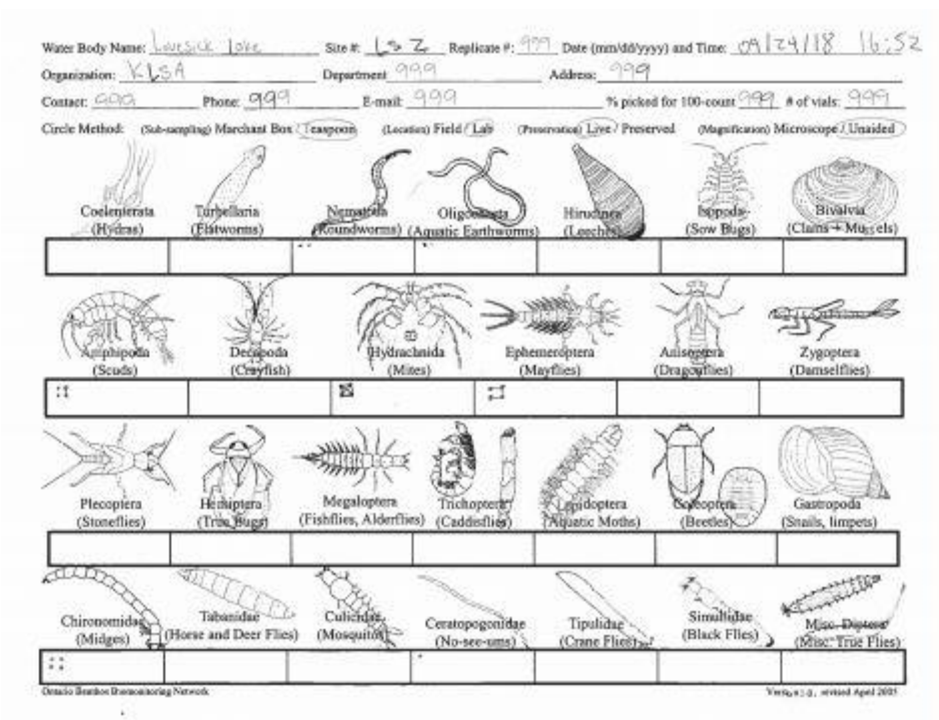
Appendix B10: Benthics for LS1



Water Body Name: Lovesick Lake Site #: LS2 Replicate #: 999 Date (mm/dd/yyyy) and Time: 09/24/18 16:52
Organization: KLSA Department: 999 Address: 999
Contact: 999 Phone: 999 E-mail: 999 % picked for 100-count: 999 # of vials: 999
Circle Method: (Sub-sampling) Marchant Box / Teaspoon (Location) Field / Lab (Preservation) Live / Preserved (Magnification) Microscope / Unaided

Coelenterata (Hydras)	Turbellaria (Flatworms)	Nematoda (Roundworms)	Oligochaeta (Aquatic Earthworms)	Hirudinea (Leeches)	Isopoda (Sow Bugs)	Bivalvia (Clams + Mussels)

Amphipoda (Scuds)	Decapoda (Crayfish)	Hydrachnida (Mites)	Ephemeroptera (Mayflies)	Anisoptera (Dragonflies)	Zygoptera (Damselflies)
[illegible]		[illegible]	[illegible]		

Plecoptera (Stoneflies)	Hemiptera (True Bugs)	Megaloptera (Fishflies, Alderflies)	Trichoptera (Caddisflies)	Lepidoptera (Aquatic Moths)	Coleoptera (Beetles)	Gastropoda (Snails, limpets)

Chironomidae (Midges)	Tabanidae (Horse and Deer Flies)	Culicidae (Mosquitos)	Ceratopogonidae (No-see-ums)	Tipulidae (Crane Flies)	Simuliidae (Black Flies)	Misc. Diptera (Misc. True Flies)
::						

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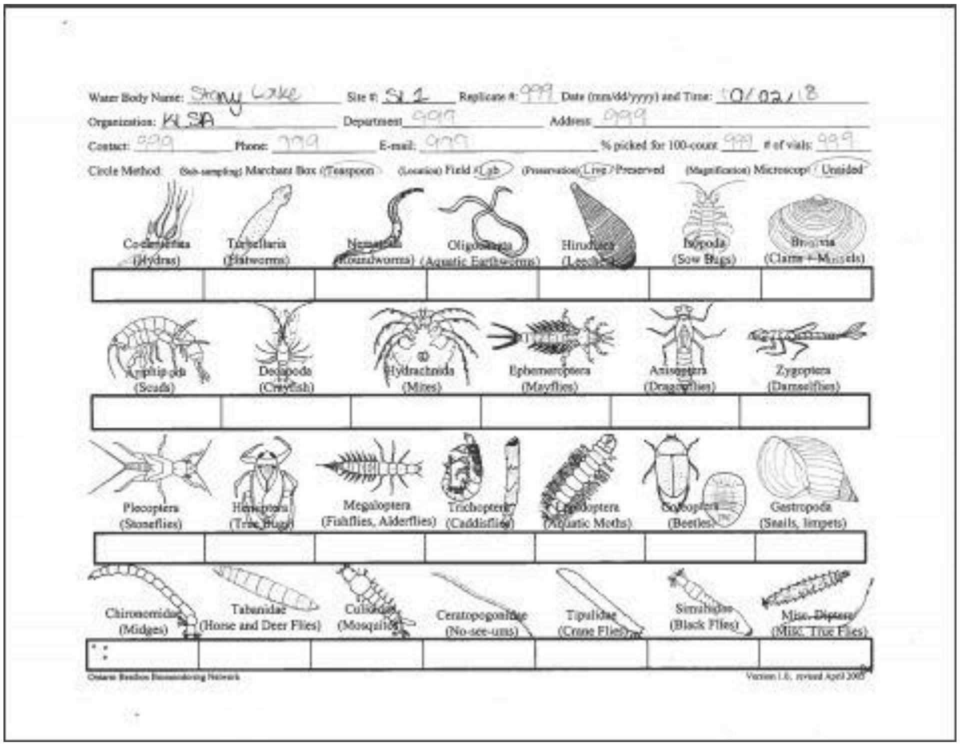
Version 1.0, revised April 2003

Appendix B11: Benthics for LS2



Water Body Name: Stony Lake Site #: SL 1 Replicate #: 999 Date (mm/dd/yyyy) and Time: 10/02/18

Organization: KLSA Department: 999 Address: 999

Contact: 999 Phone: 999 E-mail: 999 % picked for 100-count: 999 # of vials: 999

Circle Method: (Sub-sampling) Marchant Box / Teaspoon (Location) Field / Lab (Preservation) Live / Preserved (Magnification) Microscope / Unaided

Coelenterata (Hydras)	Turbellaria (Flatworms)	Nematoda (Roundworms)	Oligochaeta (Aquatic Earthworms)	Hirudinea (Leeches)	Isopoda (Sow Bugs)	Bivalvia (Clams + Mussels)

Amphipoda (Scuds)	Decapoda (Crayfish)	Hydrachnida (Mites)	Ephemeroptera (Mayflies)	Anisoptera (Dragonflies)	Zygoptera (Damselflies)

Plecoptera (Stoneflies)	Hemiptera (True Bugs)	Megaloptera (Fishflies, Alderflies)	Trichoptera (Caddisflies)	Lepidoptera (Aquatic Moths)	Coleoptera (Beetles)	Gastropoda (Snails, limpets)

Chironomidae (Midges)	Tabanidae (Horse and Deer Flies)	Culicidae (Mosquitoes)	Ceratopogonidae (No-see-ums)	Tipulidae (Crane Flies)	Simuliidae (Black Flies)	Misc. Diptera (Misc. True Flies)

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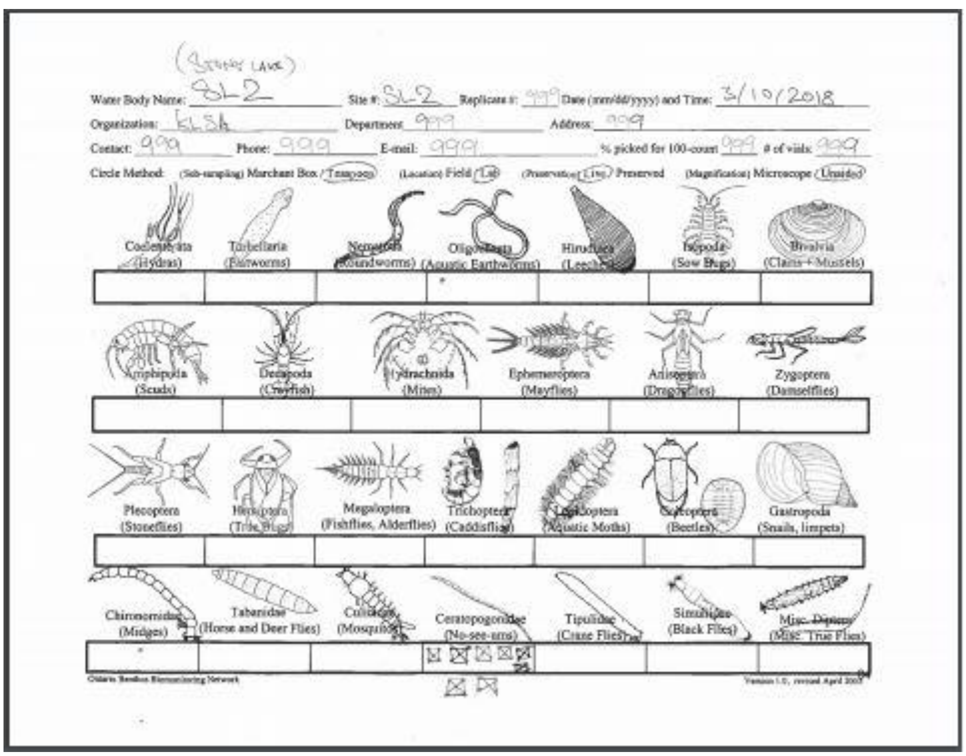
Appendix B12: Benthics for SL1



Water Body Name: (Stoney Lake) SL 2 Site #: SL 2 Replicate #: 999 Date (mm/dd/yyyy) and Time: 3/10/2018

Organization: KLSA Department: 999 Address: 999

Contact: 999 Phone: 999 E-mail: 999 % picked for 100-count: 999 # of vials: 999

Circle Method: (Sub-sampling) Marchant Box / Teaspoon (Location) Field / Lab (Preservation) Live / Preserved (Magnification) Microscope / Unaided

Coelenterata (Hydras)	Turbellaria (Flatworms)	Nematoda (Roundworms)	Oligochaeta (Aquatic Earthworms)	Hirudinea (Leeches)	Isopoda (Sow Bugs)	Bivalvia (Clams + Mussels)

Amphipoda (Scuds)	Decapoda (Crayfish)	Hydrachnida (Mites)	Ephemeroptera (Mayflies)	Anisoptera (Dragonflies)	Zygoptera (Damselflies)

Plecoptera (Stoneflies)	Hemiptera (True Bugs)	Megaloptera (Fishflies, Alderflies)	Trichoptera (Caddisflies)	Lepidoptera (Aquatic Moths)	Coleoptera (Beetles)	Gastropoda (Snails, limpets)

Chironomidae (Midges)	Tabanidae (Horse and Deer Flies)	Culicidae (Mosquitoes)	Ceratopogonidae (No-see-ums)	Tipulidae (Crane Flies)	Simuliidae (Black Flies)	Misc. Diptera (Misc. True Flies)
			☒☒☒☒☒ ☒☒			

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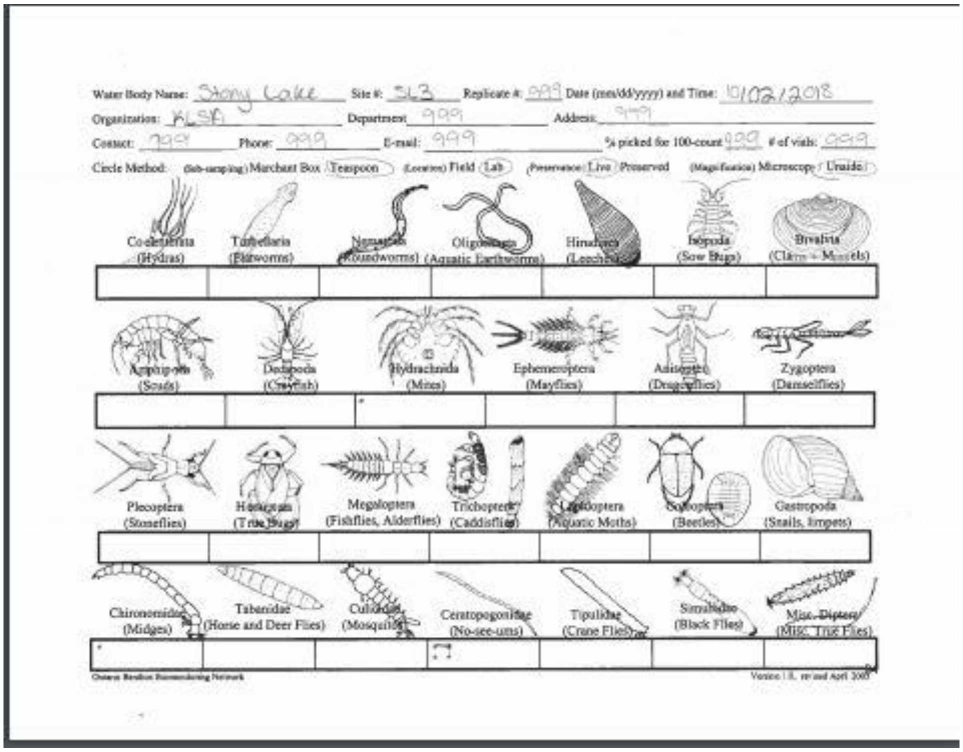
Appendix B13: Benthics for SL2



Water Body Name: Stony Lake Site #: SL3 Replicate #: 999 Date (mm/dd/yyyy) and Time: 10/02/2018
Organization: KLSA Department: 999 Address: 999
Contact: 999 Phone: 999 E-mail: 999 % picked for 100-count 999 # of vials: 999
Circle Method: (Sub-sampling) Merchant Box Teaspoon (Location) Field Lab (Preservation) Live Preserved (Magnification) Microscope Unaided

Coelenterata (Hydras)	Turbellaria (Flatworms)	Nematoda (Roundworms)	Oligochaeta (Aquatic Earthworms)	Hirudinea (Leeches)	Isopoda (Sow Bugs)	Bivalvia (Clams + Mussels)

Amphipoda (Scuds)	Decapoda (Crayfish)	Hydrachnida (Mites)	Ephemeroptera (Mayflies)	Anisoptera (Dragonflies)	Zygoptera (Damselflies)

Plecoptera (Stoneflies)	Hemiptera (True Bugs)	Megaloptera (Fishflies, Alderflies)	Trichoptera (Caddisflies)	Lepidoptera (Aquatic Moths)	Coleoptera (Beetles)	Gastropoda (Snails, limpets)

Chironomidae (Midges)	Tabanidae (Horse and Deer Flies)	Culicidae (Mosquitoes)	Ceratopogonidae (No-see-ums)	Tipulidae (Crane Flies)	Simuliidae (Black Flies)	Misc. Diptera (Misc. True Flies)

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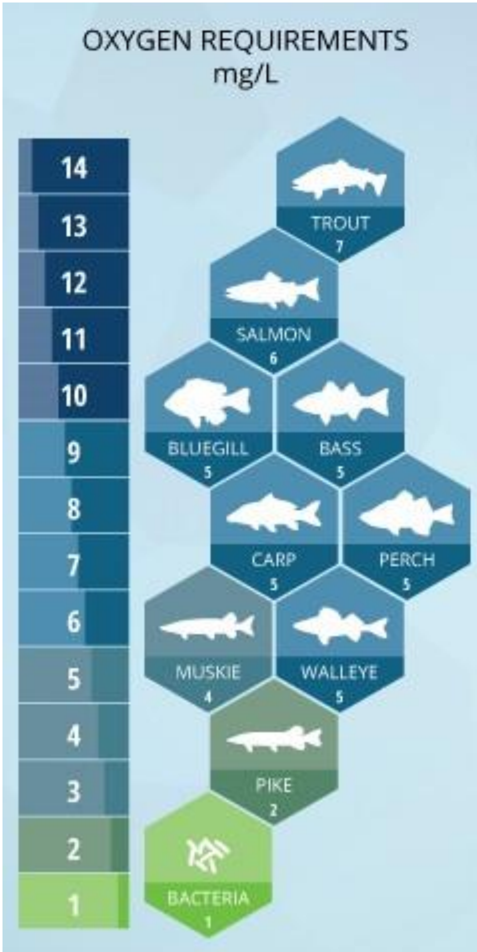
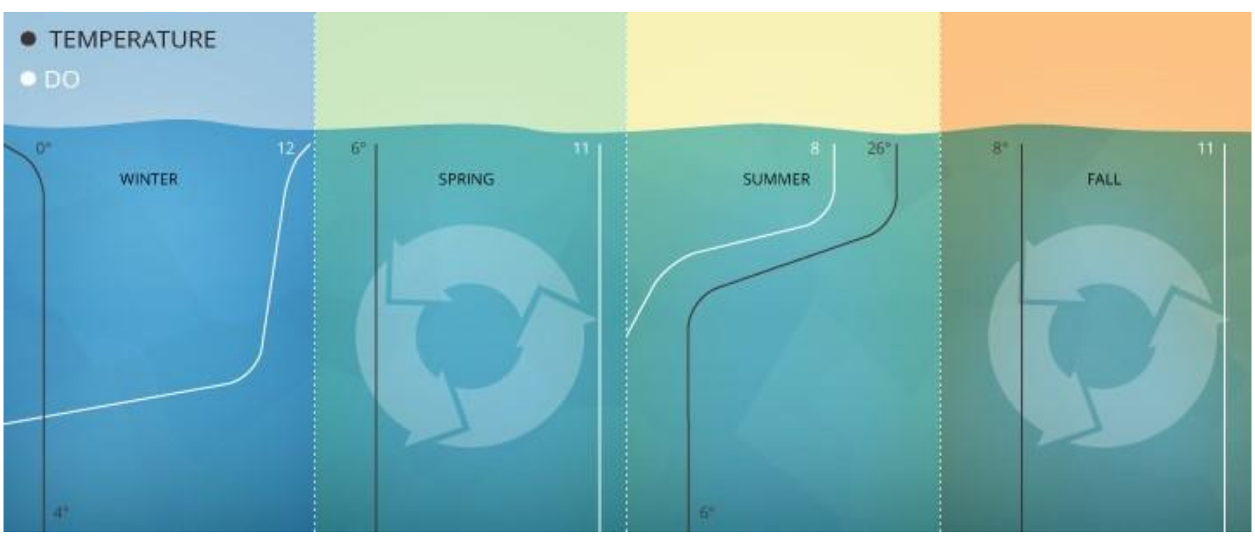
Appendix B14: Benthics for SL3



Appendix B15: Chart showing a pictorial representation of the Oxygen concentration range to support various fish species.



Appendix B16: Seasonal characteristics of water temperature and dissolved oxygen. As noted above, Pigeon Lake temperature and DO profiles are similar to those expected during the summer months while Lovesick Lake and the Stony/Clear Lake sampling sites illustrate typical spring/fall conditions.

Appendix C: Credit for Product

Appendix C1: Literature Review 1: Connor Hill, Implications of below threshold DO concentrations on a Lake

Dissolved oxygen is an inert gas that is essential to a healthy ecosystem which can cause an ecosystem to crumble if the levels are too low. The current literature on dissolved gas explores why it is important, what levels of dissolved oxygen certain species need, what causes a flux in the levels, and what environmental parameters have the largest impact on dissolved oxygen. The focus of this literature review will be on the importance of dissolved oxygen and what can cause the levels to fluctuate in an aquatic environment, with a specific interest on environmental factors.

Bulai, I. M., & Venturino, E. (2017). Two mathematical models for dissolved oxygen in a lake—CMMSE-16. *Journal of Mathematical Chemistry*, *55*(7), 1481–1504.

Two mathematical models for dissolved oxygen in a lake is a journal article that discusses two mathematical models for water pollution. The first model assumes algae and fungi are in competition for resources that come from waste water. The second model introduces an equation for nutrients. The paper would be important to

discussing what factors affect dissolved oxygen levels in the KLSA C4P project, specifically dealing with pollution. A conclusion was proposed for the first model in that both algae and fungi depend on dissolved oxygen for growth. Algae produce their own and at a faster rate than the dissolved oxygen within the environment. If fungi and algae can coexist, the competition is stable which means the two are able to acquire enough dissolved oxygen for proper growth. To follow up, if the competition is not

high, their coexistence reaches equilibrium without a constant input of dissolved oxygen. The second model determined matching points of equilibrium within the first model, in which two equilibria were found. The journal article has a small reference list and could be considered an unreliable source. However, the information within this paper could provide important context to the relationship between algae, dissolved oxygen and pollution for the KLSA C4P project. If need be, the information could be double checked by looking into similar topics.

Fondriest Environmental, Inc. "Dissolved Oxygen." Fundamentals of Environmental Measurements. 19 Nov. 2013. http://www.fondriest.com/environmental-measurements/parameters/water-quality/dissolved-oxygen/

Dissolved oxygen (DO) is a type of gas that is used for aquatic respiration and nutrient supply for different species. This webpage provides an insight into what DO is, its relationship to aquatic life, where it comes from, the dangers of high or low DO, how a stratified water column affects DO, how to report DO measurements, and a few examples of freshwater organisms' requirements regarding DO. The webpage would be an asset to the KLSA C4P project as it provides easy to understand explanations and touches on many important aspects of DO in relation to the projects goal. Prime DO levels are discussed for various types of freshwater organisms including: Walley, Lake Trout, Salmon, Largemouth Bass, Yellow Perch, and bottom dwelling invertebrates. For example, Largemouth Bass and Yellow Perch prefer dissolved oxygen levels that surpass 5mg/L and generally avoid DO levels that are below 3mg/L. Fatalities start to become common near the 2mg/L level of DO. The page has a plethora of references that range from credible scientific journals from the Academic Press to informational government pages on fish specifications making it a reliable source. The last part of the page discusses DO reporting and calculating which could be valuable when writing the final report and composing proper data sheets.

Hudson, J. J., & Vandergucht, D. M. (2015). Spatial and temporal patterns in physical properties and dissolved oxygen in Lake Diefenbaker, a large reservoir on the Canadian Prairies. *Journal of Great Lakes Research*, *41*, 22–33

Lake Diefenbaker is a deep storage reservoir that experiences complex longitudinal zonation. Water quality was assessed based on stratification patterns, turbidity, and dissolved oxygen. The quality of the water factored in how climate change may affect the previously stated parameters. One example is that rising temperatures will increase the temperatures of the water bodies themselves. The increase in water temperature causes the thermal stability and the duration of stratification of the columns of water to rise. An oxygen gradient forms when the vertical movement of oxygen is suppressed from oxidative decomposition of organic matter in the hypolimnion and bottom sediments. Oxidative decomposition can lead to hypoxic or anoxic conditions (lowdissolved oxygen levels) in the hypolimnion. Hypoxic or anoxic conditions can lead to an increased rate of internal loading of nutrients and release of noxious substances fromthe bottom sediments in the water column. The journal article would be helpful to the KLSA C4P project because it gives insight into what factors affect dissolved oxygen levels and also how hypoxic or anoxic conditions can affect the water quality. An assessment was conducted during the ice free periods from 2011-2013. The features were compared to Kimmel and Groeger (1984) using the longitudinal zonation concept. The current study had results that were similar to a drought year (1984). Parts of the hypolimnia were hypoxic or sub optimal for cold water fish. Hypolimnetic oxygen depletion rates were 0.034 to 0.12mg/L/Day and were similar to other surrounding lakes and reservoirs. Above average peak flows for the three years and in 2013 the peakflows caused an increase in turbidity and organic matter deposition. The result was a metlimnetic dissolved oxygen minimum. Similar results were found in 1984, during the drought, in which anoxic conditions and algal blooms increased.

Li, J. L. Molot, M. Palmer, J. Winter, J. Young and E. Stainsby. 2018. Long-term changes in hypolimnetic dissolved oxygen in a large lake: Effects of invasive mussels, eutrophication and climate change on Lake Simcoe 1980-2012. *Journal of Great Lakes Research* :44(4) pg: 779-787

The lowest water layer in a lake is called the Hypolimnion. Many small benthic organisms' dwell in the deepest layers of the lake and provide a lot of productivity to the lake's ecosystem. Dissolved oxygen can be found in the hypolimnion layer at lower concentrations and is used for respiration by the small organisms. In this journal, long term patterns of dissolved oxygen in the hypolimnetic layer of Lake Simcoe were examined for three decades. Environmental changes were observed over the three decades, leading to a decrease in habitat suitability. A few changes that occurred include eutrophication, phosphorus reduction, and an invasive species introduction that all led to a reduction in dissolved oxygen concentrations at the hypolimnetic layer. This paper could be very useful when discussing the implications of low DO concentrations and what may cause a decrease in DO levels.

Katsumi. M, K. S. Tokos, and C. Gregory. Ventilation and dissolved oxygen cycle in Lake Superior: Insights from a numerical model. *Geochemistry*, *Geophysics, Geosystems*. (2015), 3097–3110.

Ventilation is the cycle by which water is transported through an aquatic environment. The surface water is exposed exchanges heat, water, and gases with the atmosphere while photosynthesis and other processes modify surface nutrient concentrations. The processes that occur near the surface "imprint signatures" on the surface water. These signatures could be temperature, nutrients, and dissolved gas concentration. The surface water carries the "signatures" into the interior. The signature tag can then be used to determine the location and condition where the water came from. Generally, a body of water that is well ventilated contains a lot of dissolved oxygen. The concentration of oxygen in the interior drops over time because aerobic respiration of organic matter consumes oxygen. Therefore, dissolved oxygen reduction can be considered a qualitative measure of ventilation. Dissolved oxygen and ventilation are important factors that can be used to determine the fate of natural and anthropogenic inputs to the lake, i.e. Lake Superior. The journal article has various definitions, concepts and results that could be incorporated into the KLSA C4P project. Age tracers and biogeochemical tracers were introduced into a configured numerical model of Lake Superior to determine the ventilation and dissolved oxygen cycle. Lake Superior is preferably ventilated over rough bathymetry and spring overturning following cold winters do not properly ventilate the lakes interior. Each part of Lake Superiors body of water is exposed to the atmosphere at least one time in a 300-day cycle. The results indicated that biological consumption is not the obvious process for the consumption of dissolved oxygen. Instead the solubility change in the water dominates oxygen cycles within the lake. A suggestion to the project for Lake Superior would be to look at similar lakes or local lakes and determine if biological processes do in fact affect dissolved oxygen levels.

Misra, A. K., Chandra, P., & Raghavendra, V. (2011). Modeling the depletion of dissolved oxygen in a lake due to algal bloom: Effect of time delay. *Advances in Water Resources*, *34*(10), 1232–1238.

A non-linear mathematical model for algal lake were used to determine the delay in conversion of detritus into nutrients. The model had four factors to it: nutrient concentration, algal population density, detritus density and dissolved oxygen concentration. This paper would provide support to our project's section of recommendations and the effects that Eutrophication can have on a lake. Eutrophication was studied in the lakes to determine its effect on dissolved oxygen levels. Some algal populations may grow fast even if the nutrient concentrations are low. Discharge of nutrients from agricultural fields was determined to be a key factor to instability in nutrient equilibrium within the lake. The journal article is a credible source as it comes for Advances of water research and is published in the faculty of science at Banaras Hindu University, India.

Skinner, J. (n.d.) Water Chemistry Lecture Noteshttp://academic.keystone.edu/jskinner/Limnology/Water_Chemistry_LectureNotes. htm

Dissolved oxygen levels are affected by different environmental components and biological processes such as: temperature, pressure, turbidity, photosynthesis, and respiration. The webpage highlights how the previous factors and processes affect DO levels, causes of gains or losses of DO in water, oxygen profiles for different lake types (Oligotrophic, Eutrophic, etc.) and how to measure DO properly. Despite this webpage of lecture notes lacking sources or references, it can assist with our project because there is easy, understandable content regarding factors that affect DO levels.

Wassenaar, L. I. (2012). Dissolved oxygen status of Lake Winnipeg: Spatio-temporal

and isotopic (δ18O-O2) patterns. *Journal of Great Lakes Research*, *38*(SUPPL. 3),

123–134

During the span of 4 years, 2006 to 2010, spatio-temporal patterns of dissolved oxygen were taken at 50 stations of Lake Winnipeg to determine the current dissolved oxygen status and the aquatic community's metabolism. This journal article would give insight into what may happen to dissolved oxygen levels and the lakes metabolism when a lake becomes eutrophicated for the KLSA project. The results came back that determined Lake Winnipeg to have surface water oxygen super saturation, but the bottom water was experiencing hypoxia. The lake was deemed largely heterotrophic and under saturated in oxygen. The hypolimnion in summer and winter, dropped to as low as 2.6mg/L of dissolved oxygen. The journal article was incorporated into Great Lakes Research and Environment Canada, making it a viable source for the KLSA project

Vilas, M. P., Marti, C. L., Adams, M. P., Oldham, C. E., & Hipsey, M. R. (2017). Invasive Macrophytes Control the Spatial and Temporal Patterns of Temperature and Dissolved Oxygen in a Shallow Lake: A Proposed Feedback Mechanism of Macrophyte Loss. *Frontiers in Plant Science*, *8*(December), 1–14

Macrophytes that are submerged strongly effect the thermal structure and dissolved oxygen levels of a lake ecosystem. Invasive macrophytes are even more dominant in controlling the thermal gradients of a lake that may cause a complete change in the structure of a lake's ecosystem. The journal article would benefit the KLSA project by providing examples of what can happen to a shallow lake's ecosystem, which is all the lakes of interest in the project, if invasive macrophytes are introduced. Fine scale measurements and 3D numeric modeling were used to determine the effects of *Potagometon Crispus L* (Curled Pondweed) on spatial and temporal aspects of temperature and dissolved oxygen. During the Pondweeds growing season, daytime stratification was evident, and stratification was strongest near the center of the macrophyte bed. Stratification began when the macrophytes controlled at least 50% of the water depth. This result was supported by creating a logistic growth curve to changes in plant height over time and comparing it to the temperature at the center of the bed. As the pondweed grew, stratification took place and a dissolved oxygen profile was generated. The profile changed from vertically homogenous oxic conditions during both daytime and nighttime, to night time anoxic conditions close to the sediment. The source is credible as it has a long list of references that are from reliable sources like: Aquatic Ecology, Aquatic science, and Ecological Modelling. Dissolved oxygen is an important nutrient to any aquatic ecosystem. Dissolved oxygen is used for respiration in living organisms but is also important in the chemical break down of organic material. Eutrophication, large algal blooms, can throw off the equilibrium in a lake causing dissolved oxygen levels to drop. Algal and other plant material use dissolved oxygen to breakdown, thus large algal blooms or invasive macrophytes may use large quantities of dissolved oxygen and deplete the ecosystem. Mathematical models have been created to determine the relationship between aquatic species, environmental factors, anthropogenic factors and dissolved oxygen. The general results indicate that a balance is needed between all the previously states aspects of a lakes ecosystem. Too much of one will throw off the system and cause dissolved oxygens levels to drop. Thus, it is important to incorporate some solutions and preventive methods to protect lakes from reaching low dissolved oxygen levels.

Appendix C2: Literature Review 2: Chelsea Houston Examining Past and Present DO Studies in the Kawartha Lakes Continuum

Thesis Statement:

Biological (aquatic plant/animal), chemical (Phosphorus loading/tributary inflow), physical (landscape/temperature) changes should be our areas of concern when analyzing our dissolved oxygen results from sampling Pigeon, Lovesick, and Stony Lake. These conditions have been found in the Kawartha Lakes continuum in past and present studies.

Introduction:

This literature review is dedicated to studying past and present dissolved oxygen studies in the Kawartha Lakes continuum. Currently, myself and 3 of my colleagues from the EMX program are completing a project focusing on DO concentrations in 3 lakes in the KL continuum for the Kawartha Lake Stewards Association. Our project is being carried out to build on the research recently collected in these lakes in the Queen's University paleolimnological study in 2017, and Trent University's water quality monitoring in the summer of 2018. Learning more about the DO in Pigeon, Lovesick, and Stony Lake allows us to measure lake health. Our project includes measuring DO concentrations, Phosphorus levels, conductivity, temperature, pH and benthic samples. In reviewing these sources, I consider their location in comparison to our study area, the relevance of the study subject and project objectives, and ways that we can interpret the sources in the context of our project. These sources provide background knowledge for us to draw on when analyzing our results.

1.

Borrowman, K.R., Sager, E.P.S., & Thum, R.A. (2014). Distribution of biotypes and hybrids of

Myriophyllum spicatum and associated *Euhrychiopsis lecontei* in lakes of Central Ontario,Canada. *Lake and Reservoir Management, 30*(1), 94-104. doi: https://doi.org/10.1080/10402381.2013.876469.

This study looks at the population of Eurasian water milfoil (Myriophyllum spicatum) across 21 lakes in Central Ontario. Since the watermilfoil appeared in Canadian waterways in the 1960's, there has been a growing concern about the increased invasiveness and resiliency to biological controls (such as the Milfoil weevil), through hybridization with the native Northern watermilfoil. During the study carried out in 2010, 2 different bio-types of milfoil hybrids were discovered. Eurasian watermilfoil creates a monoculture in the water columns of lakes so dense that it changes the social, biological, and functional structure of water bodies. Dissolved oxygen

levels are reduced because of this excessive plant growth. Of the 21 sampling lakes, Pigeon Lake and Stony Lake were included. This study gives us further context to the historical conditions of these lakes, and again solidifies how important it is to consider the presence, absence, and abundance of organisms including plants, fish, and benthos in our analyses and interpretation of our results.

2.

Crossman, J, & Elliott, J. (2017). Bridging the gap between terrestrial, riverine and limnological research: Application of a model chain to a mesotrophic lake in North America. *Science of the Total Environment, 622-623*, 1363-1378. doi: https://doi.org/10.1016/j.scitotenv.2017.12.052

This study strives to examine the terrestrial riverine, and limnological nutrient transport and ecological response by linking limnology and catchment hydrology. This unique-basin wide application of a process-based model chain was used to study the watershed of Lake Simcoe.

Two integrated catchment models were used in the Lake Simcoe watershed; INCA-P and INCA-N, to drive the PROTECH lake model. Using these systems, they were able to build a

dissolved oxygen component into PROTECH, and are able to monitor multiple stressor controls on high frequency monitoring data. These methods are applied to model outputs to identify the main drivers of critically low dissolved oxygen events in the lake. From 2010-2016, the monthly and annual dissolved oxygen measurements within 5 m of the lake bottom remained in line with the observed data. This horizon of the lake was chosen because it has been noted as a habitat for juvenile Lake trout in late summer. Analysis of the DO results determined that losses related to algal growth were not the main driver of low DO events. Instead, temperature and tributary inflow conditions seemed to have a greater role to play. This is important to consider when analyzing our dissolved oxygen values, and considering the reasons for them. As previously stated, Lake Simcoe is the watershed nearest to Kawartha on the Western side, and conditions found in the lake may mirror those found in ours. This gives us context into some lake models that have been previously used in the region, and into the role that tributary inflows and temperatures can play on DO levels.

3.

Doka, S.E., Minns, C.K, Moore, J.E., & St. John, M.A. (2011). Temporal trends and spatial patterns in the temperature and oxygen regimes in the Bay of Quinte, Lake Ontario, 1972–2008. *Aquatic Ecosystem Health & Management, 14*(1) 9-20. doi: 10.1080/14634988.2011.547327

This article details the long-term monitoring of temperature and oxygen in the Bay of Quinte that took place between 1972-2008, and the trends that were observed. The objectives of the study included assessing long-term trends and spatial patterns in seasonal surface temperature and vertical thermal structure at monitoring sites, assessing spatial and temporal patterns in hypolimnetic warming and apparent oxygen depletion, and assessing the influence of water quality, climatic, and hydrologic conditions on the temporal trends (Doka, Minns, Moore, & St.

John, 2011). The overall results of this study determined that oxygen depletion varied from

year-to-year, but showed a long-term downward trend once point-source Phosphorus loading into the Bay was decreased. Due to how long monitoring of oxygen levels in the Bay was undertaken, the authors note in the discussion that it was clear to see apparent oxygen depletion in response to physical processes, such as solar-heating and wind-mixing of the thermal layers.

Apparent oxygen depletion during stratification was present at middle and lower Bay sites. The oxygen depletion rates observed over the study period did not show any indicators of hypoxia, and the oxygen depletion rates had a direct relationship with reduced P loading levels. This study is applicable to our own because the Bay of Quinte and Kawartha Lakes continuum are both in the greater Lake Ontario Watershed Basin. All of the water in this basin drains into the same area, so conditions found in one area could be applicable to another. On a smaller scale, within the Lake Ontario Watershed Basin, the Kawartha Lakes watershed flows into the Trent watershed, and into Lake Ontario, meaning that the results we may find in our study could have implications for the Bay of Quinte, among other water bodies. Furthermore, the Bay of Quinte is a part of Lake Ontario, located in the St. Lawrence Lowlands. The geological and morphological conditions surrounding the lake may be similar to those found at Pigeon Lake, one of our sampling sites.

4.

Kawartha Conservation. (2010). *Lake Scugog Environmental Management Plan: May 2010*.

Retrieved October 8. 2018 from https://www.kawarthaconservation.com/library?view=document&id=9:lake-scugog-environmental-management-plan&catid=58:lake-management-plans.

This report was prepared by Kawartha Conservation, analyzing data collected from

2004-2008. The conservation authority carried out water quality and quantity monitoring during these years that was used to calculate water, phosphorus, and nitrogen budgets for Lake Scugog

in the report. The environmental management plan was created because of growing concern about the lake health and ecology. In recent years, there has been excessive input of phosphorus and nitrogen, causing eutrophication, siltation, and overproduction of vegetation. These processes have begun to impede the activities of residents on the lake, and stakeholders determined that they need to protect the environmental health of Lake Scugog in order to continue enjoying it. In terms of dissolved oxygen, ecologists were concerned about how excessive plant and algal growth can diminish the amount of dissolved oxygen in the water column. Furthermore, when the tributaries to Lake Scugog were sampled, they were found to have severe dissolved oxygen deficiencies. The main tributary of concern for this waterbody is Nonquon River, which frequently has low dissolved oxygen levels. This is due to the excessive amount of plant and algal growth and high proportion of swamp water in the river in summer months. The study completed on Lake Scugog is applicable to our lakes because they are in the same geographic region and conditions in one may be applicable to the others. Seeing as dissolved oxygen was even historically a concern in Lake Scugog allows us to again understand the context of the work we are doing.

*5.

Kawartha Lake Stewards Association. (2011). *KLSA's Guide to the Watermilfoil Weevil*.

Retrieved September 24, 2018 from

https://klsa.wordpress.com/published-material/milfoil-weevil-guide/#Authors.

In 2011, the KLSA had another group of Fleming College students carry out a project looking at the use of the milfoil weevil to manage Eurasian watermilfoil. Although not a study focused on dissolved oxygen, DO is a variable in this study. Eurasian watermilfoil can deplete the amount of dissolved oxygen in the water, and limit oxygen exchange.

The native aquatic weevil had been found in many of the Kawartha Lakes, however the population density was not high enough to cause Eurasian watermilfoil decline. Stocking or augmenting native weevil populations was a potential solution the group was considering, barring the impacts on lake ecology and health. At the time of the report, some current management techniques included mechanical harvesting, chemical, and biological methods using insect species.

This source is important for us to consider in our study of the DO variables in Pigeon, Stony, and Lovesick Lake when looking toward our future recommendations. This study helps us to contextualize how parameters such as DO can be impacted so easily, and how best to deal with these changes.

*6.

Ontario Ministry of the Environment. (2001). *Phosphorus Loading to Lake Simcoe, 1990-1998: Highlights and Preliminary Interpretation in Historical and Ecosystem Concepts.*

Retrieved from https://www.lsrca.on.ca/Shared%20Documents/reports/lsems/phos_load_historical_ecosystem.pdf.

This report was prepared under the Lake Simcoe Environmental Management Strategy (LSEMS). The document focuses specifically on the sources of phosphorus loading to Lake Simcoe from 1990-1998, but examines the historical lake conditions and causes that may impact lake ecology today. This report strived to interpret the lake data collected over these years in a historical, regional, and ecological context. It is written for specialists and lay people alike, as Lake Simcoe is used for recreation, drinking water, and as a receiving water for sewage effluent. The conditions of the lake impact both environmentalists and the general public. In the context of dissolved oxygen, the report touches on the impacts that elevated TP levels have on DO. The report details that 2-3 centuries ago, the end-of-summer dissolved oxygen concentration sat around 8 mg/L. This value is representative of deep, natural lakes removed from human disturbance with a significant cold-water fish population. When the report was written, DO levels had fallen to only 3 mg/L, as a result of TP levels increasing 3-fold. The cold-water fish population was suffering. Later in the document, it further breaks down the relationship between land use in the Lake Simcoe watershed and the loss of deepwater dissolved oxygen in the lake.

Phosphorus enters the lake from agricultural and municipal sources, causing the growth and then

decomposition of algae, which all led to the loss of deep-water dissolved oxygen. This source is valuable to our study on the DO concentrations in Pigeon, Stony, and Lovesick Lakes because TP is another variable that we are testing, and understanding the correlation between the two will help us to interpret our results.

At the end of the study period, it was clear that maintaining green space, especially forested stream valley lands, is extremely important in limiting TP loading in Lake Simcoe. At this time,restoring remnants of natural ecosystems including wooded areas and shorelines, posed a great challenge to maintaining lake health. The Total Phosphorus Management (TPM) system was suggested as a partial solution at the conclusion of this study. This system is based around the concept that phosphorus loading can be traded within a watershed and its users.

*7.

Ontario Ministry of the Environment. (1972). Report of Water Quality in Lake Scugog. Retrieved from http://www.ontla.on.ca/library/repository/mon/25002/106542.pdf.

Growing developmental pressure on the shoreline of Lake Scugog prompted the Ministry of the Environment to carry out sampling on the lake to determine water quality in 1972. The ministry attempted to mitigate the new stress being put on the lake by the influx of human activity and development through various means. Some of these included the cottage pollution control program (1967-1970), and ongoing studies that looked at waste disposal systems, septic tank operations, and other variables in lake health. The sampling was carried out in June, August, and October, and the main parameters tested were bacterial, algal, and mineral chemistry. The concentrations of plant nutrients and dissolved oxygen in the water column were also determined. Through sampling, the MEC discovered that dissolved oxygen concentrations were uniform from the surface to the bottom of the lake. There were no serious oxygen depletions observed during any of their sampling campaigns. At all mid-lake sampling sites (with the exception of one), DO levels were near or above saturated levels. The outlying site, Station 42, experienced only 30% saturation of DO in the bottom of the lake during the first and second sampling days. This information is applicable to our project because it gives us a historical context for DO values in the Kawartha Lakes region, and gives us another Lowland lake to compare to Pigeon.

8.

Ontario Ministry of the Environment. (2008). *Water Quality in Ontario Report 2008*. Retrieved October 9, 2018 from http://www.ontla.on.ca/library/repository/mon/23004/291608.pdf.

In this report, the Ontario Ministry of the Environment (MOE) conducted a study on the success in Lake Simcoe phosphorus management as a potential strategy in the management of phosphorus in other Ontario lakes. They chose to look at Lake Simcoe because it is the largest inland lake in Southern Ontario, so it makes up a significant amount of our water resources. At the time, the government and other stakeholders had been working for 20 years to reduce P levels in the lake. The lake is a source of drinking water for many communities, as well as being a known fishery and recreation area. In the 1990's, the amount of P in the lake was three times higher than in 2008, and as a result dissolved oxygen in the lakes deep water zones was extremely low. The Lake Simcoe Environmental Management Strategy (LSEMS) was formed in 1990 as a coalition between the Lake Simcoe Region Conservation Authority, federal, provincial, and municipal government, First Nations, and the watershed community to deal with the environmental problems the lake was facing. From 1990-2008, the total P input was reduced below a target of 75 tonnes per year, and subsequently dissolved oxygen levels rose to 5 mg/L in the deep waters of the lake at the end of summer. This source is applicable to our study because Lake Simcoe is in the Lake Simcoe watershed, the watershed due West of the Kawartha watershed and our study lakes. It shows us that the parameter of dissolved oxygen is not an independent variable, it depends on many other factors and variables; if other parameters change, dissolved oxygen can change as a result.

9.

Powles, P.M., & Sandeman, I.M. (2007). Growth, summer cohort output, and observations on the reproduction of brook silverside, *Labidesthes sicculus* (Cope) in the Kawartha Lakes, Ontario. *Environ Biol Fish, 82*(4), 421-431. doi: 10.1007/s10641-007-9304-8.

This study details observations on the reproductive behaviours of Brook silverside in the Kawartha Lakes from 1996 - 2004. Populations in Rice Lake, Katchawanooka, Otonabee River, and Pigeon Lake were observed. Historically, Brook silverside have been found to be extremely sensitive to a lack of oxygen. A component of this study included maintaining Brook silversides in tanks, where this characteristic needed to be considered. It was found that the fish needed a quick transfer from the field to lab tanks, and mortality in sampling was high in the past. In this case, the coolness of late fall, combined with a lower metabolism and more saturated oxygen allowed the fall and winter specimens to survive. Although not directly related to dissolved oxygen, this study was carried out directly in the Kawartha Lakes continuum, using Pigeon Lake as a sampling location. This source gives us a more biological view into how lake organisms, including fish and benthos are impacted by a lack in DO. The Ecosystem Management principles of complexity and connectedness, as well as context and scale, encourage us to consider all of the other factors that may be impacting the species or parameter we are studying.

Conclusion:

Most sources agree that the main factors contributing to low DO concentrations are an increase in nutrients, algal growth, temperature, and low DO tributary inflow. With this knowledge, the goal is to focus on these conditions as potential causes for any low DO levels we may find in Pigeon, Lovesick, or Stony Lake. Through my research I learned how important it was for us to determine whether the lakes were no longer stratified (Fall turnover) when sampling, because temperature has such a significant impact on DO. In order to gain a more comprehensive understanding of the issue in the Kawartha Lakes specifically, future studies should narrow their scope to focus on this watershed and sample many different sites within it. Many of these sources have sampling sites spread throughout Southern Ontario, and though applicable, it would be interesting to see whether the results from lake-to-lake in the Kawartha region differ.

Appendix C3: Literature Review 3: Mara Van Meer Impact and Outcome of Total Phosphorus Levels in Freshwater Lakes

In freshwater lake ecosystems, phosphorus is a limiting nutrient (RMB Environmental Labratories, 2018). As a result, the biomass of macrophytes in a system is dependent on the amount of phosphorus present. A large input of phosphorus into lakes is a result of human activity, such as sewage treatment, erosion of soil, or agricultural run off (RMB Environmental Labratories, 2018). In lake ecosystems, soluble reactive phosphorus (SRP) and total phosphorus (TP) are measured to estimate the impact of phosphorus in a system. SRP is used by vegetation directly, and is taken up quickly. As a result, an improved way to measure phosphorus in a system is to measure TP, which includes SRP as well as phosphorus loaded into the system (RMB Environmental Labratories, 2018). The biodiversity of a freshwater lake ecosystem is impacted by the total phosphorus therefore TP can be used to analyze the resiliency of a system against eutrophication, harmful algal species, and analyze point sources of phosphorus loading. As TP indicates how much phosphorus is in a lake ecosystem, the measurement can be used to predict a variety of factors, such as the over productivity of a system and therefore the tropic status of the lake being studied. The calculation of TP in freshwater lakes can aid in indicating point sources of phosphorus loading in a system, and as a result is an important component of restoration in over productive systems. Total phosphorus is linked to transparency of a system, therefore it is an indicator of water quality (Carlson & Simpson, n.d.). TP is also linked to several other variables indicating the productivity of a lake, including dissolved organic carbon (DOC), chlorophyll *a,* dissolved organic nitrogen (DON), and iron (Fe). As a result, TP is an essential quantitative measurement that is required for evaluating the health of a freshwater system and an important measurement in restoring lake quality.

Brabrand, A., Faafeng, B. A., Nilssen, J. P. M. (1990). Relative Importance of Phosphorus Supply to Phytoplankton Production: Fish Excretion versus External Loading. *Canadian Science Publishing.* 47: 364-372.

It is evident that fish are extremely important in nutrient cycling and energy flow in lakes. For example, excrements released by carp cause an increase in phosphorus in lakes, resulting in increased algae growth. Blooms of cyanobacteria can also increase as a result. It has been found that phosphorus released by zooplankton is more significant than that released by fish, accounting for an increased percentage. As a result, the impact of phosphorus released by fish is understood best when compared with phosphorus released via external loading. It has been suggested in past studies that fish act to stabilize plankton as they are a small source of available phosphorus for algae to grow. The purpose of this study was to analyze the interaction between fish and phytoplankton, specifically the nutrients from fish excretion available for the growth of phytoplankton. The phosphorus input via fish was quantified in relation to the external supply of phosphorus from tributaries and sediments, resulting in a high pH. To study this, bream, perch and roach were placed in laboratory tanks. The phosphorus release from fish was estimated based on the release of phosphorus in relation to the size of fish and total fish biomass. It was found that phosphorus and nitrogen increased with as time increased. Phosphorus was released mainly as soluble reactive phosphorus, nitrogen releases as ammonium. This increased the more the fish species foraged on littoral sediments and as the size of the fish decreased. Bioessays were performed on the algae species, and it became evident that phosphorus released by the fish was available for the growth of the algae. The test lake was then analyzed for the total supply of phosphorus. This was calculated via tributary supply and phosphorus estimation released by roach biomass in the lake. It was found that, from May to October, the phosphorus released by the fish population was approximately of equal magnitude as phosphorus entering the system via the tributaries. The period with the least phosphorus supply to phytoplankton was summer to early fall, in which phosphorus supplied by fish was double of what was contributed from external sources. As a result, it is evident that fish play an important role in eutrophication of lakes.

Dillon, P. J. Molot, L. A. (2005). Long-term trends in catchment export and lake retention of dissolved organic carbon, dissolved organic nitrogen, total iron, and total phosphorus: The Dorset, Ontario, study, 1978=1998. *Journal of Geophysical Research.* 110: G01002.

Organic matter dissolved in lake water is usually quantified as dissolved organic carbon. Dissolved organic carbon is essential in fresh water ecosystems, as higher concentrations lead to a reduced water quality because dissolved carbon regulates light penetration in the water column. The purpose of this paper was to analyze the variation in the catchment of dissolved carbon and similar substances including TP, dissolved organic nitrogen, and total iron in central Ontario lakes from 1978 to 1998. To complete this, seven selected lakes in the Dorset area of Ontario were analyzed for dissolved organic carbon from the lake, rainfall, and surrounding streams. TP was measured via acid-molybdate colorimetry after the samples were soaked in sulphuric acid. Iron was measured in the streams samples taken, collected every 1-4 weeks. It was found that yearly water discharge and dissolved oxygen into lakes were similar in the lakes studied. The export of dissolved organic carbon decreased in drier years, responding to changes in amount of rainwater. The dissolved organic carbon absorbed by the lakes by the sediments increased during dry periods (less rainfall). It was found that increased rain runoff causes an increase in iron, total phosphorus, and dissolved organic nitrogen concentrations in freshwater lakes. The authors found that this increase occurs because runoff increases matter input into the lakes and increases the water table position. Drier conditions, therefore with less runoff, lead to lakes of a lower tropic level that are less productive, with less available iron, TP and DOC available for productivity. Therefore, an increase of runoff causes an increase in lake tropic level and a increase in productivity lake, with increased total phosphorus, dissolved organic carbon, and iron in the lake. In conclusion, amount of rainfall increases the input of nutrients into the lake, and can result in eutrophication due to the increased amount of TP and other nutrients.

**Dolan, D.M., McGunagle, K.P. (2005). Lake Erie Total Phosphorus Loading Analysis and Update: 1996-2002. *Journal of Great Lakes Research.* 31(2): 11-22.

To fully comprehend the degradation of Lake Erie, eutrophication must be quantified before restoration efforts can occur. Eutrophication in lake systems occurs when phytoplankton biomass increase due to a significant influx of nutrients in the system. The increase of algae growth is an indicator of a degraded system that could be caused by numerous factors. As a result, dissolved oxygen in the system may decrease. In the case of Lake Erie, eutrophication is caused by high total phosphorus concentrations and loading. Recordings of TP loading in Lake Erie have been ongoing since 1967. The authors of this study were able to estimate the loading of TP by using government databases and the Lake Erie Tributary Monitoring Program. Using this data, the results indicate that there are both direct and indirect sources of TP in Lake Erie, 95% of the load being released by sewage treatment plants. Types of loading into the lake include tributary loading, which varied influenced by rainfall throughout the years. Atmospheric loading also varied, but throughout the data analyzed is less than 10% of TP loaded. To truly analyze where the phosphorus loads originated, Lake Erie was divided into sub-basins: western, eastern, and central. The hardest portion of TP load estimation is retrieving point source data. The responsibility of recording of total phosphorus loading in Lake Erie has been shared throughout the last decade, retrieval of the data is difficult. However, although there has been less monitoring on the chemical and physical properties of the Great Lakes, there are still sources of TP loading data. Through concern about missing data, there is motivation and effort to control sources of phosphorus into the Lake Erie beginning in 1972 when the Great Lakes Water Quality Agreement was signed. Data is still available to identify TP loadings into Lake Erie. Further sampling and analysis of TP to quantify the trophic status of Lake Erie would advance the load estimation and points of access.

French, T. D., Petticrew, E. L. (2006). Chlorophyll *a* seasonality in four shallow eutrophic lakes (northern
British Columbia, Canada) and the critical roles of internal phosphorus loading and temperature. *University of Northern British Columbia.* 575: 285-299.

A main source of carbon in a lake ecosystem is phytoplankton, but overgrowth caused by nutrient loading reduces overall water quality. The purpose of this scientific study was to analyze the concentration of chlorophyll *a*, an indicator of phytoplankton growth, in shallow lakes annually. Maximum concentration of chlorophyll *a* occurs in the late summer or early fall, the same time period in which total phosphorus is at its highest. As a result chlorophyll *a* levels were assessed in comparison with total phosphorus and total dissolved phosphorus as well as temperature and pH. To analyze the biomass of phytoplankton, the deepest locations in four lakes were sampled once every two weeks, and once when covered in ice. The data used in this study was collected throughout 1994 and 2001. Samples of water were collected from 1m below the surface of the water and 1m above the sediment to assess for phosphorus content. Temperature profiles and pH was also recoded for the lake studied. Tributaries and outlets were also sampled for phosphorus content approximately every 5 days for a month in 1997. It was found that in chlorophyll *a* levels were lowest in May to mid July in two of the lakes studied, and from December to March for the third and fourth lake. In this case, the chlorophyll *a* levels were still low in the spring and early summer, but a bloom would occur in May after the lake was no longer covered by ice. Chlorophyll *a* concentrations, temperature and total phosphorus were found to be highest in the late summer/ early fall. It was found that the concentration of phosphorus was highest after loading from external sources, which indicates that high values in the summer and autumn result from internal lake sources. In summary, chlorophyll *a* concentrations were highest in late summer and early fall. Variation occurs due to the diverse characteristics of the lakes including geology and topography. Based on this study and the methods used, it is best to compare temperature and total phosphorus with chlorophyll *a* to predict lake variations.

Gächter, R. Müller. (2003). Why the phosphorus retention of lakes does not necessarily depend on the oxygen supply to their sediment surface. *The American Society of Limnology and Oceanography.* 48(2): 929-933

Lake sediments in anoxic lakes contain less phosphorus when compared to oxic lakes. This is because, for a lake to become anoxic, phosphates have been released from the sediments. Iron absorbs phosphates or undergoes a chemical reaction to create Fe(III) oxyhydroxide. In anoxic conditions, the opposite occurs; more phosphate is introduced into the system as this compound dissolute. In this study, Lake Sepach in Switzerland was studied to attempt to improve its tropic state. Classified as eutrophic, the phosphorus load from external sources has decreased. The hypolimnion receives oxygen artificially in order to decrease phosphorus cycling within the system. As a result of less external loading, the amount of phosphorus in the lake has decreased. However, the oxygen provided to the hypolimnion has not reduced the release of phosphorus from sediments in summer or caused an increase in retention in the system. As a result, it is important to revaluate the restoration strategy. Evident by this study, creating and managing an aerobic sediment base does not necessarily result in the decrease of internal phosphorus. Instead, the authors of this study suggest that increasing oxygen will cause phosphorus absorption in the sediment if an increase of iron phosphate is produced, and less sulfide and FeS is contained in the substrate. The results of this study are that it is not the oxic sediment that impacts the phosphate substrate absorption, but the ratio of reactive iron ions in the bottom substrate. It was concluded that the rate of substrate settlement and iron as well as oxygen, nitrate and sulfate impact retention of phosphorus in lake sediment.

Hall, S. R., Pauliukonis, N. K., Mills, E. L., Rudstam, L. G., Schneider, C. P. Lary, S.J., Arrhenius, F. (2003). A comparison of Total Phosphorus, Chlorophyll *a*, and Zooplankton in Embayment, Nearshore, and Offshore Habitats of Lake Ontario. *International Association Great Lakes Research.* 29(1): 54-69.

Lake Ontario has experienced changes in ecological structure within the past forty years due to a reduction in phosphorus intake as well as the introduction of mussel species. Less phosphorus loading the lake has resulted in an adjustment of the tropic state, becoming oligotrophic. As a result, the lowest tropic levels in the lake have been negatively impacted. As phosphorus loading in the lake decreased, the production of offshore zooplankton has decreased. The purpose of this study was to analyze the impact of nearshore/offshore/embayment habitat changes in TP on lower tropic level species. To complete this, these three habitats were sampled for three years (1995-97). Variables measured include water clarity, temperature, total phosphorus, chlorophyll *a*, and abundance/density of zooplankton. It was found that embayment habitat had increased concentrations of total phosphorus, chlorophyll *a,* zooplankton density and biomass, and temperature than nearshore and offshore habitat types. The biomass of zooplankton was highest in offshore habitats. Nearshore TP concentration and zooplankton density is similar to offshore variables than measured in the past. Nearshore chlorophyll *a* per TP was lower than the other habitat types recorded. This is a result of the mussel species introduced in the lake as well as erosion of the shore and sediment suspension in the lake. As predicted, the habitat displaying eutrophic qualities is the embayment habitats, due to the higher concentrations of TP, chlorophyll *a*, and higher density/biomass of zooplankton. As a result, this habitat type has diverse seasonal patterns. For example, TP concentrations were highest during late summer, early fall, and constant in the spring. This is a result of the geomorphic shelter usually found in embayment habitats, receiving nutrient input from municipal water.

**Post, D.M., Pace, M.L., Hairston Jr, N.G. (2000). Ecosystem size determines food-chain length in lakes. *Letters to Nature.* 405: 1047-1049.

Ecological communities are extremely complex, relying on a variety of factors to function successfully. The size of a food chain within an ecosystem is an influential factor in the composition, structure, and function of biomass within the biotic community. This chain varies across ecosystems, and there are many hypotheses suggesting why. In this study, three hypotheses were tested to predict the length of a food chain in relation to productivity in a system, the size of said system, or a combination of both of these factors. The combination hypothesis suggests that both the size and productivity of an ecosystem will increase with availability of resources, whereas the productivity hypothesis suggests that the size of a system does not directly impact availability. The size hypothesis suggests that ecosystem size and diversity impact the availability of habitat. To test these, the authors of this study estimated the length of food chains in 25 lakes using isotope techniques were used in combination with relative distance of the lakes to estimate the size of the ecosystem. Stable isotopes were used to discover the maximum trophic level, which in this study was used as the length of the food chain in the community. Species in the lake were studied, including snails in the pelagic and littoral food webs of the lakes. The lakes in this study are northern temperate, meaning there are limited in phosphorus, so TP indicates primary productivity in these areas. As water quality increases, the length of a food chain in the system also increases. It was found that as the size of the lake increased, the maximum tropic level also increased, but TP did not increase with volume. To discover lake productivity, total phosphorus measurements were gathered in the summer, when the TP levels are the highest. It was found that the food chain increased in larger lakes due to the presence of a top predator, whereas changes to the top predator of a system can only occur with longer food chains at the top and bottom of the food web. As diversity in an ecosystem can indicate the maximum tropic level, it is evident that the cause of varied food chain length will impact diversity of the species in a food web.

**SØndergaard, M., Jeppesen, E., Jensen, J.P., Amsinck, S.L. (2005). Water Framework Directive: ecological classification of Danish lakes. *Journal of Applied Ecology.* 42: 616-629.

Numerous factors influence the overall health of a lake ecosystem. The resiliency of a lake is reflective of general health, defined as the ability to restore function. However, as freshwater lakes have several diverse functions based on geology and morphology, it is difficult to measure quantitative values and attribute certain ranges to lake heath. However, total phosphorus is a valuable measurement because it can indicate the resiliency of a freshwater system when degraded by eutrophication. In this study, the authors used total phosphorus as a condition to reference overall water quality. This was completed by aligning several healthy ecosystem attributes along a total phosphorus scale, such as alkalinity and depth of the freshwater system. One of the goals of this project was to determine indicators of ecosystem health and evaluate their position along the TP scale. To complete this, 709 lakes greater than 1 ha were studied in Denmark, grouped based on their alkalinity. Variables measured include chemical and physical properties, macrophytes, phytoplankton, zooplankton and fish in response to TP levels in freshwater. It was found that several chemical and physical factors decreased with an increase of TP, including Secchi depth. The depth of macrophytes decreases as TP increases, while phytoplankton, zooplankton and fish (specifically piscivores) increased. As these indicators were impacted by TP, they can be used to classify eutrophication in lakes. Overall, TP is a useful indicator to monitor the resiliency and health of a freshwater lake ecosystem because it is a constant variable across lake classification and many indicators of ecosystem health respond to different levels of TP.

Trimbee, A. N., Prepas, E. E. (1987). Evaluation of Total Phosphorus as a Predictor of the Relative Biomass of Blue-Green Algae with Emphasis on Alberta Lakes. *University of Alberta.* 44: 1337-1342.

Blue- green algae in freshwater lakes is problematic, resulting in a sour odour and taste as well as a greatly reduced water quality. As well as the buildup of scum on the surface of the water, blue green algae is not a source of nutrients for species in the tropic structure. In this study, the hypothesis for the cause of blue-green algae include presence of organic compounds which prevent the growth of diverse algal species, resistance to zooplankton consumption, and intake of inorganic carbon. A study conducted in 1986 suggests that when the total nitrogen and total phosphorus ratios in the lake are below 29:1, and blue green algal growth was not common above this ratio. The goal of this study is to analyze if TP is a successful method to analyze blue-green algae growth when compared to values for TN or TN/TP ratios. To complete this study, information about 16 lakes in Alberta was obtained and analyzed. These lakes were sampled a minimum of 2 times for blue-green algae biomass, phytoplankton, TP, TN, and water clarity during the spring and summer. The result was 36 data points wherein data was available for multiple years for lakes with loading of nutrients, data from several sites within a lake was averaged. As well, data collected from limnocorrals was not included. Past studies indicate TP, TN and light availability as the main variables associated with blue green algal growth. However, in this study it was found that the biomass of blue green algae is more closely associated with TP and the depth of the Secci depth. In summary, through analysis of the data collected, TP values and water quality (Secchi depth) more closely related to the growth of blue green algae then TN or TN/TP ratios as the variables are so interconnected. As a result, it is evident that a decrease in TP levels in a lake would indicate a decrease in blue-green algae. As well as analyzing the past data, the authors of this study also research past literature that indicate that decreases in loading of phosphorus result in less growth of blue-green algae. Overall, TP and Secchi disc depth are closely related with biomass of blue-green algae.

CONCLUSION

After reviewing this literature it is evident that total phosphorus in a system directly impacts many aspects of water quality. As a variable in a study, TP it is useful in analyzing human sources of phosphorous. For example, data from the Lake Erie Tributary Monitoring Program proved that 95% of the phosphorus load being released in to Lake Erie was caused by sewage treatment plants. The loading of phosphorus directly impacts the biotic community, as TP does not increase with the size of a lake, but the productivity of the species inhabiting it. Overall, TP can be used to indicate the health of a lake because it indicates the tropic level of the system. Based on this, phosphorus in the lake can be used to determine the resiliency of a system against eutrophication and overproduction but is also essential for identifying phosphorus loading and restoration of a system.

Appendix C4: Literature Review 4: Chris Vieau Preventing Eutrophication: Nutrient loading, function, mechanisms and mitigation approaches in freshwater systems.

In freshwater systems, Phosphorous load, Temperature and dissolved oxygen are extremely important measurable qualities which can be reliable indicators of lake ecosystem productivity, trophic structure, and level of sustainability as their relative and individual values have important implications for lake primary producer population dynamics. It is necessary to continuously monitor these variables within lakes and watersheds of concern to guide mitigation strategies to which there are a variety of options. The need for protection of water resources is especially dire in light of the impacts of anthropogenic development and climate change.

French, T.D; Petticrew, E.L.(2007)Chlorophyll a seasonality in four shallow eutrophic lakes(northern British Columbia, Canada) and the crucial roles of internal phosphorous loading and temperature. Hydrobiologica.575, pp285-299

This article summarizes the Limnological research on Lakes Charlie, Tabor, Nulki and Tachick , British Columbia. The lakes have different Depth and local development conditions. Sampling was conducted on these lakes at different times per lake between 1990 and 2001 in all seasons and measured for chlorophyll a, Total dissolved Phosphorous, Dissolved oxygen, temperature, and Ph. The authors summarized the data and measured the correlation of variables to chlorophyll concentration to determine their reliability as predictors where they may theoretically have a positive correlation, and accounted for inconsistencies in the data to infer the magnitude of effect of the lakes internal nutrients and consequent chlorophyll concentrations. The authors found that among these lakes, models that incorporated Total phosphorous in addition to temperature accounted for 57-70% of within lake variations in chlorophyll on an instantaneous basis. They suggested the importance of temperature on algal productivity and refer to several studies which focused on the relationship between latitude and chlorophyll concentrations. The authors attribute differences in Oxygen and Phosphorous gradients in the lakes to their depth profiles and thermal stability over the seasons, postulating that internal phosphorous loads accounted for much of the productivity in these BC lakes however they also suggest that macrophyte decomposition at the bottom of these lakes contributes a significant amount of internal phosphorous loads based on previous studies conducted on the lakes.

Frost, P.;Schindler D; Porter-Goff, E.; Middleton, C.(2012) The Algae of Kawartha Lakes: Their place in the ecosystem, when they become a problem, and what controls their growth. Kawartha lake stewards association, 37 pp

This document was produced in response to concern of residential homeowners living near the shores of the Kawartha lakes continuum in southern Ontario. The authors summarize general relationships between algae and nutrients, provide a description of common algal species with suggestions of the implications of presence, and also provide current (to 2012) knowledge of algae community, population and nutrient loading conditions in the Kawartha lakes. They provide reference to some recent studies conducted in the Kawartha Lakes area, and conclude with suggestions for landowners. Reference to a study on the area is made which suggests that phosphorous load is positively correlated with lake location eastward. Another study undertook by the authors of the article demonstrated that the reduction of any nutrient in lake water, would limit growth and proliferation of algal communities, but they suggest continued focus on phosphorous due to the fact that it is limited, it is measurable, and there is already a body of information profiling the location of P in the Kawartha lakes.

J. Barica (1993) BOUNDARIES OF ECOLOGICAL SUSTAINABILITY OF

PRAIRIE LAKES AND RESERVOIRS, Canadian Water Resources Journal, 18:3, 291-297

This document is a summary of the work author J Barica to 1993 on algal growth in prarie lake systems in Western Canada. The author focuses on the mechanisms involved in eutrophication, interactions between nutrients and phytoplankton species and makes some suggestions about development with some specific reference to qualities characteristic of shallow(~2-5m depth) prarie lake systems. Graphs explain the dynamics which are to be expected for important limnological variables before and after a eutrophication event in winterkill and summerkill situations, leading to eutrophication in prarie lakes. The author also delineates the difference in values to be expected for limnological parameters over the span of a year, to define what is considered a sustainable, unstable oscillating or unsustainable system with regards to nutrient inputs and consequent chlorophyll concentrations. The author suggests chlorophyll concentrations of 20 – 30 µg/l to be sustainable. His final point is that that the praries would be unsuitable for development as high productivity in lakes in these areas would need to be treated for, and also that the waters would be particularly vulnerable to nutrient loading through waste and agriculture as the carrying capacity of these lakes are almost fully utilized.

Mildner, J; Friedl, M.; Fresner, R.; Sena, F. Ghiani, M.; Noges, T.; Noges, P. (2011) Increased nutrient loading and rapid changes in phytoplankton expected with climate change in stratified south European lakes: Sensitivity of lakes with different trophic state and catchment properties. Hydrobiologica 667: pp255-270

Warming Temperature regimes associated with climate change are expected to impact nutrient cycling dynamics in freshwater systems with short residence times(time water stays before it is flushed out of the water body). Noges and Ghiani collected chemistry and phytoplankton data over two years in two stratified lakes to determine the potential impact that increasingly rainy winters would have on trophic status in northern Italy in relation to several lake characteristics. Each lake had a different trophic state and water retention time(ogilo mesotrophic,7.9 years, eutrophic, 1.7 years). They found that higher nutrient loading during a rainy winter and spring in the lakes studied functioned to increase nutrient concentrations(N, P Si) and also induce a *phytoplankton based* trophic state index, while at the same time, N/p ratio decreased in both lakes. Higher Si also resulted in increased Diatom concentrations. The eutrophic lake experienced an interruption of commonly occuring algal blooms , while the ogilo-meso trophic lake, chlorophyll *a* increased. The impact of rainy period on trophic state was more related to runoff/ in lake concentration of nutrients than the lakes retention time. Higher magnitude affects were also exhibited in the lake with a lower trophic state.

Orihel, D.; Baulch, H.; Casson, N.; North, R.; Parsons, C.; Seckar, D.; Venkiteswaran, J. (2017) Internal phosphorous loading in Canadian fresh waters: a critical review and data analysis. Can J. Fish. Aquat. Sci. 74, pp. 2005-2029

Phosphorous loading by means of sediment erosion is a primary mechanism responsible for the occurrence of algal blooms in freshwater systems. The authors of this study reviewed 43 Canadian studies on internal Phosphorous loading in freshwater lakes to obtain 618 estimates of internal phosphorous loading from Canadian freshwater ponds lakes, reservoirs and coastal wetlands. 618 estimates of internal phosphorous loading were derived from the studies. Oxygen pH, geology, and trophic state were found to be related to the variation in short term gross benthic phosphorous flux(Lgross) and net internal Phosphorous loading rate. They also found through their observation that prarie lakes had higher phosphorous loading rates, and also that loading was higher during the open-water season. The authors also suggest that there are holes in the research on phosphorous loading, particularly in the anthropogenic impacts of sulfur pollution and aquaculture, the relative impact of different mechanisms, especially in response to climate change and quantifying phosphorous loading rates in understudied systems of human importance such as reservoirs. They conclude that currently imposed regulatory schemes are based from incomplete knowledge, and more work must be done to establish a distinctive Canadian regulatory scheme that can sufficiently encompass all lake systems.

Paerl, H.; Gardner, G.;Havens, K.;Joyner, A.; McCarthy, M.; Newell, S.;Qin, B.;Scott, T.;(2015) Mitigating cyanobacterial harmful algal blooms in aquatic ecosystems impacted by climate change and anthropogenic nutrients. Harmful Algae 54, pp.213-222

The effectiveness of mitigation techniques to prevent algae blooms in aquatic systems concerns resource managers and researchers, as climate change and population growth will alter the physical context in which these events occur in terms of nutrient loading and temperature. The authors of this article explore the current mitigation strategies commonly applied to systems threatened by harmful cyanobacterial blooms, and address how they may be able to adapt to the coming conditions of the future. It is the expectation that harmful cyanobacterial species blooms will occur more frequently, given a climate trajectory that predicts higher temperatures and greater precipitation in the future. To reduce bloom occurences, a variety of approaches have been used by conservationists, including N and P reduction regulations, Increased flushing, Enhanced mixing of water, Manipulations of food webs, Ultrasonic treatments, upstream wetland development, treating chemically, encouraging macrophyte growth, and sediment capping or dredging, summarized in the article. To remain effective however, the authors assert that those mitigation strategies should correspond with climate change by adopting new targets for nutrient loading, and cyanobacterial growth.

Smith, V.H.; Schindler, D.W.(2009)Eutrophication science: where do we go from here?. Trends in Ecology and Evolution 24: 201-207

This is a review and Summarizes the effects of anthropogenic nitrogen and phosphorous pollution caused eutrophication on lakes reservoirs rivers and coastal zones. It includes a summary of the primary mechanisms involved in the process of nutrient contamination and eutrophication, implications for humans, including increased disease occurrence and increased virulence and abundance of water-borne human pathogens, evidenced from studies focused on sites where water has been commonly used for bathing and these effects bringing concerns in relation to climate change. Interestingly, the authors have included descriptions of novel mitigation and restoration examples in lakes exhibiting eutrophication symptoms. They describe biomanipulation as the removal or prevention of removal of species with activities and natural histories associated with increased or decreased phosphorous in lakes. They note work that suggests high biomass algal phases commonly occur when lakes contain one or 3 tropic levels, while low biomass phases are common with two or four trophic levels. Controlling trophic cascades appears to show promise in situations where there are few consumer species feeding at more than one trophic level. Referring to a few very reputable cases, including the famous Experimental lakes study area eutrophication experiment, the authors suggest that reducing phosphorous loads in rivers is a cost effective way to improve water quality since nitrogen abundances in water bodies are commonly attributed to nitrogen fixing cyanobacteria, who's concentrations are directly related to available phosphorous. They also discuss the successes in remediation and mitigation actions taken by researchers and conservationists in the past and suggest that watershed specific limitations on nitrogen phosphorous and other toxic contaminants be placed but that the effectiveness of methods is an area in the literature that still needs research.

Søndergaard, M. (2007) Chapter 2: Retention of phosphorous and nitrogen, (pp. 17 – 33) From: Nutrient dynamics in lakes – with emphasis on phosphorus, sediment and lake restorations. Doctor's dissertation (DSc). National Environmental Research Institute, University of Aarhus, Denmark. 276 pp.

This chapter is educational in nature and summarizes the conclusions of many peer reviewed authors and also includes his own study on the specific topic of deposition and resuspension of phosphorous and nitrogen in freshwater systems, with some mention of the implications that these dynamics have on lake trophic status. More specifically, the author describes several important points from the current literature. The author cautions that models quantifying phosphorous retention in lakes and for lakes in an equilibrium state may not account for high or low magnitude loading events because they do not address quantities of P seasonally but rather annually. The author applied phosphorous retention model to 9 Danish lakes and found that they had a tendency to overestimate the actual phosphorous retention. The author thus suggests which factors important to lake nutrient depositional dynamics may be considered and cannot be accounted for in the equation, and also emphasizes the point that the equations cannot estimate the differences in concentration attributable to lake turbidity, a substantial determinant of retention capability. Sondergaard also Makes note of the physical process of sediment accumilation at the bottom of lakes and where in the lake sedimentation may be more concentrated, in deep areas, and variation within and between lakes bearing different chemical physical and temporal properties as well as the close relationship sediment retention of P has with lake water P.

P concentration in the lake is equal to the difference of the input to the out put of phosphorous in the lake- and loss is closely associated with organic compound content.

He describes different processes of applying chemical treatments to samples to extract phosphorous content from the several forms it occurs in, and illustrates in simple terms that the quantity of phosphorous sampled will only depend on the specific chemical treatment which is applied, to which there are many, and all destroy the sample in the process of extraction with the suggestion there is potential for error in data acquired through these methods. Different forms of phosphorous also occur in different proportions throughout the year. Sondergaard notes the following mechanism high phytoplankton production → high pH → large pool of loosely bound phosphorus → high phosphorus release from the sediment → high phytoplankton abundance and suggests that the interaction between sediment phosphorous pools and phosphorous fractions of different types, and the interaction this may have with the water and sediment are unknown, and therfore modelling for the sediment phosphorous release predictions cannot be entirely accurate. Secchi depth conditions in relation to phosphorous retention are also considered. Some other less fundamental points are made, specifically regarding what is to be expected for seasonal dynamics, transitional periods and measurement in lakes which should constitute phosphorous retention dynamics.

Søndergaard, M. (2007) Chapter 3: Mechanisms behind the sediment release and uptake of phosphorous, (pp. 33 – 39) From: Nutrient dynamics in lakes – with emphasis on phosphorus, sediment and lake restorations. Doctor's dissertation (DSc). National Environmental Research Institute, University of Aarhus, Denmark. 276 pp.

The third chapter of Sondergaards dissertation focuses on the mechanisms of the resuspension of phosphorous and nitrogen deposited in lake bottoms. Depth, wind, wind speed, exposed surface area/ wave height can have profound effects on sediment mixing at the bottom of lakes, especially where water is shallow. In addition to measuring the above to make determinations of lake sediment mixing state, established empirical equations can be used which utilize the relationship between secchi depth, and water depth as determinants of phosphorous. Higher wind speed is also noted to have a positive effect on Total Phosphorous, evident within days. When resuspension of lake bottom sediments occurs, it may also trigger the release of nutrients and impact phytoplankton development by the above mentioned, however the effect also depends on lake chemical properties and importantly, the proportion of particular bound phosphorous and dissolved phosphate present, under the conditions of the lake (such as Ph, Oxygen, iron content).

Temperature also impacts almost all processes and may be explanatory in empirical relations between nutrient input and nutrient concentration, since temperature increases the rate of chemical diffusion and chemical processes, but biological processes are most important since they have a large proportionate impact on nutrient release in lakes. High temperatures stimulate mineralization of organic matter in sediment and release of organic phosphate. Solubility of oxygen in water is temperature dependent which impacts organism and oxidation of minerals, importantly iron, and iron compounds which have implications for phosphorous release from sediment and concentrations in water.

The author also gives importance to the fact that the frequency of binding of phosphorous to iron compounds decreases when there are higher pH vales within water bodies. When there is high photosynthesis activity in a water body, this can increase pH and consequently stimulate phosphorous resuspension. Chemical diffusion flux to determine sediment phosphorous and water phosphorous exchange can be calculated using Ficks first law and depends on the concentration gradient, and porousity in the sediment. Some organisms such as chironomids and bottom feeding fish, also contribute to the resuspension of bottom materials through physical contact and excecretion, and the magnitude of their impact also depends on the properties of the sediment.

Submerged macrophytes impact the exchange of nutrients between sediment and water substantially and it can be a positive or negative relationship. They may limit water mixing which results in low dissolved oxygen at high elevations, Alter pH balances in water, or reduce the affect that wind has on water mixing. Some studies have shown however, that macrophytes do not significantly affect nutrient retention.

Conclusion

Water quality is detrimental to, and is also a reflection of local ecosystems. Excessive nutrient loading due to human activities is preventable and requires careful examination of the freshwater systems in question in order to develop plans for mitigation. Among a wide variety of variables to be considered in these determinations, Phosphorous is the most limiting, and central to studies which attempt to quantify and predict lake productivity. P loading flux appear almost as specific as the lakes themselves, and much has to be taken into account in the investigation of these dynamics, including lake depth, chemistry, climate, and surface area.

While the deposition of nutrients in lake systems can be a simple factor for various land users to regard and overlook, the complex processes which occur in streams and lakes are incredibly complex and still yet to be understood entirely. In addition to anthropogenic loading, the stability of aquatic systems is also threatened by climate warming which would imply faster chemical processes, less stratification, and ultimately increased lake productivity and increased global frequency of eutrophic conditions. The body of literature surrounding the dynamics involved in the process of eutrophication and human and environmental implications are practical, and should become more valuable overtime, considering the above.

Appendix C5: Project Plan

KLSA DETERMINATION OF DO IN PIGEON LAKE, LOVESICK LAKE, AND STONY LAKE

Project Title	Determination of Dissolved Oxygen Concentrations and Implications in Pigeon Lake, Lovesick Lake and Stony Lake
Project Management Team	Connor Hill, B.Sc. Environmental Science, Carleton University Chelsea Houston, Ecosystem Management Technology program, Fleming College. Mara Van Meer, Ecosystem Management Technology program, Fleming College. Chris Vieau, BA Environmental Geography, University of Toronto
Faculty	Sara Kelly, Professor Ecosystem Management Technology, Fleming College Barb Elliot, Professor Ecosystem Management Technology, Fleming College
Project Sponsor(s)	Bill Napier, Chair, Kawartha Lakes Stewards Association Debbie Blaika, Water Quality Specialist, Kawartha Conservation Brett Tregunno, Aquatic Biologist, Kawartha Conservation
Purpose	The mission of the KLSA is to monitor phosphorus and E.coli levels throughout the Kawartha Lakes. One part of the mission is to comprehend the dynamics of aquatic ecosystems including potential issues like overgrowth and invasive species. The KLSA works to educate cottagers, permanent residents and the public about the value of conserving the Kawartha Lakes. Along with these goals, the KLSA develops positive working relationships and partnerships with several agencies to promote KLSA objectives. The purpose of this project is to monitor temperature, dissolved oxygen, pH, conductivity, total phosphorus, and analyse the benthic community in Pigeon Lake, Lovesick Lake, and Stony Lake. As nutrient levels increase macrophytes increase in their population.

	Macrophytes will eventually decompose which results in less dissolved oxygen in a system and an unsustainable system. Recent studies within the KLSA support the claim that human activity has resulted in algal population growth in the Kawartha Lakes. This study, with supporting data, will aid in the determination of potential algal overproductivity and hypoxia/anoxia. Comprehensive and succinct reporting of the current issues and future plans is also necessary to communicate with the general public and between organizations.
Issue	Dissolved oxygen levels are indicative of lake productivity and trophic structure, and it is important in the determination of aquatic ecosystem health and sustainability. Internal phosphorus loading and temperature are variables which can be used to predict the state of lake ecosystem as they are detrimental to the community, growth, and concentration of lake primary producers.
Deliverables	Report: ● A 12-15 page report on the current DO levels, TP concentration, and benthic communities in Pigeon Lake, Lovesick Lake, and Stony Lake. It will include an introduction providing the context for the report, a section regarding data collection methods, and a section for interpretation of the data and recommendations for future projects. This report will be handed to the KLSA as a PDF and Ms Word document the USB provided, as well as a hard copy. Background Information: ● Peer literature reviews providing summative information on dissolved oxygen, temperature in lake systems, total phosphorus, benthic communities, and implications for lake ecosystems. Provided to KLSA as a PDF and Ms Word document. Past studies: ● Overview of past studies and current efforts to monitor DO and TP in the Kawartha Lakes ● provided to KLSA as a PDF and Ms Word document Graphics: ● Maps of study locations and DO levels throughout the profile of each lake ● Graphs depicting the DO and TP at each site ● Will be included in the report Future Projects: ● Recommendations for future studies based on data analysed ● Provided to KLSA as a PDF and Ms Word document

	Presentation: ● An introductory presentation about the project to the members of the KLSA will take place October 13th, followed by a meeting depicting the results mid-November (date TBD)
Exclusions	The following will be provided to team STRIVE to complete the deliverables of this project: The KLSA will provide: ● Aquatic craft and aquatic safety equipment ● Selection of site sampling locations ● Transportation to and from sampling locations located over water bodies ● Supplying scientific literature and reports to acquire context for which the project is taking place, including past KLSA water quality reports ● Paying full expense of project related travel, which includes $0.55/km with anticipated expenses of $200.00 ● Report printing costs anticipated to be approximately $30.00 Kawartha Conservation will Provide: ● Training on the use of instruments and data sampling in the specific context of this project ● Equipment including YSI to measure DO
Stakeholders	Kawartha Lakes Stewards Association ● The KLSA is the host organization for this project, providing funding and materials for data collection ● The KLSA delivers and annual report depicting the water quality of the Kawartha Lakes for public viewing. This document is important to cottagers, full time residents of the lake, and the surrounding community. Data collected and depiction of results will be included in a water quality report for 2019 ● Students will strive to maintain a positive working relationship with the KLSA to ensure future project partnered with Fleming College. Kawartha Conservation: ● Kawartha Conservation is providing equipment for data collection as well as training for the Van Dorn to collect TP samples and the YSI to measure DO

	● Partnered with the KLSA, Kawartha conservation will aid in proficient data collection to ensure unbiased results for an accurate analysis of water quality Fleming college: ● Interest in the development of skills for the team undertaking the project ● Creating a realistic working environment for students to network and create quality deliverables Sara Kelly ● Communications between the host organization and the program of the institution ● Support for the student team in terms of deliverable expectations and results Barbara Elliot: ● Expert in water quality results, will ensure that team STRIVE is knowledgeable in water quality protocol and can gather accurate data ● Will aid in the interpretation of results William Napier-: ● Chair of the KLSA, will take team STRIVE sampling ● Has experience gathering water quality data, will aid in sampling techniques ● Will supply the required materials to sample the data as well as background information on the KLSA and expected deliverables
Scope	The quality standards to be achieved include creating a document that uses standardized data collection and interpretation, is easy to read, and offers future recommendations for the KLSA. Success will be measured through open communication with our mentor, Mr. Napier, to ensure that we understand his expectations of us, and by the final outcome of the results. Limitations and Time Restraints: ● The total budget for this project is $500.00, provided by the KLSA to cover travelling expenses for the team and printing costs ● The team will spend Monday September 17th, 24th, and October 1st collecting data on Pigeon, Lovesick, and Stony Lakes respectively

	● 9am - 5pm on the 8 Mondays in which sampling will not take place will be dedicated to completing other project deliverables. The team will meet at least twice a week to talk about the progress of the project ● Background information on past data collected by the KLSA will be used to interpret the results ● The project is to be completed by week 13 (Nov. 27th), but draft deliverables will be presented to Mr. Napier by October 15th where a face-to-face project meeting will take place ● Training of equipment use by Kawartha Conservation will ensure correct and accurate data collection ● Resources provided by Sara Kelly and Barbara Elliot will ensure project deliverables meet or exceed the standards set by the KLSA and that proper sampling protocol is applied
Project Tasks and Timelines	Submitted as an Excel document
Health and Safety Plan	See Appendix A attached to the end of this document
Background	Data collection for this study will include measuring dissolved oxygen, total phosphorus concentrations and benthic community composition in the profundal zone in Pigeon Lake, Lovesick Lake, and Stony Lake at the end of Autumn. Water quality measurements will be acquired on site using Secchi disk, and water chemistry will be assessed using an YSI meter. Samples taken from the Van Dorn, and Eckman dredge will be analysed in laboratory. Past reports and current studies on lake ecosystem dynamics, trophic structure and aquatic sustainability will be used to develop the report. Student teams from Fleming College have been working with the KLSA for many years. Team STRIVE will continue to develop the positive working relationship between the KLSA, Fleming College, and Kawartha Conservation in the hopes of future projects and opportunities for Fleming College.

Project Plan Sign-Off

- Student team must bring 3 copies of approved Project Plan to Week 6/7 Progress Meeting.
    - Must be signed-off by all team members (all students, lead mentor, and faculty) during Progress Meeting.
    - A signed copy must be retained by student team, by mentor, by faculty.00

___________________________________ __________________________

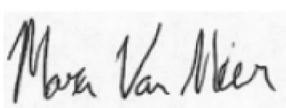
(Mentor Signature) **(dd/mm/yr)**

___________________________________ __25/08/18______________________

(Student Signature) **(dd/mm/yr)**

___________________________________ __25/08/18______________________

(Student Signature) **(dd/mm/yr)**



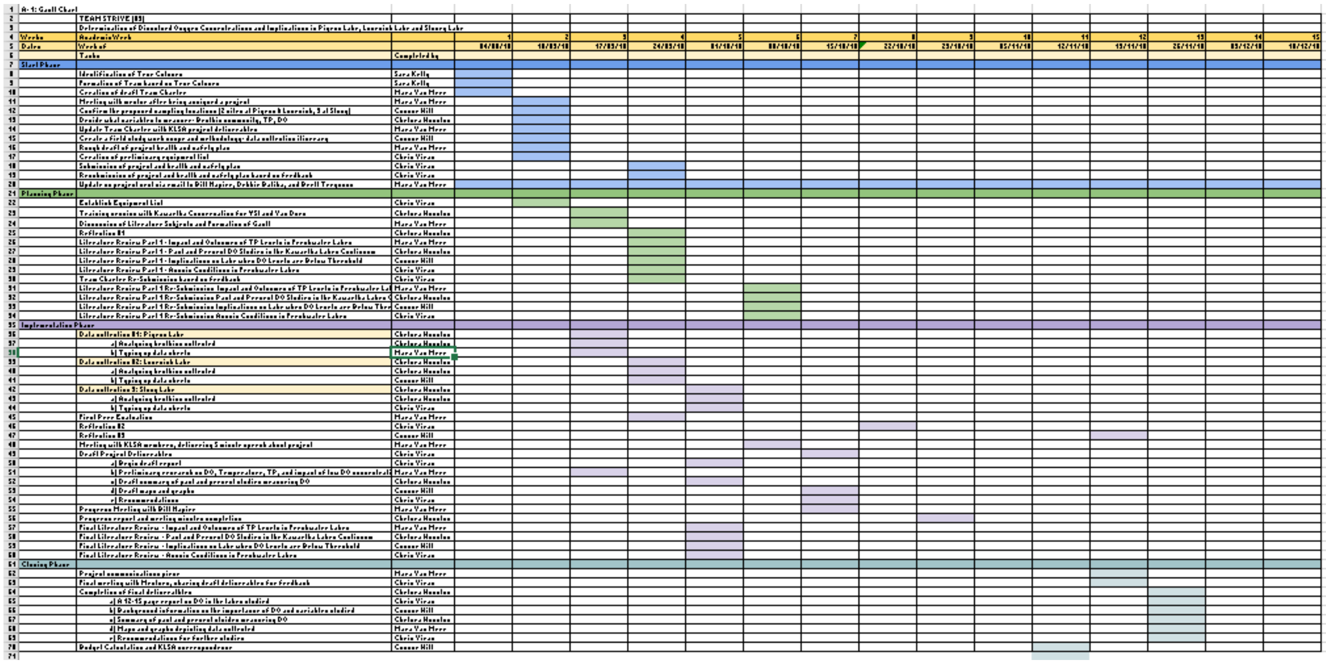
___________________________________ __25/09/18____________________

(Student Signature) **(dd/mm/yr)**

___________________________________ __25/08/18______________________

(Student Signature) **(dd/mm/yr)**

Appendix C6: Original Gantt Chart



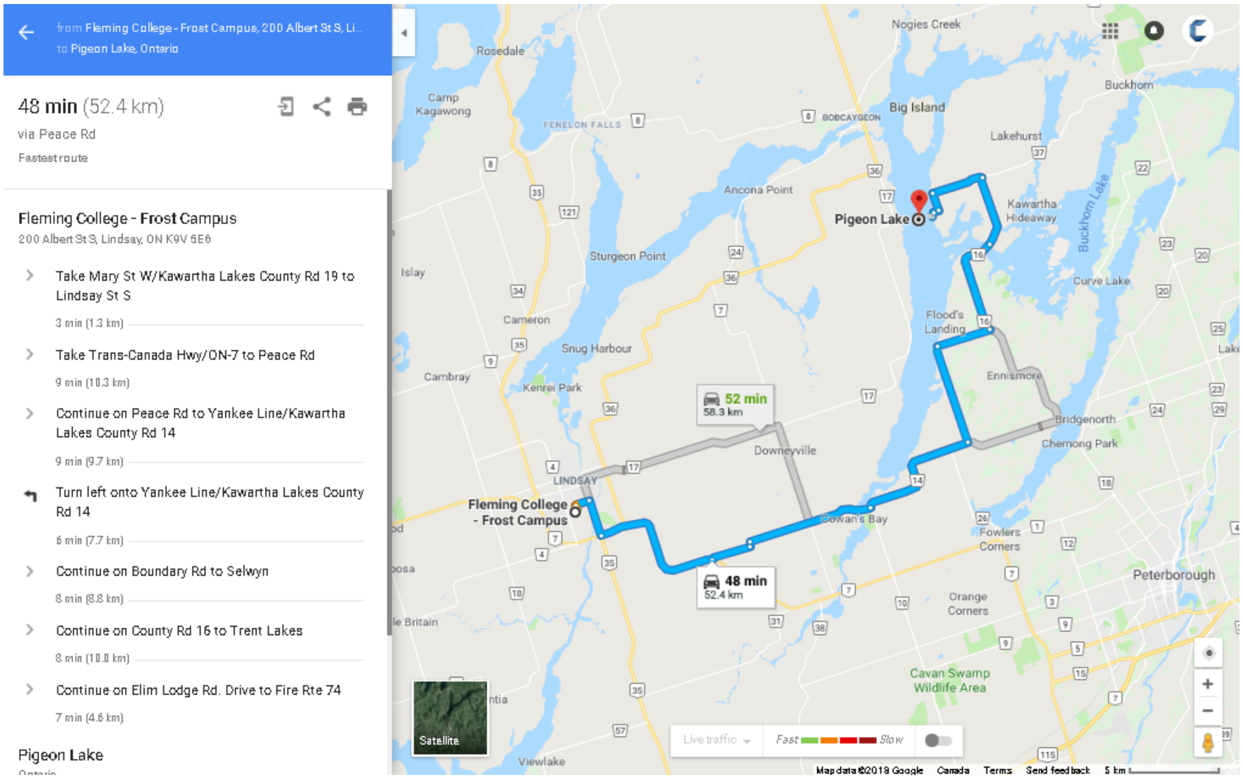
Appendix C7: Health and Safety Plan for Determination of Dissolved Oxygen Concentrations and Implications in Pigeon Lake, Lovesick Lake and Stony Lake

Project Name (same as on Project Proposal and Project Plan)	Determination of Dissolved Oxygen Concentrations and Implications in Pigeon Lake, Lovesick Lake and Stony Lake
Project Management Team (ie. student names)	Chelsea Houston, Connor Hill, Mara Van Meer and Chris Vieau
Cell Number + Area Code (ie. number for phone that will always be fully charged and in the field with you)	Mara Van Meer (Cell phone): 613 - 920 - 0750
Date H&S Plan Completed (dd/mm/yr)	September 13, 2018
Project Location(s) (Lot, Concession, Township) (street address including 911 emergency number) (attach google map and set of directions for route from Frost Campus to Project Location)	Pigeon Lake ● Bobcaygeon and Ennismore (Appendix A-1) Lovesick Lake ● Burleigh Falls (Appendix A-2) Stony Lake ● Burleigh Falls (Appendix A-3)
Permission to be on Property/Project Location(s) (granted by: Name, title, organization, date)	Mentor(s) Name: William Napier Mentor(s) Position: Chair Host Organization Name: Kawartha Lake Stewards Association Date: September 12, 2018

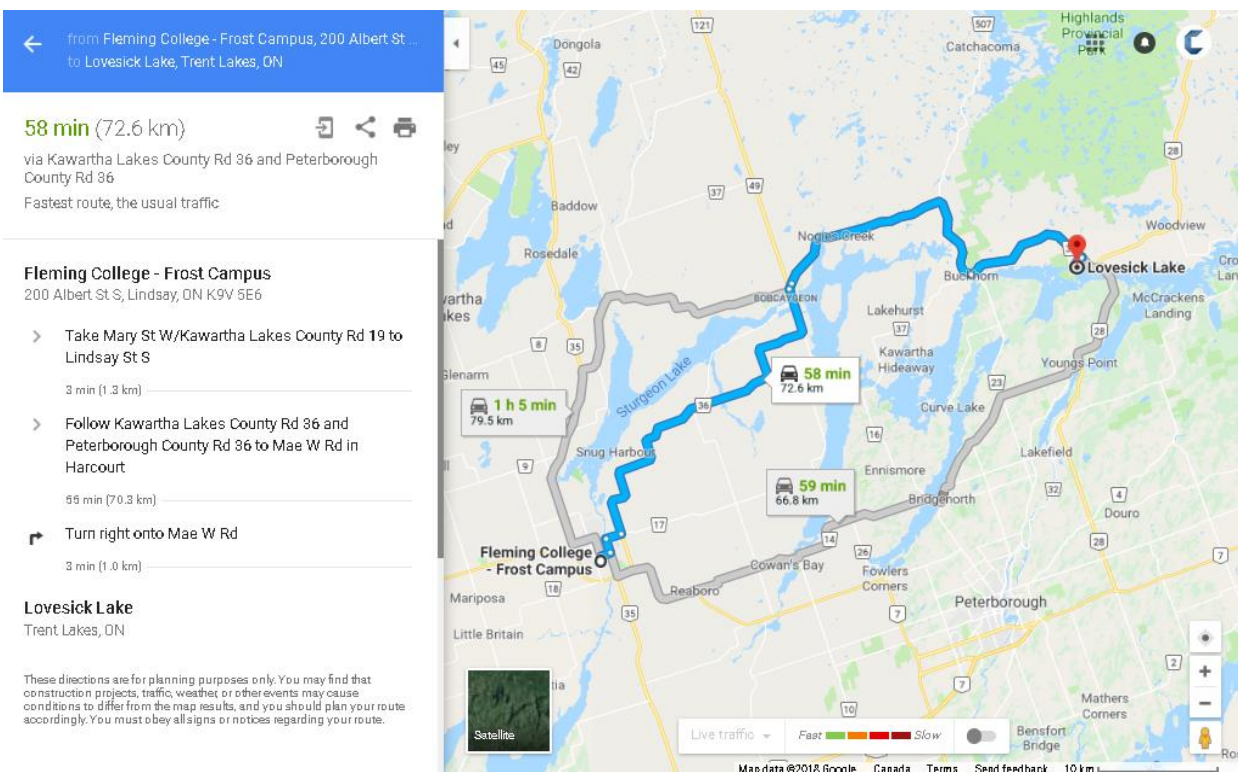
Description of all fieldwork involved in project (brief, descriptive, bullet points)	1. Create scope for field work and methodology for sampling. 2. Parameters to record include ● Dissolved Oxygen every metre from the surface to the bottom of sampling location ● Water clarity using Secchi Disk at each site ● Total Phosphorus taken one metre above lake bottom and one meter below the surface ● Benthic sample at each site (Using Ekman Dredge) 3. Kawartha Conservation will lead a training session on equipment during the first field sampling day (September 17th, 2018) including use of the DO meters and the Van Dorn.
Nearest Hospital to Project Location	Peterborough Regional Healthcare : 1 Hospital Dr, Peterborough, ON K9J 7C6 (Appendix A-4 appendix A-5, appendix A-6)
To report a life threatening emergency situation dial (to be confirmed by student team, before going into field, as may not apply in all locations)	**911**
The course faculty member and host organization mentor must be informed by email within 24hrs of all incidents requiring first aid, and/or emergency care.	
Potential Hazard Identification (eg. hunting season, slips/trips/falls, bears, working near/on water, poison ivy, heat stroke, etc.)	1. Working near water 2. Slip/Trip or fall 3. Boat mechanical threats 4. Inclement Weather- Lightning and high winds 5. Sunstroke/ heat exhaustion

Add/subtract numbers as needed.	
Hazard Mitigation Plan (Actions taken to mitigate potential hazards identified above. Each sentence begins with an action verb… Eg. 1. Wear "hunter orange" vests and ball caps whenever in the field.) (Listed in same order as above section.)	1. Wear PPE (High visibility vest, hat, safety boots, sunscreen and long pants) 2. Use precaution when operating near a motorized boat 3. Supervision from peers 4. Do not work in unsafe conditions (storms for example) 5. Monitor weather in the field
Personal Protective Equipment (PPE) Required (eg. cell phone, hunter orange vests and ball caps, appropriate footwear, lifejacket,etc.) Add/subtract bullets as needed.	● Fully charged cell phone ● Hats ● Ankle high boots (non-slip) ● Long pants ● Life jacket ● Gloves ● Sun glasses ● Food and water ● High visibility vest ● Bug spray and Sunscreen

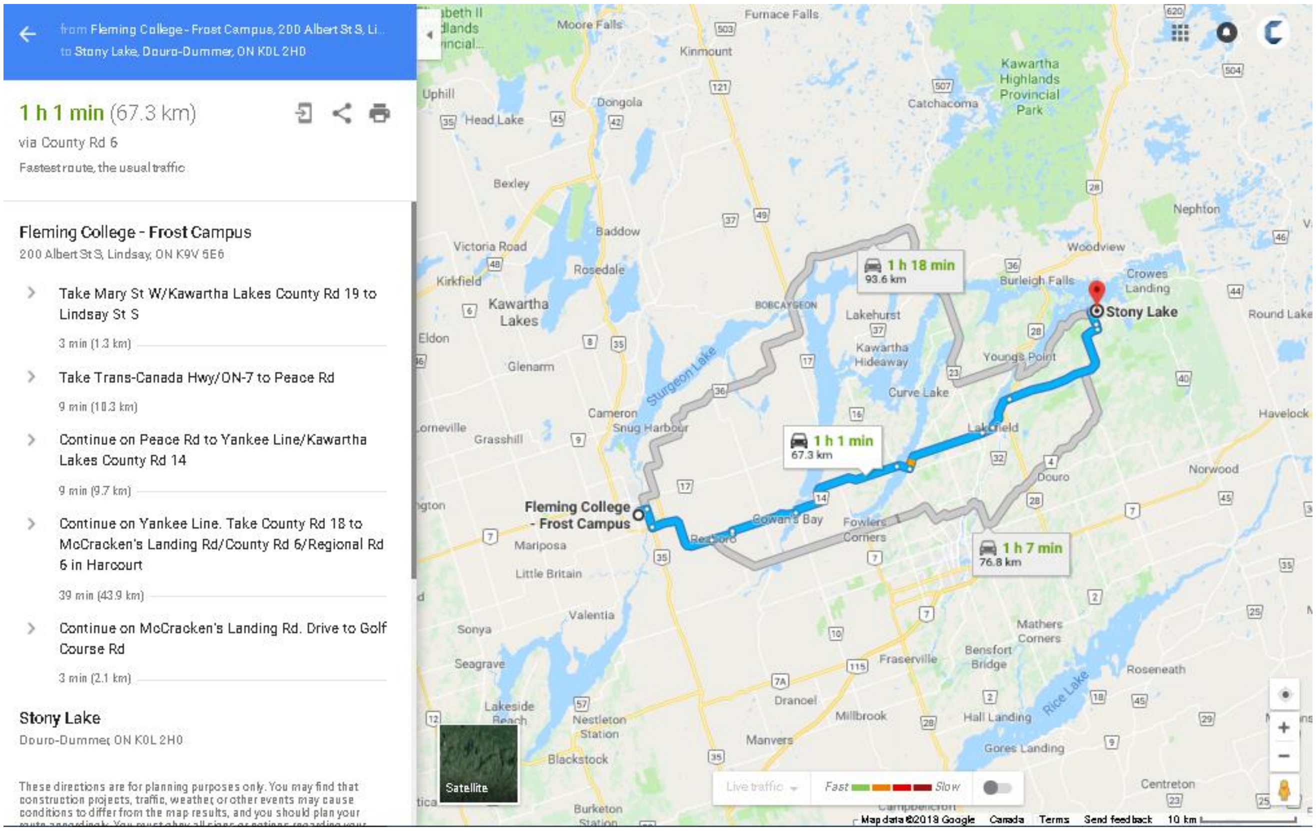
Directions and Map from Frost Campus to Pigeon Lake



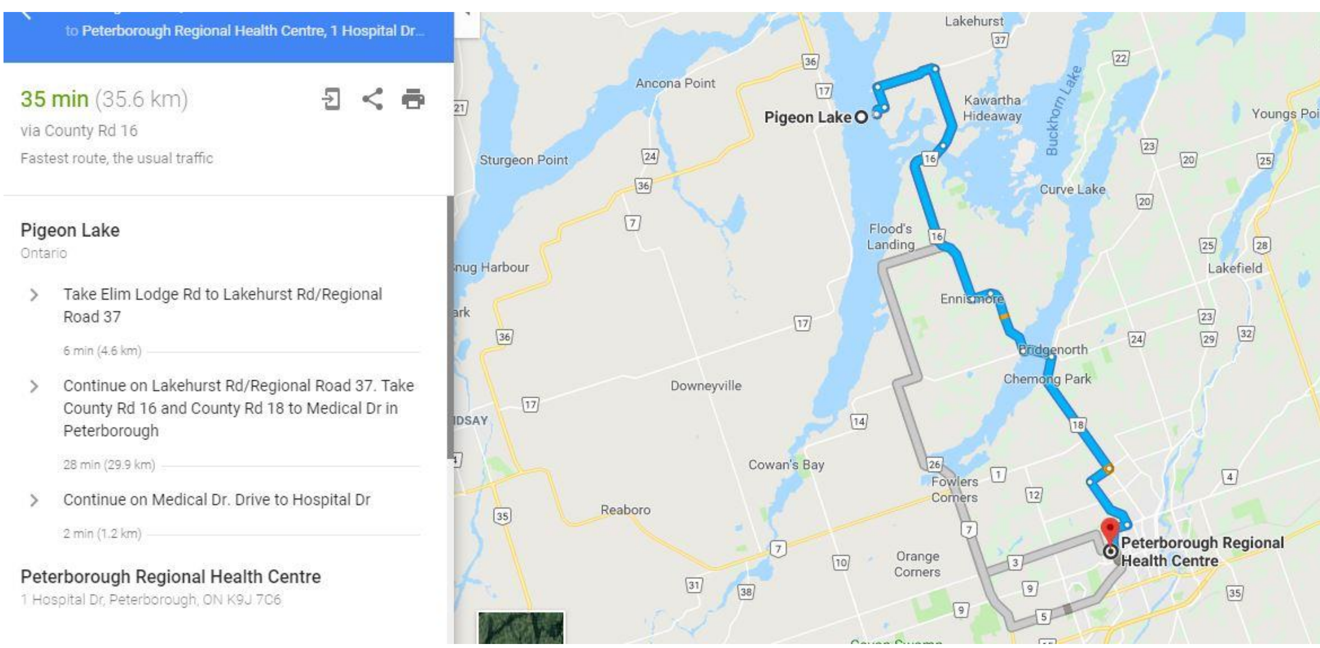
Directions and Map from Frost Campus to Lovesick Lake



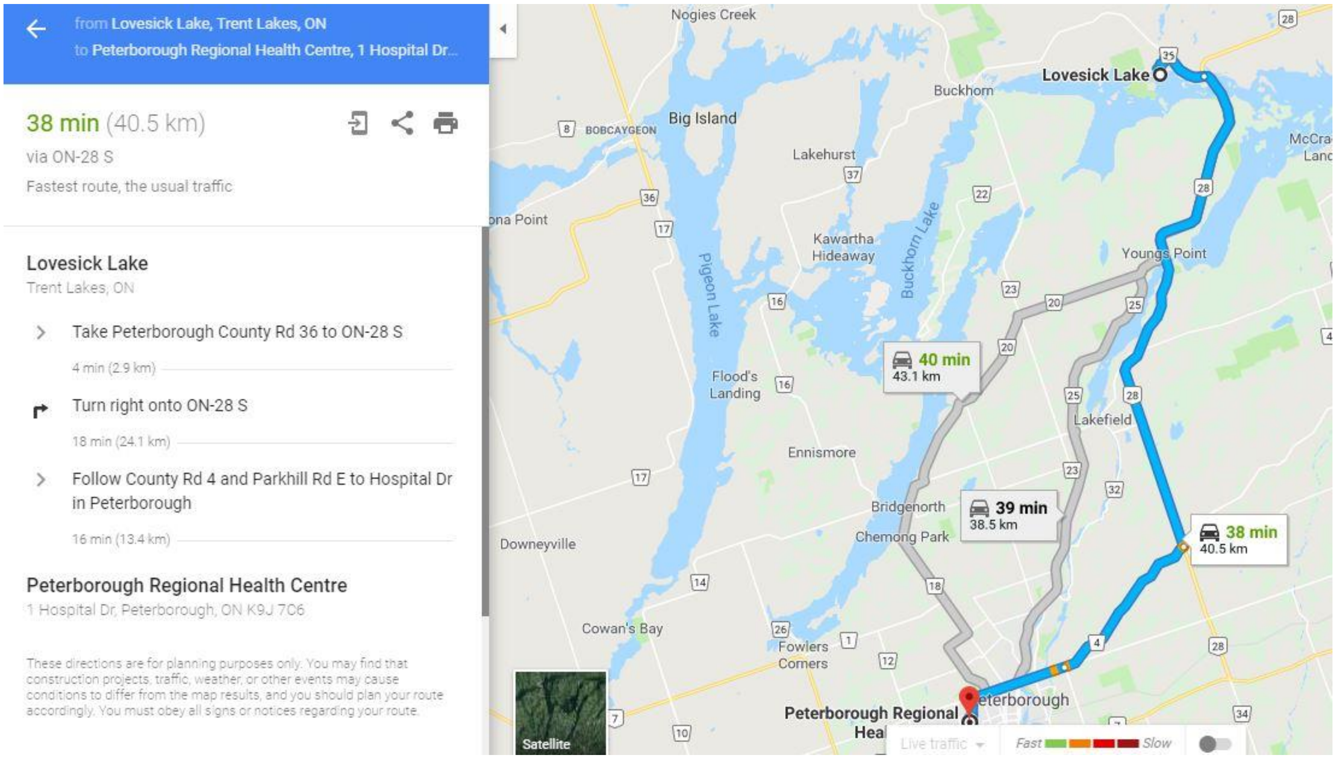
Directions and Map from Fleming College to Stony Lake



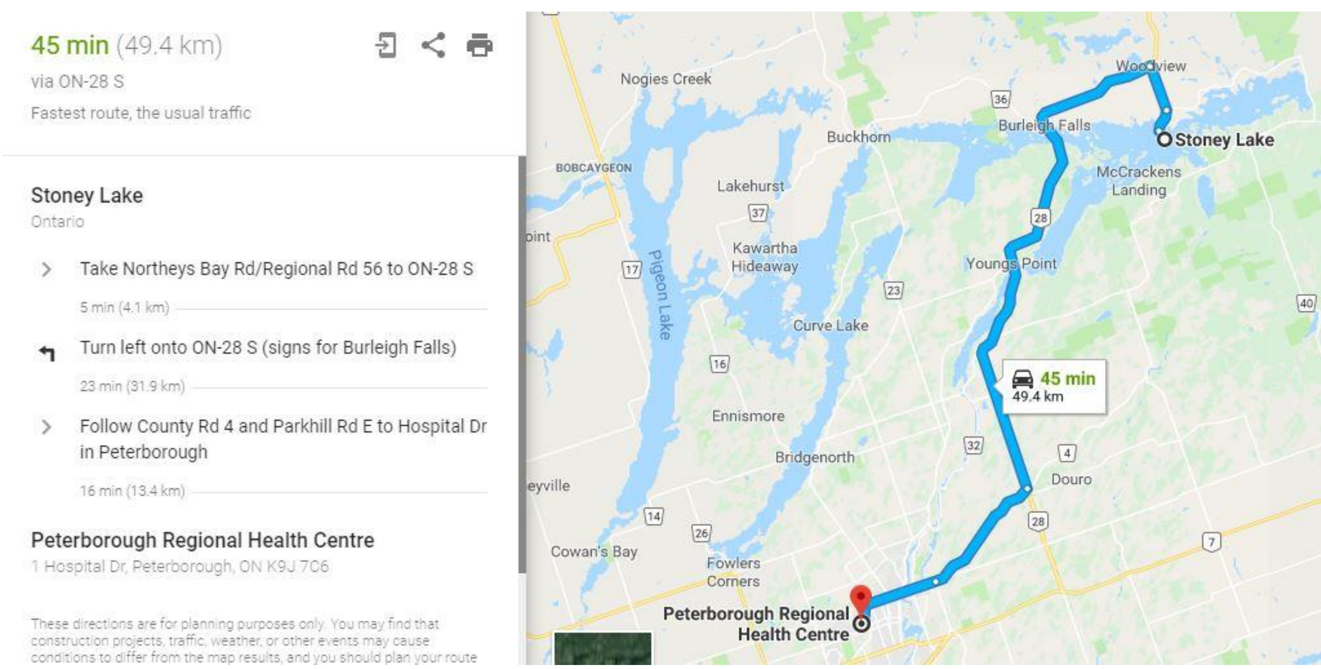
Directions and Map from Pigeon Lake to Peterborough Regional Healthcare



Directions and Map from Lovesick Lake to Peterborough Regional Healthcare



Directions and Map from Stony Lake to Peterborough Regional Healthcare



Appendix C8: Progress Report

Credit For Product
Meeting Date: 15/10/2018
Location: Room 252, Fleming College
Time: 14:00
Chair: C. Houston
Minutes Taken By: C. Hill, M. Van Meer, C. Vieau
Present:. Dempster, C. Hill, C. Houston, S. Kelly, B. Napier, M. Van Meer, C. Vieau

	Key Points / Actions	Action Items / Responsibility / Due Date
1.	**Call to Order/Welcome/Chair's Remarks** C. Houston called the meeting to order at 14:08 and stated welcoming remarks.	
2.	**Approval of Agenda** The agenda was distributed by C. Houston to all meeting attendees. S. Kelly moved the approval of the agenda, seconded by C. Dempster.	
3.1	**Review of Draft Results** C. Hill presented data collected, graphs, a map of study sites at Pigeon, Lovesick and Stony Lake, and final literature reviews, and how this data should be represented, and current budget update. TP results	- All Team members are to add numbered pages to literature reviews - B. Napier presented why certain sites were picked: Deeper locations in each lake, provide consistency, based off prior paleolimnology study. - C. Vieau in charge of completing error and mitigation of error in report, completed by 11/13/18 - C. Vieau to make sure what elements of assessment should be addressed in the future recommendations section: this includes

	were not discussed as data from all three lakes had not yet been received.	chlorophyll a, iron, etc. This should also include why dissolved oxygen concentration is not consistent. - Benthic analysis will be facilitated by C. Houston, with analysis being completed by 11/13/18. - M. Van Meer will include peep holes and trough information in report by 11/13/18. - C. Hill is to send out an updated budget by 11/13/18. - Meeting with Dr. Sager should occur no later than 11/09/18 to discuss pigeon lake in the winter. This meeting will be facilitated by M. Van Meer. - C. Hill will ensure draft product is sent to B. Napier by 11/13/18.
	3.2 Gantt Chart C. Vieau summarized the completed Gantt chart at 14:42 and the portions we have yet to complete. Stated that we are currently caught up in terms of the schedule outlined by the Gantt chart.	- Project closing to be completed by 12/10/15, facilitated by C. Hill - S. Kelly is going to book at room for November 26th from 12:30 – 2:30 for KLSA board meeting. - Presentation of Final results will be completed by entire team from 12:30-1:30 - B. Napier addressed project scope creep, the team must make sure extra presentations do not impact final results.
	3.3 Document Sign-off M. Van Meer distributed a completed project and health and safety plan at 15:04 to meeting attendees. Issues with the plan were brought up and changed before sign off.	M. Van Meer to update changes made in the project and health and safety plan by 12/12/18
	3.4 Printing of the Final Product	C. Hill is responsible for printing and distributing final deliverables

	C. Vieau confirmed how the final product will be distributed to the KLSA.	Project communications piece was completed via KLSA fall meeting
4.	**Conclusion** C. Houston suggested the conclusion of the meeting.	
5.	**Next meeting** C. Houston addressed the mentors of the project and discussed when the next meeting should be.	Emails with project updates will be sent every Monday by Mara Van Meer. The next email should be sent during reading week, Monday October 21st.
6.	**Other Business** The mentors were asked if there was any other business they would like to address	Bill Napier would like completed final literature reviews by December 10th to distribute to consulting companies. He addressed each member of the team and what they should fix. This includes: - Spelling and grammar - Adjusting scientific language - Including more relevant sources; lake partner program has reports available - Include information about lake productivity and characterizing the lakes. - Stick to Kawartha lakes - Total phosphorus should focus on which levels are “good” in certain ecosystems- 20 mg/L is eutrophic. - Conceptualize total phosphorus or dissolved oxygen
7.	**Adjournment** The meeting was adjourned by Chelsea Houston, moved by C. Hill and seconded by C. Dempster at 15:45.	

Credit For Product

Meeting Date: 7/09/2018
Location: Library, Fleming College
Time: 11:30
Chair: Mara Van Meer
Minutes Taken By: C. Hill, C. Houston, C. Vieau
Present:C. Hill, C. Houston, M. Van Meer, C. Vieau

	Key Points / Actions	Action Items / Responsibility / Due Date
1.	**Call to Order** The meeting was called to order at 11:30 by Mara Van Meer.	Meeting was called to order at 11:30 on Friday, September 7th, once all group members had arrived to study room in the library.
2.	**Approval of Agenda** The agenda was distributed by M. Van Meer to all meeting attendees. C. Houston moved the approval of the agenda, seconded by C. Vieau.	
3.	**Review of Team Charter Rubric** M. Van Meer stated what would be completed in the meeting by going through the requirements for the project.	M. Van Meer brought up the Team Charter rubric on D2L and it was reviewed as a group. The group decided that: ● the Team Mission Statement, Team Goals, Team Ground Rules, and Consequences of Unacceptable Behaviour would all be completed as a group. ● Team Roles would be discussed and then completed individually, and Team Member Profiles would be completed individually.
4.	**Completion of Group-work Components** The team discussed grammar, wording, and what was important in	The group worked together to complete the Team Mission Statement, Team Goals, Team Ground Rules, and Consequences of Unacceptable Behaviour.

	terms of project deliverables.	
5.	**Delegation of Individual Components** C. Houston delegated what would be completed individually based on project timeline.	● Discussed that Team Member Profiles would be completed individually. ● M. Van Meer inserted everyone's profile picture into the Google Document, and shared the document with all other members of the group. ● All individual components had to be completed to review at our next meeting on Monday, September 10th.
6.	**Discussion about Interview Day** C. Hill led the discussion about what to expect on interview day, and who was responsible for talking at each interview.	● The team had an open discussion about any questions or concerns about Interview Day, and specific skills or strategies we could employ to be successful. ● C. Houston is going to talk about water quality testing and benthos experience ● M. Van Meer is going to discuss the variety of educational backgrounds the group has ● C. Hill is going to talk about past working experiences and GIS experience ● C. Vieau will discuss group dynamics and a positive working environment. ● Reviewed all Project Proposals and decided that the Kushog Lake, Leech Lake, and EcoSpark projects would be our top priority (obviously after meeting Bill and Colleen our priorities changed!)
7.	**Conclusion** C. Vieau suggested the conclusion of the meeting.	
8.	**Next meeting**	Group decided that the next meeting would be held on Monday, September 10th at 10:00, in a study room in the Library.
9.	**Adjournment** The meeting was adjourned by M. Van Meer at 16:35, moved by C. Houston and seconded by C. Hill	

Credit For Product
Meeting Date: 15/10/2018
Location: Room Silent Study Room - Library, Fleming College
Time: 12:00
Chair: Connor Hill
Minutes Taken By: C. Houston, and C. Vieau
Present:C. Hill,C. Houston, M. Van Meer, and C. Vieau

	Key Points / Actions	Action Items / Responsibility / Due Date
1.	**Call to Order/Welcome/Chair’s Remarks** C. Hill called the meeting to order at 12:00 and stated welcoming remarks.	
2.	**Approval of Agenda** The agenda was distributed by M. Van Meer to all meeting attendees. C. Hill moved the approval of the agenda, seconded by C. Vieau.	The agenda included a practice run of the first progress meeting that took place later in the afternoon, at 14:00 on October 15th, 2018
3.	**Review of Draft Results**	Team members compiled draft products for meeting. ● Literature reviews, maps, and Project/Health and Safety Plan were printed by M. Van Meer. ● Data sheets, graphs, and budget update were printed by C. Hill. ● Meeting agendas for circulation to mentors were printed by C. Houston. ● Gantt Chart was printed by C. Vieau.
4.	**Gantt Chart** C. Vieau summarized the completed Gantt chart at 12:28 and the portions we	C. Vieau compiled Gantt chart, marked what has yet to be completed. The team reviewed project deliverables. During the progress meeting, C.Vieau is responsible for discussing: ● Deliverables that are on track (eg. creating graphs)

	have yet to complete. Stated that we are currently caught up in terms of the schedule outlined by the Gantt chart.	● What we have yet to complete (draft report) ● What deliverables are in progress (analysing data)
5.	**Printing of the Final Product**	Team discussed who will print and submit the final document. ● C. Hill will print and submit a hard copy as well as an electronic soft copy of the document on December 10th, 2018. ○ Decided to ask Bill and Colleen how they would prefer to receive the document electronically (USB/email, PDF/Word document).
6.	**Practice Run of Progress Meeting**	The team completed the practice run of the progress meeting. ● Followed logical sequence and offered pointers to group members who needed guidance.
	Conclusion M. Van Meer suggested the conclusion of the meeting.	
5.	**Next meeting** C. Houston determined when the next team meeting should take place	The next meeting will take place on October 29, 2018 to discuss the faculty meeting, meeting minutes, and go over the distribution of the final project
6.	**Other Business** Team STRIVE group members were asked if there was any other business they would like to address	● Draft report should be started in Week 9 29/10/18 ● C. Houston will type of progress meeting minutes by Week 9
7.	**Adjournment** The meeting was adjourned by C. Hill, moved by C. Vieau and	

	seconded by C. Houston at 12:45.	

Progress Report:

A-1: Gantt Chart										
	TEAM STRIVE (#3)									
	Determination of Dissolved Oxygen Concentrations and Implications in Pigeon Lake, Lovesick Lake and Stoney Lake									
Weeks	Academic Week		1	2	3	4	5	6	7	8
Dates	Week of		2018-09-04	10-09-18	17-09-18	24-09-18	01-10-18	08-10-18	15-10-18	22/10/18
	Tasks	Completed by								
Start Phase										
	Identification of True Colours	Sara Kelly	Completed							
	Formation of Team based on True Colours	Sara Kelly	Completed							
	Creation of draft Team Charter	Mara Van Meer	Completed							
	Meeting with mentor after being assigned a project	Mara Van Meer		Completed						
	Confirm the proposed sampling locations (2 sites at Pigeon & Lovesick, 3 at Stony)	Connor Hill		Completed						
	Decide what variables to measure- Benthic community, TP, DO	Chelsea Houston		Completed						
	Update Team Charter with KLSA project deliverables	Mara Van Meer		Completed						
	Create a field study work scope and methodology- data collection itinerary	Connor Hill		Completed						
	Rough draft of project health and safety plan	Mara Van Meer		Completed						
	Creation of preliminary equipment list	Chris Vieau		Completed						
	Submission of project and health and safety plan	Chris Vieau				Completed				
	Resubmission of project and health and safety plan based on feedback	Chris Vieau				Completed				
	Update on project sent via email to Bill Napier, Debbie Balika, and Brett Tregunno	Mara Van Meer	Completed	Completed	Completed	Completed				
Planning Phase										
	Establish Equipment List	Chris Vieau		Completed						
	Training session with Kawartha Conservation for YSI and Van Dorn	Chelsea Houston			Completed					
	Discussion of Literature Subjects and Formation of Gantt	Mara Van Meer			Completed					
	Reflection #1	Chelsea Houston				Completed				
	Literature Review Part 1 - Impact and Outcomes of TP Levels in Freshwater Lakes	Mara Van Meer				Completed				
	Literature Review Part 1 - Past and Present DO Studies in the Kawartha Lakes Continuum	Chelsea Houston				Completed				
	Literature Review Part 1 - Implications on Lake when DO Levels are Below Threshold	Connor Hill				Completed				
	Literature Review Part 1 - Anoxic Conditions in Freshwater Lakes	Chris Vieau				Completed				
	Team Charter Re-Submission based on feedback	Chris Vieau				Completed				
	Literature Review Part 1 Re-Submission Impact and Outcomes of TP Levels in Freshwater La	Mara Van Meer					Completed			
	Literature Review Part 1 Re-Submission Past and Present DO Studies in the Kawartha Lakes	Chelsea Houston					Completed			
	Literature Review Part 1 Re-Submission Implications on Lake when DO Levels are Below Thre	Connor Hill					Completed			
	Literature Review Part 1 Re-Submission Anoxic Conditions in Freshwater Lakes	Chris Vieau					Completed			

Starting Phase and Planning Phase of Gantt Chart

	Literature Review Part 1 Re-Submission Anoxic Conditions in Freshwater Lakes	Chris Vieau					Completed								
Implementation Phase															
	Data collection #1: Pigeon Lake	Chelsea Houston			Completed										
	a) Analyzing benthics collected	Chelsea Houston			Completed										
	b) Typing up data sheets	Mara Van Meer			Completed										
	Data collection #2: Lovesick Lake	Chelsea Houston				Completed									
	a) Analyzing benthics collected	Chelsea Houston				Completed									
	b) Typing up data sheets	Connor Hill				Completed									
	Data collection 3: Stony Lake	Chelsea Houston					Completed								
	a) Analyzing benthics collected	Chelsea Houston					Completed								
	b) Typing up data sheets	Chris Vieau					Completed								
	First Peer Evaluation	Mara Van Meer				Completed									
	Reflection #2	Chris Vieau								Completed					
	Reflection #3	Connor Hill												In progress on track	
	Meeting with KLSA members, delivering 5 minute speech about project	Mara Van Meer						Completed							
	Draft Project Deliverables	Chris Vieau							1) In progress off track						
	a) Begin draft report	Chris Vieau					2) In progress- off tack								
	b) Preliminary research on DO, Temperature, TP, and impact of low DO co	Mara Van Meer			Completed										
	c) Draft summary of past and present studies measuring DO	Chelsea Houston					Completed								
	d) Draft maps and graphs	Connor Hill							Completed						
	e) Recommendations	Chris Vieau							3) In progress- off track						
	Progress Meeting with Bill Napier	Mara Van Meer							Completed						
	Progress report and meeting minutes completion	Chelsea Houston								Completed					
	Final Literature Review - Impact and Outcomes of TP Levels in Freshwater Lakes	Mara Van Meer						Completed							
	Final Literature Review - Past and Present DO Studies in the Kawartha Lakes Continuur	Chelsea Houston						Completed							
	Final Literature Review - Implications on Lake when DO Levels are Below Threshold	Connor Hill						Completed							
	Final Literature Review - Anoxic Conditions in Freshwater Lakes	Chris Vieau						Completed							

1) Draft project deliverables are in progress but off track because we have not yet started our draft report or recommendation section. We plan on mitigating this with a team meeting delegating who will assist complete what and when it should be completed.

2) The draft report has not been started, though preliminary research has begun. This deliverable is off track because more progress has to be made to meet the project due date. The team will be meeting frequently throughout week nine to assign tasks and catch up on this draft deliverable.

3) The recommendation section of the report has been discussed and notes have been recorded, however, no actual progress has been made in the completion of this deliverable. Progress will be made this week when the team discusses next steps.

Implementation Phase of the Project

	Final Literature Review - Anoxic Conditions in Freshwater Lakes	Chris Vieau						Completed									
Closing Phase																	
	Project communications piece	Mara Van Meer												Completed			
	Final meeting with Mentors, sharing draft deliverables for feedback	Chris Vieau												in progress on track			
	Completion of final deliveralbles	Chelsea Houston													in progress on track		
	a) A 12-15 page report on DO in the lakes studied	Chris Vieau													in progress on track		
	b) Background information on the importance of DO and variables studie	Connor Hill													in progress on track		
	c) Summary of past and present stuides measuring DO	Chelsea Houston													in progress on track		
	d) Maps and graphs depicting data collected	Mara Van Meer													in progress on track		
	e) Recommendations for further studies	Chris Vieau													in progress on track		
	Budget Calculation and KLSA correspondence	Connor Hill											in progress on track				
	Project closing	Chelsea Houston											in progress on track				in progress on track
	Final Deliverables Hand- Over	Connor Hill															in progress on track
Weeks	Academic Week		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Dates	Week of		2018-03-04	10-03-18	17-03-18	24-03-18	01-10-18	08-10-18	15-10-18	22/10/18	29-10-18	05-11-18	12-11-18	19-11-18	26-11-18	03-12-18	10-12-18

Closing Phase of Project