Otter Lake, Seguin Twp.

Embayment Water Quality Monitoring 2017

and

Historical data Review

Prepared for the Otter Lake Ratepayers' Association

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Contents

Background

Water Quality was determined to be a priority for members of the Otter Lake Ratepayers' Association. Although the water quality in Otter Lake as determined by the Ministry of the Environment and Climate Change (MOECC), Lake Partner Program (LPP) is excellent, there were concerns that the isolated embayments may have water quality that is degraded when compared to the main open water areas of the lake. This concern was elevated by a recent algal bloom in one of the enclosed embayments.

Otter Lake has been a participant in the MOECC Lake Partner Program for many years, but these observations are made only at the deepest location in the lake and cannot provide information that is transferrable to the enclosed embayments. A more detailed survey of several isolated embayments was therefore planned for the 2017 ice-free season.

In the open water season in 2017, Otter Lake was sampled monthly in 6 enclosed bays (see map). The focus was to see whether there were differences in water quality in these bays compared to the main lake. One additional site was sampled in Little Otter Lake with the samples sent to LPP.

This report contains data collected in the 6 embayments in 2017 together with any available historical data collected by MOECC.

Historical Data Review

Phosphorus and oxygen

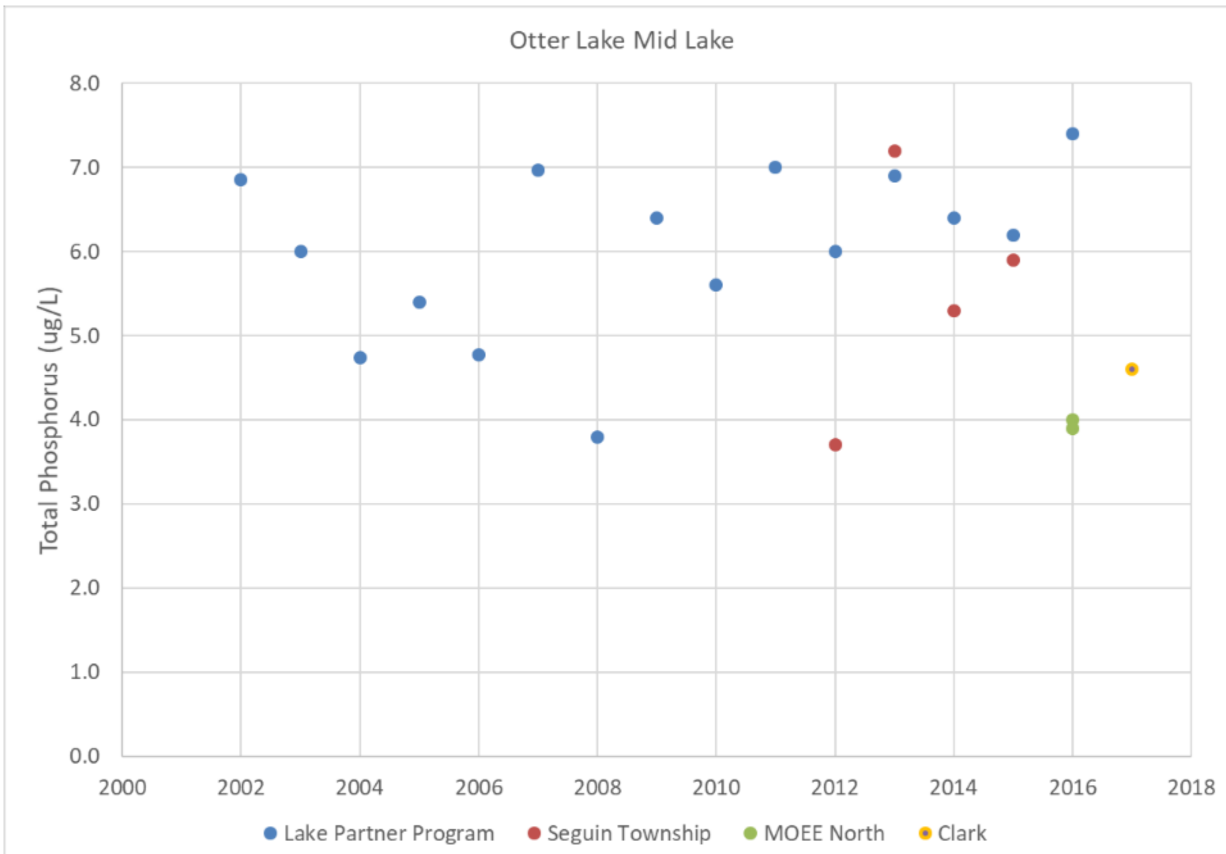
Good historical data has been collected for Otter Lake as it relates to water clarity, phosphorus and dissolved oxygen. Phosphorus data has been collected by multiple agencies because modeled and measured phosphorus concentrations are compared to background concentrations to determine the capacity for development on individual lakes by MOECC and by Seguin Township. Oxygen profile data has been collected by the Ministry of Natural Resources to determine suitability of oxygen habitat for cold water stenotherms. Habitat quality expressed as mean volume weighted hypolimnetic dissolved oxygen(MVWHDO) is used to determine capacity for development on Lake Trout Lakes.

AECOM modeling (2010) determined Otter Lake to be over capacity with both measured and modeled P concentrations above background + 50% (background + 50% for Otter = 4.3 µg/L) and the lake is also assessed to be at capacity with respect to MVWHDO which takes priority for capacity assessment in Lake Tout lakes (lakes must have >7 mg/L MVWHDO). This does not mean that the water quality in Otter Lake is substantially degraded. Lakes with low background phosphorus concentrations like Otter Lake have very low and pristine (oligotrophic) total phosphorus concentrations even when at threshold and the oxygen climate in the lake is only marginally below concentrations that are considered optimal (7mg/L) (See inset).

	Basin	whole lake long-term, mvwhdo	times	hypo %		
Measured	1	7.517	x	0.6076	equals	4.567
Data (above)	2	6.743	x	0.2204	equals	1.486
	3	5.4	x	0.1711	equals	0.923
Whole lake, long-term mvwhdo - measured (observed)						**6.976**
With	1	7.233	x	0.6076	equals	4.394
90 seasonal	2	6.528	x	0.2204	equals	1.438
lots (above)	3	5.242	x	0.1711	equals	0.897
Whole lake, long-term mvwhdo - with 90 seasonal lots added						**6.729**

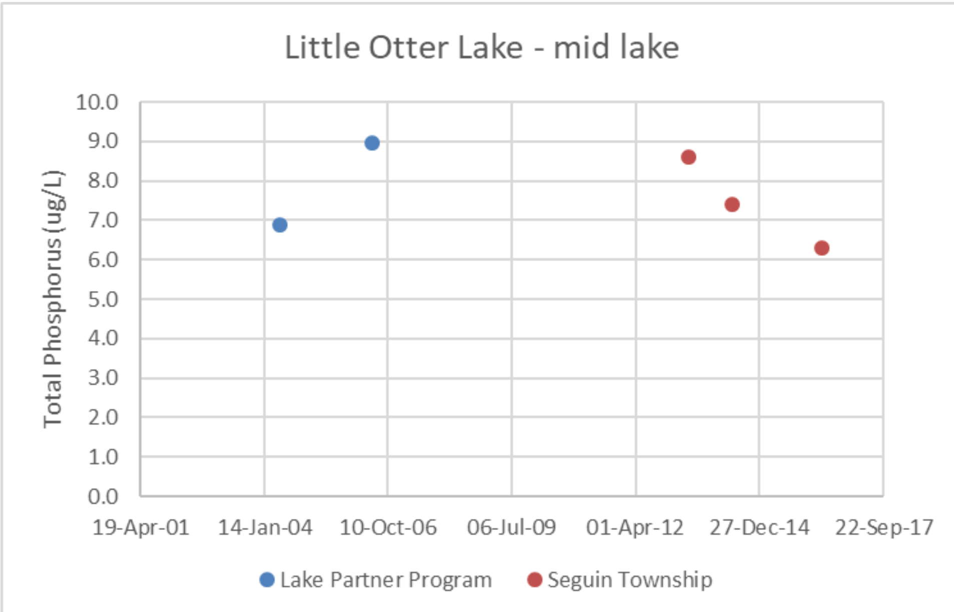
Phosphorus concentrations in Otter Lake have been measured in the spring by volunteers for the MOECC - LPP since 2002 (Figure 1). Although there is no trend during this period there is some variation in the data with values ranging from about 4 to 7 µg/L. This variation is more than would be noticed in some lakes but the range in values is captured by all agencies indicating a natural range in values. The average of all measurements is 5.7 µg/L indicating an oligotrophic lake (P less than 10 µg/L).

Figure 1 – Total phosphorus concentrations at the deepest loaction in Otter Lake (approx. latitude = 45^{0}17'15", longitude = 79^{0}57'48").



Total phosphorus concentrations have also been measured by the same agencies in Little Otter Lake but with less frequency (Figure 2). Average concentration is 7.6 µg/L. Concentrations here may be slightly higher due to the shallow nature of the lake (< 6m) or due to inflows with higher concentrations from Rankin Lake.

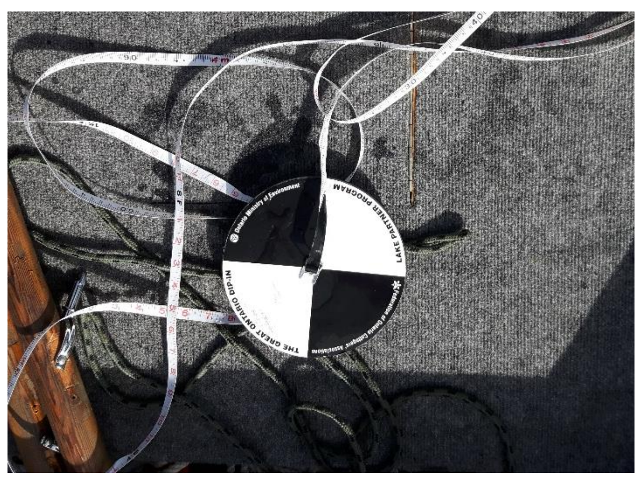
Figure 2 - Total phosphorus concentrations at the centre of Little Otter Lake (approx. latitude = 45⁰17’49”, longitude = 79⁰56’35”).



Water Clarity

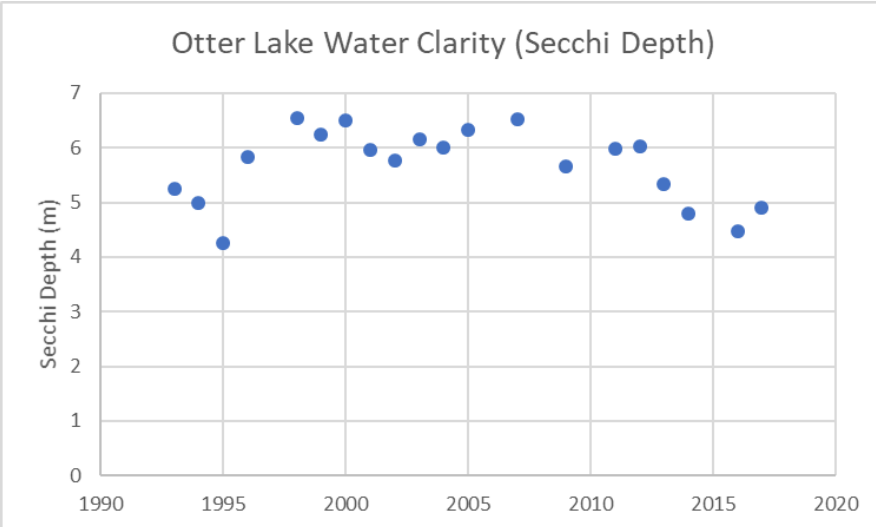
Water clarity observations are made using a Secchi disc on visits to collect water chemistry data. Water clarity can be used as a surrogate for nutrient status, but this relationship is not a good substitute for collecting phosphorus data. As a result, these water clarity observations are seldom used to reflect water chemistry parameters, but they can be useful to track changes that may occur in water clarity which are not linked to general chemistry measurements. This would occur, for example, in cases where zebra mussels have changed the water clarity with no associated change in phosphorus concentrations.

There are trends in the annual mean water clarity observations through time in Otter Lake (Figure 3) but the reasons for this are unclear. The data indicate a loss of water clarity since 2005 to levels that were measured in the 1990s. This may be due to variations in the phosphorus concentrations measured during the same period. In 2017 we observed considerable variation in Secchi depth observations between locations and between visits. It may be that Otter Lake experiences variations in both phosphorus and water clarity measurements that are somewhat higher than expected due to in-lake or watershed processes.



Secchi disc

Figure 3 – Average annual water clarity (Secchi depth in meters) for Otter Lake.



General Water Chemistry

Although there are considerable phosphorus and oxygen data available for Otter Lake there is very little data available for general water chemistry parameters. This is a condition that is shared for the majority of Ontario Lakes. A search of the Dorset Inland Lakes Database shows some measurements (Table 1) from the 1980s for Otter and Little Otter Lakes and these data are typical for what is expected in Lake Trout Lakes on the shield in Ontario, i.e. neutral pH, low alkalinity, low conductivity, low Dissolved Organic Carbon.

There are not enough of these data to draw any conclusions other than to say that the numbers fall into the same range as the observations made in 2017 during this project.

Table 1 – Historic water chemistry data for Otter Lake (MOECC, Dorset).

STN	LAKE_NAME	SDATE	SLOCATION	Secchi	PH	ALK	COND	DOC	CA	MG	NA	K	SO4	TKN	
4197	OTTER LAKE (BIG OTTER)	08-Aug-80	DEEP HOLE		6.42	2.80	32		2.80				7.10		
4196	OTTER LAKE (LITTLE)	07-Aug-80	DEEP HOLE		6.54	6.06	48		4.00				8.85		
4193	OTTER LAKE (BIG OTTER)	14-Jul-81	MID LAKE		6.36	2.36	32	3.40	2.80	0.80	1.10	0.45	8.00		
4193	OTTER LAKE (BIG OTTER)	04-Jun-00	Stn 1, North end	6.5										262	(pre 2002 mean)

Sample Methods

Six sample sites were selected to examine the water quality of enclosed embayments in Otter Lake in 2017 (see map). One additional location was sampled at the mid lake location in Little Otter Lake. The locations and depths for each location are shown in Table 2. Samples were collected once per month between May and October (six visits).

Map - showing the six sample locations.

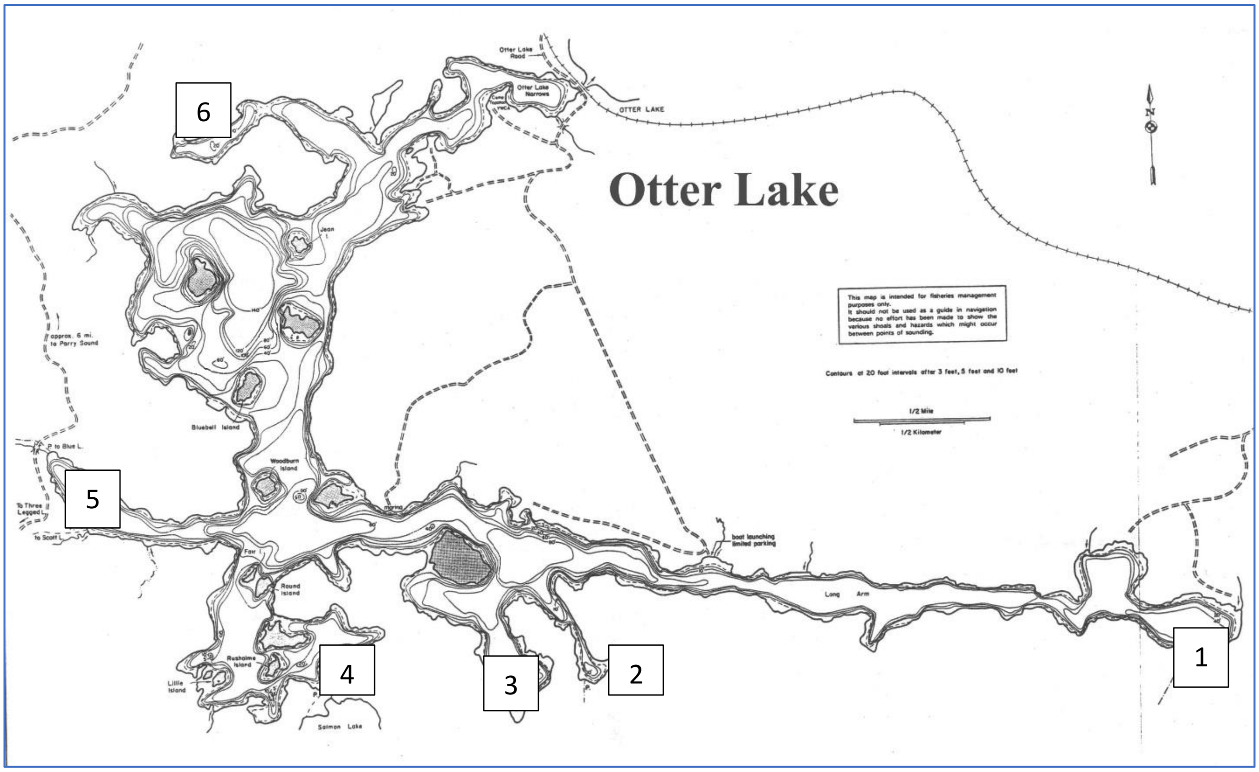


Table 2 – Locations and depths (m) of the 6 sample locations in Otter Lake and the sample location for Little Otter Lake (lol).

Site	Lat	Long	Depth
1	45 15 51.4	79 54 10.2	13
2	45 15 44.4	79 56 50.4	5.6
3	45 15 43.0	79 57 06.0	13
4	45 15 47.7	79 58 04.0	13.5
5	45 16 13.6	79 59 05.6	11
6	45 17 25.1	79 58 28.7	7
lol	45 17 38.8	79 56 36.1	5

On each visit, duplicate samples for total phosphorus were collected from the mixed surface layer for analysis at the Dorset Environmental Science Centre, Trent University Laboratory for low level phosphorus (P) analysis (2 Standard Deviations between duplicates = +/- 0.7 µg/L). At the end of August samples were also collected at 1 meter off bottom to test for internal loads of P from sediments.

On each visit the mixed layer was also tested for pH, conductivity, oxygen, temperature and water clarity (Secchi Depth). At the end of August temperature and oxygen profiles were measured for each meter from surface to bottom to observe mixing depths, potential for anoxia (depleted oxygen in bottom water) and internal loads that can transfer phosphorus from sediments into the water column during anoxia.

On the first visit to the lake a survey was conducted to observe the conductivity at numerous locations throughout the lake. This test generally measures the abundance of elements in the water that can increase electrical conductivity. The test can be used to tell whether the water in different areas of the lake has originated from sources where there are different watershed characteristics and possibly different water chemistry in the inflows. This is valuable in a study such as this where enclosed embayments are being measured. Bays with large inflows from different watersheds might be expected to have different conductivities. Conductivity measurements could be considered as a screening test to explain variations, if any, in the sources of water to the lake or to the nature of the water from place to place in the lake.

Results

Conductivity Survey

Conductivity measurements were made at multiple locations throughout Otter and Little Otter Lakes including the six enclosed embayments selected for this study. The conductivity throughout Otter Lake was similar ranging between 20 and 25 µS/cm. These are low values indicating very dilute water. The narrow range in values indicates that the water in all locations has been supplied from areas with similar watershed characteristics. Otter Lake is not a headwater lake, but it is fed by numerous smaller headwater lakes. The conductivity survey indicates that the watersheds and water chemistry are likely similar throughout this headwater “system”.

Conductivity in Little Otter Lake is approximately double the values found elsewhere and this may be due to the shallow nature of the lake or due to inflows from Rankin Lake which is higher in phosphorus.

The conclusions from this survey indicate that water quality conditions should be similar throughout the system since the sources of water to the lake come from watersheds that are similar in their export of ions and anions.

Conductivity at 25 locations throughout Otter and Little Otter lakes is shown in Figure 4.

Figure 4 – Conductivity measurements throughout Otter and Little Otter Lakes on May 28, 2017.

Conductivity values were in a narrow range throughout the open water season in each of the 6 enclosed bays and in Little Otter Lake (Table 3). Values are slightly higher in Bay #6 and about 2 times as high in Little Otter Lake. The conductivity in all cases is low as would be expected for lakes on the Canadian Shield.

Table 3 – Monthly conductivity measurements for the six embayments and for Little Otter Lake (LOL). Values in the right column are measurements from the deep hole in Otter Lake.

	Conductivity							
	1	2	3	4	5	6	LOL	deep
28-May-17	24.1	23.0	21.2	21.4	25.1	27.4	43.4	
02-Jul-17	22.7	20.2	23.4	23.2	22.9	25.0	46.0	
27-Jul-17	24.0	19.0	24.4	24.4	24.0	26.5	51.6	24.4
30-Aug-17	23.7	19.0	23.7	23.6	23.8	25.7	58.6	
02-Oct-17	22.8	19.7	22.3	22.4	22.1	24.1	49.1	22.2
22-Oct-17	21.2	18.8	20.6	20.7	20.6	22.6	44.8	20.8

Total Phosphorus

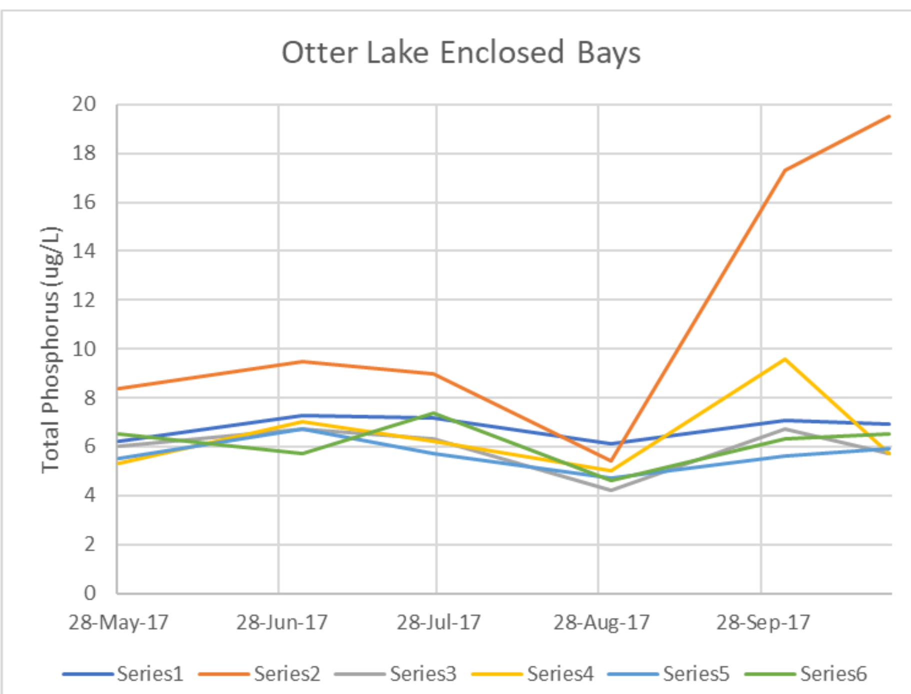
Total phosphorus (P) is the element that controls the growth of algae in most lakes. It is therefore measured to assess nutrient status and the potential for algal blooms. Generally, values below 10 µg/L are considered as having low potential to support algal blooms. These lakes are classed as oligotrophic and include most Lake Trout lakes. Concentrations between 10 and 20 µg/L typify mesotrophic lakes and although algal blooms often occur in these lakes it is generally accepted that avoidance of nuisance algal blooms is possible with P concentrations below 20 µg/L. These are mesotrophic lakes. Lakes with greater than 30 µg/L P are referred to as eutrophic lakes and these often support nuisance blue green algal blooms.

At five of the six sample locations the P concentrations in surface waters were, on each visit, below 10 µg/L (Figure 1). Concentrations ranged from about 4 to 7 µg/L which is the range in values noted for the main areas of the lake through time by the Lake Partner Program (Figure 1).

Notably, the concentrations in Bay#2 are mostly higher than those noted in the other 5 bays and were over 10 µg/L on the last two sample dates. This is due to an internal load and is explained further in the temperature/oxygen section below.

Reports of past blooms in Bay#2 were likely due to small amounts of blue green algae and their toxins that were entrained by filamentous algae. This is not a typical blue green bloom. It is rare to see algal blooms at less then 10 µg/L P but a few species of algae can bloom at these concentrations by taking nutrients from the sediments. It is important to note that conditions favourable to algal blooms can also be amplified by climate change even when there is no increase in nutrients associated with shoreline development.

Figure 5 - Total phosphorus concentrations measured in 6 enclosed bays in Otter Lake in 2017. Concentrations in Bay #2 are higher than in the other 5 bays especially in the fall.



Temperature/Oxygen

Surface measurements

Surface temperature measurements were taken on each visit to see whether any of the locations experiences elevated temperatures. There was very little variation in temperature between locations on each visit (Table 4). The same was true of oxygen measurements at the surface (Table 5).

Table 4 – surface water temperatures at sample locations in 2017.

	Temperature							
	1	**2**	**3**	**4**	**5**	**6**	**LOL**	deep
28-May-17	17.7	18.0	17.7	18.8	16.6	17.1	17.9	
02-Jul-17	21.0	21.3	21.6	21.1	21.0	21.8	21.1	
27-Jul-17	22.8	23.2	23.2	23.0	23.1	23.5	23.4	23.5
30-Aug-17	21.5	21.0	21.3	21.3	21.6	21.2	22.4	
02-Oct-17	18.3	16.8	18.2	18.3	17.9	17.9	18.0	17.9
22-Oct-17	15.3	15.4	14.9	15.0	15.2	14.7	15.1	15.0

Table 5 – Surface oxygen concentrations at sample locations in 2017.

	Dissolved Oxygen							
	1	**2**	**3**	**4**	**5**	**6**	**LOL**	deep
28-May-17	10.5	10.3	10.2	10.1	10.6	10.4	10.1	
02-Jul-17	9.9	9.5	9.9	9.9	10.1	9.5	9.5	
27-Jul-17	9.4	8.3	9.3	9.0	9.4	9.0	9.1	9.5
30-Aug-17	9.6	9.0	9.6	9.7	9.7	9.2	9.0	
Aug 30 1MOB	0.8	0.7	0.8	0.7	0.7	1.0	9.0	
02-Oct-17	9.8	8.6	9.8	9.6	9.9	8.9	9.0	9.9
Oct 02 1MOB	1.3	0.8	1.0	1.0	1.1	1.0	9.0	
22-Oct-17	10.0	9.8	9.7	9.7	9.9	9.6	10.2	10.0

Temperature/Oxygen Profiles

The period of interest for temperature and oxygen profiles is focused on the end of summer when stratified areas of the lake can develop anoxia in the unmixed bottom waters. This happens over the course of the summer with the lowest oxygen in bottom waters occurring in the late summer just before the lake turns over (mixes to the bottom) following the onset of lower temperatures. In most cases where blue green algal blooms occur there is an internal phosphorus load that happens when stratified bottom waters lose their oxygen (anoxia). This does not normally happen in the deep locations of a typical Lake Trout lake but anoxia can be common in shallower areas that stratify. Anoxia allows phosphorus from the sediments to enter the water column and potentially support algal blooms in late summer.

Oxygen and temperature profiles collected on August 30 at the sample sites are shown in Table 6. Stratification is noted at all sites except Little Otter. Thermal stratification is where the bottom waters remain colder and do not mix with the upper layers of warmer water. The upper layer of warm, mixed water is called the Epilimnion (green cells in Table 6). The zone where there is a rapid change in temperature is called the metalimnion (blue cells in table 6). The bottom layer of water which remains cooler and does not mix with upper layers during stratification is called the hypolimnion (yellow cells in Table 6). The hypolimnion can lose its oxygen due to sediment and bacterial consumption and when concentrations go below about 1 µg/L there can be phosphorus released from the sediments. In five of the six bays the oxygen concentrations at the bottom fell below 1.0 µg/L (1.0 at site 6). This is shown by the red numbers in Table 6. The bottom row in Table 6 shows corresponding increases in bottom phosphorus concentrations in 3 of the 6 bays (sites 2, 5 and 6). Although these concentrations are higher they are not high enough to cause concerns.

The bottom line is that these bays do stratify, they do go anoxic, and they do have sediment release of phosphorus in some cases (sites 2, 5 and 6). This indicates that the conditions may be in place to support algal blooms. However, the concentrations of phosphorus in the mixed layer are generally too low to support nuisance blooms and late summer concentrations of P in the mixed layer did not increase (Figure 5) as a result of internal loads except for Bay#2. At Bay#2 the internal load increased the mixed layer phosphorus concentrations so that they approached (but did not exceed) 20 µg/L in late summer (see Figure 5). *Note: It is suggested by the Provincial Water Quality Objectives that P concentrations remain below 20 µg/L to avoid nuisance algal blooms (MOECC, 1994).*

It is important to understand that the oxygen conditions in bottom waters are influenced by basin shape and extent of the stratified season (Molot 1992). In addition, there was a great deal of rain in 2017 which led to high water levels and these conditions may affect stratification and nutrient supply variables making it difficult to determine whether the conditions observed in 2017 at Bay#2 are normal. In addition, the enclosed bay at site 2 is:

- substantially isolated from the remainder of the lake,
- shallow with a large hypolimnetic volume to sediment surface area ratio, and
- bordered by marshy areas.

These characteristics contribute to elevated P in both surface and bottom waters such that the conditions that were observed may occur naturally, i.e. unrelated to shoreline development.

pump to sample bottom waters

Table 6. Temperature, oxygen depth profiles for Aug 30, 2017. Green cells are epilimnion, blue cells are metalimnion and yellow cells are hypolimnion. All sites experience anoxia in the bottom few meters except for Little Otter Lake which remains mixed to the bottom and does not stratify. Bottom row in table shows phosphorus concentrations at 1 m off bottom with increased P at sites 2, 5 and 6 (shown in bold).

	Aug 30 2017													
	Site 1		Site 2		Site 3		Site 4		Site 5		Site 6		Little Otter	
Depth (m)	Temp	O2	Temp	O2	Temp	O2	Temp	O2	Temp	O2	Temp	O2	Temp	O2
0	21.5	9.6	21.0	9.0	21.3	9.6	21.3	9.7	21.6	9.7	21.2	9.2	22.4	9.0
1	21.1	9.5	20.7	8.9	21.2	9.6	21.2	9.6	21.3	9.6	20.6	9.0	22.0	9.1
2	21.0	9.5	20.4	8.9	20.9	9.5	21.0	9.5	21.1	9.6	20.4	8.7	21.8	9.2
3	20.9	9.5	20.0	8.5	20.7	9.5	20.9	9.5	21.0	9.6	20.2	8.1	21.5	9.1
4	20.9	9.4	18.4	3.8	20.7	9.5	20.8	9.4	20.9	9.6	19.6	6.8	21.1	9.1
5	20.8	9.2	13.5	**0.9**	20.7	9.4	20.7	9.3	20.8	9.5	16.2	1.5	21.0	9.0
6	16.0	8.7	12.9	**0.7**	20.6	9.2	20.6	9.2	20.7	9.4	11.7	1.1		
7	12.3	8.8			16.2	8.5	16.0	5.3	15.3	7.8	11.8	1.0		
8	10.0	7.5			12.2	8.3	12.9	5.0	12.2	4.9				
9	8.5	6.8			10.6	8.2	10.8	4.2	9.9	2.1				
10	7.7	5.6			9.4	7.8	8.6	3.0	8.9	**0.9**				
11	7.2	2.8			8.8	7.1	7.3	1.3	8.5	**0.7**				
12	6.4	1.2			8.0	1.9	6.6	**0.8**						
13	6.2	**0.8**			7.8	**0.8**	6.3	**0.7**						
	total phosphorus 1 meter off bottom (ug/L)													
	8.7		**35.4**		5.7		9.8		**19.2**		**16.6**		NA	

epi
meta
hypo

Otter Lake

Water Clarity

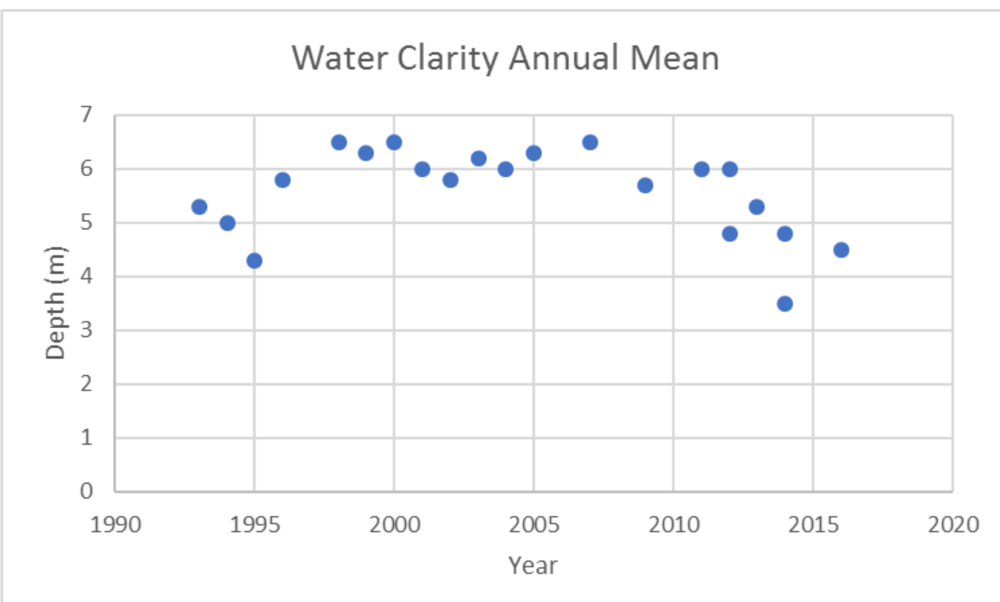
There is a fair amount of variation in water clarity between sites and between visits at the sample locations (Table 7). This is caused by variations in the algal communities at each site and the differences do not appear to be caused by variations in dissolved organic carbon (DOC) which can cause the water to appear "tea stained" and lower the clarity. This is based on field observations; no DOC data was collected.

There is also between-year variation in average water clarity at the deep location in Otter Lake (Figure 6). The factors contributing to these inter-annual changes are unclear.

Table 7 – Water clarity (Secchi depth) observations for the sample sites in 2017.

	Secchi Depth							
	1	**2**	**3**	**4**	**5**	**6**	**LOL**	deep
28-May-17	6.2	3.3	4.1	3.7	4	3.6	3.2	
02-Jul-17	3.3	2.8	3.1	3.5	3.6	4.2	3.4	
27-Jul-17	3.6	2.4	2.8	3.7	2.9	3.3	2.9	3.7
30-Aug-17	3.6	3.6	3.9	4	3.4	3.3	2.7	3.9
02-Oct-17	3.2	3.2	4.2	3.3	4.4	3.4	2.9	5.2
22-Oct-17	4.9	5.2	5.7	4.3	5.3	4.4	4.8	5.9

Figure 6 - Annual mean water clarity observations by Lake Partner Program volunteers between 1993 and 2017.



pH

The pH of surface water was measured at each visit (Table 8). This information is not important within the context of nutrients or algal blooms but is presented here to show that there are some variations between locations which may be linked to CO2 produced by algal communities. There are also some large increases and decreases in pH between sample visits especially at site 6 but we do not have enough data to assess the factors contributing to these changes.

Table 8 – pH measurements in surface water at each sample location in 2017.

	pH							
SITE	**1**	**2**	**3**	**4**	**5**	**6**	**LOL**	deep
28-May-17	6.7	6.5	6.5	6.6	6.7	6.7	6.9	
02-Jul-17	6.4	6.4	6.8	6.7	6.8	6.7	6.8	
27-Jul-17	6.8	5.9	5.8	5.8	5.4	3.5	5.0	5.5
30-Aug-17	6.5	6.6	6.7	7.2	7.3	8.0	7.6	7.1
02-Oct-17	6.6	6.7	6.8	5.9	6.6	7.1	6.9	6.9
22-Oct-17	7.7	7.6	7.6	6.1	6.5	6.4	5.6	6.4

Oxygen, conductivity and pH meters

Conclusions

The following conclusions can be drawn from the water quality results derived from this project.

- Conductivity surveys indicate that water throughout Otter lake has similar watershed origins. The water in Little Otter lake is slightly different and this may reflect differences in watershed or inflow characteristics.
- Phosphorus concentrations indicate that Otter and Little Otter Lakes are dilute, oligotrophic lakes with excellent water quality and no apparent trends since low-level testing began in 2002. Testing in Little Otter Lake is sparse.
- Phosphorus concentrations in the enclosed embayments that were studied in 2017 are similar in range to those measured over time in the main body of the lake by the Lake Partner Program.
- Bay#2 had elevated P concentrations compared to the other sample sites and higher concentrations approaching 20 µg/L in the late summer which are likely due to internal P loads that are introduced through anoxia in the bottom few meters of water. These conditions are likely natural and related to basin morphometry and watershed characteristics.
- Phosphorus measurements show some variation through time and from location to location but with no trends. There are trends in the long-term, Lake Partner Program water clarity results but the reasons for this are unclear.

Lake Partner Program results from Otter and Little Otter Lakes should be available for review in 2018.

Recommendations

1. Best management practices should be encouraged to minimize the movement of anthropogenic phosphorus into Otter Lake.
2. Volunteers should continue to collect phosphorus and water clarity data at the main basin locations on Otter and Little Otter Lakes. Volunteer dedication is required to collect all samples.
3. If algal blooms occur there should be photographs and water samples taken at the time to assess the extent and species responsible for the bloom.
4. It is not absolutely necessary to establish additional Lake Partner Program sample locations in the enclosed bays because the LPP does not accommodate 1 m off bottom samples.
5. Further test sites could be established if there is evidence of increased development or if typical blue green algal blooms develop in any of the enclosed bays. Water quality measurements do not indicate that this is likely.
6. It would be of some use to conduct annual fall surveys of the enclosed bays to observe temperature oxygen profiles and collect 1 m off bottom samples. This could be accomplished through the Georgian Bay Biosphere enhanced sampling program.

References

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