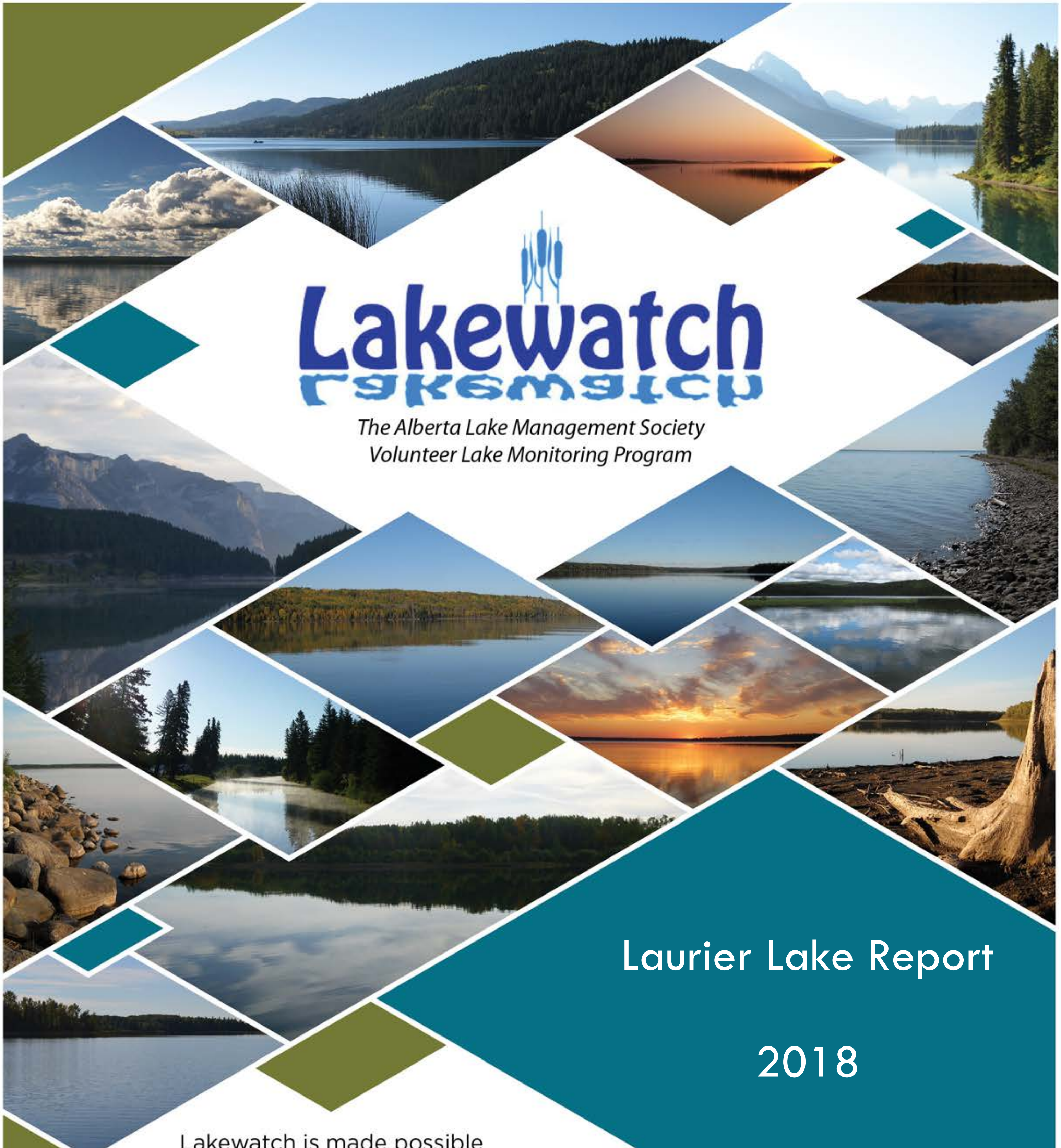

Lakewatch

The Alberta Lake Management Society
Volunteer Lake Monitoring Program

Laurier Lake Report

2018

Lakewatch is made possible
with support from:

Alberta
PIGEON LAKE WATERSHED ASSOCIATION
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ALBERTA LAKE MANAGEMENT SOCIETY'S LAKEWATCH PROGRAM

LakeWatch has several important objectives, one of which is to collect and interpret water quality data on Alberta Lakes. Equally important is educating lake users about their aquatic environment, encouraging public involvement in lake management, and facilitating cooperation and partnerships between government, industry, the scientific community and lake users. LakeWatch Reports are designed to summarize basic lake data in understandable terms for a lay audience and are not meant to be a complete synopsis of information about specific lakes. Additional information is available for many lakes that have been included in LakeWatch and readers requiring more information are encouraged to seek those sources.

ALMS would like to thank all who express interest in Alberta's aquatic environments and particularly those who have participated in the LakeWatch program. These leaders in stewardship give us hope that our water resources will not be the limiting factor in the health of our environment.

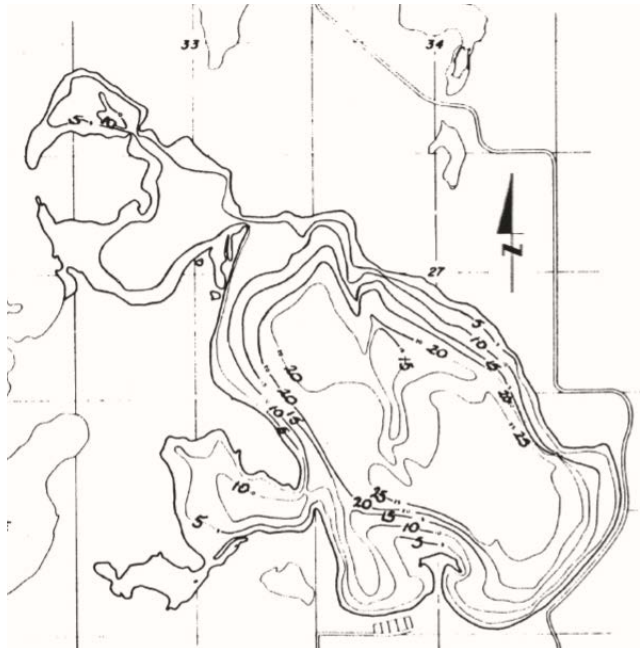
If you require the data in this report for your own purposes, please contact ALMS for the raw data files.

ACKNOWLEDGEMENTS

The LakeWatch program is made possible through the dedication of its volunteers. At Laurier Lake, we would like to thank Bev Smith for her years of dedication to LakeWatch. We would also like to thank Alanna Robertson, Lindsay Boucher and Shona Derlukewich, who were summer technicians in 2018. Executive Director Bradley Peter and Program Coordinator Laura Redmond were instrumental in planning and organizing the field program. This report was prepared by Caitlin Mader and Bradley Peter.

LAURIER LAKE

Laurier Lake is one of five beautiful lakes that were left behind 10,000 years ago when glaciers carved a hummocky terrain of kettles, eskers, and lake basins. Archaeological evidence indicates that the area was inhabited 7000 years ago, with Europeans arriving in 1754 by way of the nearby North Saskatchewan River. The Whitney Lakes Provincial Park adjacent to Laurier Lake was established in 1982. It boasts a diverse setting of jack pine (*Pinus banksiana*) meadows, aspen (*Populus* spp.) groves, willow (*Salix* spp.) thickets, marshes, fens, and mixed wood forests.



Bathymetric map of Laurier Lake circa 1856 (Angler's Atlas).

Loons on Laurier Lake, 2017 (photo by Elashia Young)

As many as 148 bird species have been observed in the park with an excellent viewing point on the west side of Laurier Lake. The land surrounding Laurier Lake includes a mixture of recreational cottage development, cleared agricultural land, and natural deciduous forest. Protected Crown Land makes up the north shore of the lake and the remainder is privately owned. The lake is enjoyed through recreational activities including hiking, wildlife viewing, and water-based recreation such as wind surfing, waterskiing, sailing, swimming, and fishing. Yellow perch (*Perca flavescens*) and northern pike (*Esox lucius*) are the sport fish of Laurier Lake. Fish stocking occurred in 1953 with sport and forage fish transferred from Moose Lake to Laurier Lake. The lake has not been managed for commercial or domestic fisheries.

The watershed area for Laurier Lake is 196 km^2 and the lake area is 6.57 km^2. The lake to watershed ratio of Laurier Lake is 1:30. A map of the Laurier Lake watershed area can be found at http://alms.ca/wp-content/uploads/2016/12/Laurier.pdf.

METHODS

Profiles: Profile data is measured at the deepest spot in the main basin of the lake. At the profile site, temperature, dissolved oxygen, pH, conductivity and redox potential are measured at 0.5- 1.0 m intervals. Additionally, Secchi depth is measured at the profile site and used to calculate the euphotic zone. On one visit per season, metals are collected at the profile site by hand grab from the surface and at some lakes, 1 m off bottom using a Kemmerer.

Composite samples: At 10-sites across the lake, water is collected from the euphotic zone and combined across sites into one composite sample. This water is collected for analysis of water chemistry, chlorophyll-a, nutrients and microcystin. Quality control (QC) data for total phosphorus was taken as a duplicate true split on one sampling date. ALMS uses the following accredited labs for analysis: Routine water chemistry and nutrients are analyzed by Maxxam Analytics, chlorophyll-*a* and metals are analyzed by Alberta Innotech, and microcystin is analyzed by the Alberta Centre for Toxicology (ACTF). In lakes where mercury samples are taken, they are analyzed by the Biogeochemical Analytical Service Laboratory (BASL).

Invasive Species: Monitoring for invasive quagga and zebra mussels involved two components: monitoring for juvenile mussel veligers using a 63 µm plankton net at three sample sites and monitoring for attached adult mussels using substrates installed at each lake.

Data Storage and Analysis: Data is stored in the Water Data System (WDS), a module of the Environmental Management System (EMS) run by Alberta Environment and Parks (AEP). Data goes through a complete validation process by ALMS and AEP. Users should use caution when comparing historical data, as sampling and laboratory techniques have changed over time (e.g. detection limits). For more information on data storage, see AEP Surface Water Quality Data Reports at aep.alberta.ca/water.

Data analysis is done using the program R.[1] Data is reconfigured using packages tidyr [2] and dplyr [3] and figures are produced using the package ggplot2 [4]. Trophic status for each lake is classified based on lake water characteristics using values from Nurnberg (1996)[5]. The Canadian Council for Ministers of the Environment (CCME) guidelines for the Protection of Aquatic Life are used to compare heavy metals and dissolved oxygen measurements. Pearson's Correlation tests are used to examine relationships between TP, chlorophyll-*a,* TKN and Secchi depth, providing a correlation coefficient (r) to show the strength (0-1) and a p-value to assess significance of the relationship.

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[1] R Core Team (2016). R: A language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria. URL https://www.R-project.org/.

[2] Wickman, H. and Henry, L. (2017). tidyr: Easily Tidy Data with 'spread ( )' and 'gather ( )' Functions. R package version 0.7.2. https://CRAN.R-project.org/package=tidyr.

[3] Wickman, H., Francois, R., Henry, L. and Muller, K. (2017). dplyr: A Grammar of Data Manipulation. R package version 0.7.4. http://CRAN.R-project.org/package=dplyr.

[4] Wickham, H. (2009). ggplot2: Elegant Graphics for Data Analysis. Springer-Verlag New York.

[5] Nurnberg, G.K. (1996). Trophic state of clear and colored, soft- and hardwater lakes with special consideration of nutrients, anoxia, phytoplankton and fish. Lake and Reservoir Management 12: 432-447.

BEFORE READING THIS REPORT, CHECK OUT A BRIEF INTRODUCTION TO LIMNOLOGY AT ALMS.CA/REPORTS

WATER CHEMISTRY

ALMS measures a suite of water chemistry parameters. Phosphorus, nitrogen, and chlorophyll-a are important because they are indicators of eutrophication, or excess nutrients, which can lead to harmful algal/cyanobacteria blooms. One direct measure of harmful cyanobacteria blooms are Microcystins, a common group of toxins produced by cyanobacteria. See Table 2 for a complete list of parameters.

The average total phosphorus (TP) concentration for Laurier Lake was 93.6 μg/L (Table 2), falling into the eutrophic, or highly productive trophic classification. This value is higher than any previously detected averages since monitoring began in 2003. Detected TP was lowest when first sampled in June at 60 μg/L, and peaked at 110 μg/L in both July sampling trips (Figure 1).

Average chlorophyll-*a* concentration in 2018 was 53.2 μg/L (Table 2), falling into the hypereutrophic, or very high productivity trophic classification. Chlorophyll-*a* was lowest in June at 6.1 μg/L and peaked at 140 μg/L in early July. This rapid increase in chlorophyll-a concentrations is characteristic of an algae bloom.

Finally, the average TKN concentration was 2.9 mg/L (Table 2) with concentrations peaking in July.

Average pH was measured as 8.87 in 2018, buffered by moderate alkalinity (462 mg/L $CaCO_3$) and bicarbonate (470 mg/L HCO_3). Magnesium and sodium were the dominant ions contributing to a medium conductivity of 970 μS/cm (Table 2).

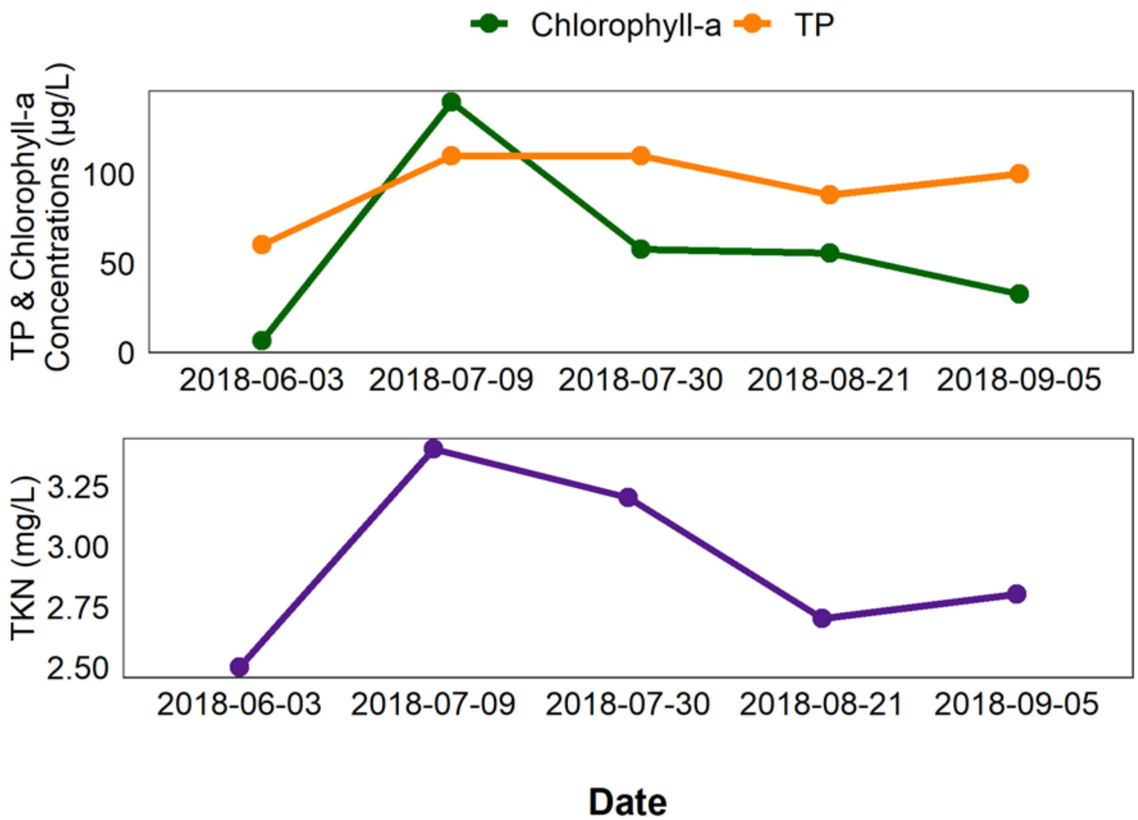


Figure 1- Total Phosphorus (TP), Total Kjeldahl Nitrogen (TKN), and Chlorophyll-*a* concentrations measured five times over the course of the summer at Laurier Lake.

METALS

Samples were analyzed for metals once throughout the summer (Table 3). In total, 27 metals were sampled for. It should be noted that many metals are naturally present in aquatic environments due to the weathering of rocks and may only become toxic at higher levels.

Metals were measured once on August 18 at Laurier Lake at the surface and all measured values fell within their respective guidelines (Table 3).

WATER CLARITY AND SECCHI DEPTH

Water clarity is influenced by suspended materials, both living and dead, as well as dissolved colored compounds in the water column. During the melting of snow and ice in spring, lake water can become turbid (cloudy) from silt transported into the lake. Lake water usually clears in late spring but then becomes more turbid with increased algal growth as the summer progresses. The easiest and most widely used measure of lake water clarity is the Secchi depth. Two times the Secchi depth equals the euphotic depth – the depth to which there is enough light for photosynthesis.

The average Secchi depth of Laurier Lake in 2018 was 2.15 m (Table 2). Secchi depth decreased drastically between June 3 and July 9. This sudden decrease in water clarity may have been due an algae bloom in early July as indicated by increasing chlorophyll-a levels (Figure 1).

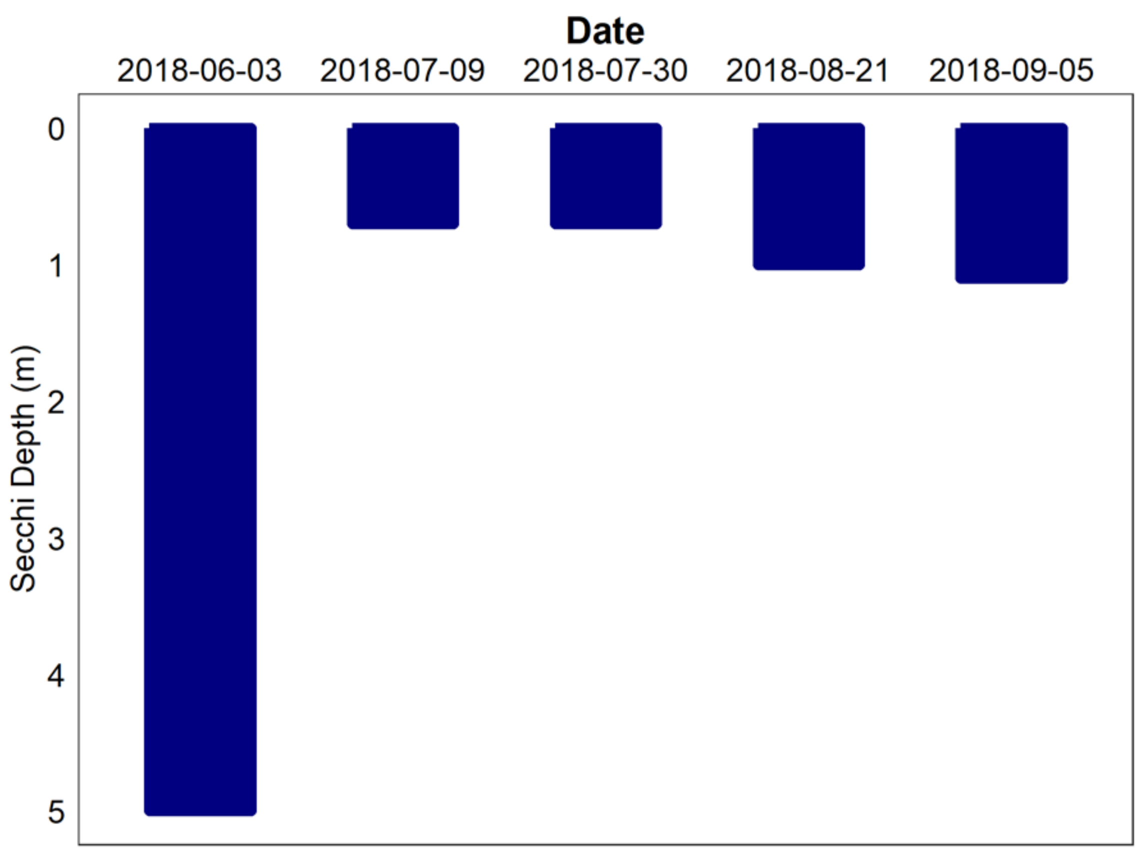


Figure 2 – Secchi depth values measured five times over the course of the summer at Laurier Lake in 2018.

WATER TEMPERATURE AND DISSOLVED OXYGEN

Water temperature and dissolved oxygen profiles in the water column can provide information on water quality and fish habitat. The depth of the thermocline is important in determining the depth to which dissolved oxygen from the surface can be mixed.

Temperatures of Laurier Lake varied throughout the summer, with a maximum temperature of 21.1°C measured at the surface on August 21 (Figure 3a). Other than a slight thermocline near lake bottom on June 3, the lake was not stratified during any of the sampling trips, with temperatures fairly constant from top to bottom. This indicates partial or complete mixing throughout the season.

Laurier Lake remained well oxygenated through most of the water column during most sampling trips, measuring above the CCME guidelines of 6.5 mg/L for the Protection of Aquatic Life (Figure 3b). The oxygen level fell below this level below 2 meters on July 30. This low-oxygen event coincides with a sudden increase in chlorophyll-a levels, indicating that an algae bloom was underway at this time. The lack of oxygen throughout most of the water column at this sampling date may have been due to oxygen consumption cyanobacteria or by decomposing organic matter at lake bottom.

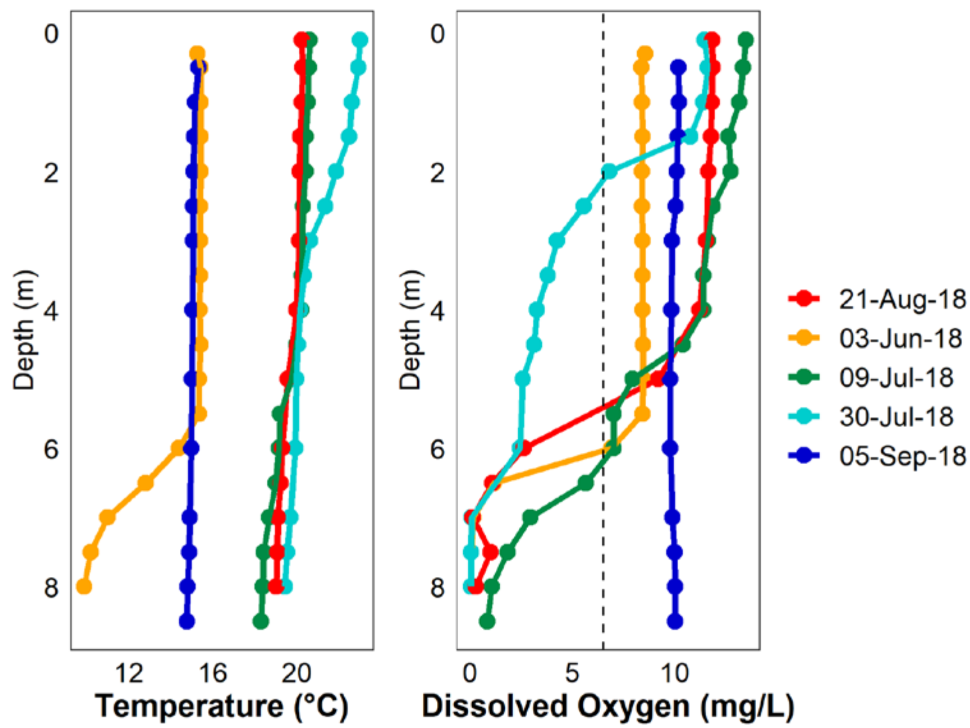


Figure 3 – a) Temperature (°C) and b) dissolved oxygen (mg/L) profiles for Laurier Lake measured five times over the course of the summer of 2018.

MICROCYSTIN

Microcystins are toxins produced by cyanobacteria (blue-green algae) which, when ingested, can cause severe liver damage. Microcystins are produced by many species of cyanobacteria which are common to Alberta's Lakes, and are thought to be the one of the most common cyanobacteria toxins. In Alberta, recreational guidelines for microcystin are set at 20 µg/L. Blue-green algae advisories are managed by Alberta Health Services. Recreating in algal blooms, even if microcystin concentrations are not above guidelines, is not recommended.

Microcystin levels in Laurier Lake fell below the recreational guideline of 20 µg/L for at the locations and times sampled in Laurier Lake in 2018. However, an individual grab sample of a cyanobacteria bloom from the centre of the lake had microcystin concentrations measuring 1611 ug/L. This indicates that the bacteria in Laurier Lake are capable of producing high concentrations of cyanobacteria toxin, and caution should be observed when recreating in visible blooms.

Table 1 – Composite microcystin concentrations measured five times at Laurier Lake in 2018.

Date	Microcystin Concentration (µg/L)
03-Jun-18	0.23
09-Jul-18	3.30
30-Jul-18	1.62
21-Aug-18	4.11
05-Sep-18	4.13
Average	2.68

INVASIVE SPECIES MONITORING

Dreissenid mussels pose a significant concern for Alberta because they impair the function of water conveyance infrastructure and adversely impact the aquatic environment. These invasive mussels have been linked to creating toxic algae blooms, decreasing the amount of nutrients needed for fish and other native species, and causing millions of dollars in annual costs for repair and maintenance of water-operated infrastructure and facilities.

Monitoring involved two components: monitoring for juvenile mussels (veligers) using a plankton net and monitoring for attached adult mussels using substrates installed in each lake. No mussels have been detected in Laurier Lake.

WATER LEVELS

There are many factors influencing water quantity. Some of these factors include the size of the lakes drainage basin, precipitation, evaporation, water consumption, ground water influences, and the efficiency of the outlet channel structure at removing water from the lake. Requests for water quantity monitoring should go through Alberta Environment and Parks Monitoring and Science division.

Since water levels were first recorded in 1968, Laurier Lake has fluctuated by 3.2 m (Figure 4). Starting in the early 1980s, lake level slowly decreased until a record low in 2004 at 564 m above sea level (ASL). Water levels then began a rapid increase to the record high reached in 2017 at 567 m ASL.

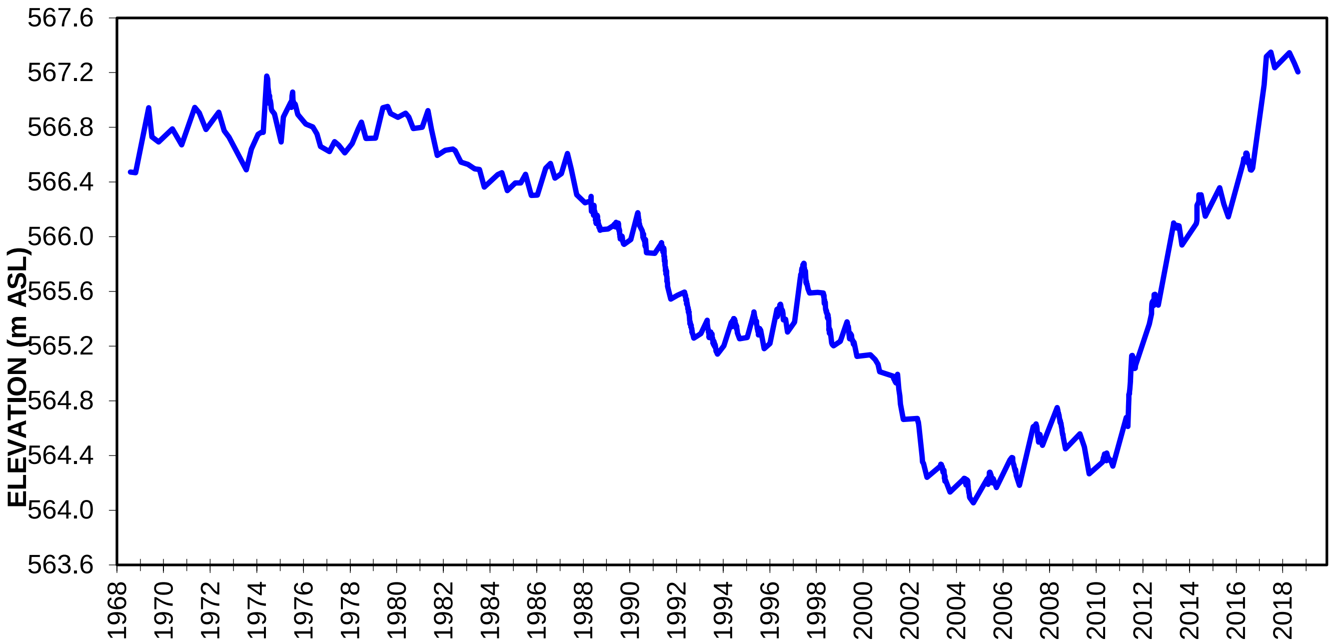


Figure 4- Water levels measured in meters above sea level (m asl) from 1968- 2018. Data retrieved from Environment Canada and the Government of Alberta.

Table 2: Average historical Secchi depth and water chemistry values for Laurier Lake.

Parameter	**2007**	**2008**	**2009**	**2010**	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**	**2018**
TP (µg/L)	41.6	51.2	50.5	37.6	36.4	73.4	48	39.2	45	53.2	93.6
TDP (µg/L)	22	18.8	20.5	16.4	19.4	31	26.2	13.4	13	11.8	16.6
Chlorophyll-*a* (µg/L)	4.29	11.93	9.13	6.96	5.85	14.37	19.6	7.8	36.4	39.6	58.34
Secchi depth (m)	2.40	1.30	2.00	1.80	3.10	1.72	1.42	2.67	1.94	1.42	1.70
TKN (mg/L)	2.2	2.7	2.8	2.6	2.2	2.3	2.2	2.2	2.4	2.5	2.92
NO_2-N and NO_3-N (µg/L)	5	6	5.75	9.6	3.4	2.5	24	5.4	4.925	2.76	13.16
NH_3-N (µg/L)	46.2	39.2	39.3	33.2	33	26.4	32.8	74	105	66.2	96.4
DOC (mg/L)	37.9	37.9	39	37.5	32.2	34.1	35.17	33	27	28.4	29.6
Ca (mg/L)	16.3	14.5	12.1	12.2	20.2	23.13	23.13	26	25	30	32.4
Mg (mg/L)	97.8	92.9	88.1	98.6	84.6	83.3	71.67	87	89	76.8	75.2
Na (mg/L)	122.7	120.7	132.3	136	101.9	100.9	108.33	98	97	87.4	86
K (mg/L)	32.83	31.9	38	34.47	31.3	35.2	32.57	30	31.5	28.8	27.4
SO_4^{2-} (mg/L)	111.7	121.3	135.7	148.7	118.3	107.3	102.67	120	110	91.2	89.2
Cl^- (mg/L)	19.5	20.2	21.2	22.7	18.7	16.6	18.23	20	19	17.4	18
CO_3 (mg/L)	86	84.7	70	85	45	55.6	63.66	52	52.5	42.2	47.4
HCO_3 (mg/L)	535.7	544.3	582.3	568	546.8	500.2	614.6	536	507.5	474	470
pH	9.11	9.03	9	9.1	8.84	8.88	8.90	8.85	8.90	8.86	8.874
Conductivity (µS/cm)	1163.3	1196.7	1246.7	1257	1143.6	1098.6	1100	1100	1100	966	970
Hardness (mg/L)	443.3	418.7	392.7	436.3	399	401	353	422	435	394	390
TDS (mg/L)	750.3	754.3	784.3	817	690.7	669	709.67	698	682.5	612	612
Microcystin (µg/L)	0.53	0.236	0.39	0.174	0.4692	/	3.514	0.49	0.925	2.29	2.678
Total Alkalinity (mg/L $CaCO_3$)	583	588	594	607.7	523.8	503	504	524	505	458	462

Table 3: Concentrations of metals measured in Laurier Lake on in each sampling year since 2004. The CCME heavy metal Guidelines for the Protection of Freshwater Aquatic Life (unless otherwise indicated) are presented for reference. Values above these guidelines are presented in red.

Metals (Total Recoverable)	2007	2008	2010	2011	2012	2013	2014	2015	2016	2017	2018	**Guidelines**
Aluminum µg/L	29.4	9.69	20.65	17.2	7.61	7.265	16.05	10.05	3.5	6.8	3.9	100[a]
Antimony µg/L	0.137	0.117	0.131	0.1245	0.115	0.0931	0.094	0.1415	0.093	0.074	0.08	/
Arsenic µg/L	2.6	3	3.185	2.825	2.435	2.35	2.165	3.89	1.93	2.56	2.13	5
Barium µg/L	20.2	16.95	17.8	19.15	29.6	35.8	37.85	23.225	39.9	43.8	53.6	/
Beryllium µg/L	<0.003	<0.003	0.002	0.003	0.010	0.002	0.004	0.004	0.004	0.006	<0.001	100[c,d]
Bismuth µg/L	<0.005	0.005	0.002	0.003	0.007	0.001	0.001	0.015	<0.001	0.006	0	/
Boron µg/L	175.5	182	188.5	189	221.5	163	171	280	171	170	140	1500
Cadmium µg/L	0.008	0.004	0.004	0.003	0.003	0.002	0.002	0.002	0.001	0.025	0.01	0.26[b]
Chromium µg/L	0.611	0.560	0.441	0.465	0.296	0.526	0.695	0.185	0.060	0.250	0.1	/
Cobalt µg/L	0.099	0.058	0.071	0.081	0.059	0.048	0.026	0.071	0.020	0.083	0.06	1000[d]
Copper µg/L	0.61	0.56	0.28	2.90	0.68	0.37	0.24	1.09	0.78	0.91	0.11	4[b]
Iron µg/L	37.1	15.8	16.855	21.05	9.5	17.15	13.4	14	8.3	8.3	12	300
Lead µg/L	0.06	0.02	0.02	0.06	0.02	0.03	0.01	0.04	0.01	0.01	0.01	7[b]
Lithium µg/L	102.9	100.2	114	114.5	111.5	87.05	75.8	149.35	94.3	89.5	75	2500[e]
Manganese µg/L	5.2	8.0	4.1	8.3	13.0	19.9	20.3	12.6	20.6	13.3	35.3	5.2
Molybdenum µg/L	0.66	0.59	0.86	0.78	0.59	0.46	0.32	0.78	0.4	0.3	0.33	73[c]
Nickel µg/L	0.28	0.13	0.13	0.2	0	0.22	<0.001	0.16	0.03	1.64	0.22	150[b]
Selenium µg/L	0.55	0.37	0.42	0.31	0.3	0.24	0.49	0.11	0.57	0.5	0.6	1
Silver µg/L	<0.003	0.009	0.001	0.043	0.002	0.025	0.018	0.002	0.001	0.003	<0.001	0.25
Strontium µg/L	84.5	62.9	58.85	72.35	114.5	134	145	89.2	166	178	210	/
Thallium µg/L	<0.001	0.002	0.001	0.001	<0.001	<0.001	0.003	0.022	<0.001	0.005	<0.001	0.8
Thorium µg/L	<0.01	0.02	0.01	0.04	0.01	0.01	<0.01	0.03	0.01	0.014	<0.01	/
Tin µg/L	<0.06	<0.03	0.02	0.02	0.03	0.02	0.01	0.02	0.01	0.15	0.06	/
Titanium µg/L	1.24	1.36	1.38	0.75	0.69	1.4	1.94	2.01	1.4	1.31	1.38	/
Uranium µg/L	0.81	0.81	1.09	0.88	0.68	0.68	0.55	2.77	0.61	0.5	0.46	15
Vanadium µg/L	0.74	0.51	0.81	0.56	0.43	0.33	0.44	0.85	0.26	0.31	0.27	100[d,e]
Zinc µg/L	1.53	0.92	0.33	1.09	1.03	0.62	1.1	1.25	1.1	2.1	1.1	30

LONG TERM TRENDS

Trend analysis was conducted on the parameters total phosphorus (TP), chlorophyll-*a*, total dissolved solids (TDS) and Secchi depth to look for changes over time in Laurier Lake. In sum, significant increases were observed in chlorophyll-*a* and TP. Significant decreasing trends were observed in TDS and Secchi depth. Secchi depth can be subjective and is sensitive to variation in weather - trend analysis must be interpreted with caution. A decrease in water clarity is likely due to an increase in chlorophyll-*a.* Data is presented below as both a line graph (all data points) and a box-and-whisker plot. Detailed methods are available in the *ALMS Guide to Trend Analysis on Alberta Lakes.*

Table 1: Summary table of trend analysis on Laurier Lake data from 2003 to 2018.

Parameter	Date Range	Trend	Probability
Total Phosphorus	2003-2018	Increasing	Significant
Chlorophyll-*a*	2003-2018	Increasing	Significant
Total Dissolved Solids	2003-2018	Decreasing	Significant
Secchi Depth	2003-2018	Decreasing	Significant

Definitions:

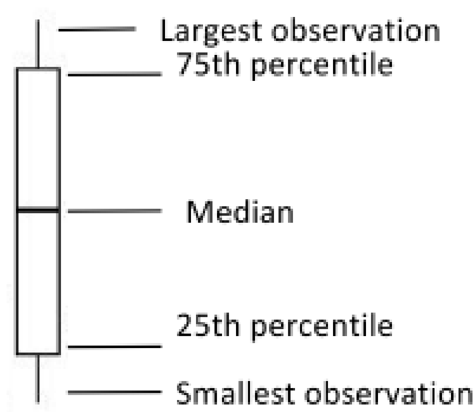
Median: the value in a range of ordered numbers that falls in the middle.

Trend: a general direction in which something is changing.

Monotonic trend: a gradual change in a single direction.

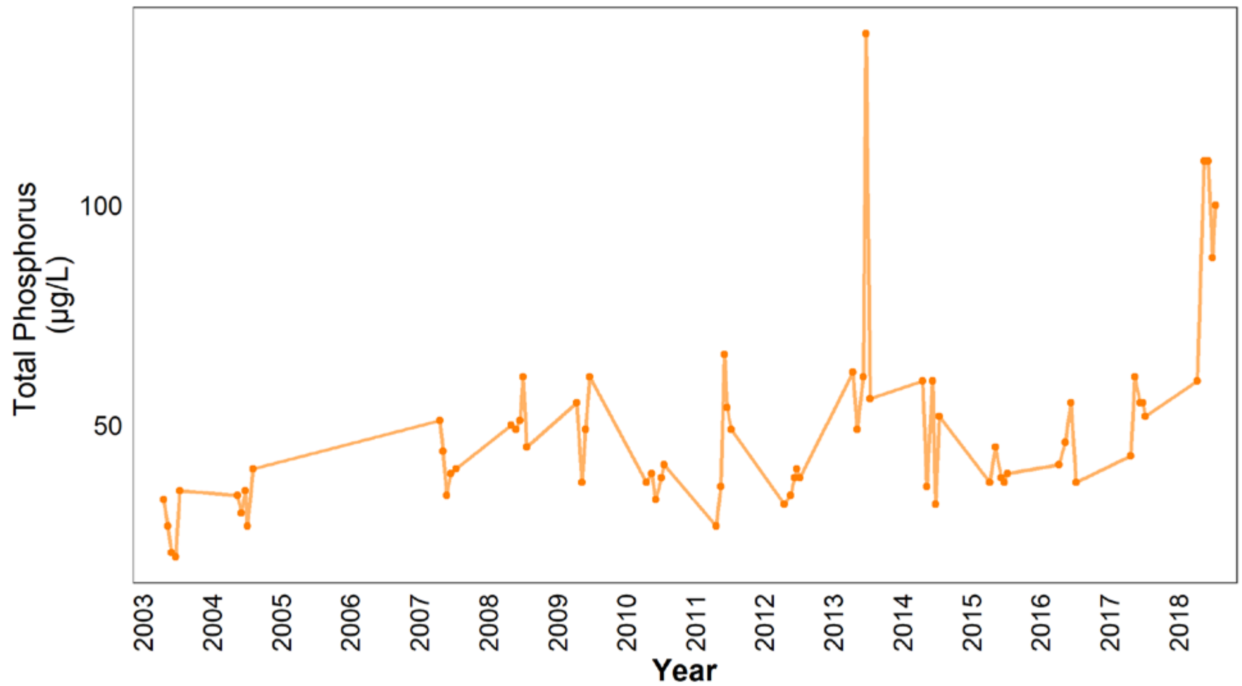
Statistically significant: The likelihood that a relationship between variables is caused by something other than random chance. This is indicated by a p-value of <0.05. Variability: the extent by which data is inconsistent or scattered.

Box and Whisker Plot: a box-and-whisker plot, or boxplot, is a way of displaying all of our annual data. The median splits the data in half. The 75th percentile is the upper quartile of the data, and the 25th percentile is the lower quartile of the data. The top and bottom points are the largest and smallest observations.



Total Phosphorus (TP)

TP has significantly increased over the course of data collection at Laurier Lake (Tau = 0.41, $p < 0.001$).



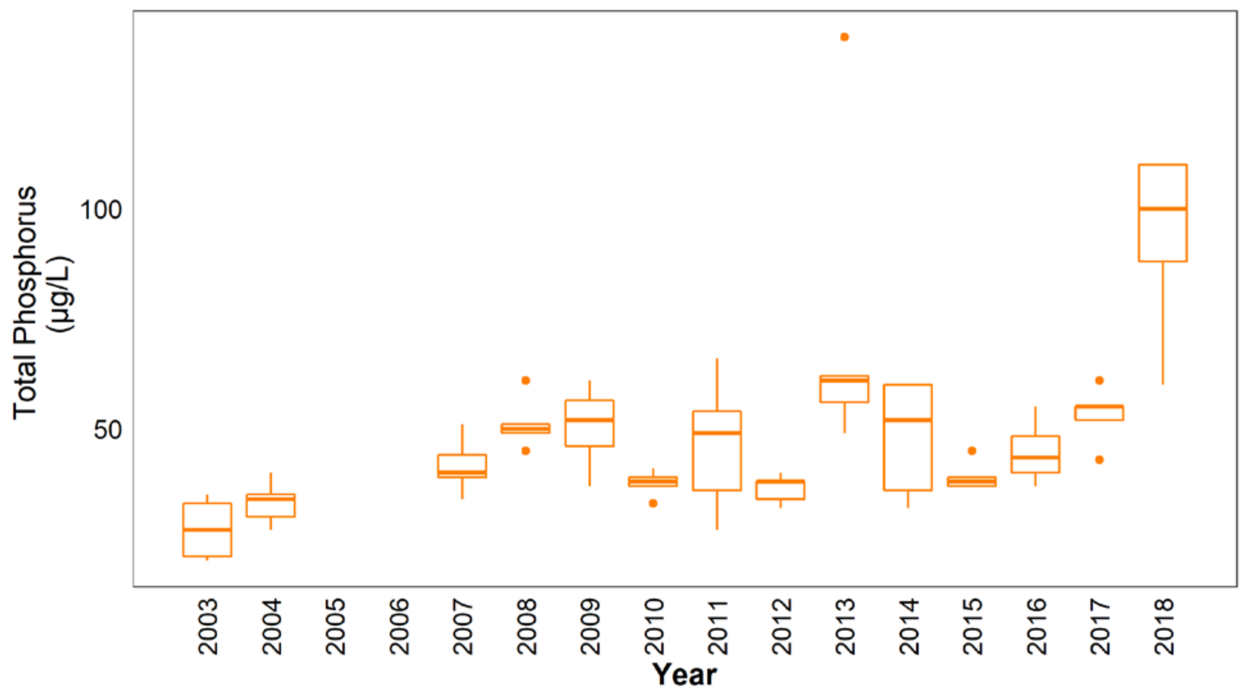


Figure 1- Total phosphorus (TP) concentrations measured between June and September over the long term sampling dates between 2003 and 2018 (n = 52).

Chlorophyll-*a*

Chlorophyll-*a* has significantly increased over the course of data collection at Laurier Lake (Tau = 0.51, p < 0.001). Chlorophyll-*a* trends follow TP trends with correlation over time (r = 0.57, P< 0.01).

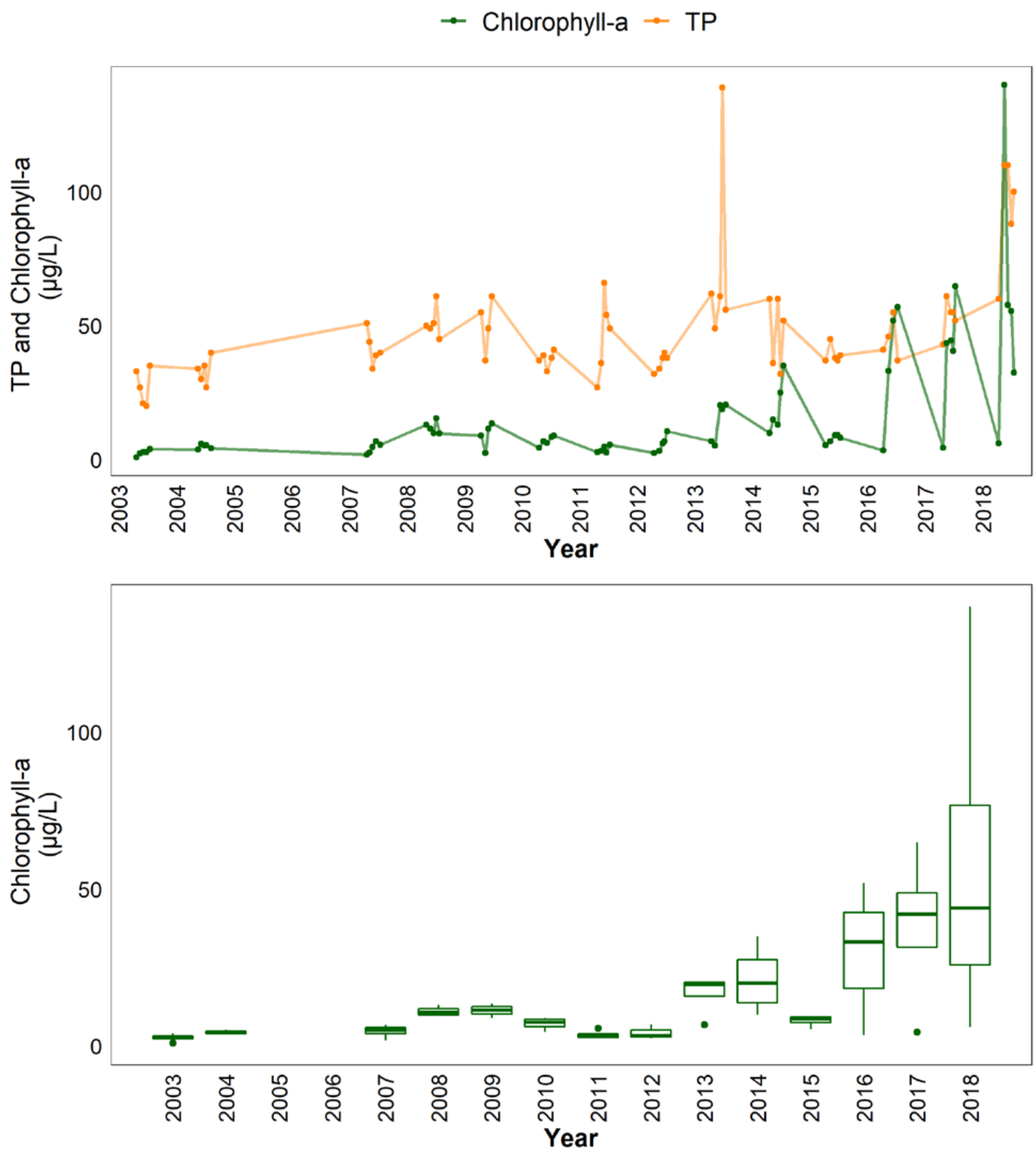


Figure 2-Chlorophyll-*a* concentrations measured between June and September over the long term sampling dates between 2003 and 2018 (n = 52).

Total Dissolved Solids (TDS)

Trend analysis on TDS shows a significant decrease in TDS over the course of sampling (Tau = -0.69, $p < 0.001$). This is likely attributed to increasing water levels and a dilution effect in Laurier Lake.

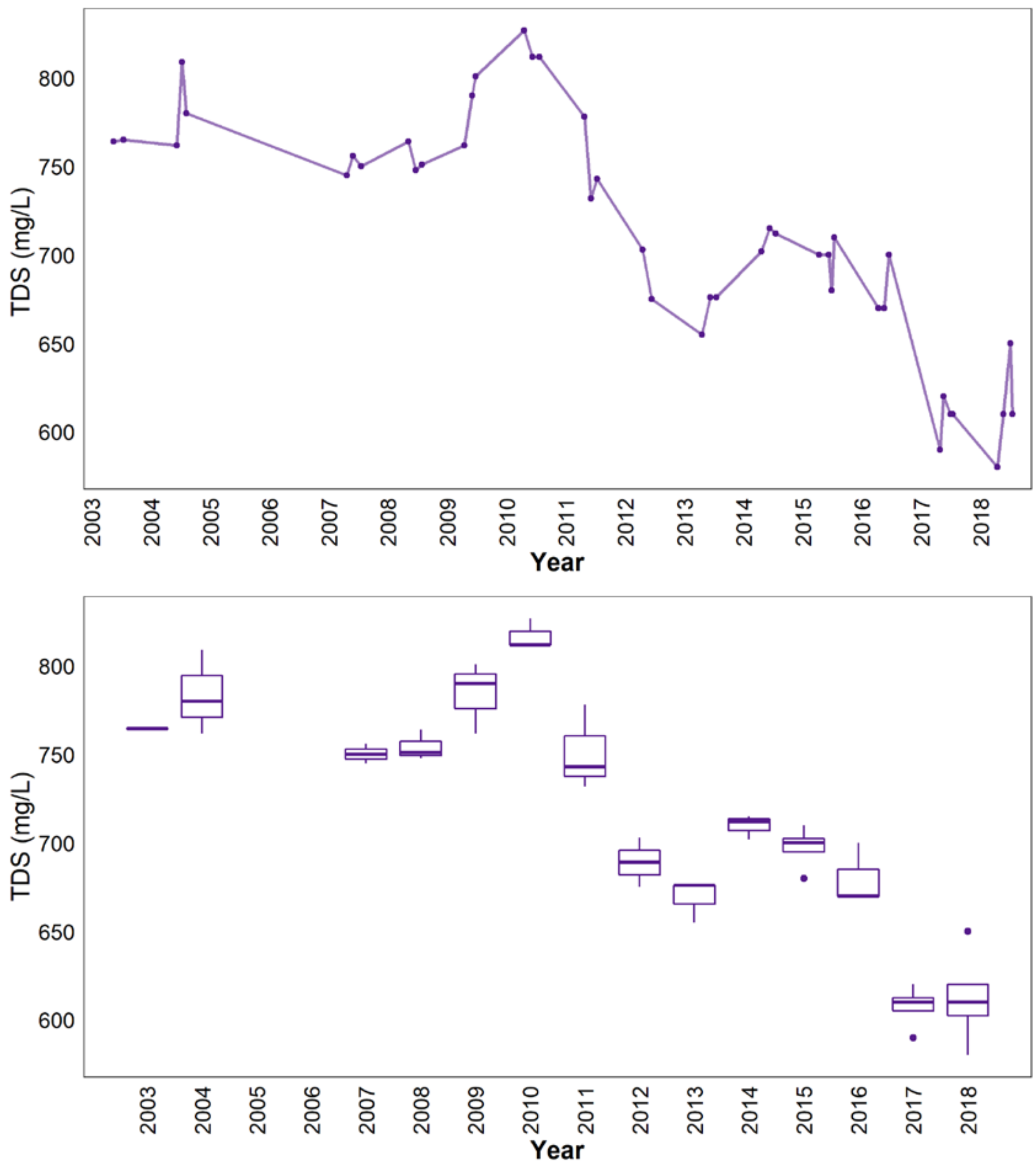
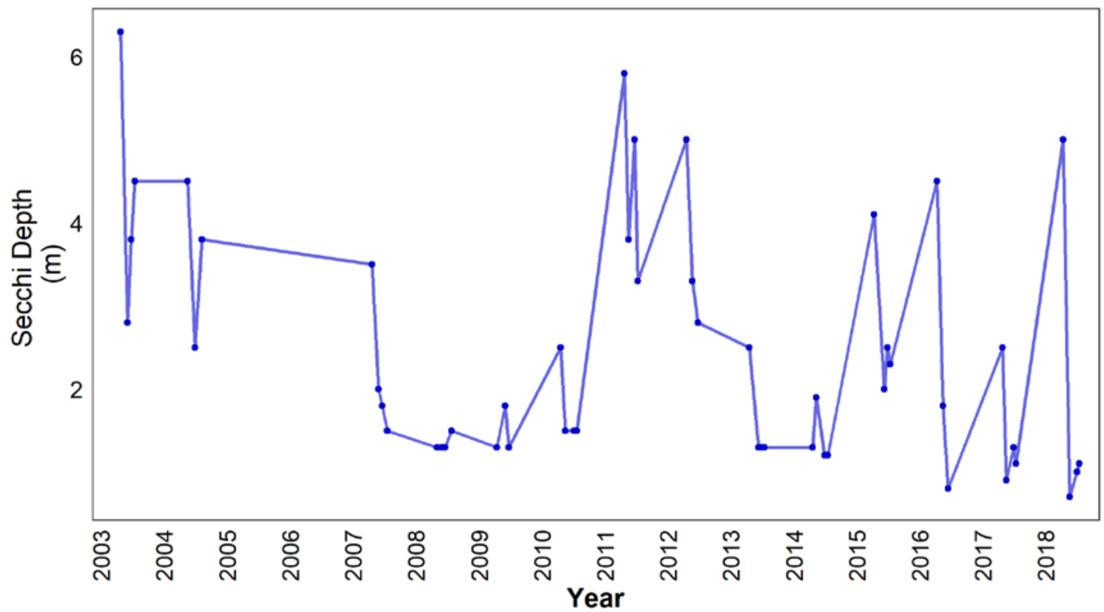


Figure 3- TDS measured between June and September over the long term sampling dates between 2003 and 2018 (n = 43).

Secchi Depth

Trend analysis found that water clarity measured as Secchi depth has decreased over the sampling period (Tau=-0.36, p <0.001).



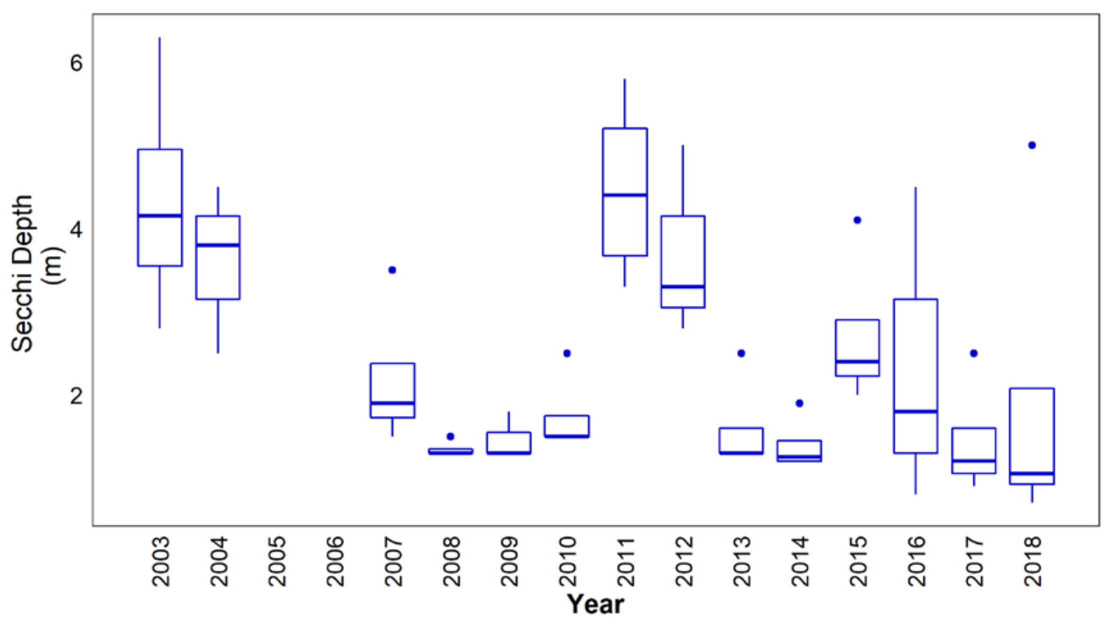


Figure 4- Secchi depth values measured between June and September over the long term sampling dates between 2003 and 2018 (n = 52).

Table 2- Results of Mann-Kendall Trend tests using total phosphorus (TP), chlorophyll-*a*, total dissolved solids (TDS) and Secchi depth data from June to September on Laurier Lake data.

Definition	Unit	Total Phosphorus (TP)	Chlorophyll-a	Total Dissolved Solids (TDS)	Secchi Depth
Statistical Method	-	Seasonal Kendall	Seasonal Kendall	Seasonal Kendall	Seasonal Kendall
The strength and direction (+ or -) of the trend between -1 and 1	Tau	0.41	0.51	-0.69	-0.36
The extent of the trend	Slope	1.54	1.37	-12.3	-0.08
The statistic used to find significance of the trend	Z	3.88	4.9	-5.78	-3.35
Number of samples included	n	52	52	43	52
The significance of the trend	*p*	<0.001*	<0.001*	<0.001*	0.001*

*$p < 0.05$ is significant within 95%