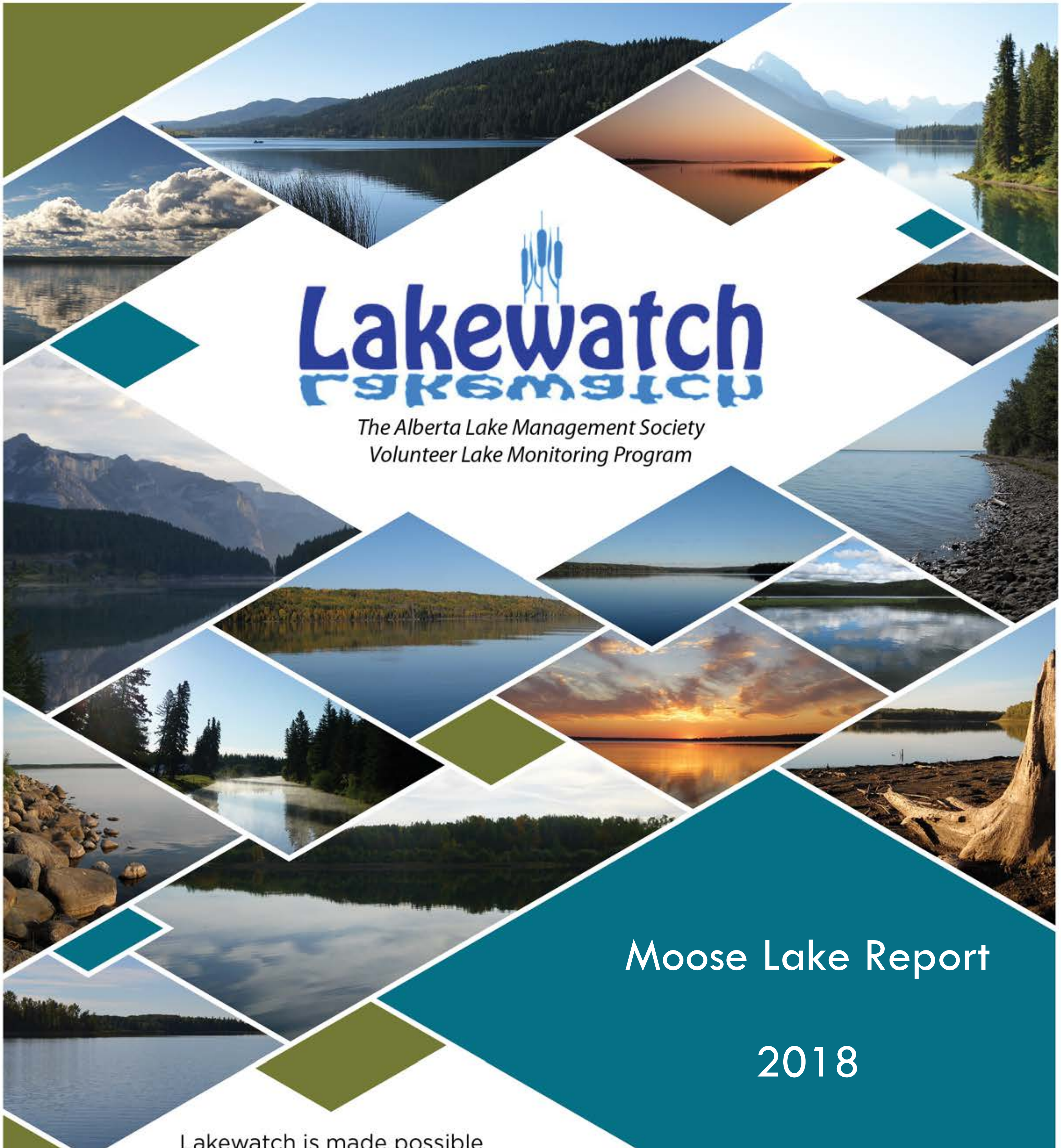

Lakewatch

The Alberta Lake Management Society
Volunteer Lake Monitoring Program

Moose Lake Report

2018

Lakewatch is made possible
with support from:

Alberta
Pigeon Lake Watershed Association
Jackfish Lake
MD 61 Wainwright
LICA Environmental Stewards
Red Deer River Watershed Alliance
Cargill

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 this data 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. A special thanks to Colin Hanusz and Grant Ferby for P commitment to collecting data at L Lake. 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.

MOOSE LAKE

Moose Lake—photo by Elashia Young 2017

Moose Lake is located 240 km northeast of Edmonton and 3.5 km west of the Town of Bonnyville. Moose Lake has over 64 km of irregular shoreline within a 40 km^2 lake surface area. The lake comprises four main bays with a maximum depth of 19 m and a mean depth of 5.6 m. A sounding (depth measurement) was last conducted in 1962.

The lake was once known by its French name Lac d'Orignal, which was inspired by the abundance of moose in the area.[1] In 1789, Angus Shaw established a trading post for the North West Company on the northwest shore of Moose Lake, one of the earliest European settlements known to Alberta. Later, in the early 1900's, French Canadian settlers began arriving in the area. In 1928, the railway was extended from St. Paul to Bonnyville. [1]

Moose Lake's abundance of natural resources was in high demand to supply a rapidly expanding population. Mink farming, agriculture, and three commercial fish-packing plants were in operation by 1936.[1] Walleye, northern pike, and yellow perch are the most popular sport fish; however, the lake also contains cisco, lake whitefish, burbot, suckers, and forage fish. Moose Lake is still heavily used, particularly on summer weekends. Shoreline development is intense and includes cottage subdivisions, campgrounds, and summer villages. Aquatic reeds fringe the shoreline, which is predominantly sheltered. Dominant emergent plants include bulrush (*Scirpus validus*) and cattail (*Typha latifolia*). Common submergent plants are pondweeds (*Potamogeton* spp.) and northern watermilfoil (*Myriophyllum sibiricum*).

The watershed area for Moose Lake is 808.01 km^2 and the lake area is 40.53 km^2. The lake to watershed ratio of Moose Lake is 1:20. A map of the Moose Lake watershed area can be found at http://alms.ca/wp-content/uploads/2016/12/Moose.pdf. Moreover, multi-basin monitoring of Moose Lake was conducted in 2016 and 2017, the results of which can be found at www.alms.ca.

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[1] Mitchell, P. and E. Prepas. 1990. Atlas of Alberta Lakes, University of Alberta Press. Retrieved from http://sunsite.ualberta.ca/projects/alberta-lakes/

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 Moose Lake was 91.3 μg/L (Table 2), falling within the eutrophic, or highly productive trophic classification. This value is higher than any previously measured historical averages. Detected TP was lowest when first sampled on July 10 at 67 μg/L, and peaked at 110 μg/L on August 17 (Figure 1).

Average chlorophyll-*a* concentration in 2018 was 94.1 μg/L (Table 2), falling into the hypereutrophic, or very high productivity trophic classification. Concentrations of chlorophyll-*a* ranged from a minimum of 41.6 μg/L on August 17 to a maximum of 170 μg/L on July 31.

Finally, the average TKN concentration was 2.2 mg/L (Table 2) with concentrations peaking in late July.

Average pH was measured as 8.81 in 2018, buffered by moderate alkalinity (325 mg/L $CaCO_3$) and bicarbonate (338 mg/L HCO_3). Sodium was the dominant ion contributing to medium conductivity of 918 μS/cm (Table 2).

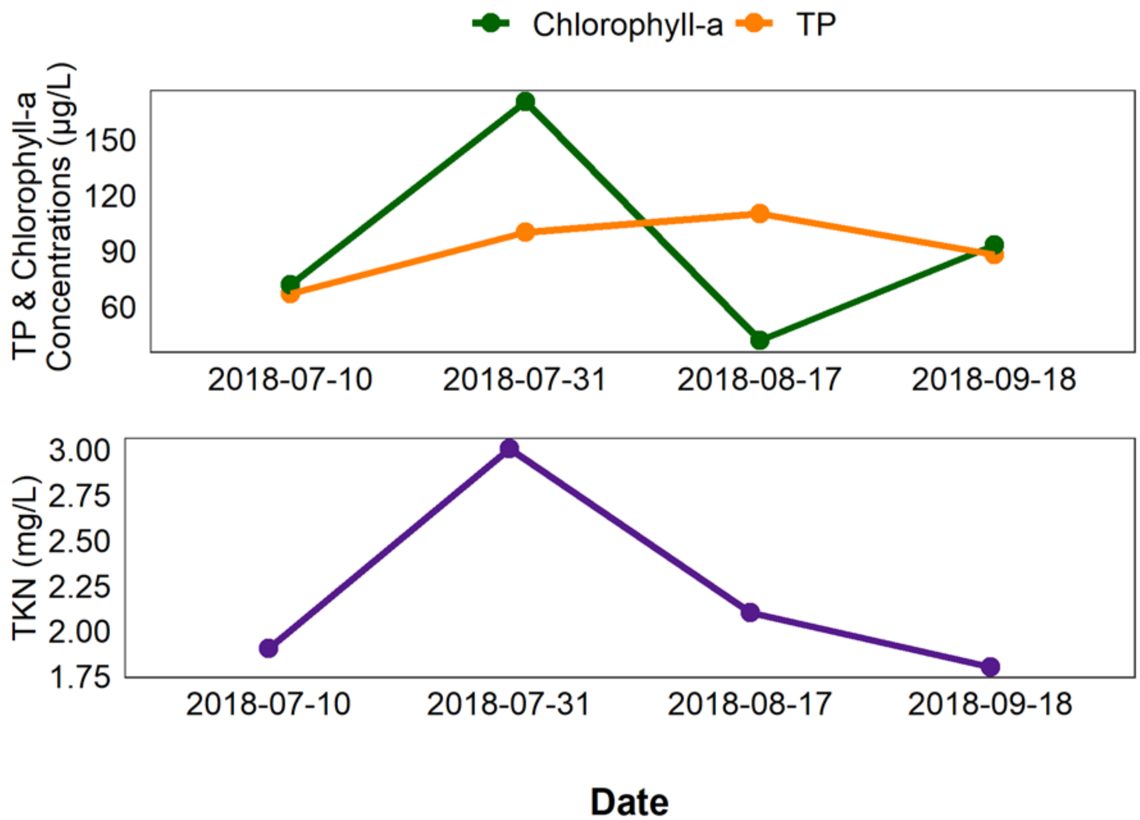


Figure 1- Total Phosphorus (TP), Total Kjeldahl Nitrogen (TKN), and Chlorophyll-*a* concentrations measured four times over the course of the summer at Moose Lake.

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 at Moose Lake on September 9, 2018. None of the metals were detected at concentrations above CCME guidelines. Table 3 presents metal concentrations from 2018 and previously sampled years.

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 Moose Lake in 2018 was 1.3 m (Table 2). Secchi depth decreased by over 50% between July 10 and July 31. This sudden decrease in water clarity may have been due to peaking algae concentrations over the season, as indicated by high chlorophyll-a levels at this time (Figure 1).

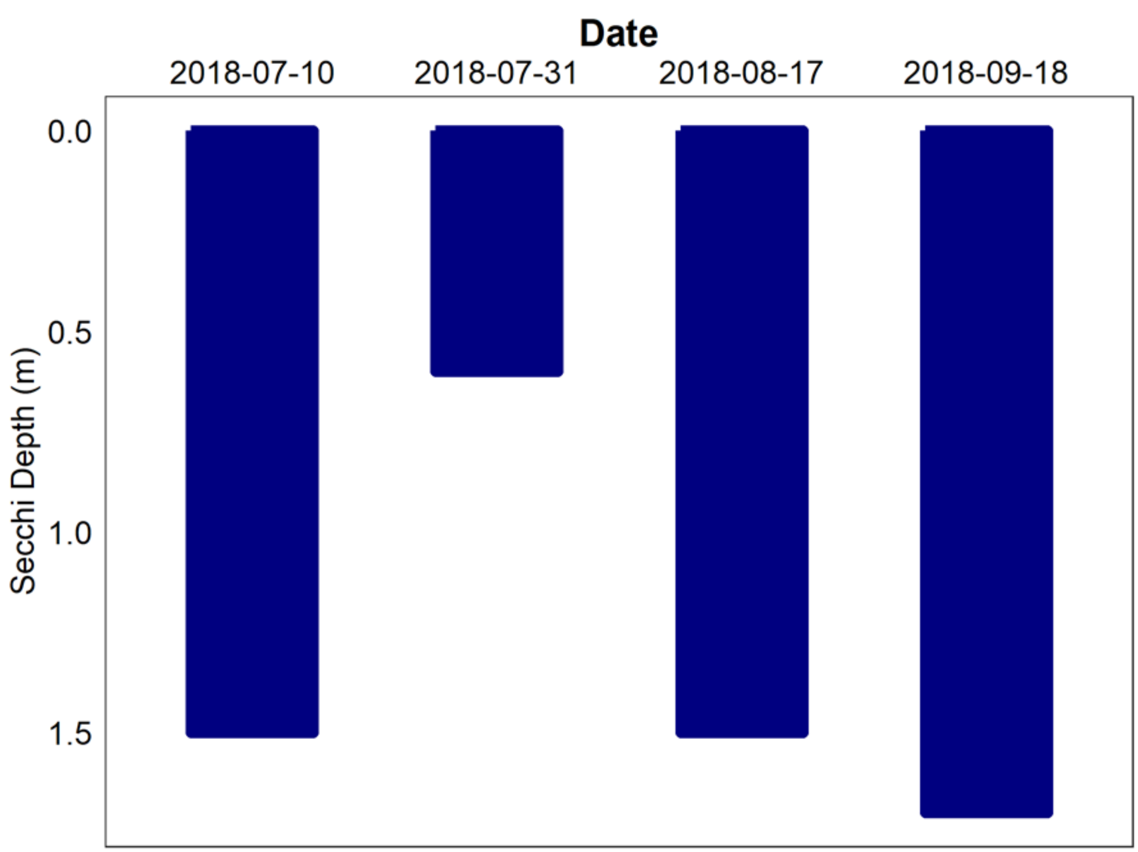


Figure 2 – Secchi depth values measured four times over the course of the summer at Moose Lake in 2018.

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. Please refer to the end of this report for descriptions of technical terms.

Temperatures of Moose Lake varied throughout the summer, with a maximum temperature of 22.1°C measured at the surface on July 10 (Figure 3a). The lake was not stratified during any of the sampling trips, with temperatures fairly constant from top to bottom, which indicates partial or complete mixing throughout the season.

Moose Lake remained well oxygenated in the upper water column throughout the summer, measuring above the CCME guidelines of 6.5 mg/L for the Protection of Aquatic Life (Figure 3b, dashed line). The oxygen level fell below this level at greater depths in July. This state of deoxygenation may have been due to decaying organic matter at lake bottom following the July algae bloom.

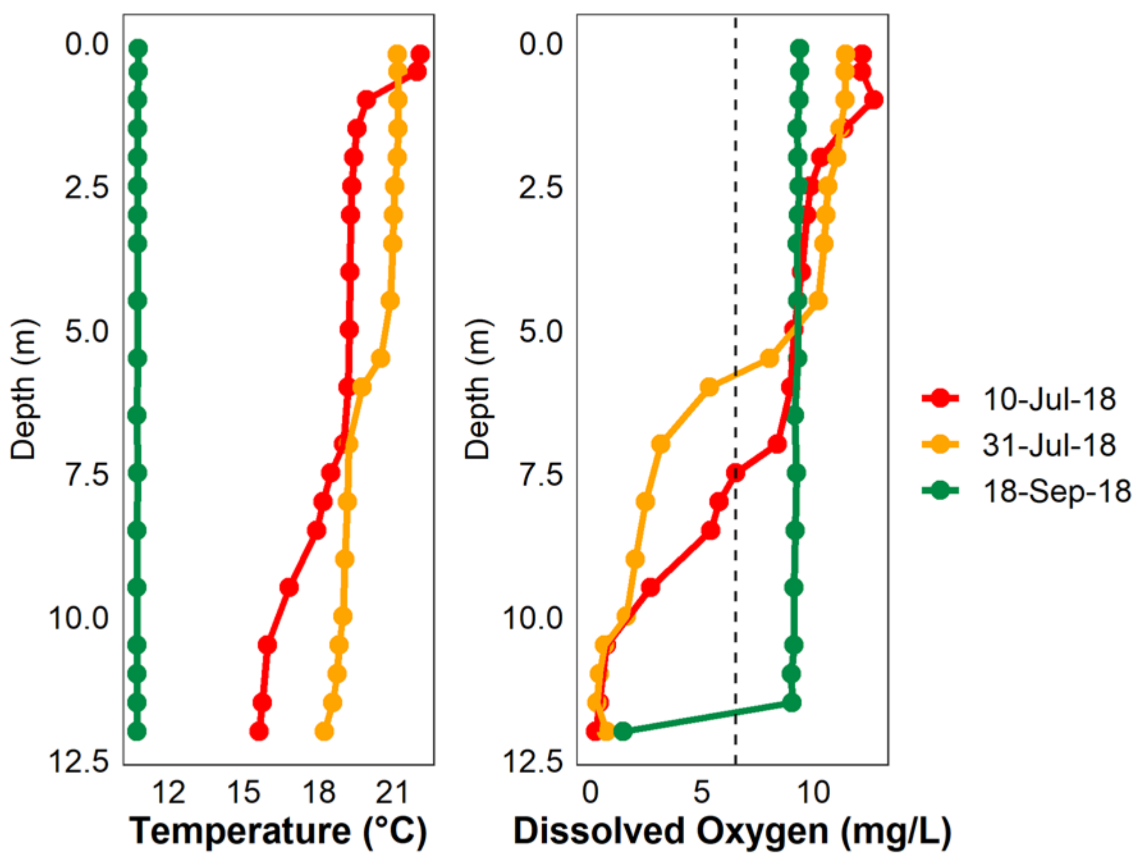


Figure 3 – a) Temperature (°C) and b) dissolved oxygen (mg/L) profiles for Moose Lake measured three times over the course of the summer of 2018. The dashed vertical line in figure 3b indicates CCME guidelines of 6.5 mg/L dissolved oxygen for the Protection of Aquatic Life.

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 Moose Lake fell below the recreational guideline of 20µg/L for at the locations and times sampled in Moose Lake in 2018.

Table 1 – Microcystin concentrations measured four times at Moose Lake in 2018.

Date	Microcystin Concentration (µg/L)
10-Jul-18	0.6
31-Jul-18	1.79
17-Aug-18	5.55
18-Sep-18	6.95
Average	3.72

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 Moose Lake.

WATER LEVELS

There are many factors influencing water quantity. Some of these factors include the size of the lake's 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.

Water levels in Moose Lake have decreased since Alberta Environment began monitoring the lake in 1956 (Figure 4). Moose Lake water levels have been increasing since the early 2000s, but within the range of historical levels. In 2017, Moose Lake increased to 533.6 m asl likely attributed to high rain fall in the region, causing flooding in developments built below the historical high water mark. In 2018, discussion was underway between MD of Bonnyville stakeholders and Alberta Environment to remove a weir between the lake and the Moose River in an attempt to lower water levels. No consensus was reached as to whether this action would be effective in lowering water levels[2].

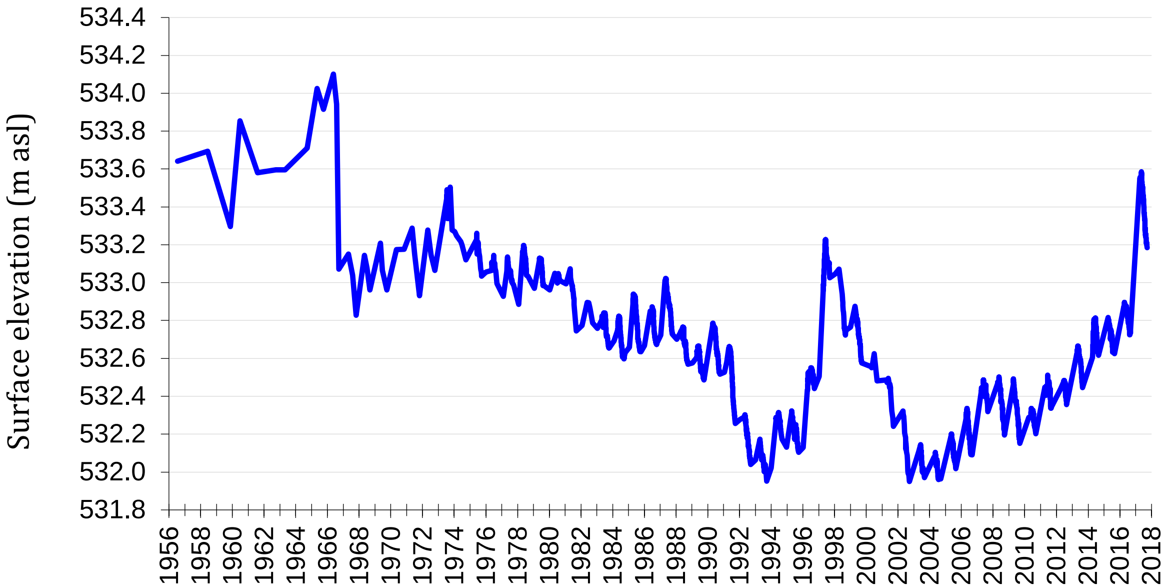


Figure 4- Water levels measured in metres above sea level (m asl) from 1956-2018. Data retrieved from Alberta Environment.

[2] Bonnyville Nouvelle, April 17, 2018. Retrieved 2018/02/06 from https://www.bonnyvillenouvelle.ca/article/alberta-environment-considers-removal-moose-lake-weir-20180417

Table 2A: Average Secchi depth and water chemistry values for Moose Lake. Historical averages are provided for comparison.

Parameter	1995	1996	1997	2003	2004	2005	2006	2009	2010
TP (µg/L)	42.7	30.9	47.9	52.5	38.0	50.5	59.2	42.8	46.5
TDP (µg/L)	/	/	/	14.5	15	13	17	20	16.75
Chlorophyll-*a* (µg/L)	17.56	5.15	16.80	39.48	22.60	27.30	35.46	15.71	19.03
Secchi depth (m)	1.98	3.45	2.75	2.25	2.69	2.15	1.30	3.06	1.56
TKN (mg/L)	1.6	/	/	1.7	1.5	1.6	1.8	1.6	1.7
NO_2-N and NO_3-N (µg/L)	22.3	25	25	21.8	20.3	25	25	13.8	7.8
NH_3-N (µg/L)	/	/	/	33.25	37.5	15.5	23.2	43	23.5
DOC (mg/L)	18	/	/	/	17.5	18.1	18	17.6	18.45
Ca (mg/L)	22.8	30.8	27.8	25.4	24.5	24.6	25.4	24.3	20.6
Mg (mg/L)	45.0	43.5	43.2	53.5	49.9	47.0	48.1	48.4	50.6
Na (mg/L)	87.0	83.9	83.8	110.7	112.0	113.5	114.7	117.3	129.0
K (mg/L)	14.6	14.5	14.6	12.2	16.7	19.5	17.4	19.7	18.6
SO_4^{2-} (mg/L)	125.0	123.5	113.0	149.3	155.5	151.0	154.7	165.0	164.0
Cl^- (mg/L)	17.55	17.20	19.20	23.40	24.55	24.90	25.40	27.67	28.60
CO_3 (mg/L)	19.0	13.0	15.0	29.3	28.5	35.0	31.7	30.3	27.5
HCO_3 (mg/L)	321.0	322.0	313.5	342.7	350.0	334.5	345.7	348.0	357.5
pH	8.76	8.56	8.64	8.87	8.86	8.99	8.81	8.90	8.85
Conductivity (µS/cm)	792.8	808.0	776.0	/	934.5	867.5	947.3	953.7	964.5
Hardness (mg/L)	240.8	268.0	245.5	283.7	266.5	255.0	261.3	259.7	260.0
TDS (mg/L)	489.0	/	/	573.0	583.5	580.0	587.0	604.0	610.0
Microcystin (µg/L)	/	/	/	/	/	0.418	0.080	0.593	0.113
Total Alkalinity (mg/L $CaCO_3$)	295.3	288.0	284.0	330.3	334.0	333.0	336.0	336.0	338.5

Table 2B: Continued- Average Secchi depth and water chemistry values for Moose Lake. Historical averages are provided for comparison.

Parameter	2011	2012	2013	2014	2015	2016	2017	2018
TP (µg/L)	49.0	53.3	109.3	74.0	33	34	69.4	91.3
TDP (µg/L)	17.8	17.8	41.3	31.2	10	12	12.24	18.13
Chlorophyll-*a* (µg/L)	46.14	26.76	50	14.26	14.56	29.6	40.7	94.1
Secchi depth (m)	2.88	1.84	0.96	3.66	2.60	1.75	1.10	1.30
TKN (mg/L)	1.6	1.7	2	1.6	1.6	1.52	2.1	2.2
NO_2-N and NO_3-N (µg/L)	3.63	2.5	2.5	36	6.6	2.5	10	13.8
NH_3-N (µg/L)	30.8	19.75	18.5	87.4	36.4	38.4	51.7	106
DOC (mg/L)	16.87	17.9	23.9	17.25	16	15.8	17.4	18.5
Ca (mg/L)	23.6	25.4	25.7	25.8	25	26.6	28.4	28.8
Mg (mg/L)	56.0	48.5	53	47.9	52	57.4	54	48.8
Na (mg/L)	114.0	107.0	116.3	129.0	110	120	110	102.5
K (mg/L)	20.3	21.3	24.1	21.3	18	22.4	21	21
SO_4^{2-} (mg/L)	156.0	161.0	150.7	150.0	168	160	148	145
Cl^- (mg/L)	27.40	27.70	27.60	33.70	33	32	31.2	31.3
CO_3 (mg/L)	18.0	28.8	36.3	29.2	27	24.8	22.6	27
HCO_3 (mg/L)	371.5	358.5	341.8	413.0	366	368	348	338
pH	8.70	8.87	8.90	8.71	8.80	8.79	8.75	8.81
Conductivity (µS/cm)	974.0	993.0	989.3	996.0	990	994	934	918
Hardness (mg/L)	290.0	263.0	282.3	261.5	280	302	294	273
TDS (mg/L)	599.0	596.7	602	639	618	628	586	575
Microcystin (µg/L)	1.178	1.002	0.2265	0.60	0.54	1.59	1.04	3.72
Total Alkalinity (mg/L $CaCO_3$)	334.0	342.3	370.5	338.6	344	342	322	325

Table 3A: Concentrations of metals were last measured in Moose Lake on September 9, 2018. The CCME heavy metal Guidelines for the Protection of Freshwater Aquatic Life (unless otherwise indicated) are presented for reference. Concentrations that exceed these guidelines are displayed in red.

Metals (Total Recoverable)	2003	2004	2005	2009	2010	2011	2018	Guidelines
Aluminum µg/L	14.75	4.95	3.34	16.05	10.7	4.08	1.3	100[a]
Antimony µg/L	0.075	0.065	0.065	0.058	0.053	0.056	0.055	/
Arsenic µg/L	1.99	2.03	2.19	2.12	2.16	2.085	2.18	5
Barium µg/L	46.1	50.2	47.8	45.4	44.9	46	50.6	/
Beryllium µg/L	0.06	0.002	0.002	0.004	0.002	0.004	<0.003	100[c,d]
Bismuth µg/L	0.00575	0.001	0.006	0.006	0.001	0.001	<0.003	/
Boron µg/L	169.5	172	176	197	185	202	172	1500
Cadmium µg/L	0.030	0.007	0.005	0.005	0.005	0.004	<0.01	0.26[b]
Chromium µg/L	0.33	0.87	0.61	0.30	0.22	0.22	<0.1	/
Cobalt µg/L	0.010	0.014	0.021	0.011	0.007	0.030	0.036	1000[d]
Copper µg/L	0.56	0.75	0.61	0.49	0.26	0.50	0.3	4[b]
Iron µg/L	3.25	1	37	8.05	7.65	22.8	12.6	300
Lead µg/L	0.079	0.047	0.080	0.216	0.011	0.013	0.036	7[b]
Lithium µg/L	40.05	53.4	57.3	61.2	53.1	70.75	54.1	2500[e]
Manganese µg/L	9.28	8.14	7.26	7.55	7.2	5.615	11.1	200[e]
Molybdenum µg/L	0.590	0.846	0.705	0.598	0.556	0.628	0.555	73[c]
Nickel µg/L	0.030	0.003	0.110	<0.005	0.003	0.163	0.410	150[b]
Selenium µg/L	0.525	0.270	0.276	0.396	0.375	0.358	0.400	1
Silver µg/L	0.0025	0.003	0.001	0.002	0.002	0.008	0.002	0.25
Strontium µg/L	282.5	309	307.5	303	281	287.5	305	/
Thallium µg/L	0.0925	0.002	0.029	0.004	0.002	<0.002	<0.002	0.8
Thorium µg/L	0.004	0.009	0.019	0.002	0.008	0.012	<0.002	/
Tin µg/L	0.08	0.02	0.02	0.04	0.02	0.03	<0.06	/
Titanium µg/L	0.65	0.67	0.86	1.13	0.76	0.49	0.69	/
Uranium µg/L	0.43	0.44	0.59	0.45	0.43	0.46	0.44	15
Vanadium µg/L	0.45	0.39	0.38	0.29	0.24	0.26	0.282	100[d,e]
Zinc µg/L	2.98	7.9	4.335	0.722	0.498	0.68	5.4	30

Values represent means of total recoverable metal concentrations.
[a] Based on pH ≥ 6.5
[b] Based on water hardness > 180mg/L (as CaCO3)
[c] CCME interim value.
[d] Based on CCME Guidelines for Agricultural use (Livestock Watering).
[e] Based on CCME Guidelines for Agricultural Use (Irrigation).
A forward slash (/) indicates an absence of data or guidelines.

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 Moose Lake. In sum, non-significant increases were observed in TP, Chlorophyll-*a*, and TDS. Non-significant decreasing trends were observed in Secchi depth. Secchi depth can be subjective and is sensitive to variation in weather - trend analysis must be interpreted with caution. Data is presented below as both a line graph (all data points) or 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 Moose Lake data from 2003 to 2018.

Parameter	Date Range	Trend	Probability
Total Phosphorus	2003-2018	Increasing	Not significant
Chlorophyll-*a*	2003-2018	Increasing	Not significant
Total Dissolved Solids	2003-2018	Increasing	Not significant
Secchi Depth	2003-2018	Decreasing	Not significant

Definitions:

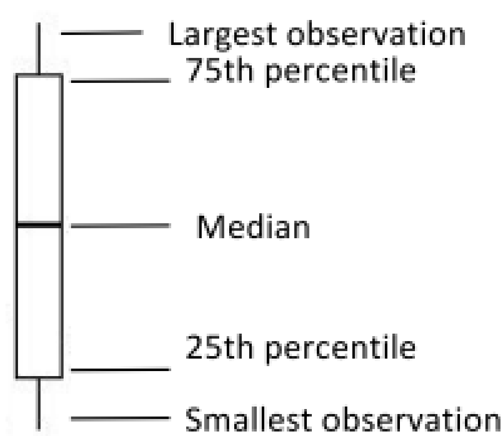
Median: the value in a range of ordered numbers that falls in the middle.

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)

Trend analysis of TP over time showed that it has not significantly changed in Moose Lake since 2003 (Tau = 0.14, p = 0.18). However, there may be an increase in variability within and between seasons in recent years.

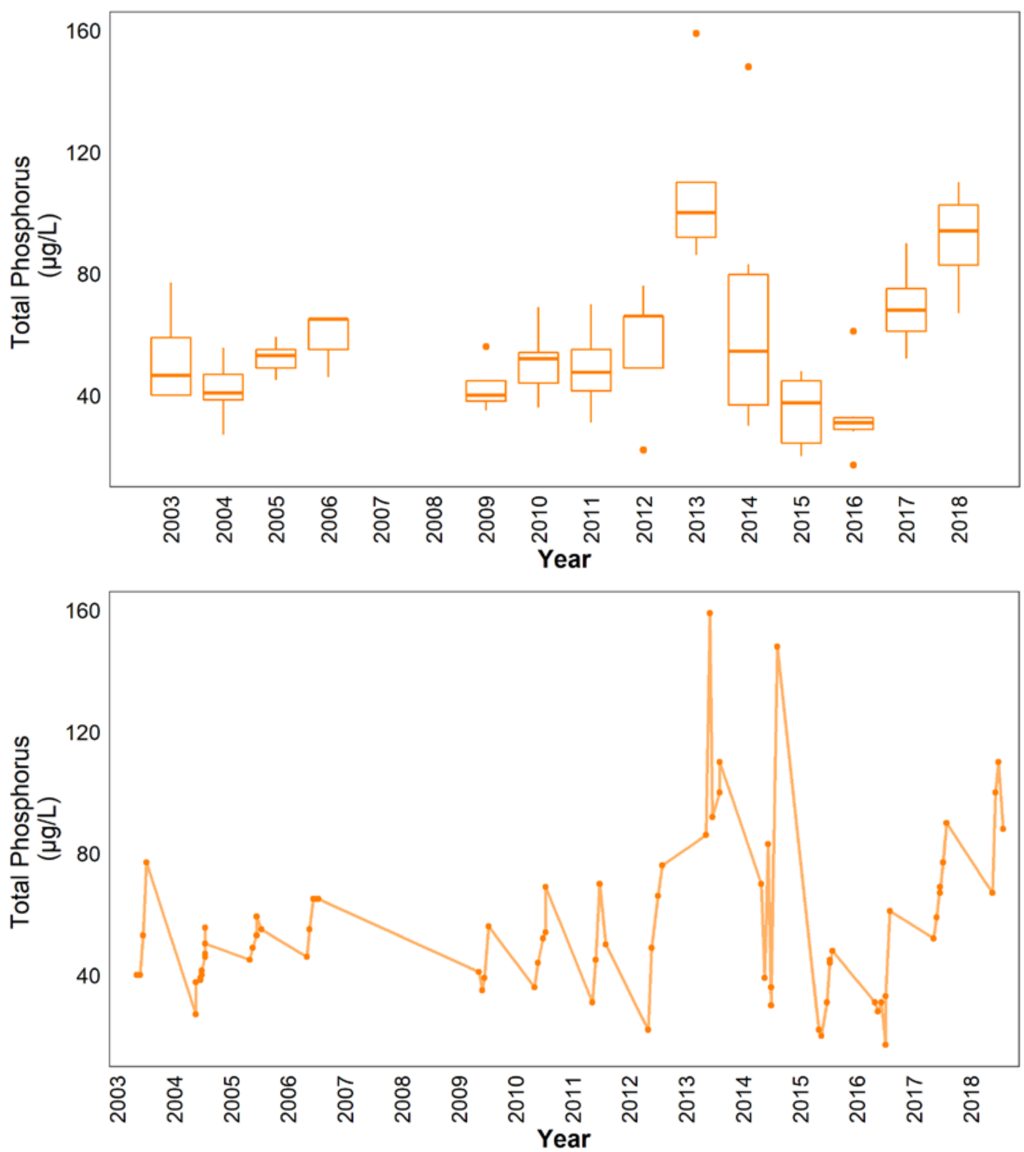


Figure 1- Monthly total phosphorus (TP) concentrations measured between June and September over the long term sampling dates between 2003 and 2018 (n = 52). The value closest to the 15th day of the month was chosen to represent the monthly value in cases with multiple monthly samples.

Chlorophyll-*a*

Chlorophyll-*a* trends are not significant over time at Moose Lake (Tau = 0.06, $p = 0.57$). Chlorophyll-*a* trends follow TP trends with correlation over time (r = 0.45, $p < 0.001$).

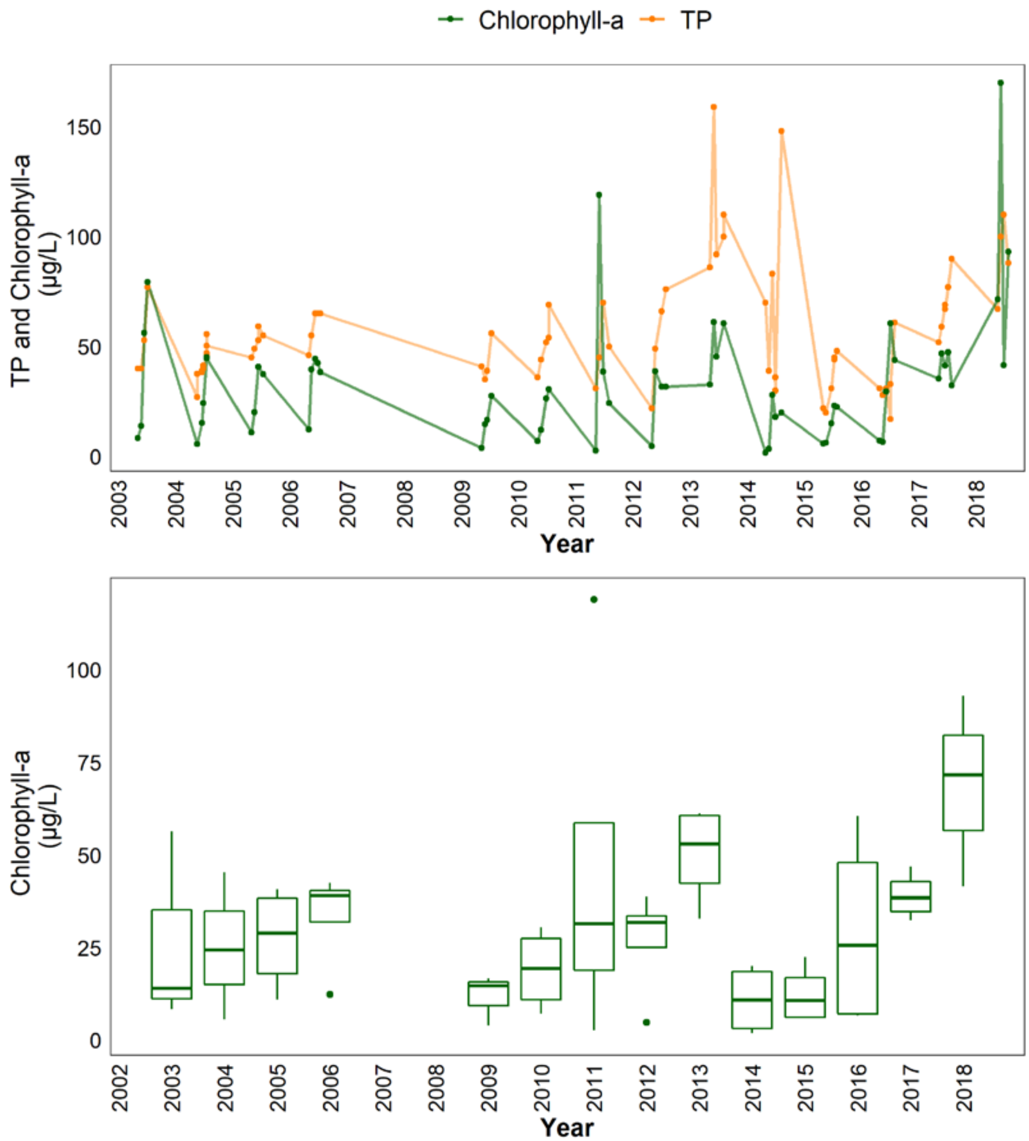
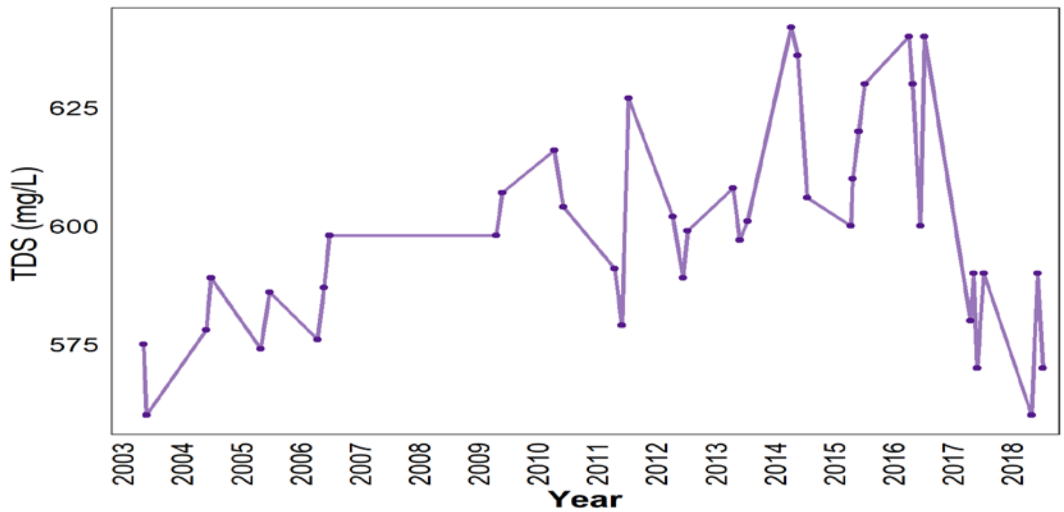


Figure 2-Monthly chlorophyll-*a* concentrations measured between June and September over the long term sampling dates between 2003 and 2018 (n = 52). The value closest to the 15th day of the month was chosen to represent the monthly value in cases with multiple monthly samples. Line graph is overlain by TP concentrations.

Total Dissolved Solids (TDS)

Trend analysis showed significantly increasing trend in TDS between 2003 and 2016 (Tau= 0.6, $p < 0.001$, slope = 3.8) in Moose Lake. However, the past two consecutive years of reduced TDS have disrupted this trend, and it is no longer significant (Tau = 0.2, $p = 0.07$). Continued monitoring of the lake will determine whether this lower TDS concentration is stable in Moose Lake.



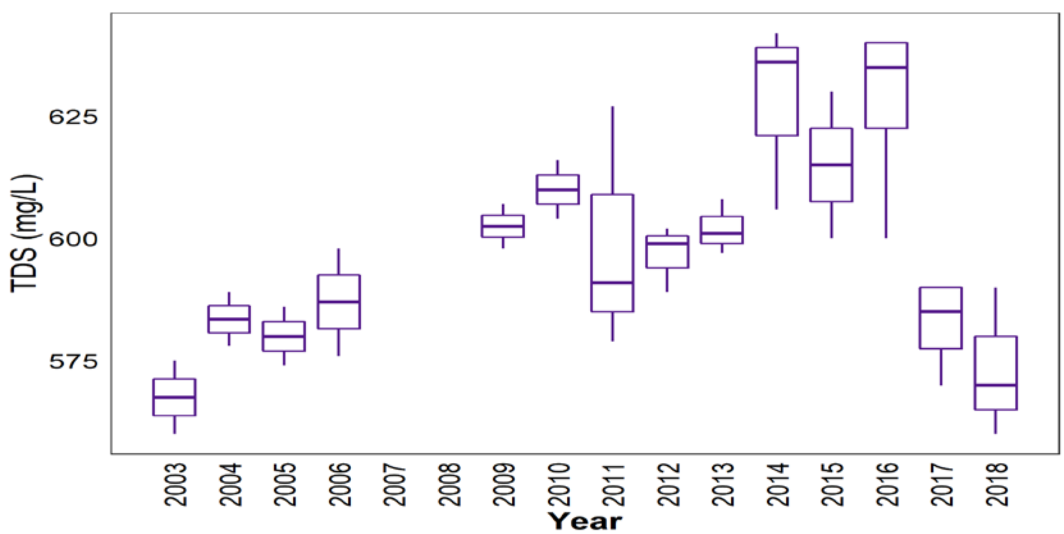


Figure 3- Monthly TDS values measured between June and September over the long term sampling dates between 2003 and 2018 (n = 40). The value closest to the 15th day of the month was chosen to represent the monthly value in cases with multiple monthly samples.

Secchi Depth

Secchi depth has not changed significantly in Moose Lake since 2003 (Tau = -0.13, p = 0.18).

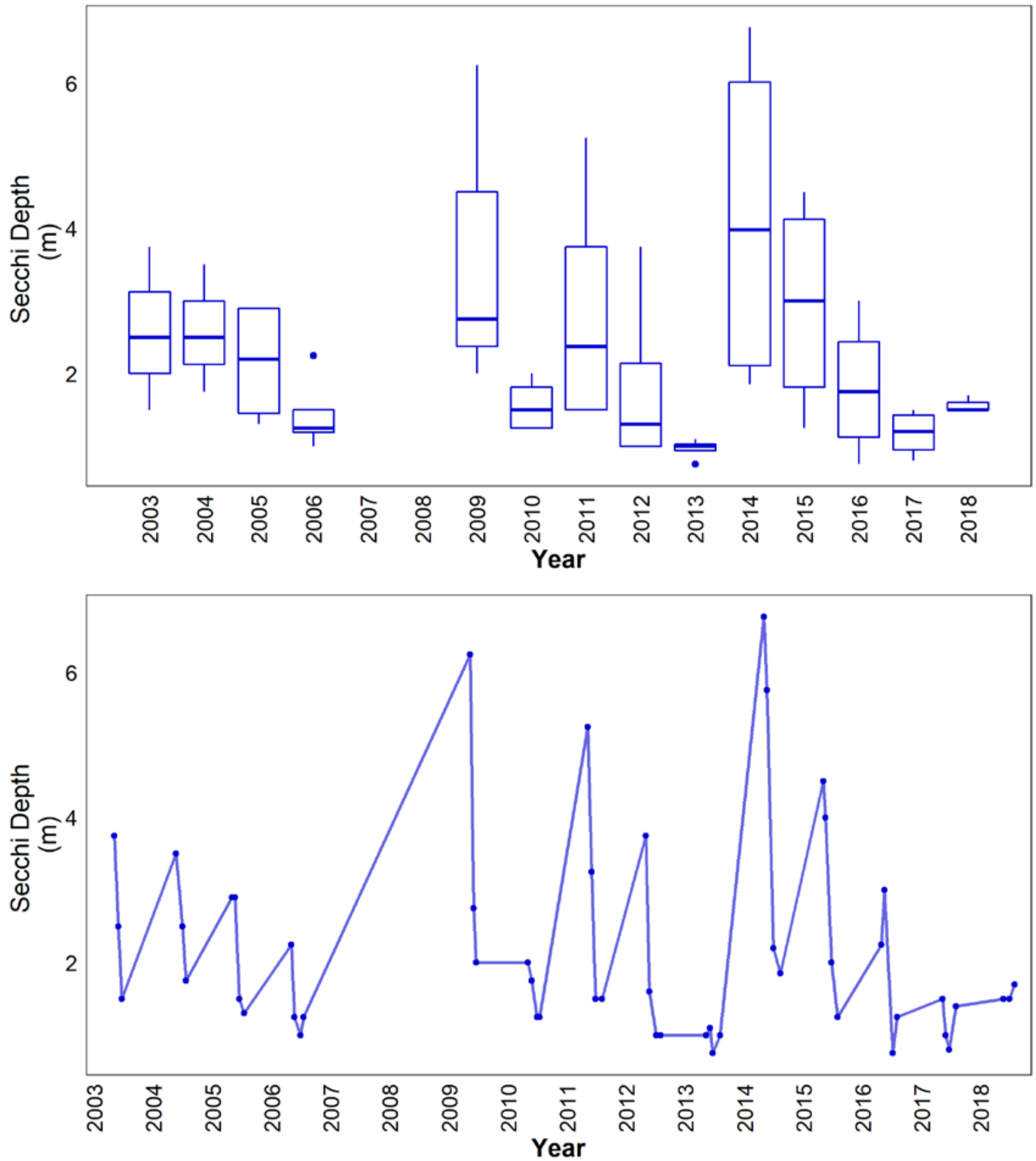


Figure 4- Monthly Secchi depth values measured between June and September over the long term sampling dates between 2003 and 2018 (n = 52). The value closest to the 15th day of the month was chosen to represent the monthly value in cases with multiple monthly samples.

Table 2- Results of trend tests using total phosphorus (TP), chlorophyll-*a*, total dissolved solids (TDS) and Secchi depth data from June to September, for sampled years from 2003-2018 on Moose 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	0.14	0.06	0.20	-0.13
The extent of the trend	Slope	1.0	0.27	1.78	-0.03
The statistic used to find significance of the trend	Z	1.33	0.57	1.77	-1.54
Number of samples included	n	52	52	40	52
The significance of the trend	*p*	0.18	0.57	0.07	0.18

*$p < 0.05$ is significant within 95%