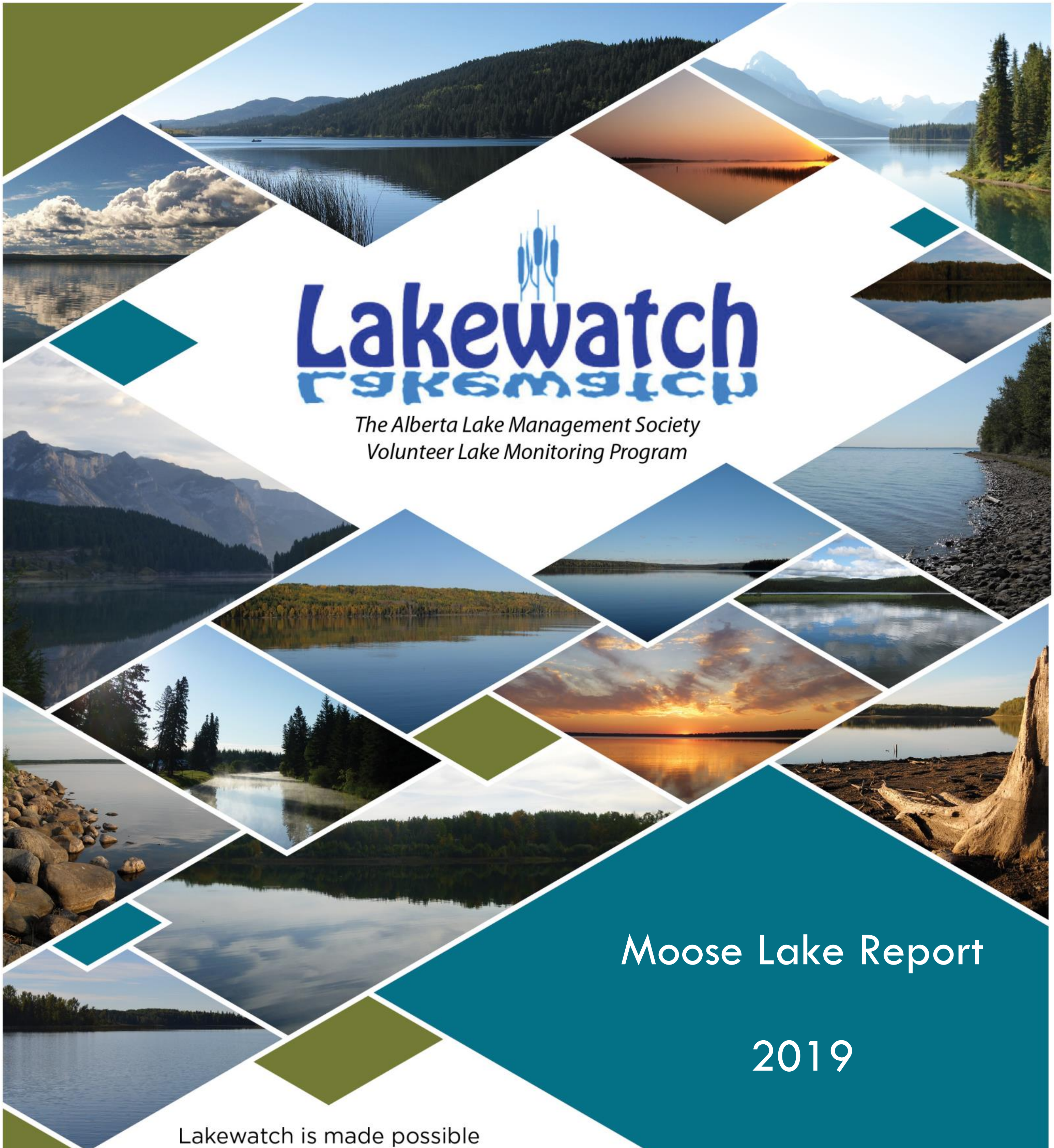


Lakewatch

The Alberta Lake Management Society
Volunteer Lake Monitoring Program

Moose Lake Report

2019

Lakewatch is made possible with support from:

Alberta Environment and Parks

Pigeon Lake Watershed Association

Lacombe County

LICA Environmental Stewards

ALBERTA LAKE MANAGEMENT SOCIETY'S LAKEWATCH PROGRAM

LakeWatch has several important objectives, one of which is to collect and interpret water quality data from Alberta's Lakes. Equally important is educating lake users about aquatic environments, 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 the widest 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.

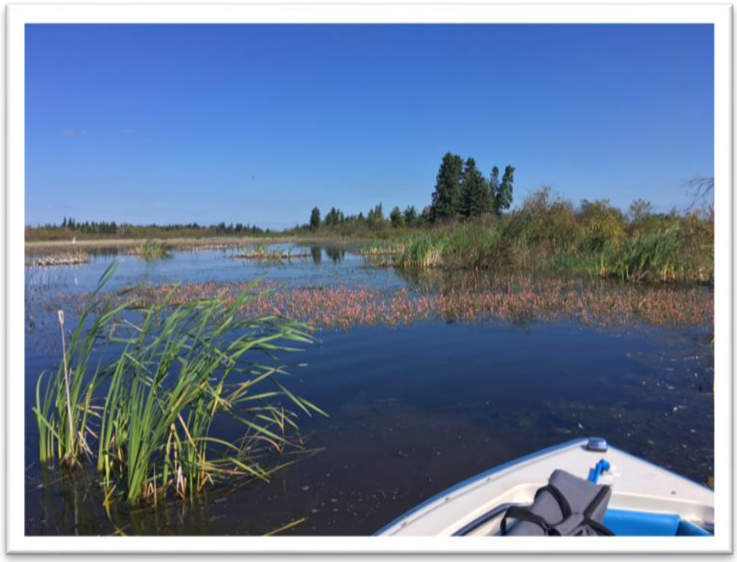
If you require data from this report, please contact ALMS for the raw data files

ACKNOWLEDGEMENTS

The LakeWatch program is made possible through the dedication of its volunteers. A special thanks to Mark Feiger and Murray Thirsk for their commitment to collecting data at Moose Lake. We would also like to thank Sarah Davis Cornet, Caleb Sinn, and Pat Heney, who were summer technicians in 2019. Executive Director Bradley Peter and Program Coordinator Caitlin Mader were instrumental in planning and organizing the field program. This report was prepared by Pat Heney, Bradley Peter, and Caleb Sinn.

MOOSE LAKE

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 (whole lake depth measurement) was last conducted in 1962.



Moose Lake—photo by Elashia Young 2017

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*). Moose Lake also provides excellent habitat to a variety of waterfowl, although residents are concerned that the current high population level of cormorants (*Phalacrocorax auritus)* in the region are contributing to poor water quality conditions at Moose Lake.

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. For select lakes, metals are collected at the profile site by hand grab from the surface on one visit over the season.

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 Innotech Alberta, and microcystin is analyzed by the Alberta Centre for Toxicology (ACTF).

Invasive Species: : Invasive mussel monitoring involved sampling with a 63 µm plankton net at three sample sites twice through the summer season to determine the presence of juvenile dreissenid mussel veligers. Technicians also harvested potential Eurasian watermilfoil (*Myriophyllum spicatum)* samples and submitted them for further analysis at the Alberta Plant Health Lab to genetically differentiate whether the sample was the invasive Eurasian watermilfoil or a native watermilfoil. In addition, select lakes were subject to a bioblitz, where a concerted effort to sample the lake's aquatic plant diversity took place.

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 www.alberta.ca/surface-water-quality-data.aspx.
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 total phosphorus (TP), chlorophyll-*a,* total kjeldahl nitrogen (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. For lakes with >10 years of long term data, trend analysis is done with non-parametric methods. The seasonal Kendall test estimates the presence of monotonic (unidirectional) trends across individual seasons (months) and is summed to give an overall trend over time. For lakes that had multiple samplings in a single month, the value closest to the middle of the month was used in analysis.

[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 49 µg/L (Table 2), falling within the eutrophic, or highly productive trophic classification. This value is similar to previously measured historical averages. Detected TP was lowest when first sampled on June 12 at 33 µg/L, and peaked at 63 µg/L on August 2 (Figure 1).

Average chlorophyll-*a* concentration in 2019 was 38.0 µg/L (Table 2), falling into the hypereutrophic, or very high productivity trophic classification. Concentrations of chlorophyll-*a* ranged from a minimum of 6.4 µg/L on June 12 to a maximum of 90.9 µg/L on August 2.

Finally, the average TKN concentration was 1.7 mg/L (Table 2) with concentrations peaking in early August.

Average pH was measured as 8.76 in 2019, buffered by moderate alkalinity (320 mg/L $CaCO_3$) and bicarbonate (348 mg/L HCO_3). Sulphate was the dominant ion contributing to medium conductivity of 905 µS/cm (Table 2).

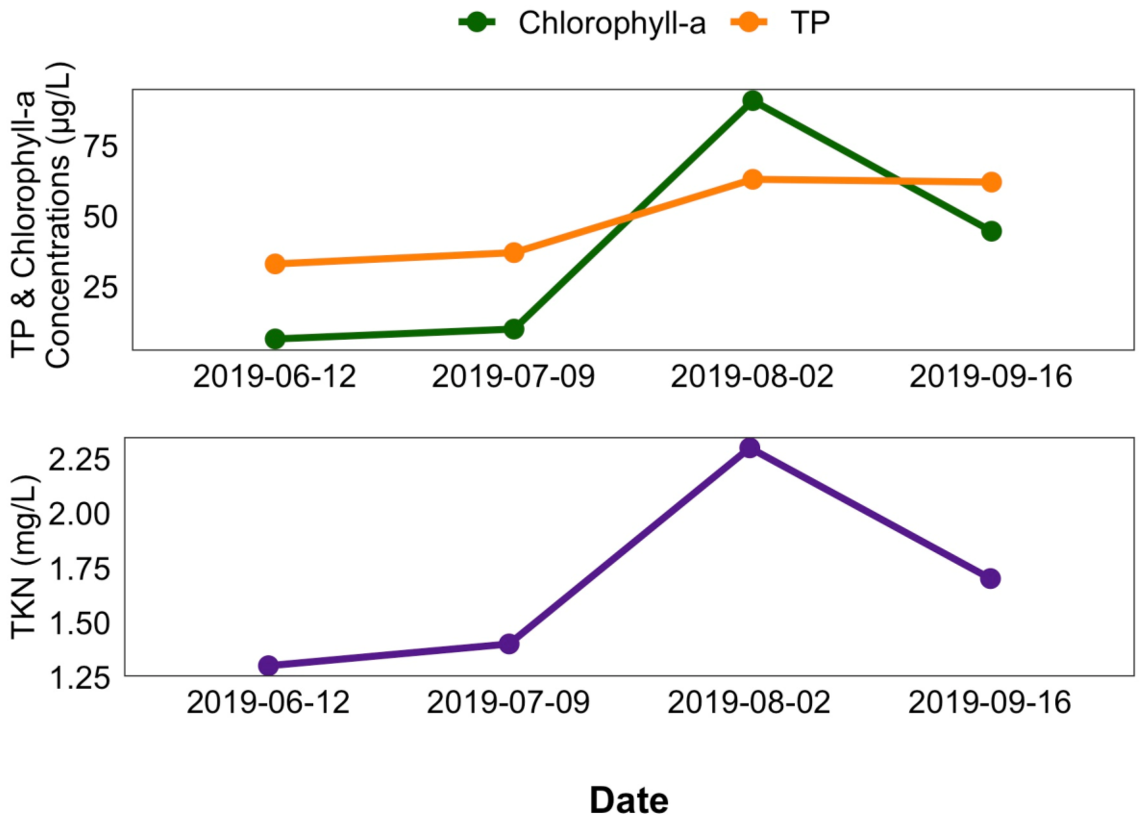


Figure 1. Total Phosphorus (TP), Total Kjeldahl Nitrogen (TKN), and Chlorophyll-*a* concentrations measured four times over the course of the summer at Moose Lake, 2019.

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 not measured at Moose Lake in 2019. 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 2019 was 2.48 m (Table 2). Secchi depth decreased by over 50% between July 7 and August 2. 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 2).

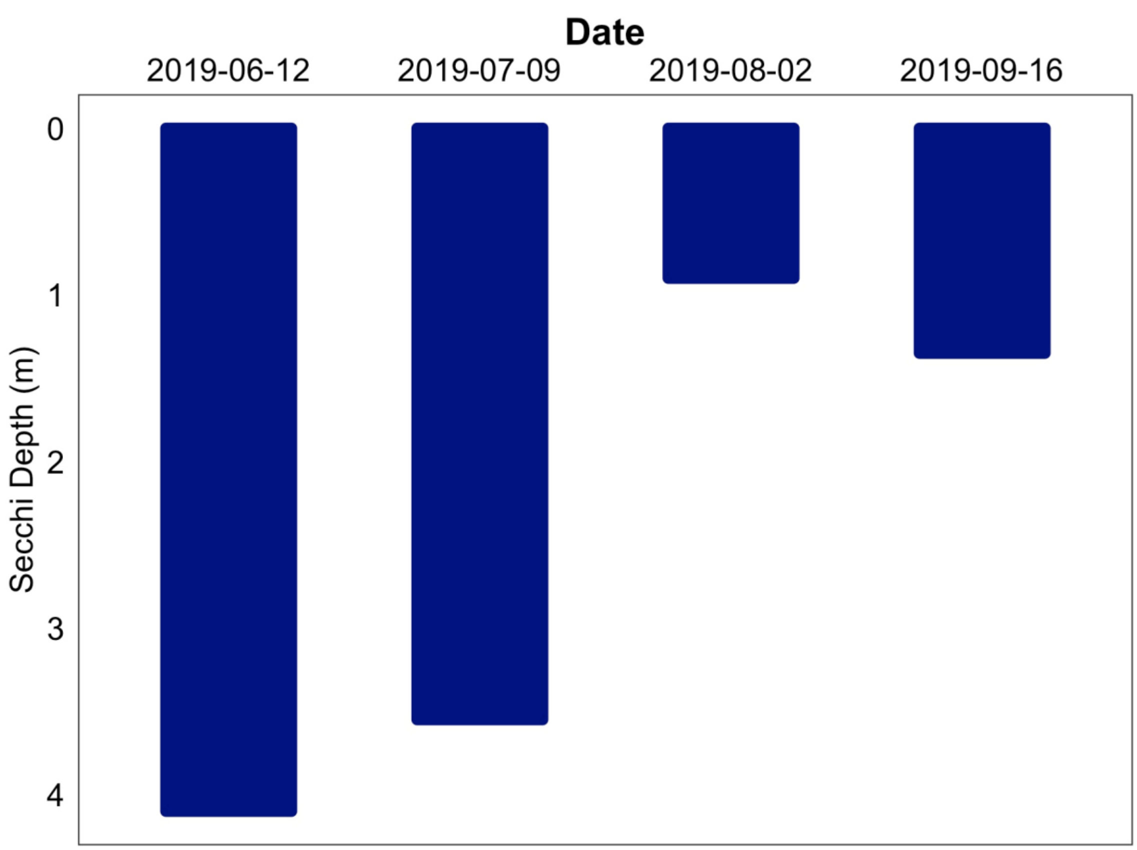


Figure 2. Secchi depth values measured four times over the course of the summer at Moose Lake in 2019.

WATER TEMPERATURE AND DISSOLVED OXYGEN

Water temperature and dissolved oxygen (DO) 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 22.6°C measured at the surface on August 2 (Figure 3a). The lake was not stratified during any of the sampling trips, indicating 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 dissolved oxygen (Figure 3b, dashed line). The oxygen level fell below this level at around 7-9 meters depth in every month. This state of deoxygenation may have been due to decaying organic matter at lake bottom following the midsummer algae blooms.

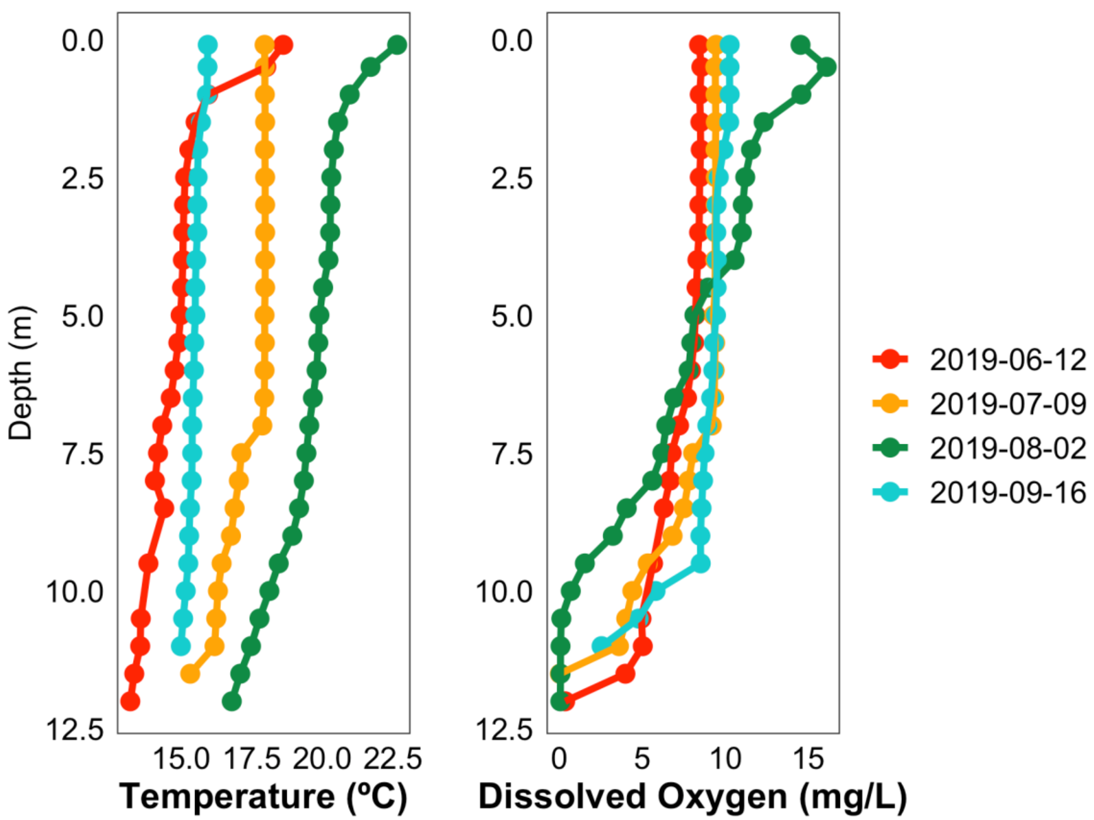


Figure 3. a) Temperature (°C) and b) dissolved oxygen (mg/L) profiles for Moose Lake measured three times over the course of the summer of 2019.

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 20 μg/L for at the locations and times sampled in Moose Lake in 2019. A concentration of 7.02 μg/L indicates that microcystin toxins may be present in high concentrations throughout the lake and recreating near visible cyanobacteria should be avoided.

Table 1. Microcystin concentrations measured four times at Moose Lake in 2019.

Date	Microcystin Concentration (μg/L)
12-Jun-19	0.16
09-Jul-19	0.20
02-Aug-19	7.02
16-Sep-19	0.45
Average	1.96

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 cyanobacteria 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 using a 63 μm plankton net at three sample sites to look for juvenile mussel veligers in each lake sampled. No mussels were detected at Moose Lake in the summer of 2019.

Eurasian watermilfoil is non-native aquatic plant that poses a threat to aquatic habitats in Alberta because it grows in dense mats preventing light penetration through the water column, reduces oxygen levels when the dense mats decompose, and outcompetes native aquatic plants.

No milfoil, native or Eurasian, was observed at Moose Lake in 2019.

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 varied since Alberta Environment began monitoring the lake in 1950 (Figure 4). Moose Lake water levels have been have been at their lowest in the mid-1990s and early 2000s, and have since increased to average levels within the recorded historical range. In 2017, Moose Lake increased to 533.6 masl 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].

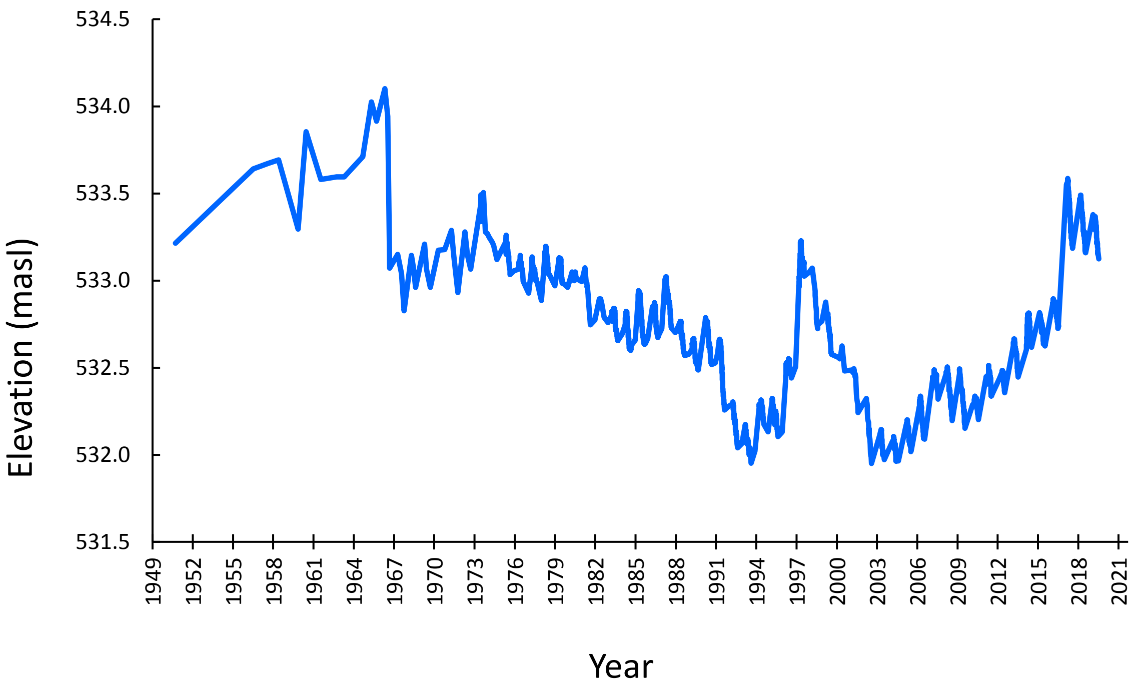


Figure 4. Water levels measured in metres above sea level (masl) from 1956-2019. Data retrieved from Alberta Environment and Parks.

[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)	43	31	48	53	38	51	59	43	47
TDP (µg/L)	/	/	/	15	15	13	17	20	17
Chlorophyll-*a* (µg/L)	17.6	5.2	16.8	39.5	22.6	27.3	35.5	15.7	19.0
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	25	25	22	20	25	25	14	8
NH_3-N (µg/L)	/	/	/	33	38	16	23	43	24
DOC (mg/L)	18	/	/	/	18	18	18	18	18
Ca (mg/L)	23	31	28	25	25	25	25	24	21
Mg (mg/L)	45	44	43	54	50	47	48	48	51
Na (mg/L)	87	84	84	111	112	114	115	117	129
K (mg/L)	15	15	15	12	17	20	17	20	19
SO_4^{2-} (mg/L)	125	124	113	149	156	151	155	165	164
Cl^- (mg/L)	18	17	19	23	25	25	25	28	29
CO_3 (mg/L)	19	13	15	29	29	35	32	30	28
HCO_3 (mg/L)	321	322	314	343	350	335	346	348	358
pH	8.76	8.56	8.64	8.87	8.86	8.99	8.81	8.90	8.85
Conductivity (µS/cm)	793	808	776	/	935	868	947	954	965
Hardness (mg/L)	241	268	246	284	267	255	261	260	260
TDS (mg/L)	489	/	/	573	584	580	587	604	610
Microcystin (µg/L)	/	/	/	/	/	0.418	0.080	0.593	0.113
Total Alkalinity (mg/L $CaCO_3$)	295	288	284	330	334	333	336	336	339

Table 2b. 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	2019
TP (µg/L)	49	53	109	74	33	34	69	91	49
TDP (µg/L)	18	18	41	31	10	12	12	18	15
Chlorophyll-*a* (µg/L)	46.1	26.8	50.0	14.3	14.6	29.6	40.7	94.1	38.0
Secchi depth (m)	2.88	1.84	0.96	3.66	2.60	1.75	1.10	1.30	2.48
TKN (mg/L)	1.6	1.7	2.0	1.6	1.6	1.5	2.1	2.2	1.7
NO_2-N and NO_3-N (µg/L)	4	3	3	36	7	3	10	14	2
NH_3-N (µg/L)	31	20	19	87	36	38	52	106	24
DOC (mg/L)	17	18	24	17	16	16	17	19	18
Ca (mg/L)	24	25	26	26	25	27	28	29	31
Mg (mg/L)	56	49	53	48	52	57	54	49	47
Na (mg/L)	114	107	116	129	110	120	110	103	99
K (mg/L)	20	21	24	21	18	22	21	21	20
SO_4^{2-} (mg/L)	156	161	151	150	168	160	148	145	138
Cl^- (mg/L)	27	28	28	34	33	32	31	31	31
CO_3 (mg/L)	18	29	36	29	27	25	23	27	21
HCO_3 (mg/L)	372	359	342	413	366	368	348	338	348
pH	8.70	8.87	8.90	8.71	8.80	8.79	8.75	8.81	8.75
Conductivity (µS/cm)	974	993	989	996	990	994	934	918	905
Hardness (mg/L)	290	263	282	262	280	302	294	273	268
TDS (mg/L)	599	597	602	639	618	628	586	575	557
Microcystin (µg/L)	1.18	1.00	0.23	0.60	0.54	1.59	1.04	3.72	1.96
Total Alkalinity (mg/L $CaCO_3$)	334	342	371	339	344	342	322	325	320

Table 3. 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 and Chlorophyll-*a*. 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 4. Summary table of trend analysis on Moose Lake data from 2003 to 2019.

Parameter	Date Range	Trend	Probability
Total Phosphorus	2003-2019	Increasing	Not significant
Chlorophyll-*a*	2003-2019	Increasing	Not significant
Total Dissolved Solids	2003-2019	No change	Not significant
Secchi Depth	2003-2019	Decreasing	Not significant

Definitions:

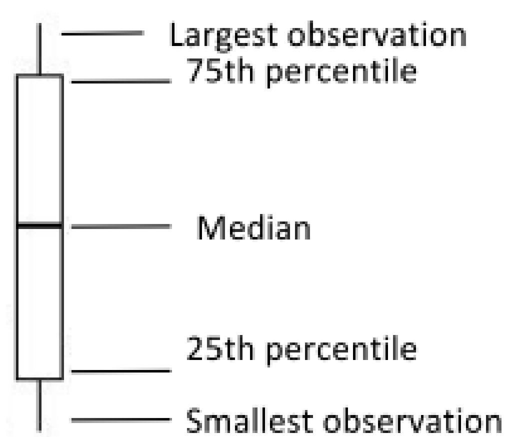
Median: the value in a range of ordered numbers that falls in the middle.

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 = 0.14). However, there may be an increase in variability within and between seasons in recent years.

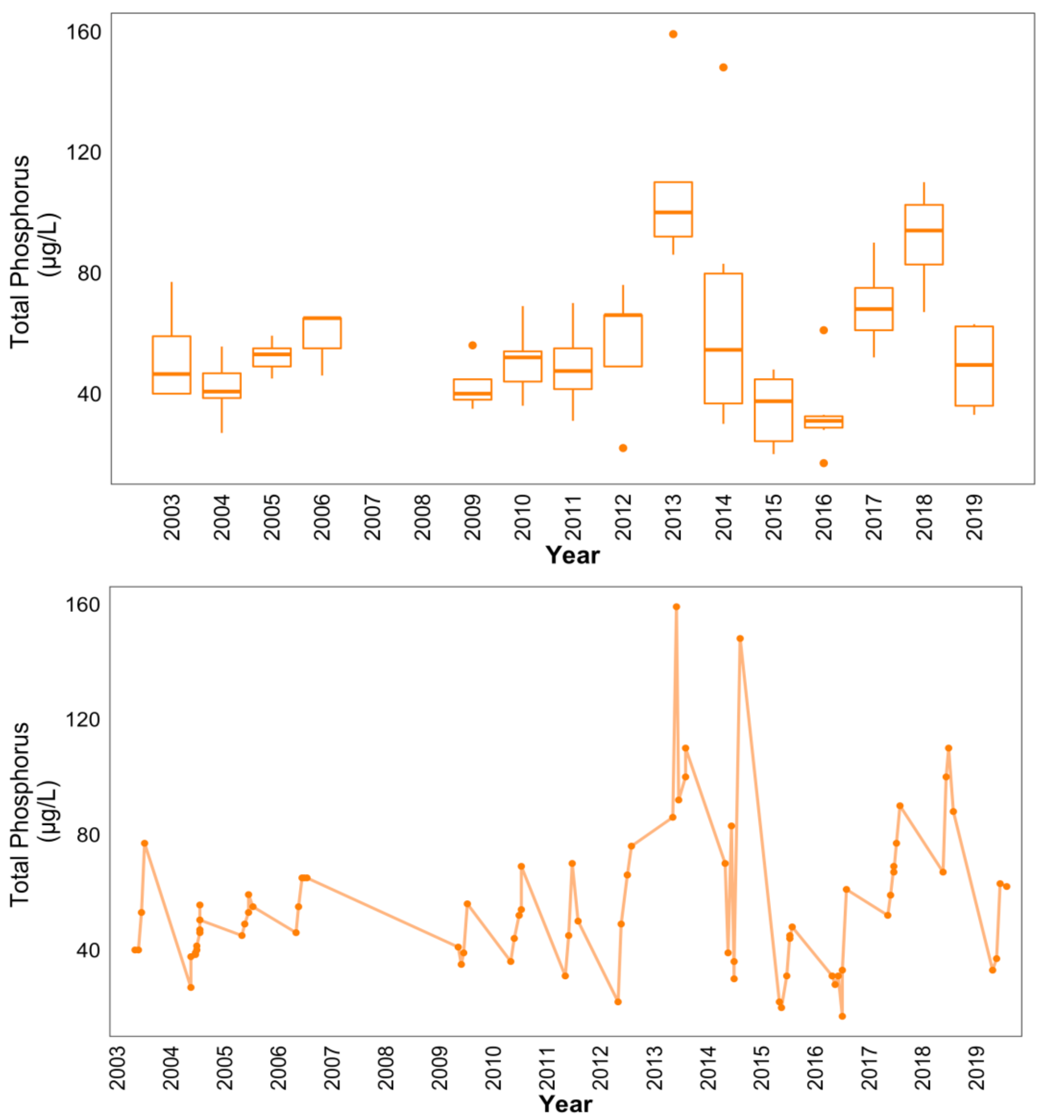
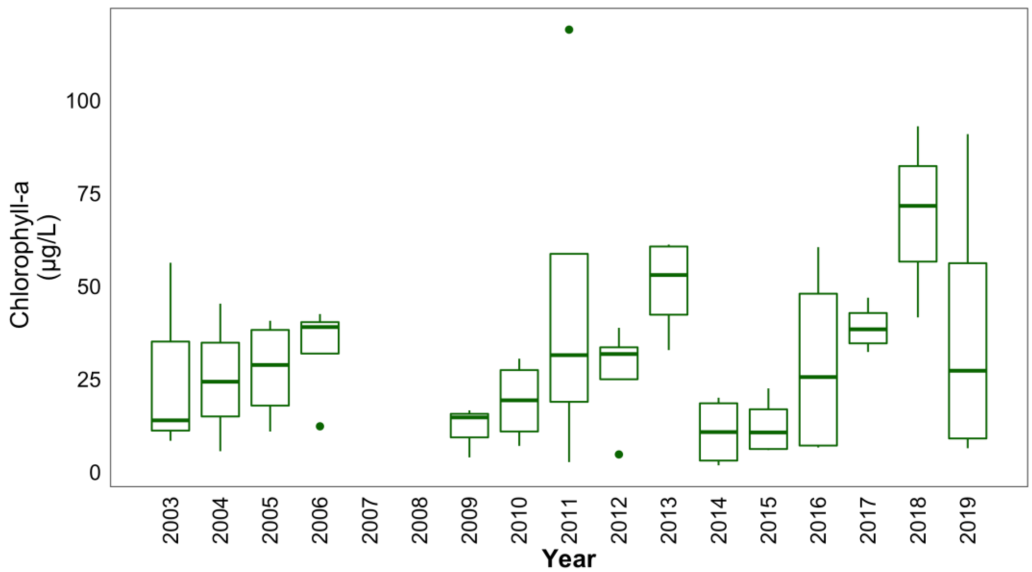


Figure 5. Monthly total phosphorus (TP) concentrations measured between June and September over the long term sampling dates between 2003 and 2019 (n = 56). The value closest to the 15th day of the month was chosen to represent the monthly value in cases with multiple monthly samples.

Chlorophyll-*a*

Chlorophyll-*a* trends are not significant over time at Moose Lake (Tau = 0.14, p = 0.12). Chlorophyll-*a* trends follow TP trends with correlation over time (r = 0.45, $p < 0.001$).



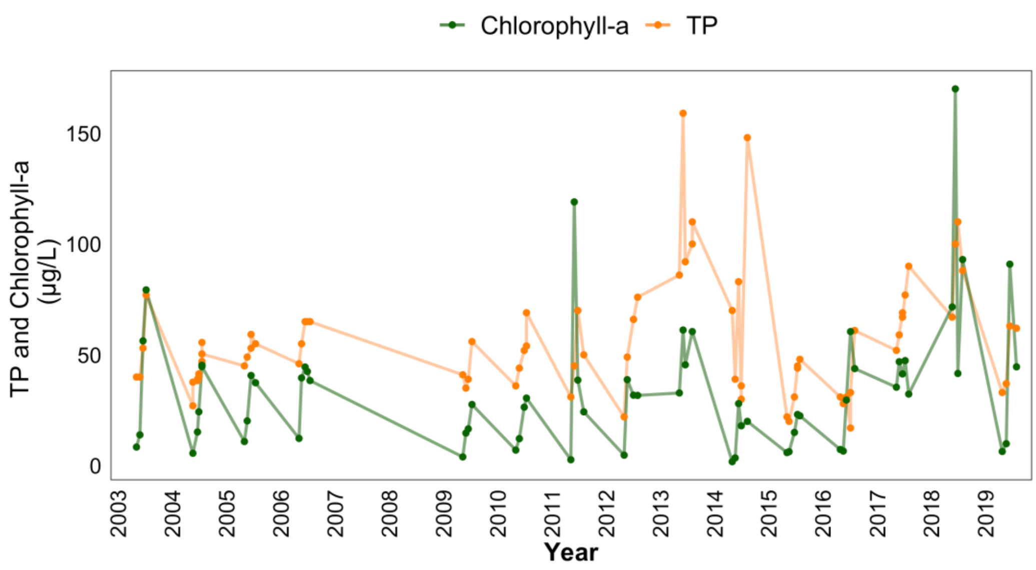


Figure 6. Monthly chlorophyll-*a* concentrations measured between June and September over the long term sampling dates between 2003 and 2019 (n = 56). The value closest to the 15th day of the month was chosen to represent the monthly value in cases with multiple monthly samples. Line graph is overlain 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 three consecutive years of reduced TDS have disrupted this trend, and it is no longer significant (Tau = 0.0053, $p = 0.97$). Continued monitoring of the lake will determine whether this lower TDS concentration is stable in Moose Lake.

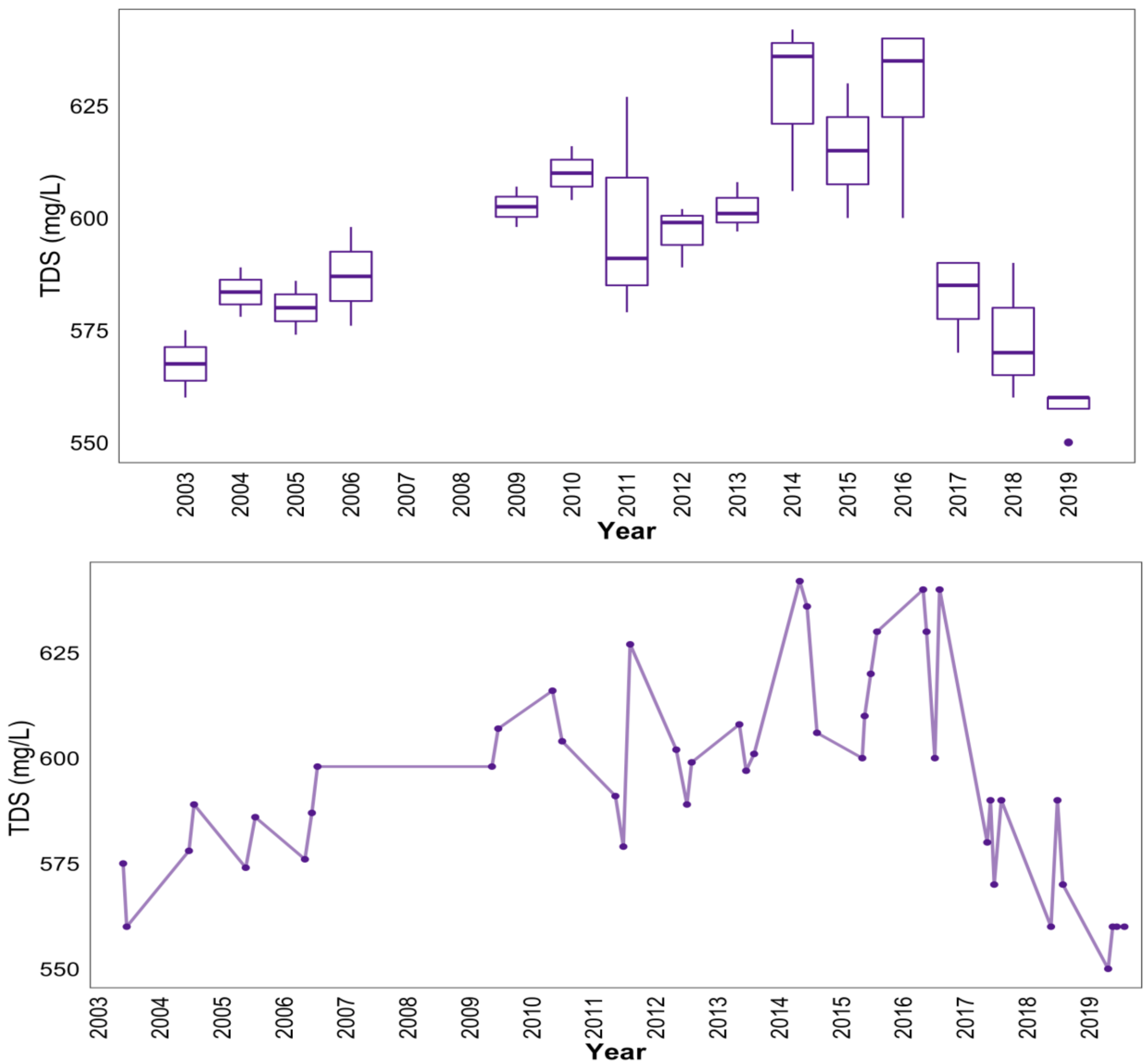
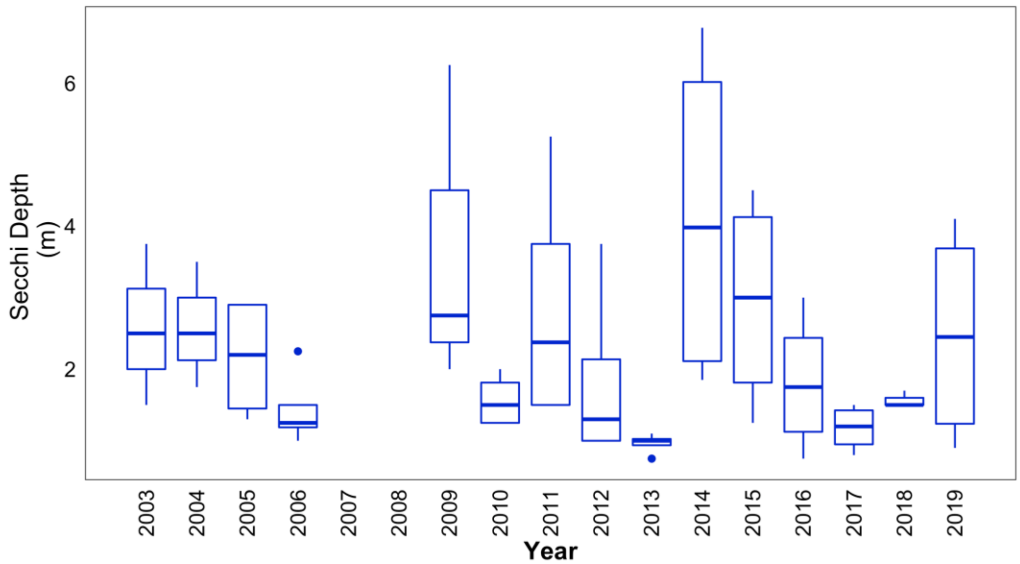


Figure 7. Monthly TDS values measured between June and September over the long term sampling dates between 2003 and 2019 (n = 44). The value closest to the 15th day of the month was chosen to represent the monthly value in cases with multiple monthly samples.

Secchi Depth

Secchi depth has not changed significantly in Moose Lake since 2003 (Tau = -0.15, p = 0.099).



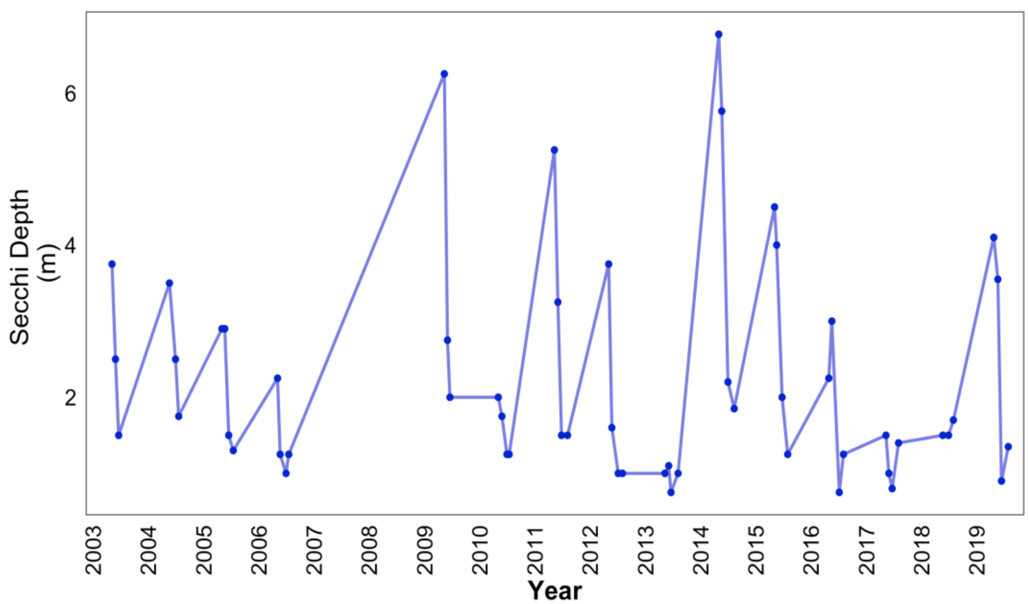


Figure 8. Monthly Secchi depth values measured between June and September over the long term sampling dates between 2003 and 2019 (n = 56). The value closest to the 15th day of the month was chosen to represent the monthly value in cases with multiple monthly samples.

Table 5. 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 2003-2019 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	0.14	5.29×10^{-3}	-0.15
The extent of the trend	Slope	0.0027	0.0023	0	-0.0001
The statistic used to find significance of the trend	Z	1.48	1.55	0.041	-1.65
Number of samples included	n	56	56	44	56
The significance of the trend	*p*	0.14	0.12	0.97	0.099

*$p < 0.05$ is significant within 95%