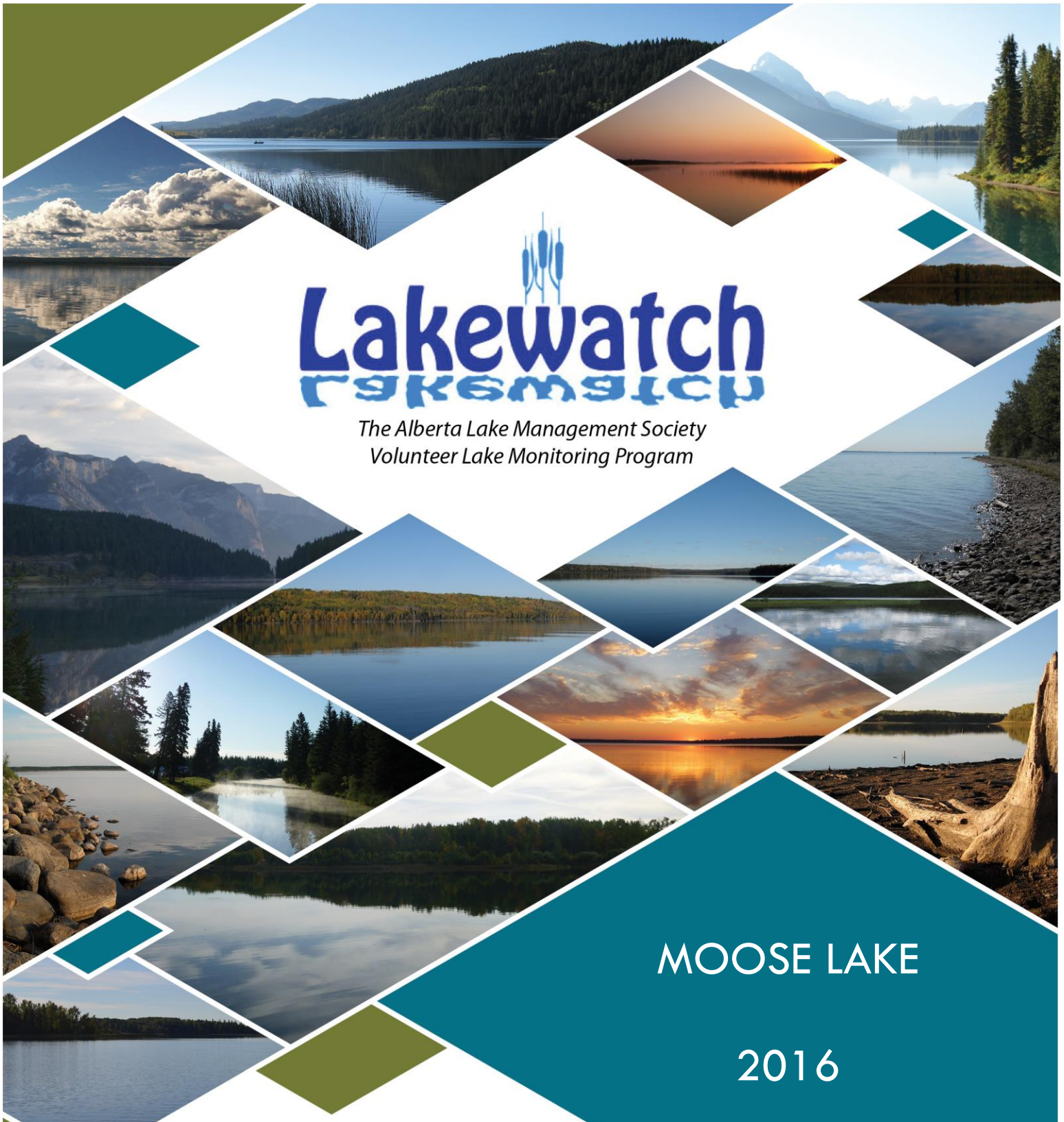


Lakewatch

The Alberta Lake Management Society
Volunteer Lake Monitoring Program

MOOSE LAKE

2016

Lakewatch is made possible with support from:

This project was undertaken with the financial support of:
Ce projet a été réalisé avec l'appui financier de :

Environment and Climate Change Canada
Environnement et Changement climatique Canada

Alberta Environment and Parks

Pigeon Lake Watershed Association

Cargill

LICA Lakeland Industry & Community Association

Beaver River Watershed Alliance

Red Deer River Watershed Alliance

MD of Wainwright No. 61

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.

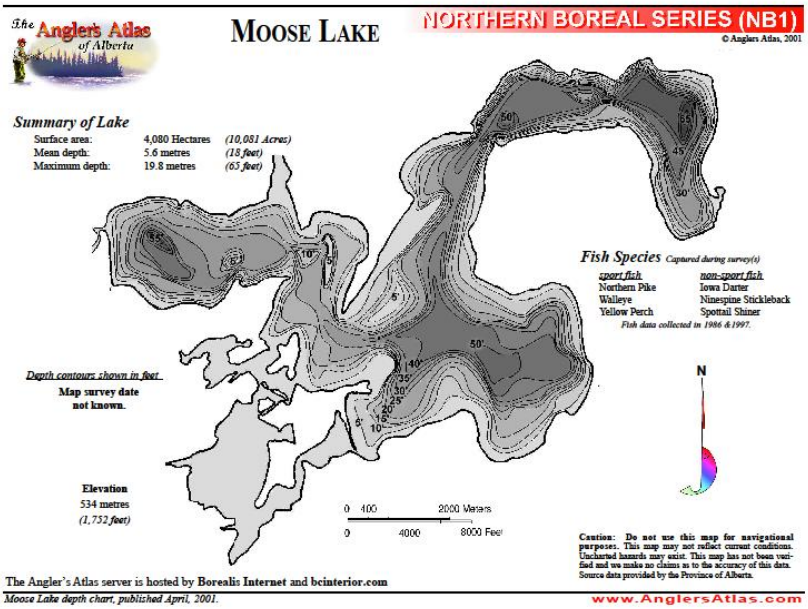
ALMS would like to thank all who express interest in Alberta's aquatic environments and particularly those who have participated in the LakeWatch program. These people prove that ecological apathy can be overcome and give us hope that our water resources will not be the limiting factor in the health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

ACKNOWLEDGEMENTS

The LakeWatch program is made possible through the dedication of its volunteers. We would like to extend a special thanks to Grant Ferbey for the time and energy put into sampling Moose Lake in 2016. We would also like to thank Kellie Nichiporik of the Moose Lake Watershed Stewardship Society for assistance in the field and for funding the project. We would also like to thank Alicia Kennedy, Ageleky Bouzetos, and Breda Muldoon who were summer technicians in 2016. Executive Director Bradley Peter was instrumental in planning and organizing the field program. Alicia Kennedy was instrumental in report design. This report was prepared by Bradley Peter and Laura Redmond. The Beaver River Watershed, the Lakeland Industry and Community Association, Environment Canada, and Alberta Environment and Parks are major sponsors of the LakeWatch program.

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 is comprised of 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.



Bathymetric map of Moose Lake (Angler's Atlas)

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 http://alms.ca/wp-content/uploads/2016/12/Moose.pdf.

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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/

In 2016, a multi-basin study was conducted on Moose Lake by the Alberta Lake Management Society. Visit http://alms.ca/wp-content/uploads/2017/02/MLWSS-2016-V2.pdf to view the full report.

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 of Moose Lake in 2016 was 34 µg/L (Table 2). This value falls just into the eutrophic, or productive, trophic classification and falls on the low end of the historical variation previously observed in Moose Lake. TP concentrations were consistent around ~30 µg/L throughout the summer, then spiking in September to a seasonal maximum of 61 µg/L (Figure 1).

Chlorophyll-*a* concentration measured an average of 29.6 µg/L in 2016 (Table 2). This average falls into the hypereutrophic, or very productive, trophic classification. This value is above the average historical variation previously observed at Moose Lake. Throughout the summer, chlorophyll-*a* concentration increased steadily, measuring a minimum of 7.3 µg/L on June 13 and a maximum of 60.5 µg/L on September 21st (Figure 1).

Finally, total Kjeldahl nitrogen (TKN) concentration measured an average of 1.52 mg/L in 2016 (Table 2). Similar to TP concentration, TKN maintained consistency throughout much of the summer, measuring a minimum of 1.3 mg/L on July 6 and a maximum of 1.7 mg/L on both July 27 and September 21 visits. (Figure 1).

Average pH measured 8.79 in 2016, buffered by moderate alkalinity (342 mg/L $CaCO_3$) and bicarbonate (368 mg/L HCO_3). Magnesium, sodium and sulphate were the dominant ions contributing to a moderate conductivity measure of 994 uS/cm (Table 2).

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 at Moose Lake and all measured values fell within their respective guidelines (Table 3).

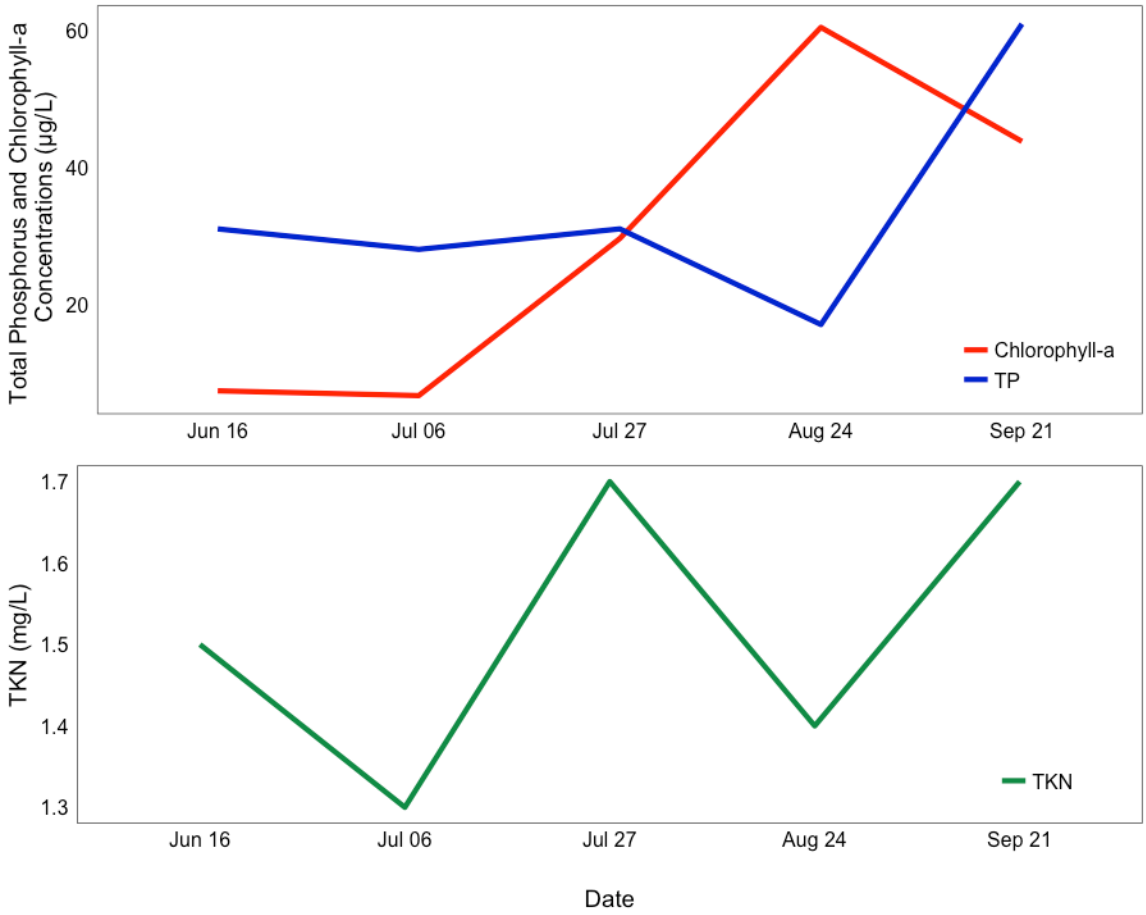

Figure 1- Total Phosphorus (TP), Total Kjeldahl Nitrogen (TKN), and Chlorophyll-*a* concentrations measured five times over the course of the summer at Moose Lake.

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 disk depth. Two times the Secchi disk depth equals the euphotic depth – the depth to which there is enough light for photosynthesis.

Secchi depth at Moose Lake fluctuated throughout the summer (Figure 2). On July 6, Secchi depth reached a seasonal maximum of 3 m, but decreased to a seasonal minimum of 0.75 m on August 24. Secchi depth was significantly negatively correlated with chlorophyll-*a* concentration (*r*= -0.943, *df*= 3, *p-value*= 0.0161). This suggests that phytoplankton blooms are the primary factor decreasing water clarity in Moose Lake. Average Secchi depth was measured as 1.75 m, which is lower than most historical values.

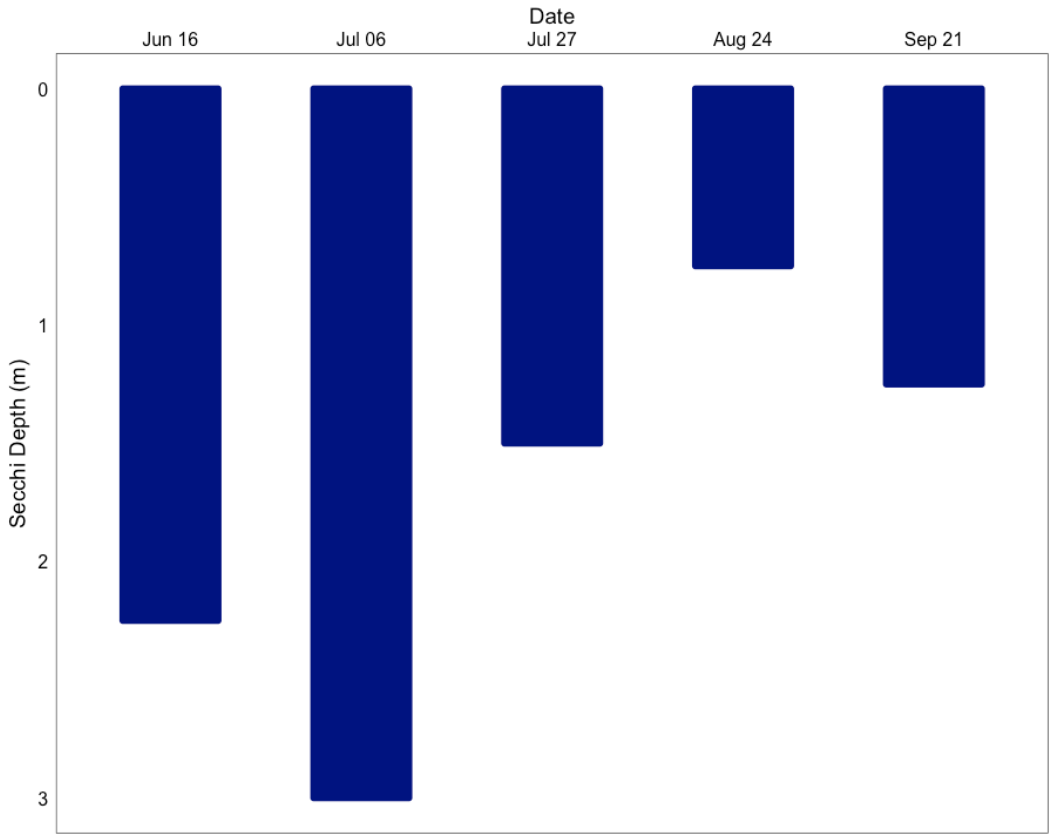

Figure 2 – Secchi depth values measured five times over the course of the summer at Moose Lake in 2016.

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.

Water temperatures fluctuated over the course of the summer, with a minimum temperature of 14.1 °C in September and a maximum of 22.2°C at the end of July (Figure 3a). Moose Lake was weakly thermally stratified on July 6 and 27 but was mixed for the rest of the summer. By September 21, the entire water column was approximately 14°C.

Moose Lake remained well oxygenated at the surface throughout the summer, measuring above the Canadian Council for Ministers of the Environment guidelines of 6.5 mg/L for the Protection of Aquatic Life (Figure 3b). Anoxic conditions were reached at the bottom of Moose Lake on July 27. Anoxic conditions are more likely under thermally stratified conditions, as it isolates oxygen-rich surface waters from oxygen-poor bottom waters. Further contributing to the oxygen decline is the process of decomposition which draws away oxygen at the lakebed. On visits when the lake was not thermally stratified, the entire water column was completely oxygenated.

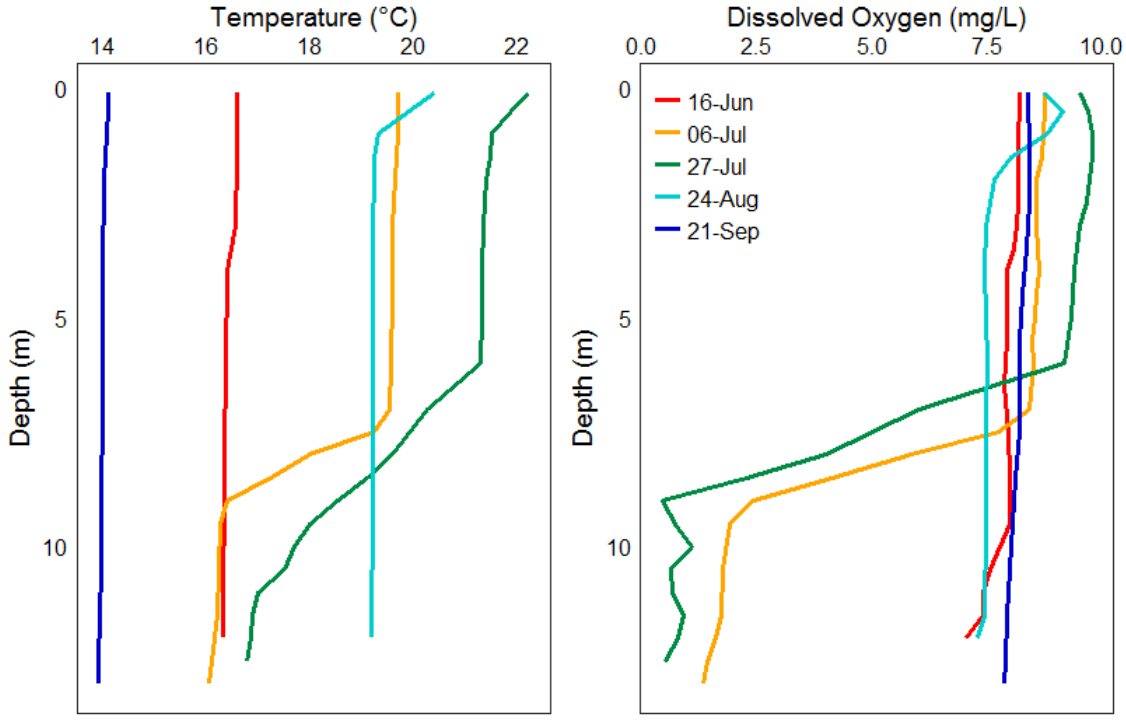

Figure 3 – a) Temperature (°C) and b) dissolved oxygen (mg/L) profiles for Moose Lake measured five times over the course of the summer of 2016.

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.

Microcystin levels fell below the recreational guideline for the entire sampling period of 2016 (Table 1). However, these measures are from the main basin of Moose Lake, and higher values have been recorded in Franchere Bay (see multi-basin report).

Table 1 – Microcystin concentrations measured five times at Moose Lake in 2016.

Date	Microcystin Concentration (µg/L)
Jun 16	0.15
Jul 6	0.17
Jul 27	5.37
Aug 24	1.88
Sep 21	0.38
Average	1.59

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 mussel veligers using a plankton net and monitoring for attached adult mussels using substrates installed in each lake. In 2016, no invasive mussels were detected in Moose 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.

Water levels in Moose Lake have decreased since Alberta Environment began monitoring the lake in 1956 (Figure 4). Since 1956, Moose Lake water levels have fluctuated between 532 m asl and 534.1 m asl.

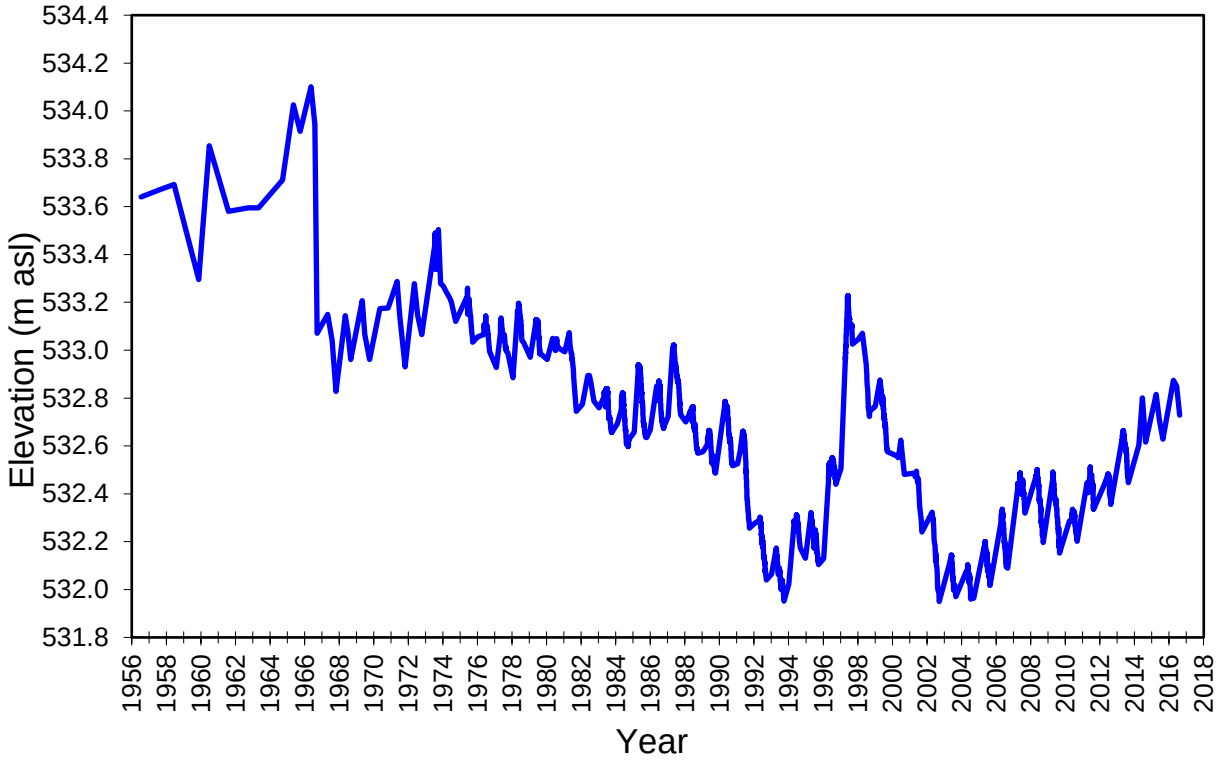

Figure 4- Water levels measured in meters above sea level (m asl) from 1956- 2017. Data retrieved from Alberta Environment.

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**
TP (µg/L)	42.7	30.9	47.9	52.5	38.0	50.5	59.2
TDP (µg/L)	/	/	/	14.5	15	13	17
Chlorophyll-*a* (µg/L)	17.56	5.15	16.80	39.48	22.60	27.30	35.46
Secchi depth (m)	1.98	3.45	2.75	2.25	2.69	2.15	1.30
TKN (mg/L)	1.6	/	/	1.7	1.5	1.6	1.8
NO_2 and NO_3 (µg/L)	22.3	25	25	21.8	20.3	25	25
NH_3 (µg/L)	/	/	/	33.25	37.5	15.5	23.2
DOC (mg/L)	18	/	/	/	17.5	18.1	18
Ca (mg/L)	22.8	30.8	27.8	25.4	24.5	24.6	25.4
Mg (mg/L)	45.0	43.5	43.2	53.5	49.9	47.0	48.1
Na (mg/L)	87.0	83.9	83.8	110.7	112.0	113.5	114.7
K (mg/L)	14.6	14.5	14.6	12.2	16.7	19.5	17.4
SO_4^{2-} (mg/L)	125.0	123.5	113.0	149.3	155.5	151.0	154.7
Cl^- (mg/L)	17.55	17.20	19.20	23.40	24.55	24.90	25.40
CO_3 (mg/L)	19.0	13.0	15.0	29.3	28.5	35.0	31.7
HCO_3 (mg/L)	321.0	322.0	313.5	342.7	350.0	334.5	345.7
pH	8.76	8.56	8.64	8.87	8.86	8.99	8.81
Conductivity (µS/cm)	792.8	808.0	776.0	/	934.5	867.5	947.3
Hardness (mg/L)	240.8	268.0	245.5	283.7	266.5	255.0	261.3
TDS (mg/L)	489.0	/	/	573.0	583.5	580.0	587.0
Microcystin (µg/L)	/	/	/	/	/	0.418	0.080
Total Alkalinity (mg/L $CaCO_3$)	295.3	288.0	284.0	330.3	334.0	333.0	336.0

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

Parameter	2009	2010	2011	2012	2013	2014	2015	2016
TP (µg/L)	42.8	46.5	49.0	53.3	109.3	74.0	33	34
TDP (µg/L)	20	16.75	17.8	17.8	41.3	31.2	10	12
Chlorophyll-*a* (µg/L)	15.71	19.03	46.14	26.76	50	14.26	14.56	29.6
Secchi depth (m)	3.06	1.56	2.88	1.84	0.96	3.66	2.60	1.75
TKN (mg/L)	1.6	1.7	1.6	1.7	2	1.6	1.6	1.52
NO_2 and NO_3 (µg/L)	13.8	7.8	3.63	2.5	2.5	36	6.6	2.5
NH_3 (µg/L)	43	23.5	30.8	19.75	18.5	87.4	36.4	38.4
DOC (mg/L)	17.6	18.45	16.87	17.9	23.9	17.25	16	15.8
Ca (mg/L)	24.3	20.6	23.6	25.4	25.7	25.8	25	26.6
Mg (mg/L)	48.4	50.6	56.0	48.5	53	47.9	52	57.4
Na (mg/L)	117.3	129.0	114.0	107.0	116.3	129.0	110	120
K (mg/L)	19.7	18.6	20.3	21.3	24.1	21.3	18	22.4
SO_4^{2-} (mg/L)	165.0	164.0	156.0	161.0	150.7	150.0	168	160
Cl^- (mg/L)	27.67	28.60	27.40	27.70	27.60	33.70	33	32
CO_3 (mg/L)	30.3	27.5	18.0	28.8	36.3	29.2	27	24.8
HCO_3 (mg/L)	348.0	357.5	371.5	358.5	341.8	413.0	366	368
pH	8.90	8.85	8.70	8.87	8.90	8.71	8.80	8.79
Conductivity (µS/cm)	953.7	964.5	974.0	993.0	989.3	996.0	990	994
Hardness (mg/L)	259.7	260.0	290.0	263.0	282.3	261.5	280	302
TDS (mg/L)	604.0	610.0	599.0	596.7	602	639	618	628
Microcystin (µg/L)	0.593	0.113	1.178	1.002	0.2265	0.6	0.54	1.59
Total Alkalinity (mg/L $CaCO_3$)	336.0	338.5	334.0	342.3	370.5	338.6	344	342

Table 3A: Concentrations of metals measured once in Moose Lake. The CCME heavy metal Guidelines for the Protection of Freshwater Aquatic Life (unless otherwise indicated) are presented for reference.

Metals (Total Recoverable)	2003	2004	2005	2009	2010	Guidelines
Aluminum µg/L	14.75	4.95	3.34	16.05	10.7	100[a]
Antimony µg/L	0.075	0.065	0.065	0.058	0.0531	6[d]
Arsenic µg/L	1.99	2.03	2.19	2.12	2.16	5
Barium µg/L	46.1	50.2	47.8	45.4	44.9	1000[d]
Beryllium µg/L	0.06	0.0015	0.0015	0.0038	0.0015	100[c,e]
Bismuth µg/L	0.00575	0.0011	0.0061	0.0061	0.0012	/
Boron µg/L	169.5	172	176	197	185	1500
Cadmium µg/L	0.03	0.007	0.00465	0.005	0.0048	0.26[b]
Chromium µg/L	0.325	0.87	0.606	0.298	0.22	/
Cobalt µg/L	0.01	0.014	0.0205	0.0107	0.0067	1000[e]
Copper µg/L	0.56	0.75	0.607	0.492	0.263	4[b]
Iron µg/L	3.25	1	37	8.05	7.65	300
Lead µg/L	0.079	0.0472	0.08015	0.216	0.0114	7[b]
Lithium µg/L	40.05	53.4	57.3	61.2	53.1	2500[f]
Manganese µg/L	9.28	8.14	7.26	7.55	7.2	200[f]
Molybdenum µg/L	0.59	0.846	0.7045	0.598	0.556	73[c]
Nickel µg/L	0.03	0.0025	0.11	<0.005	0.0025	150[b]
Selenium µg/L	0.525	0.27	0.2755	0.3955	0.375	1
Silver µg/L	0.0025	0.0025	0.0013	0.0016	0.0018	0.25
Strontium µg/L	282.5	309	307.5	303	281	/
Thallium µg/L	0.0925	0.0019	0.02925	0.0042	0.0021	0.8
Thorium µg/L	0.00425	0.009	0.01925	0.00245	0.0083	/
Tin µg/L	0.08	0.015	0.015	0.037	0.015	/
Titanium µg/L	0.65	0.67	0.862	1.129	0.756	/
Uranium µg/L	0.43	0.437	0.5905	0.454	0.433	15
Vanadium µg/L	0.445	0.388	0.3845	0.29	0.244	100[e,f]
Zinc µg/L	2.98	7.9	4.335	0.722	0.498	30

Values represent means of total recoverable metal concentrations.

[a] Based on pH ≥ 6.5

[b] Based on water hardness > 180mg/L (as $CaCO_3$)

[c] CCME interim value.

[d] Based on Canadian Drinking Water Quality guideline values.

[e] Based on CCME Guidelines for Agricultural use (Livestock Watering).

[f] Based on CCME Guidelines for Agricultural Use (Irrigation).

A forward slash (/) indicates an absence of data or guidelines.

Table 3B: (Continued) Concentrations of metals measured once in Moose Lake. The CCME heavy metal Guidelines for the Protection of Freshwater Aquatic Life (unless otherwise indicated) are presented for reference. Values represent means of total recoverable metal concentrations.

Metals (Total Recoverable)	2011	2012	2013	2014	2015	2016	Guidelines
Aluminum µg/L	4.08	5.175	19.15	7.215	4	6.6	100[a]
Antimony µg/L	0.05605	0.05795	0.2195	0.0469	0.052	0.05	6[d]
Arsenic µg/L	2.085	2.21	6.055	2.06	1.93	1.78	5
Barium µg/L	46	46.95	30.15	48.9	45.85	44	1000[d]
Beryllium µg/L	0.00385	0.00375	0.00565	0.004	0.004	0.004	100[c,e]
Bismuth µg/L	0.0005	0.0005	0.00795	0.0005	0.00325	5.00E-04	/
Boron µg/L	202	191	184.5	189	187.5	192	1500
Cadmium µg/L	0.0043	0.01	0.0028	0.002	0.001	0.001	0.26[b]
Chromium µg/L	0.2175	0.351	0.3355	0.817	0.34	0.04	/
Cobalt µg/L	0.03045	0.0027	0.0559	0.007285	0.012	0.001	1000[e]
Copper µg/L	0.4985	0.6635	0.9385	0.5545	0.46	0.73	4[b]
Iron µg/L	22.8	1	25.95	9.03	8.15	6.6	300
Lead µg/L	0.0134	0.04765	0.0555	0.06535	0.0145	0.014	7[b]
Lithium µg/L	70.75	55.05	75.15	52.85	53.45	60.7	2500[f]
Manganese µg/L	5.615	7.99	6.315	8.51	5.35	7.96	200[f]
Molybdenum µg/L	0.6275	0.6245	0.6305	0.523	0.517	0.461	73[c]
Nickel µg/L	0.16275	0.0025	0.3131	0.03485	0.004	0.277	150[b]
Selenium µg/L	0.3575	0.2535	0.2115	0.528	0.045	0.58	1
Silver µg/L	0.007675	0.004025	0.01155	0.001	0.001	0.001	0.25
Strontium µg/L	287.5	242	169.6	297	275.5	272	/
Thallium µg/L	0.00045	0.00015	0.001	0.001375	0.001925	0.0016	0.8
Thorium µg/L	0.0118	0.00015	0.0298	0.00045	0.004375	0.0062	/
Tin µg/L	0.0318	0.0387	0.015	0.005725	0.02	0.012	/
Titanium µg/L	0.4875	0.6475	1.285	1.025	0.81	0.66	/
Uranium µg/L	0.463	0.445	1.3055	0.4455	0.494	0.423	15
Vanadium µg/L	0.2605	0.3	0.672	0.3855	0.16	0.19	100[e,f]
Zinc µg/L	0.68	1.054	1.0815	0.8145	0.35	1.5	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 Canadian Drinking Water Quality guideline values.

[e] Based on CCME Guidelines for Agricultural use (Livestock Watering).

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