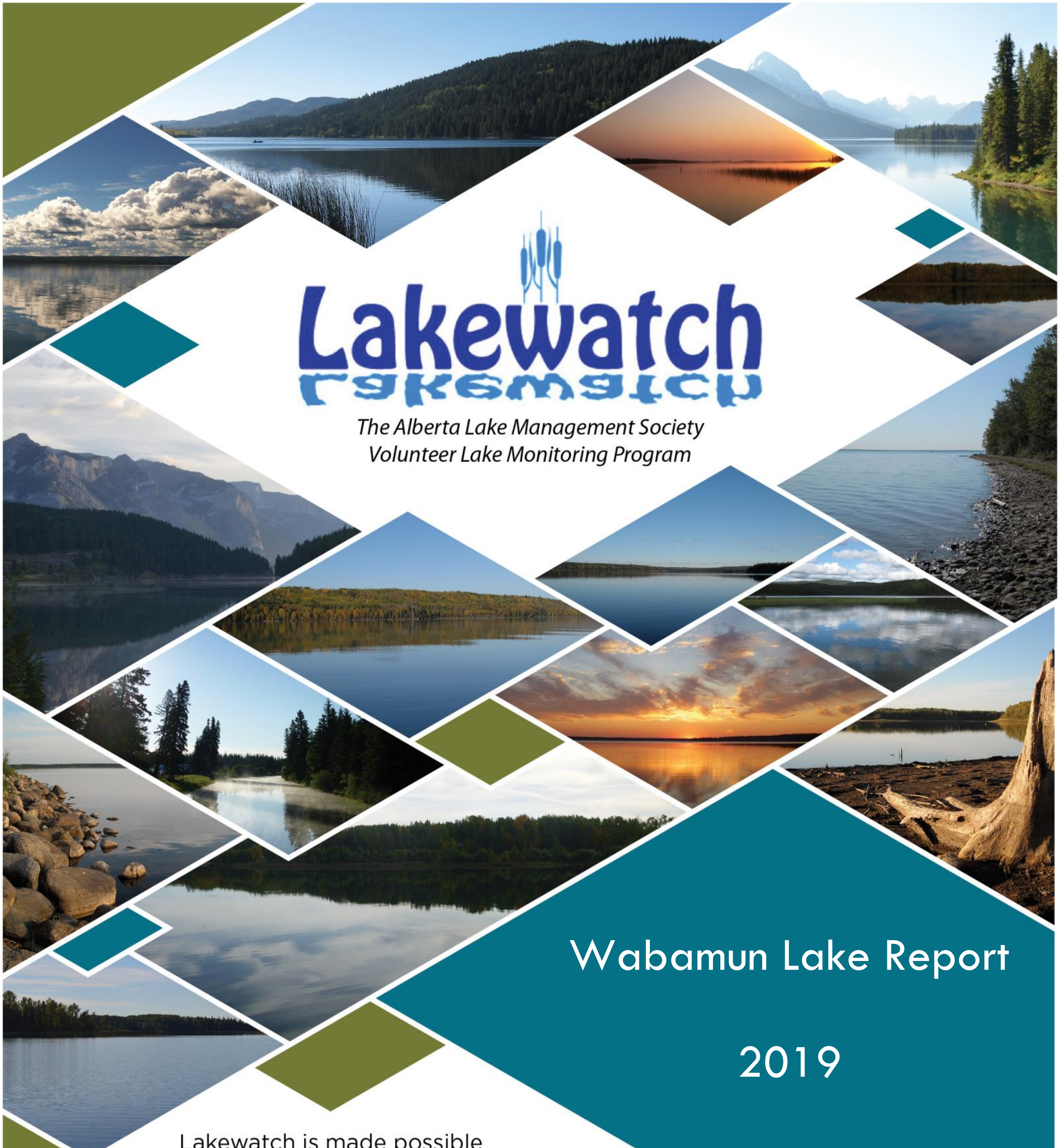

Lakewatch

The Alberta Lake Management Society
Volunteer Lake Monitoring Program

Wabamun 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. At Wabamun Lake, we would like to thank Stan Franklin and Neil Fleming for their dedication to LakeWatch. 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.

WABAMUN LAKE

Wabamun Lake Watershed. Base data provided by the Government of Alberta under the Alberta Open Data License (2020).

Wabamun Lake is a well-known, large lake situated 60km west of Edmonton in the North Saskatchewan watershed. The lake's watershed is approximately 351 km^2, and the lake itself has a surface area of 79 km^2, a mean depth of 5.1 m, with the deepest area being approximately 11 m deep.[1] *Wabamun* is Cree for "mirror," and has been the historical name of the lake, but was also called White Whale Lake for most of the 1800s due to the size of large Whitefish harvested from the lake at that time.[2] The Paul Band reserve is situated on the Eastern edge of the lake, and many other communities line Wabamun's shore. Of them, the Village of Wabamun was established in 1912, and the summer villages of Lakeview and Kapasiwin were some of the first summer villages to be established in Alberta. Other communities across the lake include Fallis, Seba Beach, Betula Beach, and Point Allison, to name just a few. Wabamun Lake Provincial Park is located in the northeast part of the lake, and protects much of the shoreline of Moonlight Bay.

There is much industrial activity in the watershed. TransAlta currently operates two coal-fired power plants and one coal mine that impact the Wabamun watershed. The Sundance plant is located near the southeast shore within the watershed, and is the largest coal-fired electrical generation plant in Western Canada.[3] While the Keephills plant is located outside of the Wabamun watershed, both Keephills' and Sundance's cooling pond drain into the lake after treatment by the Wabamun Water Treatment Plant.[4] SunHills Mining, a subsidiary of TransAlta, also operates the Highvale Mine located on the south shore of the lake, and stretches southeast to the North Saskatchewan River. TransAlta also operated the Wabamun Power Plant and Whitewood Mine on the northeast shore from 1962 - 2010.[5]

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[1] Aquality Environmental Consulting (2013). Wabamun Lake State of the Watershed Report. Wabamun Watershed Management Council.
[2] Mitchell, P. and E. Prepas (1990). Atlas of Alberta Lakes, University of Alberta Press.
[3] TransAlta Corporation (2018). Retrieved from https://www.transalta.com/facilities/plants-operation/sundance/
[4] Associated Environmental (2018). Water Quality Status and Trends in Wabamun Lake.
[5] TransAlta Corporation (2018). Retrieved from https://www.transalta.com/facilities/mines-operation/whitewood-mine/

A railway runs along the north shore of the lake, and even crosses over the lake at the mouth of Moonlight Bay. On August 3, 2005, a Canadian National (CN) train travelling west from towards Vancouver, BC derailed and spilled approximately 400,000 L of Bunker C oil and 88,000 L of toxic pole treating oil, with unknown quantities of each being released into the lake.[6] Subsequently, oil was spread across the northern, eastern and southern shores of the lake, severely impacting aquatic and riparian habitat for numerous aquatic species, and waterfowl. Cleanup efforts commenced immediately, and a report released by the Alberta Government in 2007 states that bulrush growth was not impacted by the toxic components of the spilt oil, but rather suffered from the treatments used to clean up the oil.[7] Although bulrush growth was not significantly impacted by the spilled materials, toxic compounds were still detectable in sediments in 2007, although they were below environmental guideline limits.

Aerial photo of Wabamun Lake (Alberta Atlas of Lakes: http://albertalakes.ualberta.ca/).

The relatively shallow lake attracts many avid fishers to catch Northern Pike, Walleye, Lake Whitefish and Yellow Perch.[8] However, since the spill in 2005, the Alberta Government has mandated a catch-and-release only fishery on the lake.[9] Sailing is a popular activity due to the strong winds and northwest orientation of the lake. The lake also attracts many boaters and visitors, due to its relatively good water quality and the scenic aspen parkland that surrounds the lake. Since the lake is one of the most extensively monitored lakes in the province, long-term trend analyses performed by the Alberta Government,[10] Associated Environmental and ALMS all confirm that algal and nutrient levels within the lake are stable at moderate levels (mesotrophic), and even slightly decreasing. Cyanobacteria blooms are relatively rare, however in 2019 Alberta Health Services issued a cyanobacteria bloom beach advisory at Wabamun for the first time. Alberta Health Services' cyanobacteria monitoring program is ever-evolving, and has been in existence only since 2010.[11] Total dissolved solids (TDS) have been increasing in the lake since the lake was first sampled in 1980, likely due to climate impacts and possibly the return of treated water to the lake from the power plant activities within the watershed.[12, 13]

The Wabamun Watershed Management Council (WWMC) is an active group that have collectively worked with Alberta Environment and Parks, the North Saskatchewan Watershed Alliance, various consultants, and municipalities on watershed studies, plans, and on-the-ground projects that aim to protect the lake and inform Wabamun Watershed residents. In addition, 2019 was the first year that ALMS collaborated with the WWMC to sample Wabamun as part of its LakeWatch program. The WWMC is expected to release a watershed management plan in 2020.

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[6] QM Environmental (2020). Retrieved from http://www.qmenv.com/Projects/Wabamun-Lake-Oil-Spill
[7] Thormann, M. N. and S. E. Bayley (2008). Impacts of the CN Rail Oil Spill on Softstem Bulrush-Dominated Lacustrine Marshes in Wabamun Lake. Alberta Environment and Parks.
[8] Mitchell, P. and E. Prepas (1990). Atlas of Alberta Lakes, University of Alberta Press.
[9] Wabamun Watershed Management Council (2019). Retrieved from https://www.wwmc.ca/wabamun-fishery
[10] Casey, R. (2011). Water Quality Conditions and Long-Term Trends in Alberta Lakes. Alberta Environment and Parks.
[11] Health Protection Branch, Alberta Health (2014). Alberta Cyanobacteria Beach Monitoring, 2010 – 2013. Alberta Health.
[12] Associated Environmental (2018). Water Quality Status and Trends in Wabamun Lake.
[13] Casey, R. (2003). Wabamun Lake Water Quality, 1982 – 2001. Alberta Environment and Parks.

METHODS

Profiles: Profile data is generally 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.[14] Data is reconfigured using packages tidyr[15] and dplyr[16] and figures are produced using the package ggplot2[17]. Trophic status for each lake is classified based on lake water characteristics using values from Nurnberg (1996)[18]. 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.

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[14] 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/.

[15] 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.

[16] 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.

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

[18] 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 Wabamun Lake was 27 µg/L (Table 2), falling into the mesotrophic, or moderately productive trophic classification. Detected TP was lowest in June at 19 µg/L, and peaked at 34 µg/L in September (Figure 1).

Average chlorophyll-*a* concentration in 2019 was 11.1 µg/L (Table 2), falling into the eutrophic, or productive trophic classification. Chlorophyll-*a* was lowest in June at 4.4 µg/L and peaked at 15.9 µg/L in September. Blooms of Gleotrichia spp. And Aphanizomenon spp. were noted during the August and September samplings. On August 16^{th}, Alberta Health Services issued a blue-green algae advisory at Wabamun Lake.

The average TKN concentration was 0.9 mg/L (Table 2) with concentrations peaking in September.

Average pH was measured as 8.59 in 2019, buffered by low alkalinity (220 mg/L $CaCO_3$) and bicarbonate (255 mg/L HCO_3). Aside from bicarbonate, sulphate and sodium were the dominant ions contributing to a moderate conductivity of 613 µS/cm (Table 2).

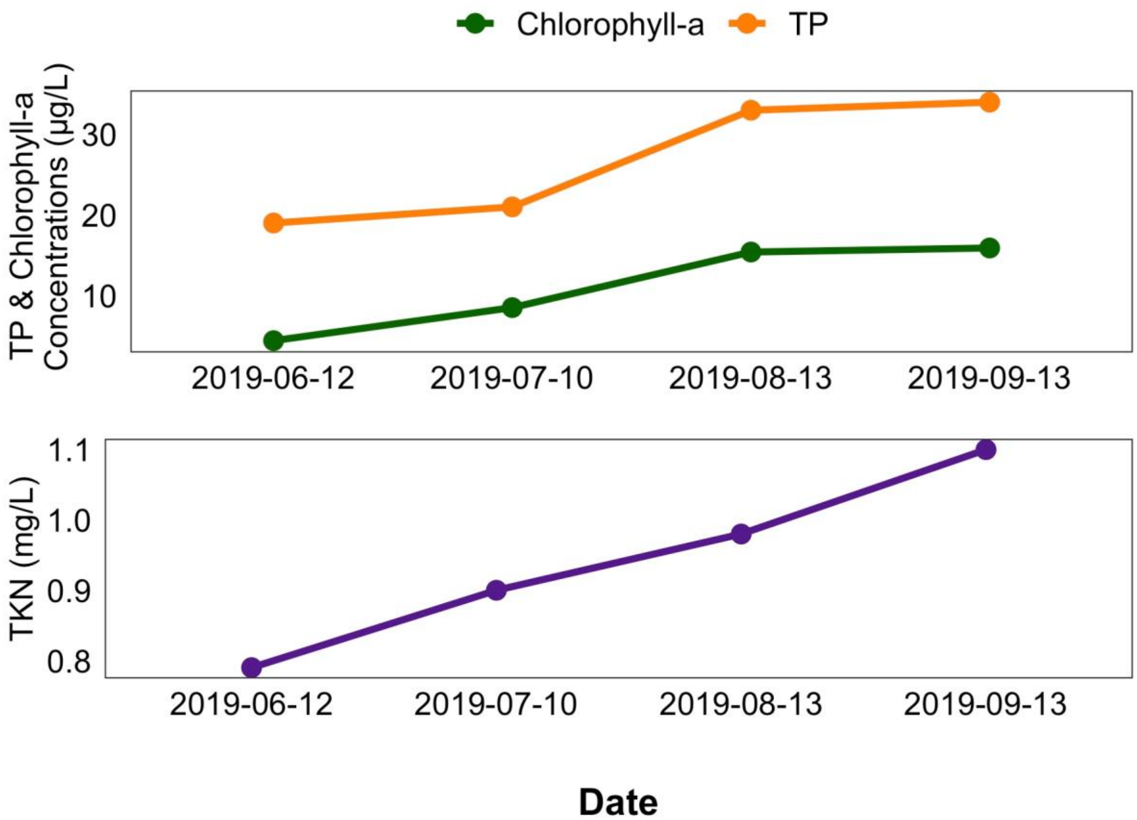


Figure 1. Total Phosphorus (TP), Total Kjeldahl Nitrogen (TKN), and Chlorophyll-*a* concentrations measured four times over the course of the summer at Wabamun Lake.

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 not measured at Wabamun Lake in 2019. Table 4 presents historical values from previously a previous year.

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 Wabamun Lake in 2019 was 2.69 m (Table 2). Secchi depth was lowest in August and September, likely due to the aforementioned algae bloom, and deepest in June (Figure 2).

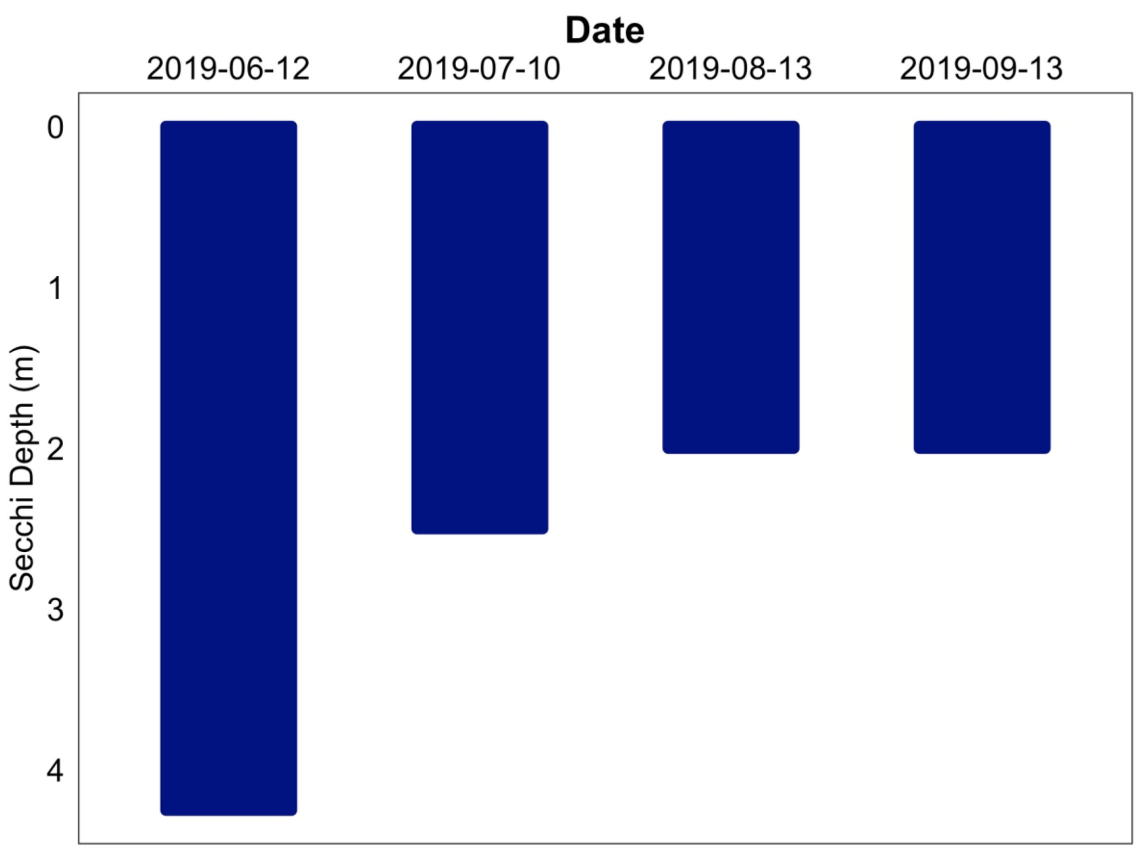


Figure 2. Secchi depth values measured four times over the course of the summer at Wabamun Lake in 2019.

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.

Water temperatures in Wabamun Lake varied throughout the summer, with a maximum temperature of 18.5°C measured throughout the water column on August 13 (Figure 3a). 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.

Wabamun Lake remained well oxygenated through the water column on all sampling trips, measuring above the CCME guidelines of 6.5 mg/L dissolved oxygen (Figure 3b).

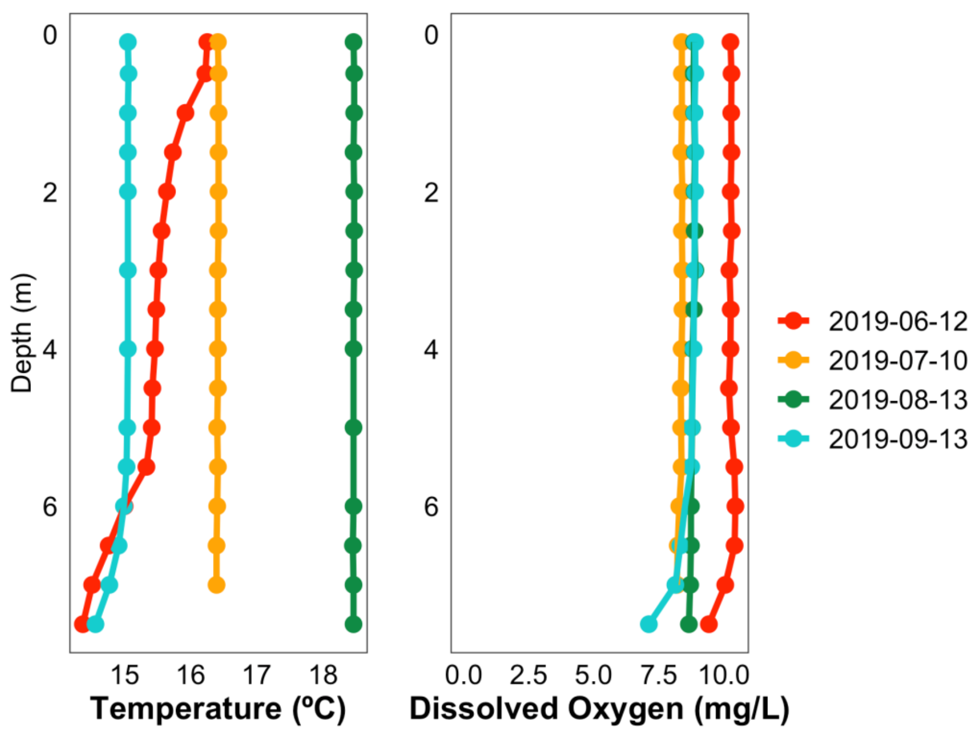


Figure 3. a) Temperature (°C) and b) dissolved oxygen (mg/L) profiles for Wabamun Lake measured four times over the course of the summer of 2019.

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 Wabamun Lake fell below the recreational guideline of 20 µg/L at the locations and times sampled in Wabamun Lake in 2019. However, evidence of cyanobacteria blooms were noted in both August and September. Despite microcystin concentrations remaining low throughout the summer, caution should be observed when recreating in visible blooms.

Table 1. Composite microcystin concentrations measured five times at Wabamun Lake in 2019.

Date	Microcystin Concentration (µg/L)
12-Jun-19	0.05
10-Jul-19	0.10
13-Aug-19	0.19
13-Sep-19	0.15
Average	0.12

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 using a 63 µm plankton net at three sample sites to look for juvenile mussel veligers in each lake sampled. No mussels have been detected in Wabamun 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.

Suspect samples collected from Wabamun Lake on July 10 were confirmed to be the native Northern watermilfoil (*Myriophyllum sibiricum)*.

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.

There is over 100 years of water level data for Wabamun Lake, as levels were first recorded in 1915. In the first half of the 20th century, levels seemed to fluctuate on about a 10 year cycle from a high of about 725 meters above sea level (masl), to a low of about 724.1 masl. Then, late in 1961, a low of 723.8 masl was reached, before coming back within the mean historical range through the 1970s and 1980s. Then a prolonged period of low levels occurred in the 1990s and early 2000s, where a historical low of 723.7 masl was recorded in September, 2002. Since then, levels have risen through the 2010s within the average historical range. Considering the 1.4 m range in which water levels have fluctuated in the lake within the last 100 years, the water levels in Wabamun Lake have remained remarkably stable. However, the declines in the 2000s were likely mitigated by the diversion of water from the North Saskatchewan River into the lake beginning in 1999.[19]

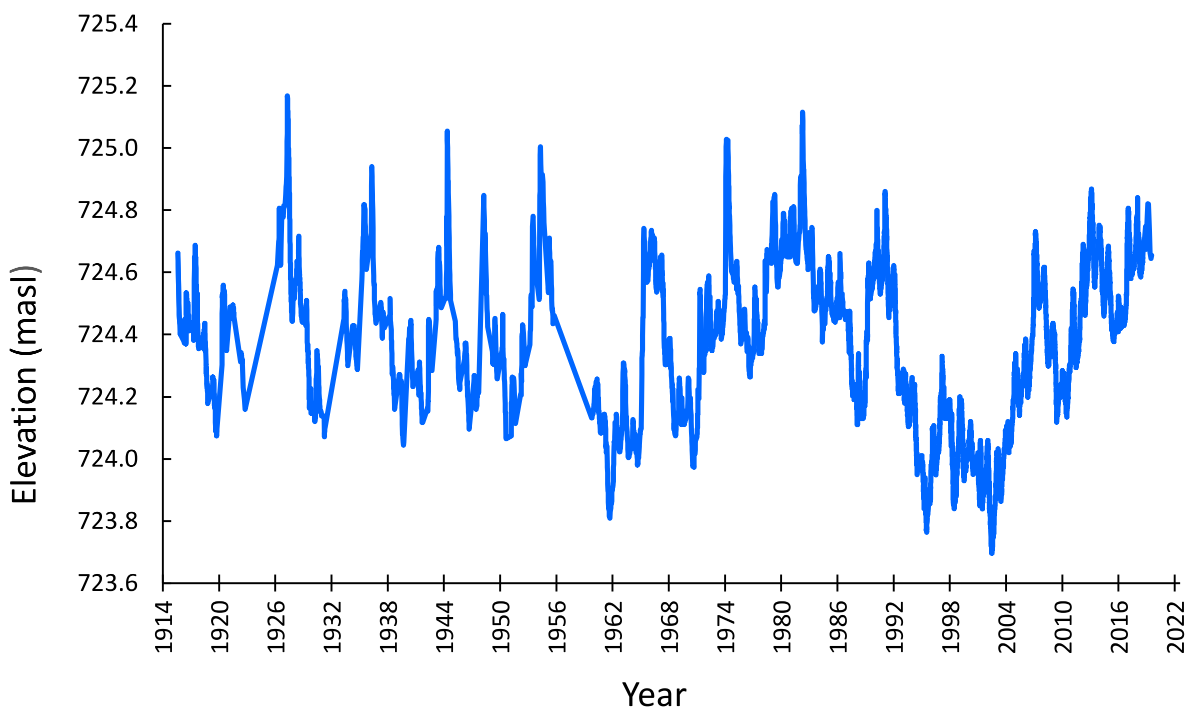


Figure 4. Water levels measured in meters above sea level (masl) from 1915 – 2019. Data retrieved from Environment Canada (1915 – 2018), and Alberta Environment and Parks (2019).

[19] Associated Environmental (2018). Water Quality Status and Trends in Wabamun Lake.

HISTORICAL DATA

Wabamun Lake has been extensively monitored by Alberta Environment, and has composite lake sampling data that dates back to 1980. Over the years, Wabamun Lake has been sampled many different ways, likely to answer specific questions. For instance, there are four different codes in the Alberta Environment database denoting different geographic samplings of the lake.

There is composite lake data for the East Basin, West Basin and Moonlight Bay, and there is data for the Main basin, which represents composite data from the entire lake. As this report aims to report data on Wabamun Lake as a whole, and not to differentiate certain areas of the lake, the data tables represent the most complete, whole lake data, with the exception of three years where only the East Basin was sampled. This means that for years where both the East and West basins were sampled at the same time, the values were averaged to capture a more accurate picture of the whole lake. Main Basin data is reported as is, and years where only the East Basin was sampled are also reported as is (this is only the case for 1982, 2014 and 2016). Generally, sampling occurred once a month from May till October, but some months had multiple samplings during certain years, and in some years' samplings in some months did not occur. This sort of variability in sampling frequency is typical of water quality data, as well as environmental data more generally. Otherwise, Wabamun Lake has a remarkably complete dataset with monthly, multi-basin sampling occurring in 36 years of the past 40 years.

Table 2a. Average historical Secchi depth and water chemistry values for Wabamun Lake (E=East Basin, W=West Basin, M=Main Basin).

Parameter	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989
TP (µg/L)	/	34	30	30	33	18	33	37	35	34
TDP (µg/L)	/	11	10	10	14	6	10	11	13	12
Chlorophyll-*a* (µg/L)	10.3	13.0	11.6	`0.4	11.8	10.6	10.3	12.5	12.0	11.2
Secchi depth (m)	2.15	1.88	/	2.30	1.87	2.46	2.58	2.74	2.86	2.72
TKN (mg/L)	1.2	1.1	0.9	0.8	0.8	0.8	0.9	0.9	1.0	0.9
NO_2-N and NO_3-N (µg/L)	4	6	1	5	6	3	2	7	2	2
NH_3-N (µg/L)	26	62	27	17	22	9	17	19	15	30
DOC (mg/L)	12	13	11	11	11	14	11	11	12	13
Ca (mg/L)	25	24	23	24	23	25	26	26	25	24
Mg (mg/L)	13	13	12	12	12	13	13	13	15	14
Na (mg/L)	41	41	43	45	47	46	47	47	51	49
K (mg/L)	8	8	7	7	8	8	8	8	8	8
SO_4^{2-} (mg/L)	25	30	28	28	26	25	27	30	28	27
Cl^- (mg/L)	2	3	3	3	3	3	4	4	4	5
CO_3 (mg/L)	/	/	/	7	11	5	9	10	11	5
HCO_3 (mg/L)	/	/	/	217	216	223	219	223	225	228
pH	8.23	8.09	8.60	8.52	8.67	8.56	8.67	8.57	8.67	8.43
Conductivity (µS/cm)	408	403	406	412	413	421	421	430	439	428
Hardness (mg/L)	120	113	/	108	108	115	117	119	125	118
TDS (mg/L)	224	231	241	233	237	235	241	247	252	245
Microcystin (µg/L)	/	/	/	/	/	/	/	/	/	/
Total Alkalinity (mg/L $CaCO_3$)	182	184	187	190	195	192	195	198	203	197
Basin Sampled	E, W	E, W	E	M	M	M	M	M	M	M

Table 2b. Average historical Secchi depth and water chemistry values for Wabamun Lake (E=East Basin, W=West Basin, M=Main Basin).

Parameter	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
TP (µg/L)	35	34	35	35	39	36	34	36	36	27
TDP (µg/L)	13	13	12	14	12	12	11	11	11	9
Chlorophyll-*a* (µg/L)	17.2	11.1	13.4	11.6	12.8	11.3	11.2	14.1	13.3	7.6
Secchi depth (m)	2.64	2.13	1.93	2.09	1.90	2.05	2.06	2.28	2.00	2.25
TKN (mg/L)	1.0	0.9	0.9	1.0	1.0	1.0	0.8	0.9	0.9	0.9
NO_2-N and NO_3-N (µg/L)	3	1	1	4	2	3	4	5	5	2
NH_3-N (µg/L)	16	14	9	13	8	10	37	16	15	8
DOC (mg/L)	12	11	12	12	13	12	13	12	/	13
Ca (mg/L)	25	25	25	22	23	23	24	24	22	24
Mg (mg/L)	15	15	15	15	15	16	15	16	15	16
Na (mg/L)	49	46	51	52	54	57	57	57	58	59
K (mg/L)	8	8	8	8	9	9	9	9	9	10
SO_4^{2-} (mg/L)	29	29	31	28	27	30	33	31	31	39
Cl^- (mg/L)	4	4	5	5	5	6	6	9	6	7
CO_3 (mg/L)	10	11	10	11	10	10	8	10	11	9
HCO_3 (mg/L)	223	222	238	235	241	239	237	238	235	249
pH	8.61	8.63	8.70	8.71	8.66	8.62	8.47	8.51	8.51	8.44
Conductivity (µS/cm)	432	435	447	444	452	459	466	470	479	483
Hardness (mg/L)	123	123	123	116	120	123	124	124	120	127
TDS (mg/L)	249	245	257	253	257	268	270	275	271	289
Microcystin (µg/L)	/	/	/	/	/	/	/	/	/	/
Total Alkalinity (mg/L $CaCO_3$)	199	200	203	203	206	212	207	213	212	218
Basin Sampled	M	M	M	M	M	M	M	M	M	E, W

Table 2c. Average historical Secchi depth and water chemistry values for Wabamun Lake (E=East Basin, W=West Basin, M=Main Basin).

Parameter	2000	2001	2002	2003	2004	2005	2006	2007	2008
TP (µg/L)	28	32	28	31	33	30	21	28	22
TDP (µg/L)	9	10	9	9	11	9	5	8	7
Chlorophyll-*a* (µg/L)	7.5	10.9	7.9	10.4	11.2	11.8	10.8	13.9	10.3
Secchi depth (m)	2.12	1.85	2.30	21.8	2.43	2.39	2.70	2.41	2.27
TKN (mg/L)	0.8	0.8	0.8	0.9	0.9	0.9	1.0	0.9	0.9
NO_2-N and NO_3-N (µg/L)	3	6	2	3	4	3	4	4	3
NH_3-N (µg/L)	12	11	13	27	35	29	48	41	57
DOC (mg/L)	12	13	13	12	13	12	12	11	10
Ca (mg/L)	23	21	21	22	23	23	25	26	26
Mg (mg/L)	16	16	16	18	18	18	19	19	20
Na (mg/L)	63	64	65	66	67	67	69	67	70
K (mg/L)	10	9	9	10	10	9	10	9	9
SO_4^{2-} (mg/L)	42	43	51	56	61	69	74	75	77
Cl^- (mg/L)	7	8	9	8	9	10	10	10	12
CO_3 (mg/L)	4	7	8	10	7	9	9	6	10
HCO_3 (mg/L)	253	246	255	240	252	244	240	241	238
pH	8.36	8.50	8.52	8.60	8.55	8.58	8.59	8.50	8.57
Conductivity (µS/cm)	499	492	517	522	528	546	562	561	577
Hardness (mg/L)	125	118	120	127	131	134	140	142	144
TDS (mg/L)	292	291	308	310	321	327	334	333	343
Microcystin (µg/L)	/	/	/	/	/	0.14	/	/	/
Total Alkalinity (mg/L $CaCO_3$)	214	213	222	213	219	215	212	208	211
Basin Sampled	E, W	E, W	E, W	E, W	E, W	E, W	E, W	E, W	E, W

Table 2d. Average historical Secchi depth and water chemistry values for Wabamun Lake (E=East Basin, W=West Basin, M=Main Basin).

Parameter	2010	2011	2012	2013	2014	2016	2019
TP (µg/L)	34	40	33	36	33	33	27
TDP (µg/L)	13	9	14	14	14	12	7
Chlorophyll-*a* (µg/L)	7.9	11.5	11.0	8.8	9.1	9.1	11.1
Secchi depth (m)	1.93	1.47	2.00	1.80	2.00	2.33	2.69
TKN (mg/L)	1.0	1.1	1.0	1.1	1.0	1.0	0.9
NO_2-N and NO_3-N (µg/L)	7	3	3	3	7	14	2
NH_3-N (µg/L)	12	12	17	11	11	16	15
DOC (mg/L)	12	/	11	/	11	12	10
Ca (mg/L)	/	/	/	/	/	/	28
Mg (mg/L)	/	/	/	/	/	/	22
Na (mg/L)	77	73	72	73	75	75	75
K (mg/L)	10	10	10	9	9	9	10
SO_4^{2-} (mg/L)	86	80	85	83	81	80	88
Cl^- (mg/L)	13	13	13	12	13	13	16
CO_3 (mg/L)	8	9	7	10	10	10	7
HCO_3 (mg/L)	243	233	245	239	238	238	255
pH	8.62	8.65	8.50	8.36	8.53	8.51	8.59
Conductivity (µS/cm)	592	583	602	608	607	608	613
Hardness (mg/L)	141	140	146	153	151	150	158
TDS (mg/L)	356	343	353	353	353	356	370
Microcystin (µg/L)	0.10	0.17	0.20	0.10	0.13	0.19	0.12
Total Alkalinity (mg/L $CaCO_3$)	213	207	212	213	212	212	220
Basin Sampled	M	M	M	M	E	E	M

Table 3. Concentrations of metals measured in Wabamun Lake; total recoverable metals have only been determined in 2013 for Wabamun Lake. 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)	2013	**Guidelines**
Aluminum μg/L	30.6	100[a]
Antimony μg/L	0.178	/
Arsenic μg/L	2.77	5
Barium μg/L	131	/
Beryllium μg/L	0.0074	100[c,d]
Bismuth μg/L	<0.001	/
Boron μg/L	921	1500
Cadmium μg/L	0.0106	0.26[b]
Chromium μg/L	0.493	/
Cobalt μg/L	0.0283	1000[d]
Copper μg/L	0.642	4[b]
Iron μg/L	18.96	300
Lead μg/L	0.0624	7[b]
Lithium μg/L	39.7	2500[e]
Manganese μg/L	37.6	5.2
Molybdenum μg/L	4.63	73[c]
Nickel μg/L	0.182	150[b]
Selenium μg/L	0.148	1
Silver μg/L	0.0185	0.25
Strontium μg/L	402	/
Thallium μg/L	0.0008	0.8
Thorium μg/L	0.0055	/
Tin μg/L	0.0423	/
Titanium μg/L	1.20	/
Uranium μg/L	0.456	15
Vanadium μg/L	0.827	100[d,e]
Zinc μg/L	1.07	30

LONG TERM DATA

Wabamun Lake has a fairly unique lake monitoring dataset, as explained above in the Historical Data section, and thus has been analyzed slightly differently than other lakes with long term data. For other lakes' long term trend analysis, any historical data used excludes any data from May and October sampling trips. This was done because generally, the historical data supplements the ALMS data, which is generally more extensive over time, and ALMS does not sample lakes in May and October. Including only a few years where May and October may bias the analysis, as lake conditions within these months are generally different than from June to September. For Wabamun though, as it was part of the provincial long term lake monitoring program, samplings occurred in May and October for the majority of years. Therefore, these month's data were included to improve the analysis' capture of seasonal variability at Wabamun Lake, where bias is reduced because the majority of years include those two months. In addition, unlike the data tables reported above, any year where only one of the East or West basins were sampled was excluded from the trend analysis. Similarly though, the data was averaged between each basin for years where both the East and West and basins where sampled at the same time each month. These steps were taken to best capture the trends for Wabamun Lake as a whole.

Trend analysis was conducted on the parameters total phosphorus (TP), chlorophyll-*a*, total dissolved solids (TDS) and Secchi depth to look for changes from 1980 to 2019 in Wabamun Lake. In summary, significant decreasing trends were observed in TP and in chlorophyll-*a,* significant increasing trends were observed in TDS, and no change was observed in Secchi depth.

Table 4. Summary table of trend analysis on Wabamun Lake data from 1980 to 2019.

Parameter	Date Range	Trend	Probability
Chlorophyll-*a*	1980-2019	Decreasing	Significant
Total Phosphorus	1981-2019	Decreasing	Significant
Total Dissolved Solids	1980-2019	Increasing	Significant
Secchi Depth	1980-2019	No change	Non-significant

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.*

Definitions:

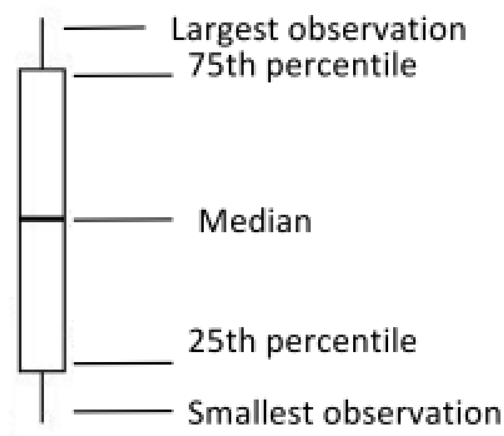
Median: the value in a range of ordered numbers that falls in the middle.

Trend: a general direction in which something is changing.

Monotonic trend: a gradual change in a single direction.

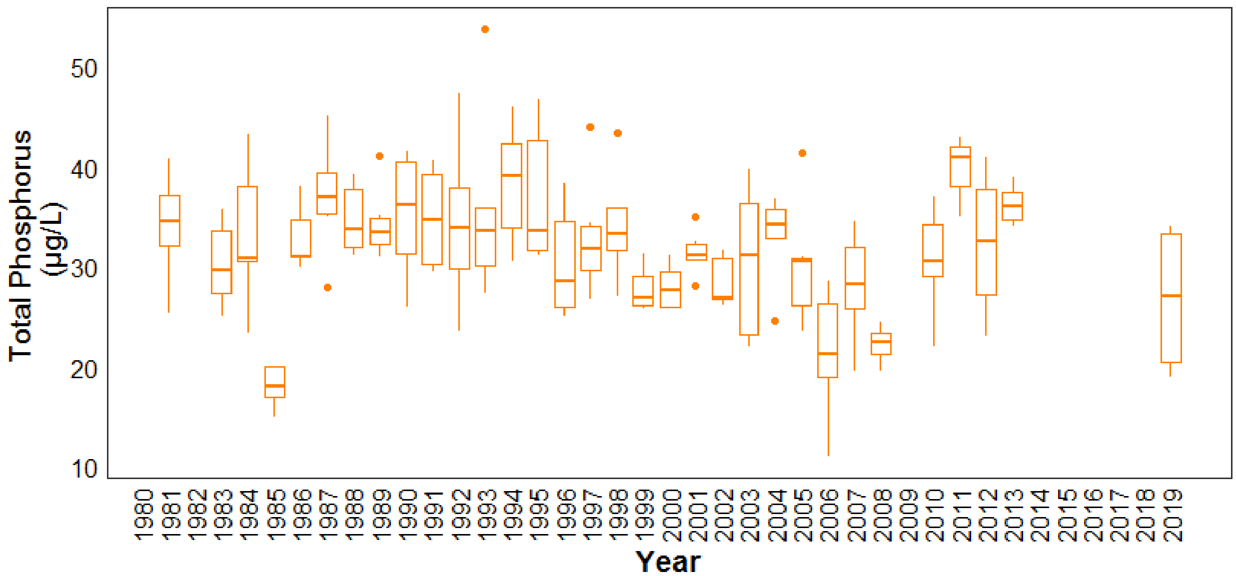
Statistically significant: The likelihood that a relationship between variables is caused by something other than random chance. This is indicated by a p-value of <0.05. Variability: the extent by which data is inconsistent or scattered.

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)

Total phosphorus (TP) decreased significantly between 1981 and 2019 at Wabamun Lake (Tau = -0.17, p = 0.0019). However, the slope was only -0.18 µg/L TP per year, which amounts to a decrease of 7 µg/L of TP over 39 years. So while the decreasing trend is significant, TP has only decreased slightly.



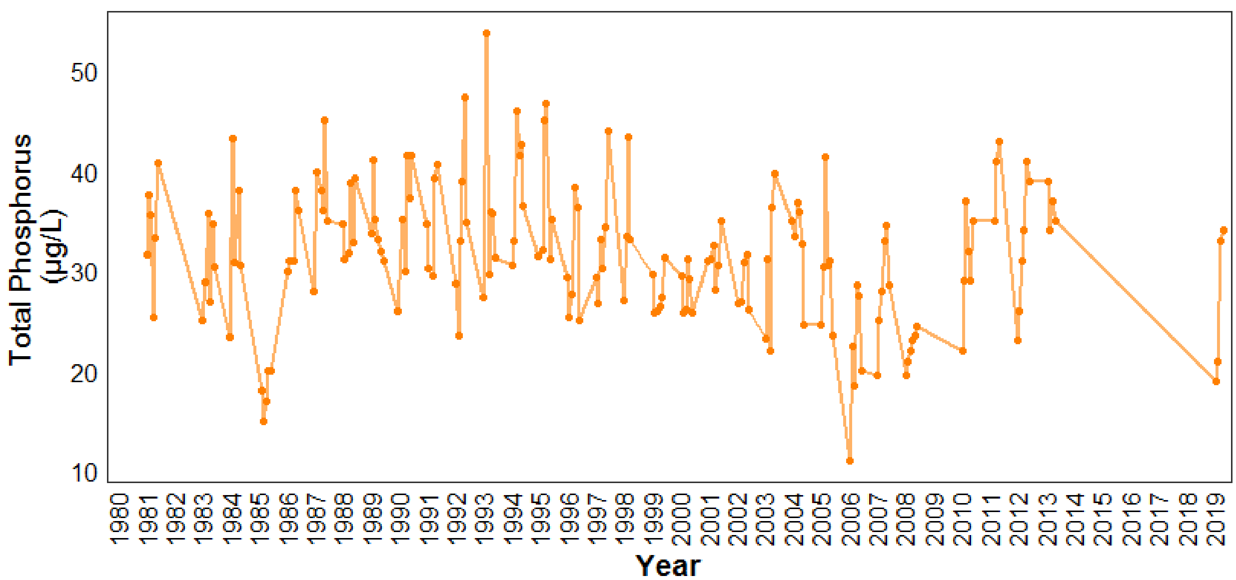
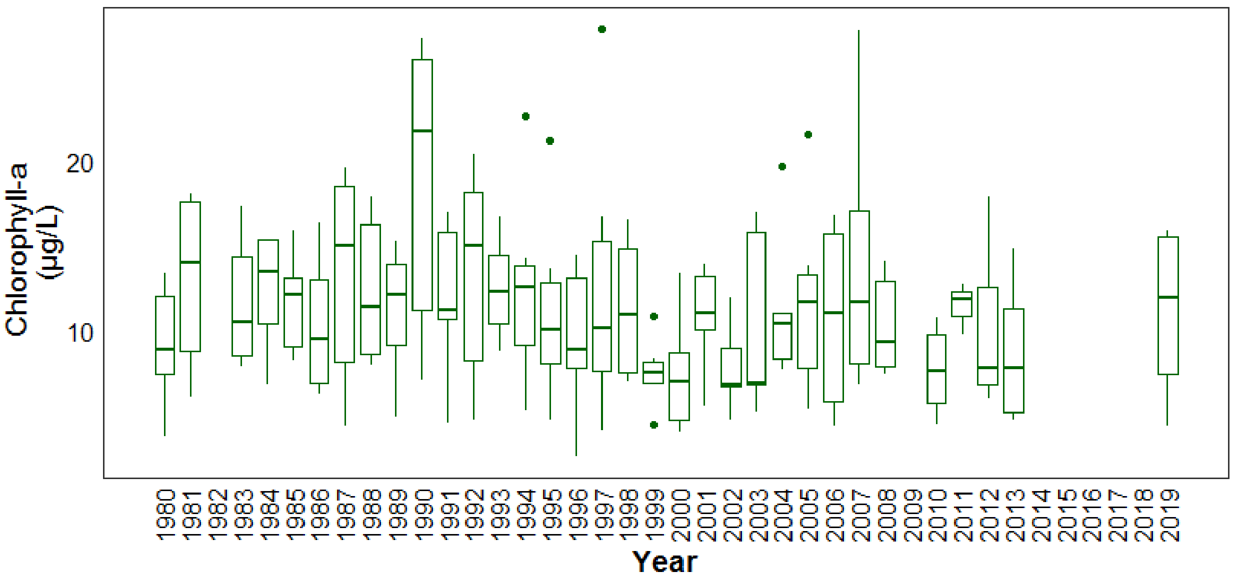


Figure 5. Monthly total phosphorus (TP) concentrations measured between May and October over the long term sampling dates between 1981 and 2019 (n = 178). The value closest to the 15th day of the month was chosen to represent the monthly value in cases with multiple monthly samples.

Chlorophyll-*a*

Chlorophyll-*a* (ChlA) decreased significantly between 1980 and 2019 (Tau = -0.15, p = 0.0031, Table 2). The decrease is also very slight (slope = -0.07 µg/L ChlA per year), only 3 µg/L less in 40 years. In addition, TP and Chlorophyll *a* were significantly correlated (r=0.47, p < 0.001).



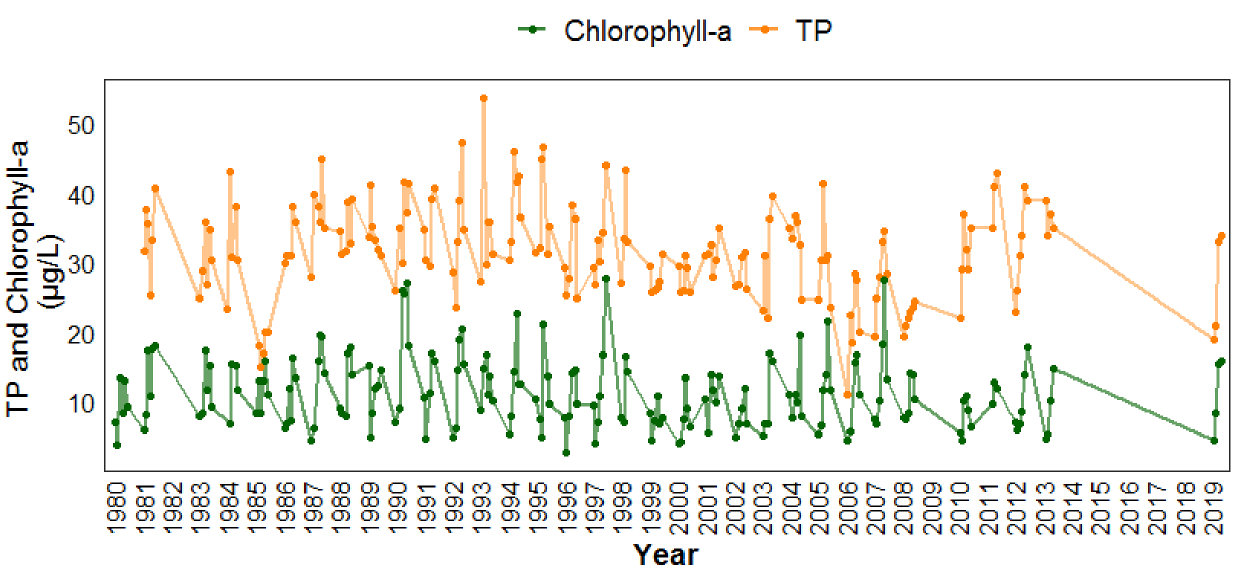


Figure 6. Monthly chlorophyll-*a* concentrations measured between May and October over the long term sampling dates between 1980 and 2019 (N=183). The value closest to the 15th day of the month was chosen to represent the monthly value in cases with multiple monthly samples. Line graph is overlain by TP concentrations.

Total Dissolved Solids (TDS)

Total dissolved solids increased significantly between 1980 and 2019 (Tau = 0.92, $p < 0.001$, Table 2). The increase was appreciable (slope = 4.25 mg/L TDS per year), where the lake saw an increase in TDS of over 150 mg/L in 40 years.

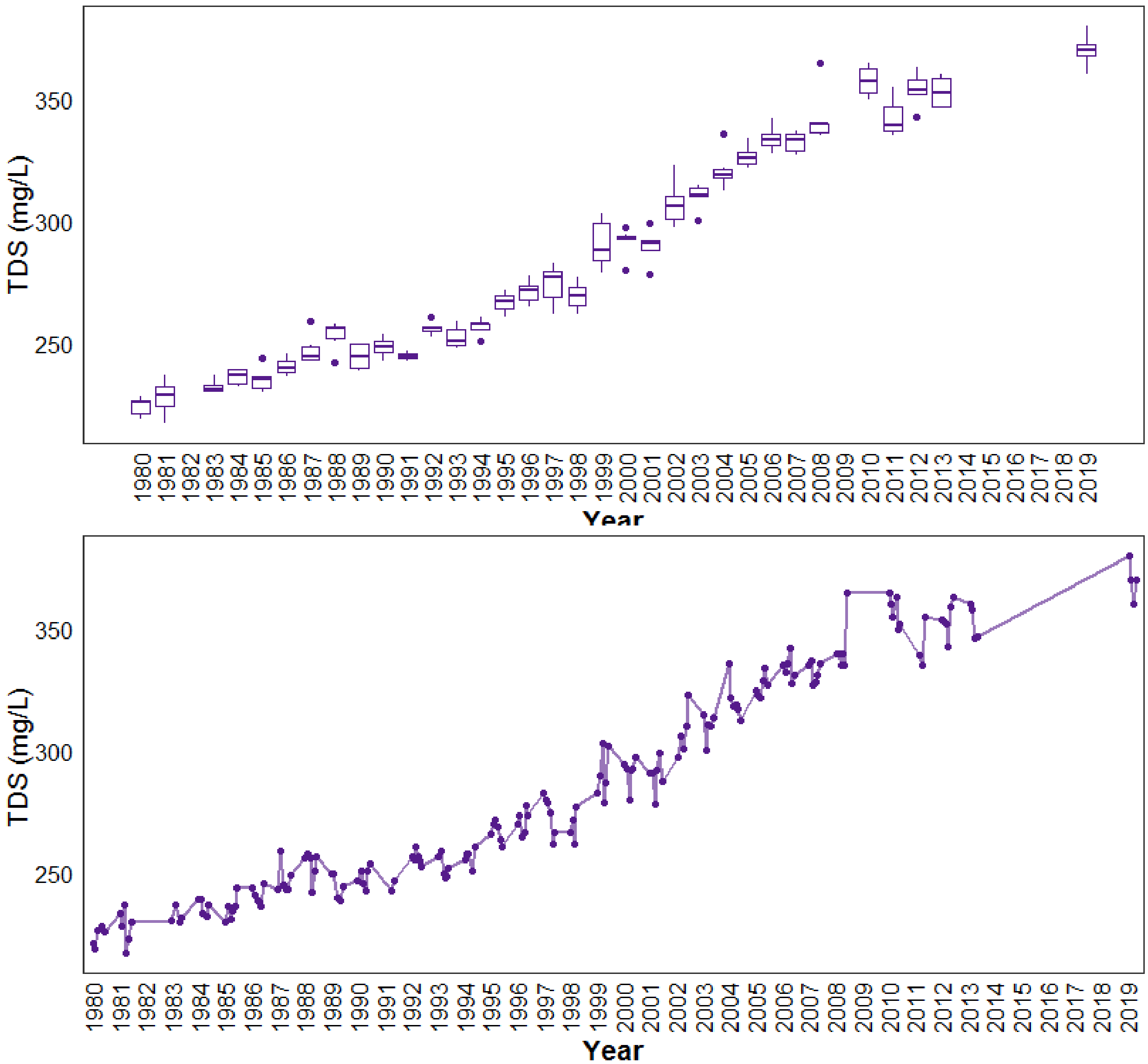
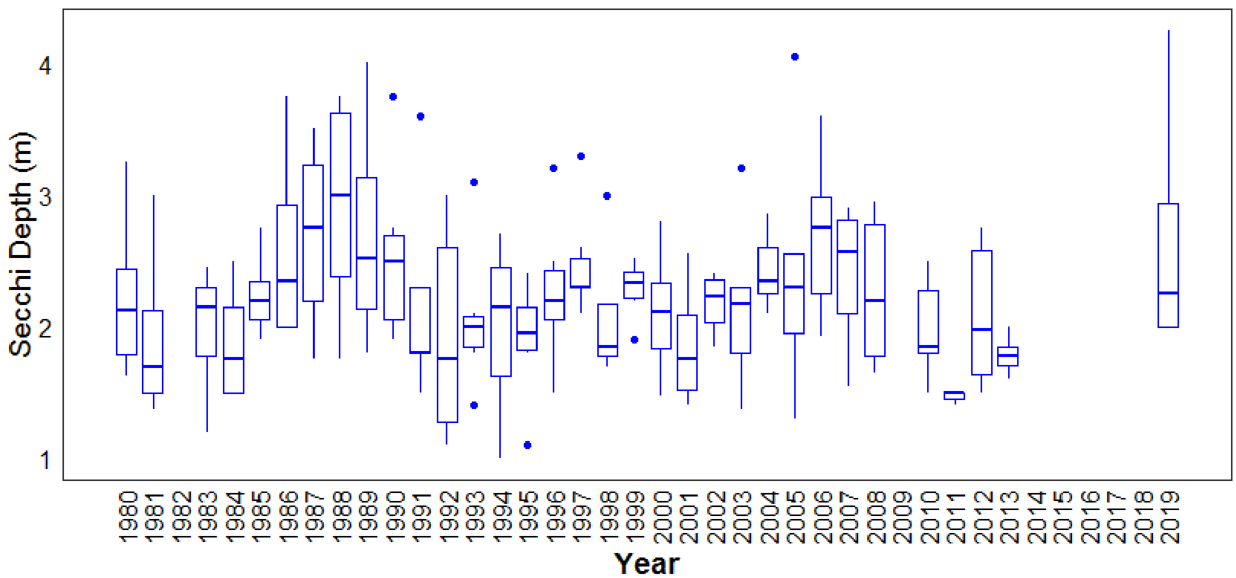


Figure 7. Monthly TDS values measured between May and October over the long term sampling dates between 1980 and 2019 (n = 177). The value closest to the 15th day of the month was chosen to represent the monthly value in cases with multiple monthly samples.

Secchi Depth

Secchi depth did not change significantly between 1980 and 2019 (Tau = 0.001, *p* = 0.88, Table 2).



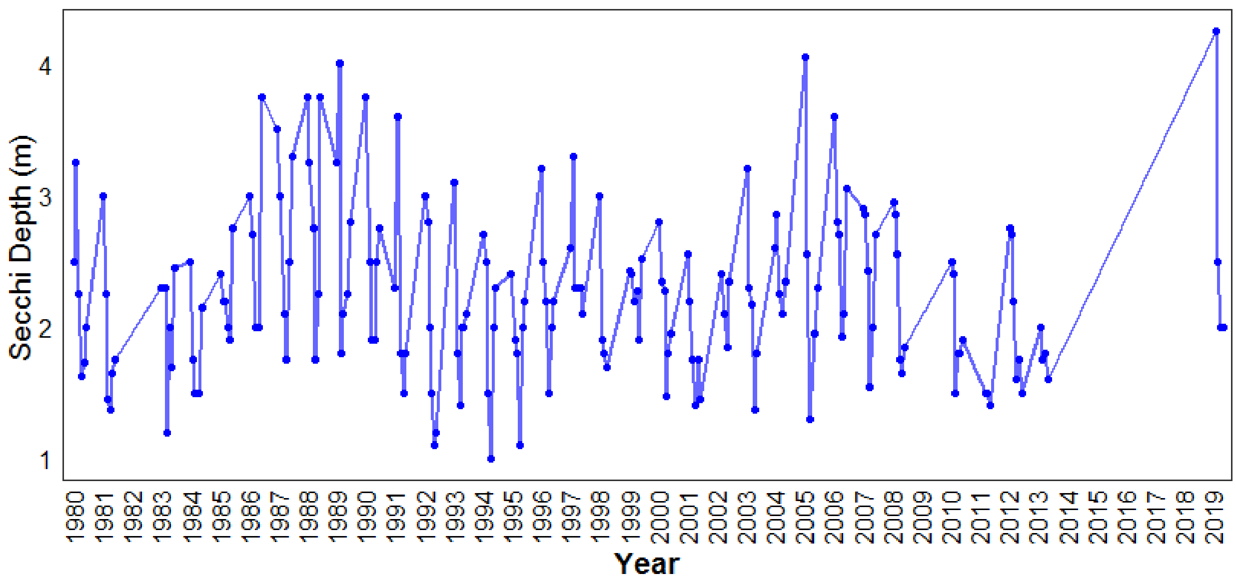


Figure 8. Monthly Secchi depth values measured between May and October over the long term sampling dates between 1980 and 2019 (n = 182). The value closest to the 15th day of the month was chosen to represent the monthly value in cases with multiple monthly samples.

Table 5. Results of Seasonal Kendall Trend test using monthly total phosphorus (TP), chlorophyll-*a* and Secchi depth data from June to September on Wabamun 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	-0.17	-0.15	0.92	0.00
The extent (slope) of the trend	Slope	-0.18	-0.07	4.25	0.00
The statistic used to find significance of the trend	Z	-3.11	-2.96	17.22	0.16
Number of samples included	n	178	183	177	182
The significance of the trend	*p*	0.0019*	0.0031*	1.91×10^{-66}*	0.88

*$p < 0.05$ is significant within 95%

Macrophyte Monitoring

ALMS conducted a bioblitz for macrophytes (aquatic plants) and macro-algae on at Wabamun Lake on July 10, 2019, as a way to identify the composition of the native plant community and to scan for the presence of invasive species. Thirty-one sampling locations were chosen before the bioblitz event, and were selected in order to be representative of the lake's macrophyte communities. At each sample point, volunteers threw a double sided rake over the side the sampling vessel, and bagged or identified plants collected. If comfortable doing so, volunteers also identified plants which could be seen from the canoe but which were not collected with a rake throw.

In total, not including emergents such as rushes and reeds, 13 unique macrophytes were identified. Four additional categories, *Potamogeton* spp., *Chara* spp., Bladderwort (*Utricularia* spp.), and White Water-Crowfoot (*Ranunculus* spp.) were included to categorize individuals which were unidentifiable to species within the *Potamogeton*, *Chara. Utricularia,* or *Ranuculus* genera. An additional group, Aquatic Moss, was also identified. In total, 99 observations were made (Table 4). Identified plants included Arrowhead (*Saggitaria latifolia*), Northern Watermilfoil (*Myriophyllum sibricum*), Richardson's Pondweed (*Potamogeton richardsonii*), Yellow Pond Lily (*Nuphar lutea*), Spiral Ditch Grass (*Ruppia cirrhosa*), Floating Leaf Pondweed (*Potamogeton natans*), Sheathed Pondweed (*Stuckenia vaginata*), Sago Pondweed (*Stuckenia pectinate*), Flat-Stemmed Pondweed (*Potamogeton compressus*), Coontail (*Ceratophyllum demersum*), Canada Waterweed (*Elodea canadensis*), Water Smartweed (*Persicaria amphibia*) and Small Pondweed (*Potamogeton pusillus*). No invasive species were detected in 2019.

Table 6. The number of observations of each plant species during the 2019 bioblitz at Wabamun Lake.

Common Name	# Observations
Chara spp.	24
Northern Watermilfoil	16
Richardson's Pondweed	9
Sheathed Pondweed	9
Bladderwort	6
Sago Pondweed	4
Spiral Ditch Grass	4
Potamogeton spp.	4
Aquatic Moss	4
Flat-Stemmed Pondweed	3
Yellow Pond Lily	3
White Water-Crowfoot	3
Coontail	3
Arrowhead	2
Floating Leaf Pondweed	2
Canada Waterweed	1
Water Smartweed	1
Small Pondweed	1
TOTAL OBSERVATIONS	**99**

Figure 9a. Macrophytes collected at Wabamun Lake on July 10, 2019. Starting from top left and going clockwise: Flat-Stemmed Pondweed (*Potamogeton compressus*), Coontail (*Ceratophyllum demersum*), White Water-Crowfoot (*Ranunculus* spp.), and Bladderwort (*Utricularia* spp.).

Figure 9b. Macrophytes collected at Wabamun Lake on July 10, 2019. Starting from top left and going clockwise: Northern Watermilfoil (*Myriophyllum sibricum*), *Chara* spp., Floating Leaf Pondweed (*Potamogeton natans*), and Water Marigold (*Bidens bidens*).

Figure 9c. Macrophytes collected at Wabamun Lake on July 10, 2019. Starting from top left and going clockwise: Sheathed Pondweed (*Stuckenia vaginata*), Small Pondweed (*Potamogeton pusillus*), Richardson's Pondweed (*Potamogeton richardsonii*), and Sago Pondweed (*Stuckenia pectinate*).

Figure 9d. Macrophytes collected at Wabamun Lake on July 10, 2019. Starting from top left and going clockwise: Spiral Ditch Grass (*Ruppia cirrhosa*), Yellow Pond Lily (*Nuphar lutea*), and Water Smartweed (*Persicaria amphibia*). Also pictured is the group of volunteers who participated in the bioblitz at Wabamun Lake on July 10, 2019.