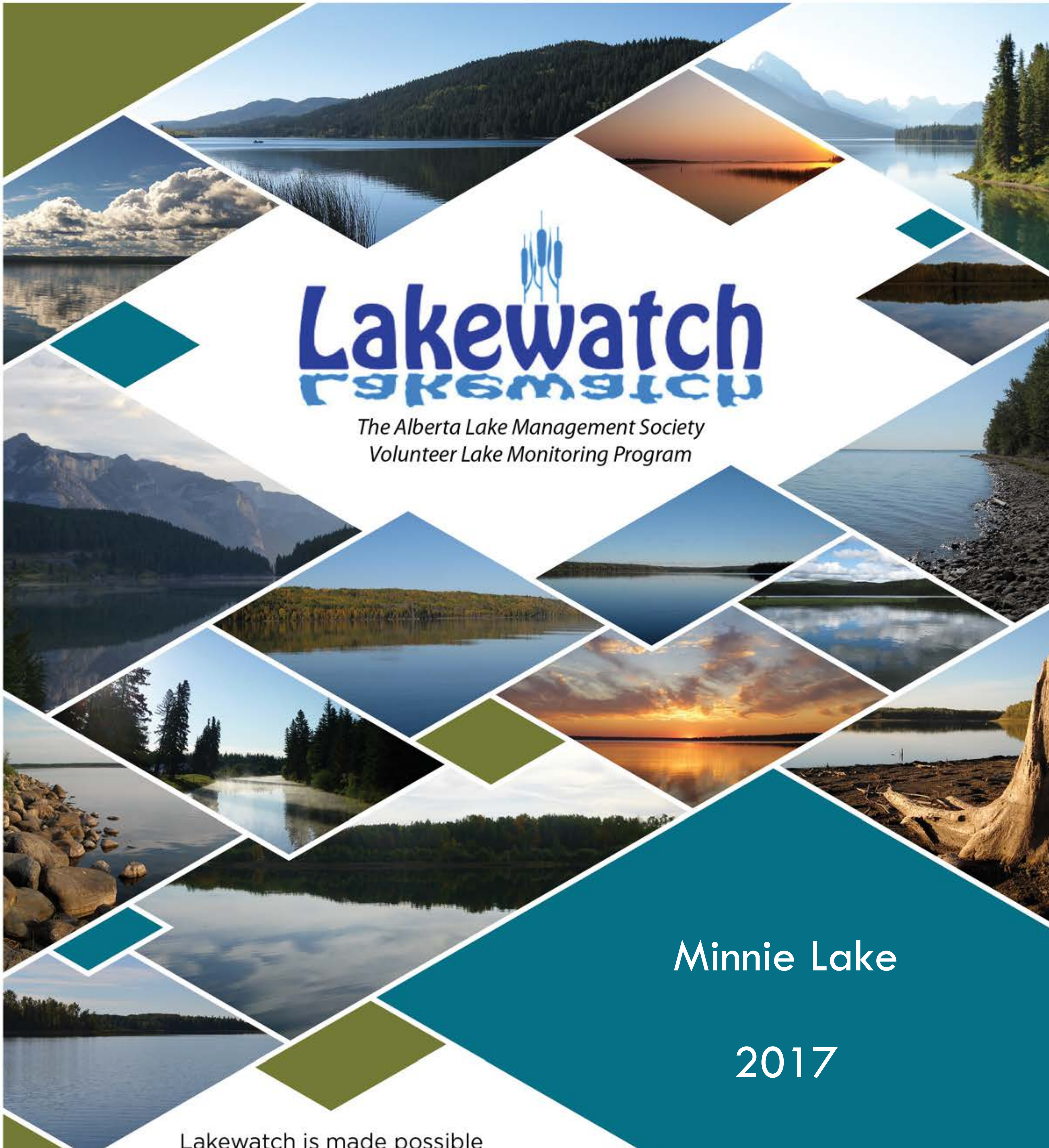

Lakewatch

The Alberta Lake Management Society
Volunteer Lake Monitoring Program

Minnie Lake

2017

Lakewatch is made possible with support from:

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LICA Lakeland Industry & Community Association
Red Deer River Watershed Alliance
Beaver River Watershed Alliance
Alberta Environment and Parks

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.

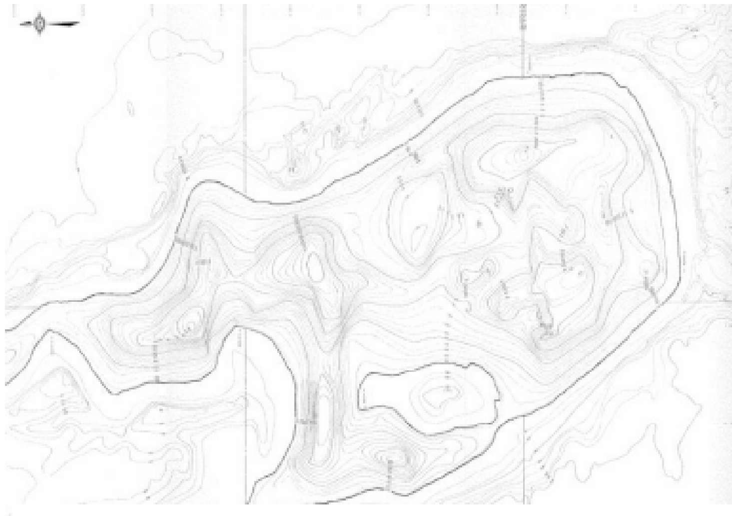
ALMS is happy to discuss the results of this report with our stakeholders. If you would like information or a public presentation, contact us at info@alms.ca.

ACKNOWLEDGEMENTS

The LakeWatch program is made possible through the dedication of its volunteers. We would like to extend a special thanks to Garry and Nadine Kissel for the time and energy put into sampling Minnie Lake in 2017. We would also like to thank Elashia Young and Melissa Risto who were summer technicians in 2017. Executive Director Bradley Peter and LakeWatch Coordinator Laura Redmond was instrumental in planning and organizing the field program. This report was prepared by Laura Redmond and Bradley Peter. The Beaver River Watershed, the Lakeland Industry and Community Association, Environment Canada, and Alberta Environment and Parks are major sponsors of the LakeWatch program.

MINNIE LAKE

Minnie Lake is a small lake located west of Bonnyville and northeast of Glendon within the Beaver River Watershed. The lake is 2 km long and 0.6 km wide, with a surface area of 0.84 km^2. Mean depth is 8.3 m and maximum depth is 21.45 m, though water levels have decreased since these values were calculated. The shoreline of the lake hosts two municipal campsites, private cabins and recreational properties, agricultural land, and boreal forest. Minnie Lake is spring-fed by the Beverly channel aquifer and surface runoff from precipitation.



Bathymetric map of Minnie Lake (Trew 1986)

In 2006-2007 the lake experienced a winterkill, which decimated stocks of northern pike and yellow perch that previously supported a recreational fishery. Fish populations have not recovered to date.

Minnie Lake- photo by Laura Redmond 2017

The watershed area for Minnie Lake is 4.43 km^2 and the lake area is 0.67 km^2. The lake to watershed ratio of Minnie Lake is 1:7. A map of the Minnie Lake watershed area can be found at http://alms.ca/wp-content/uploads/2016/12/Minnie.pdf

METHODS

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

Composite samples: At 10-sites across the lake, water is collected from the euphotic zone and combined across sites into one composite sample. This water is collected for analysis of water chemistry, chlorophyll-a, nutrients and microcystin. Quality control (QC) data for total phosphorus was taken as a duplicate true split on one sampling date. ALMS uses the following accredited labs for analysis: Routine water chemistry and nutrients are analyzed by Maxxam Analytics, chlorophyll-*a* and metals are analyzed by Alberta Innovates Technology Futures (AITF), 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. For lakes with >10 years of long term data, trend analysis is done with non-parametric methods. Mann Kendall tests are used with non-normal data to assess unidirectional trends over time in a dataset (a non-parametric linear regression).

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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 Minnie Lake was 28.6 µg/L (Table 2), falling into the mesotrophic, or moderately productive, trophic classification. This value falls within the range of historical records. TP decreased for the extent of the sampling season (Figure 1).

Average chlorophyll-*a* concentration in 2017 was 9.4 µg/L (Table 2), putting Minnie Lake just into the eutrophic, or productive classification. Chlorophyll-*a* concentrations were highest on Jun 12, measuring 16.3 µg/L (Figure 1).

Finally, the average total Kjeldahl nitrogen (TKN) concentration was 1.46 mg/L (Table 2), and the maximum concentration was measured on August 8.

Average pH was measured as 8.84 in 2017, buffered by moderate alkalinity (344 mg/L $CaCO_3$) and bicarbonate (354 mg/L HCO_3). Sulphate and magnesium were the dominant ions contributing to a high conductivity of 1320 µS/cm (Table 2).

METALS

Samples were analyzed for metals (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 on August 21 at Minnie Lake at the surface. Arsenic was measured as above the recommended guideline measuring 9.65 µg/L. Historically, arsenic levels have been high at Minnie Lake. In 2017, all other measured values fell within their respective guidelines (Table 3).

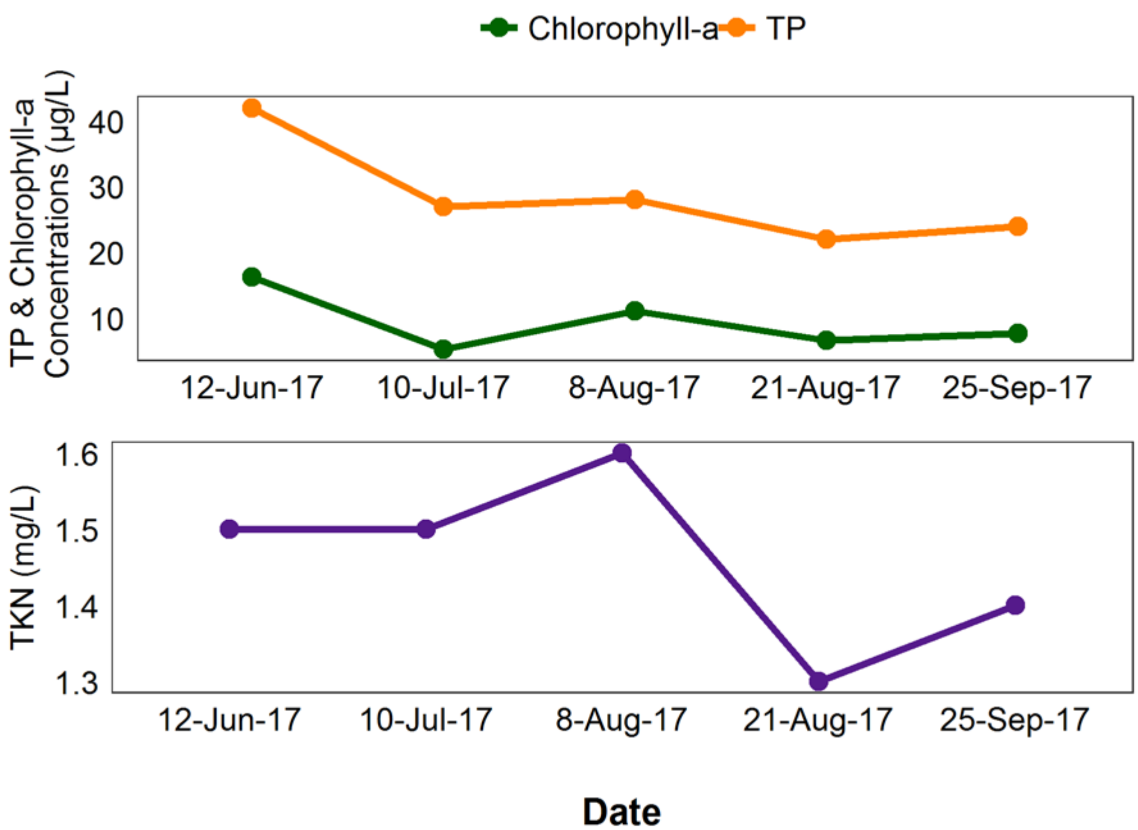


Figure 1- Total Phosphorus (TP), Total Kjeldahl Nitrogen (TKN), and Chlorophyll-*a* concentrations measured five times over the course of the summer at Minnie Lake.

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 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 Minnie Lake in 2017 was 1.86 m (Table 2). Water clarity measured as Secchi depth stayed within a small range of change throughout the sampling season, between 1.5 m and 2 m.

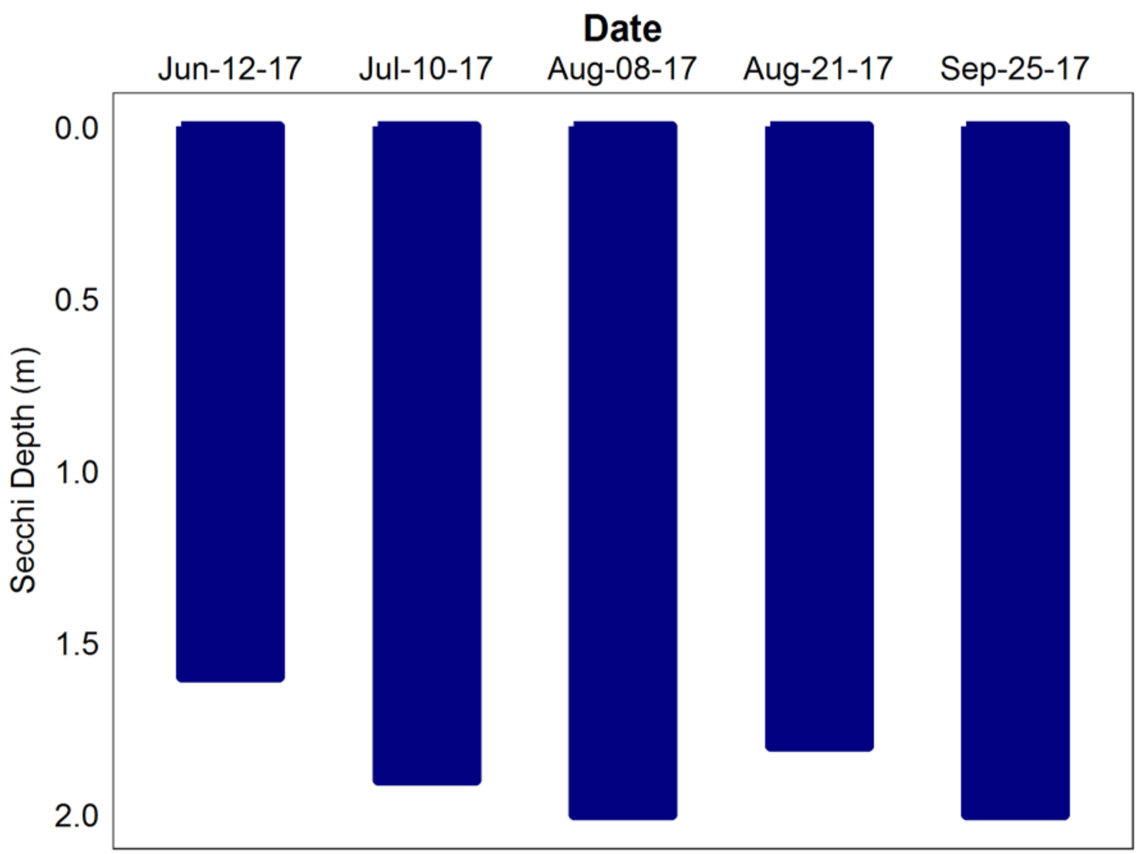


Figure 2 – Secchi depth values measured five times over the course of the summer at Minnie Lake in 2017.

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 Minnie Lake varied throughout the summer, with a maximum temperature of 23.7 °C measured at the surface on July 10 (Figure 3a). The lake was strongly stratified for the extent of the sampling season, with the thermocline deepening as the lake warmed.

Minnie Lake remained well oxygenated at the surface throughout the summer, measuring above the CCME guidelines of 6.5 mg/L for the Protection of Aquatic Life (Figure 3b). During thermal stratification, oxygen levels decreased near the bottom due to separation from atmospheric oxygen that is circulated at the lake's surface.

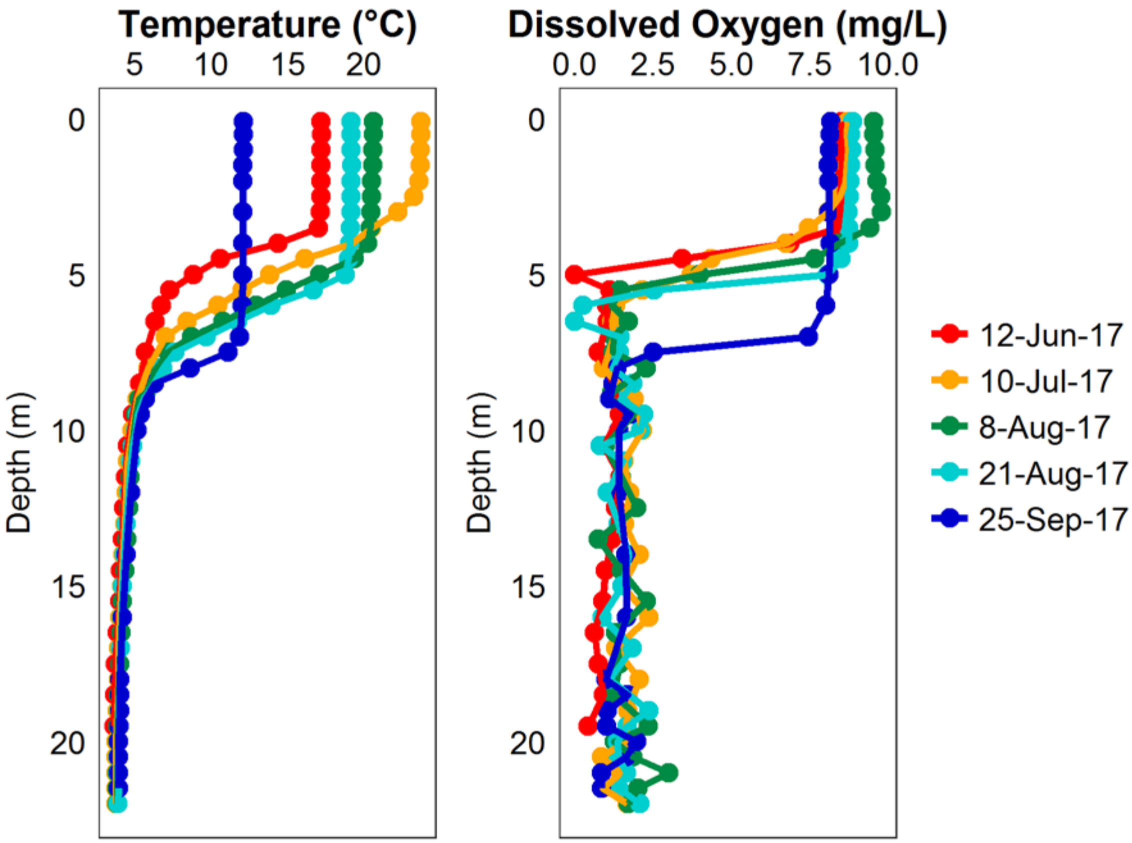


Figure 3 – a) Temperature (°C) and b) dissolved oxygen (mg/L) profiles for Minnie Lake measured five times over the course of the summer of 2017.

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 Minnie Lake fell below the recreational guideline for the entire sampling period of 2017 (Table 1).

Table 1 – Microcystin concentrations measured five times at Minnie Lake in 2017.

Date	Microcystin Concentration (µg/L)
Jun-12-17	0.11
Jul-10-17	0.12
Aug-08-17	0.12
Aug-21-17	0.11
Sep-25-17	0.13
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 two components: monitoring for juvenile mussel veligers using a plankton net and monitoring for attached adult mussels using substrates installed in each lake. No mussels have been detected in Minnie Lake since invasive species monitoring began in 2013.

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 Minnie Lake have declined since Alberta Environment began monitoring the lake in 1981 (Figure 4). Since 1981, Minnie Lake water levels have fluctuated and declined 3.3 m from 554.5 m asl and 551.2 m asl. Data from Alberta Environment was only available until 2014.

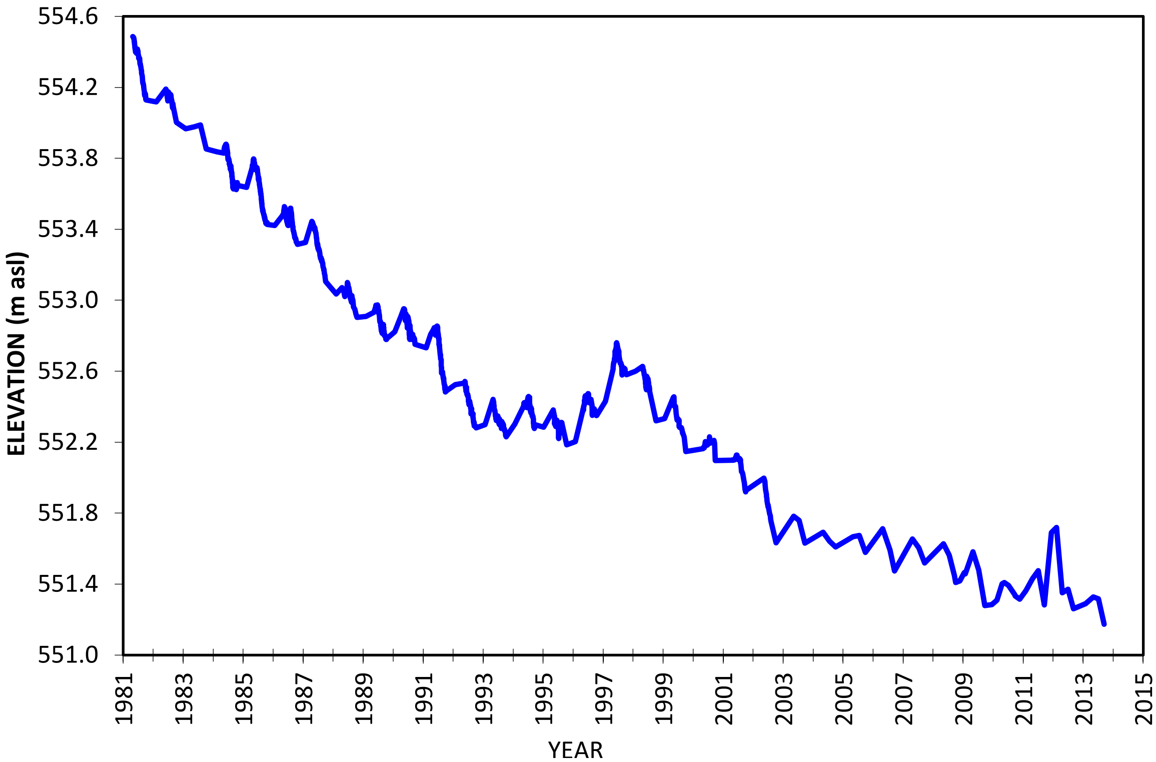


Figure 4- Water levels measured in meters above sea level (m asl) from 1981- 2014. Data retrieved from Alberta Environment.

Table 2: Average Secchi depth and water chemistry values for Minnie Lake. Historical values are given for reference.

Parameter	**1978**	**1979**	**1985**	**2008**	**2009**	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**
TP (µg/L)	/	/	21	40	42.25	38.8	52.4	44.75	32.2	33.75	24.4	19	28.6
TDP (µg/L)	/	/	11	23.8	22.5	27	25.6	22	21.2	24.25	10.6	8	9.52
Chlorophyll-*a* (µg/L)	/	/	6	5.26	4.03	3.44	5.16	6.42	3.02	4.1*	4.76	7	9.4
Secchi depth (m)	/	/	/	4.5	2.19	4.7	3.85	3.81	3.32	3.67	2.55	1.9	1.86
TKN (mg/L)	/	/	1.153	1.504	1.533	1.608	1.834	1.655	1.644	1.460	1.520	1.48	1.46
NO_2-N and NO_3-N (µg/L)	/	/	6	21	7.625	12.1	13.9	11.38	2.5	38	2.5	2.5	2.26
NH_3-N (µg/L)	/	/	50	6.2	35.75	99.2	35	42.25	23.6	50.2	31	25	21.6
DOC (mg/L)	/	/	13.2	18.27	19.5	19.6	19	19.4	22.03	17.7	18	18.6	17.6
Ca (mg/L)	29	30	19.4	26.6	25.73	21.8	25.6	24.2	22.93	22.67	26.4	22.6	29.2
Mg (mg/L)	90	87	91	120.3	121.3	123.3	131.3	121	143.67	124	144	142	136
Na (mg/L)	62	61	68	94.23	96.6	97.2	95.8	95.63	98.9	103.33	95.5	96.6	93
K (mg/L)	11.7	9.4	13.1	23.3	19.07	18.57	18.5	19.87	21.03	20.17	20	20	19.6
SO_4^{2-} (mg/L)	223	211	197	398.7	421	408.67	400	450.7	391	433.33	440	428	420
Cl^- (mg/L)	3	3	4.4	7.13	6.93	7.47	7.3	7.6	6.8	7.5	7.95	7.86	7.82
CO_3 (mg/L)	/	/	21	25.67	31.33	23	29	28	44.8	37.94	36.8	37.8	32.2
HCO_3 (mg/L)	340	398	368	408.3	389.67	412	393.4	398	358.6	424.6	376	360	354
pH	8.9	8.6	8.6-8.9	8.627	8.8	8.65	8.77	8.73	8.88	8.78	8.82	8.86	8.84
Conductivity (µS/cm)	922	981	992	1340	1323.3	1370	1350	1367.5	1418	1360	1400	1400	1320
Hardness (mg/L)	442	435	422	561.67	563.67	562.3	605	558.3	648.67	567	660	634	630
TDS (mg/L)	614	611	595	897.3	914	902.67	902	943.3	906	948.33	962	932	912
Microcystin (µg/L)	/	/	/	0.1275	0.1125	0.076	0.11	0.135	0.088	0.076	0.07	0.11	0.12
Total Alkalinity (mg/L $CaCO_3$)	324	316	338	378.3	371.67	376	371.2	373	369	352	370	356	344

*Value has been corrected April 11 2019

Table 3: Concentrations of metals measured once in Minnie Lake. The CCME heavy metal Guidelines for the Protection of Freshwater Aquatic Life (unless otherwise indicated) are presented for reference. Values in red exceed the recommended guidelines.

Metals (Total Recoverable)	**2008**	**2009**	**2010**	**2011**	**2013**	**2014**	**2015**	**2016**	**2017**	**Guidelines**
Aluminum µg/L	13.7	13	14.26	14.84	22.55	17.4	9.95	7.1	3.9	100[a]
Antimony µg/L	0.382	0.375	0.392	0.3725	0.3685	0.349	0.3985	0.415	0.395	/
Arsenic µg/L	9.15	9.33	9.56	9.07	9.83	9.875	10.36	8.34	9.65	5
Barium µg/L	20.6	18.7	18.5	18.25	12.65	12.35	14.9	12	17.4	/
Beryllium µg/L	<0.003	<0.003	0.005	0.0015	0.0057	0.004	0.004	0.004	0.0055	100[c,d]
Bismuth µg/L	0.0073	0.0057	0.00385	0.0005	0.00795	0.0005	0.0005	5.00E-04	0.0055	/
Boron µg/L	162	205.5	159.5	204.5	186.5	185	185	187	194	1500
Cadmium µg/L	0.0124	0.0187	0.01725	0.01385	0.0036	0.00186	0.002	0.001	0.025	0.26[b]
Chromium µg/L	0.494	0.394	0.169	0.2575	0.3065	0.292	0.125	0.07	0.25	/
Cobalt µg/L	0.111	0.092	0.0972	0.07485	0.09775	0.0687	0.0875	0.102	0.124	1000[d]
Copper µg/L	0.332	2.09	0.6815	1.0825	1.3	0.9025	1.665	1.48	2.7	4[b]
Iron µg/L	10.9	43.6	16.1	8.9	29.3	16.85	13.1	10.7	9	300
Lead µg/L	0.0274	0.0544	0.0851	0.03275	0.0617	0.01115	0.029	0.03	0.01	7[b]
Lithium µg/L	74.1	101.5	84.05	106.5	93.95	92.95	89.3	101	99.8	2500[e]
Manganese µg/L	8.61	6.36	5.905	15.75	4.515	6.78	7.38	2.94	5.44	200[e]
Molybdenum µg/L	0.799	0.727	0.746	0.735	0.6685	0.5695	0.6185	0.597	0.484	73[c]
Nickel µg/L	0.271	0.665	0.3805	0.15125	0.5225	0.3475	0.3825	0.775	1.87	150[b]
Selenium µg/L	0.2	0.292	0.232	0.228	0.089	0.123	0.085	0.12	0.5	1
Silver µg/L	0.0022	0.0082	0.0029	0.00025	0.01125	0.001	0.001	0.001	0.0025	0.25
Strontium µg/L	74	69.7	55	73.25	49.7	58.7	76	50.1	84.4	/
Thallium µg/L	0.0026	0.0029	0.00555	0.000275	0.0015	0.00085	0.00045	9.0E-04	0.011	0.8
Thorium µg/L	0.0628	0.00215	0.01825	0.01015	0.0321	0.01137	0.002225	0.0086	0.01	/
Tin µg/L	0.0308	<0.03	0.015	0.015	0.015	0.00825	0.0135	0.01	0.15	/
Titanium µg/L	0.667	0.691	1.0995	0.686	1.1145	0.685	0.875	0.54	0.42	/
Uranium µg/L	2.3	2.08	2.16	2.14	2.1	2.165	2.26	2.31	2.02	15
Vanadium µg/L	1.31	1.22	1.165	1.06	1.035	1.04	1.265	1.36	0.957	100[d,e]
Zinc µg/L	1.58	1.34	1.165	1.48	1.465	1.58	1.55	2.3	3.8	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 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 Minnie Lake. In summary, non-significant increasing trends were observed in chlorophyll-*a* and TDS and significant decreasing trends were observed in Secchi depth and TP. 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) and a box-and-whisker plot. Detailed methods are available in the *ALMS Guide to Trend Analysis on Alberta Lakes.*

Table 1: Summary table of trend analysis on Minnie Lake data from 2008 to 2017.

Parameter	Date Range	Trend	Probability
Total Phosphorus	2008-2017	Decreasing	Significant
Chlorophyll-*a*	2008-2017	Increasing	Non-significant
Total Dissolved Solids	2008-2017	Increasing	Non-significant
Secchi Depth	2008-2017	Decreasing	Significant

Definitions:

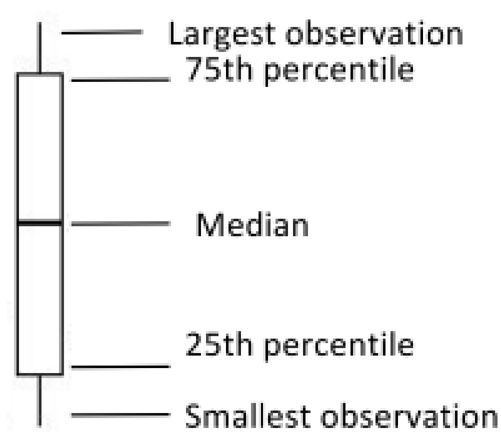
Median: the value in a range of ordered numbers that falls in the middle.

Trend: a general direction in which something is changing.

Monotonic trend: a gradual change in a single direction.

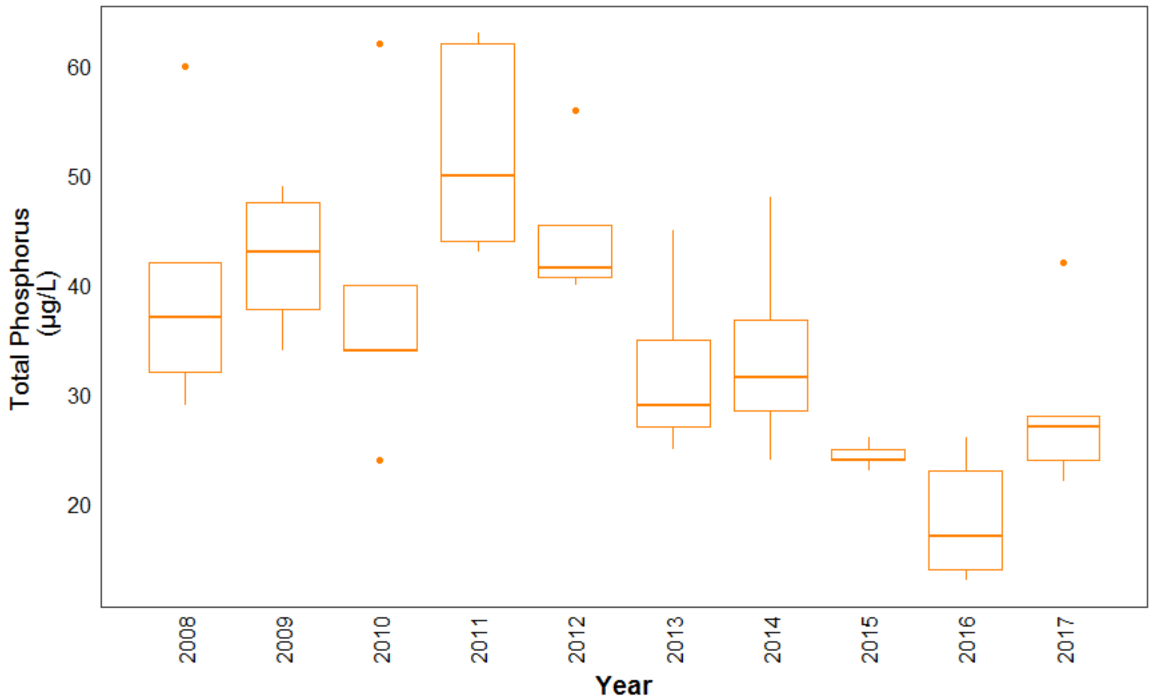
Statistically significant: The likelihood that a relationship between variables is caused by something other than random chance. This is indicated by a p-value of <0.05. Variability: the extent by which data is inconsistent or scattered.

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



Total Phosphorus (TP)

Total phosphorus (TP) has decreased significantly over the course of data collection at Minie Lake (Tau = -0.46, $p < 0.001$).



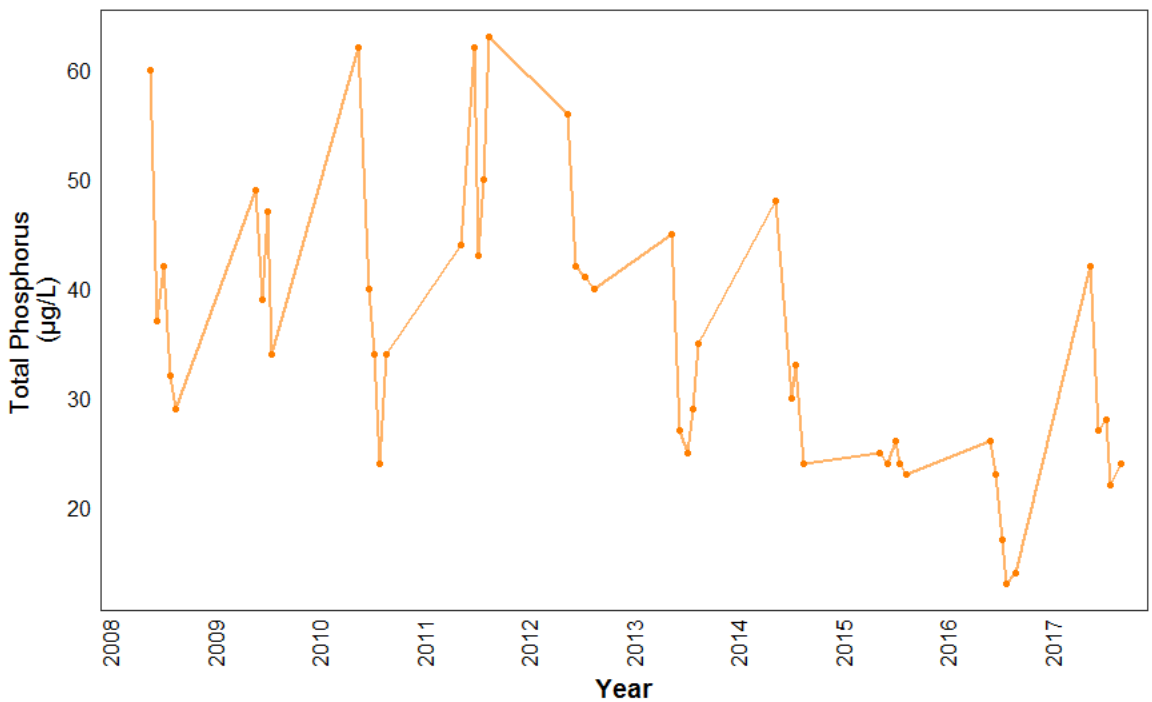
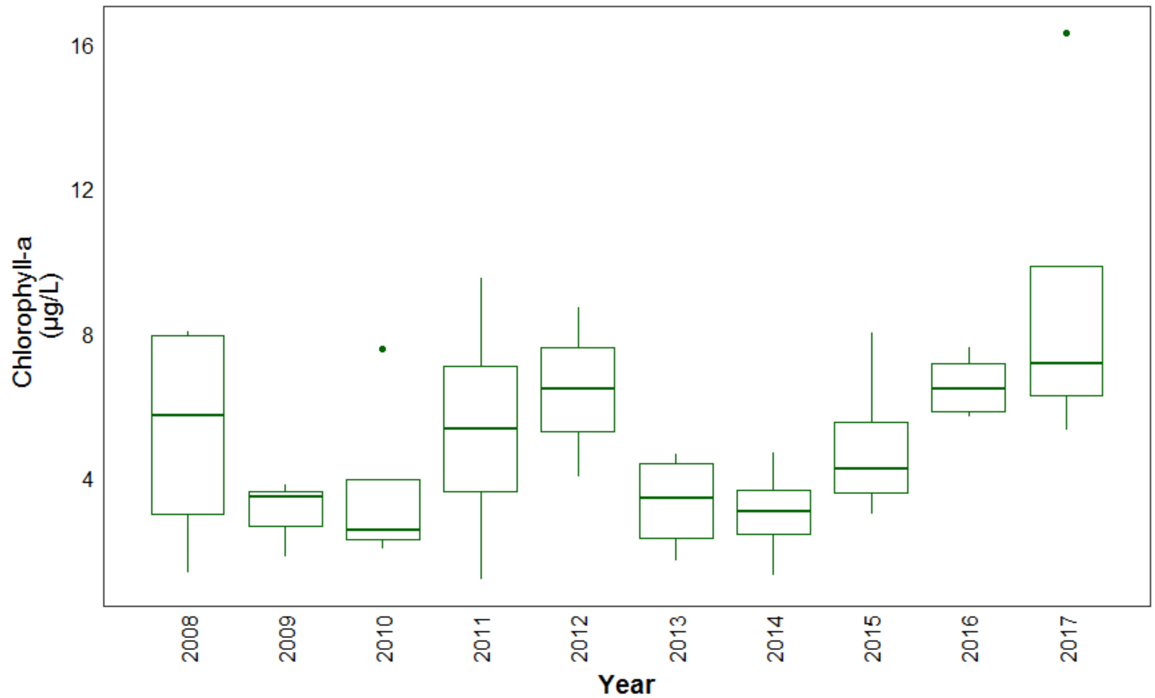


Figure 1- Total phosphorus (TP) concentrations measured between June and September over the long term sampling dates between 2008 and 2017 (n = 47). All data used in trend analysis is shown. Note: One outlier from July 14, 2017 was removed because the sample exceeded hold time at the lab and was not an accurate value.

Chlorophyll-*a*

Chlorophyll-*a* has not changed significantly since sampling began at Minnie Lake (p = 0.1, Table 2).



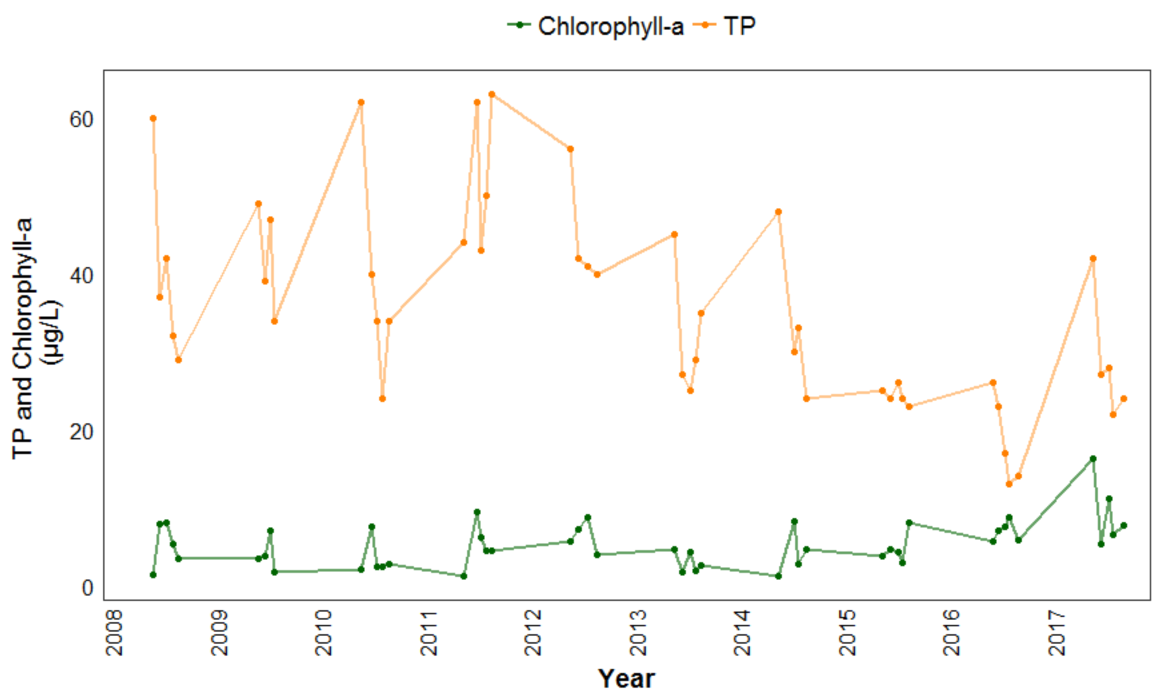


Figure 2-Monthly chlorophyll-*a* concentrations measured between June and September over the long term sampling dates between 2008 and 2017 (N=39). The value closest to the 15th day of the month was chosen to represent the monthly value in cases with multiple monthly samples. Line graph is overlain by TP concentrations.

Total Dissolved Solids (TDS)

Total dissolved solids have not significantly changed since sampling began in 2008 (Tau= 0.1, p = 0.20).

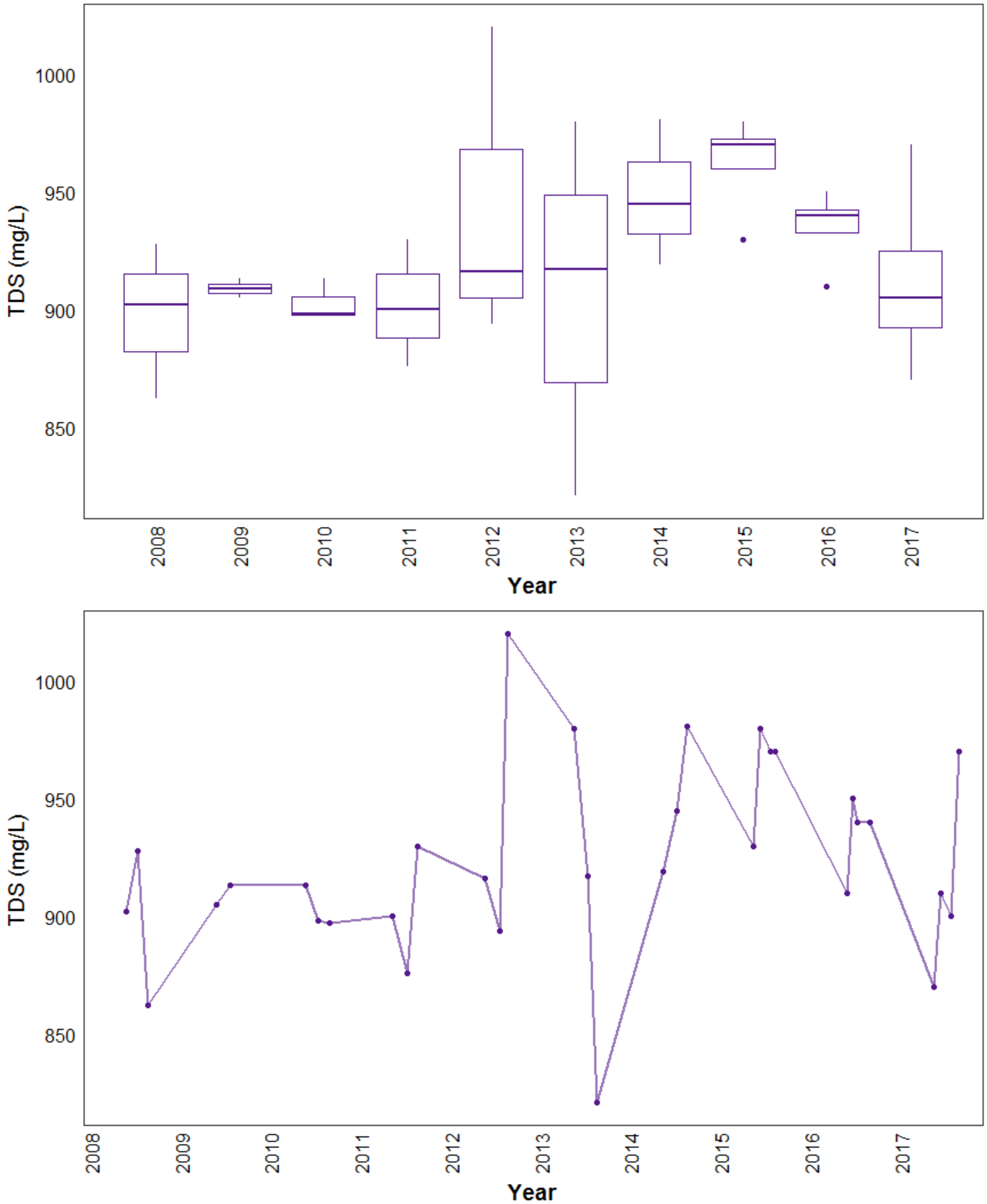
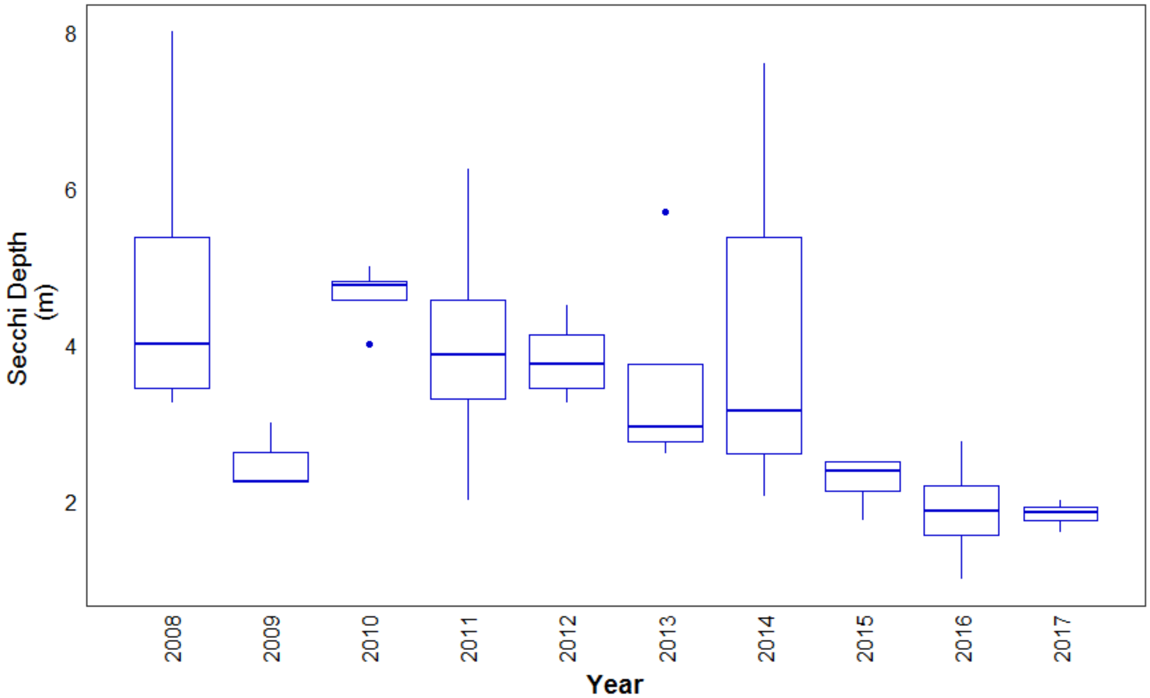


Figure 3-Monthly TDS values measured between June and September over the long term sampling dates between 2008 and 2017 (n = 32). The value closest to the 15th day of the month was chosen to represent the monthly value in cases with multiple monthly samples.

Secchi Depth

Trend analysis found that water quality measured as Secchi depth has decreased (become less clear) over the sampling period (Tau = -0.53, p <0.001).



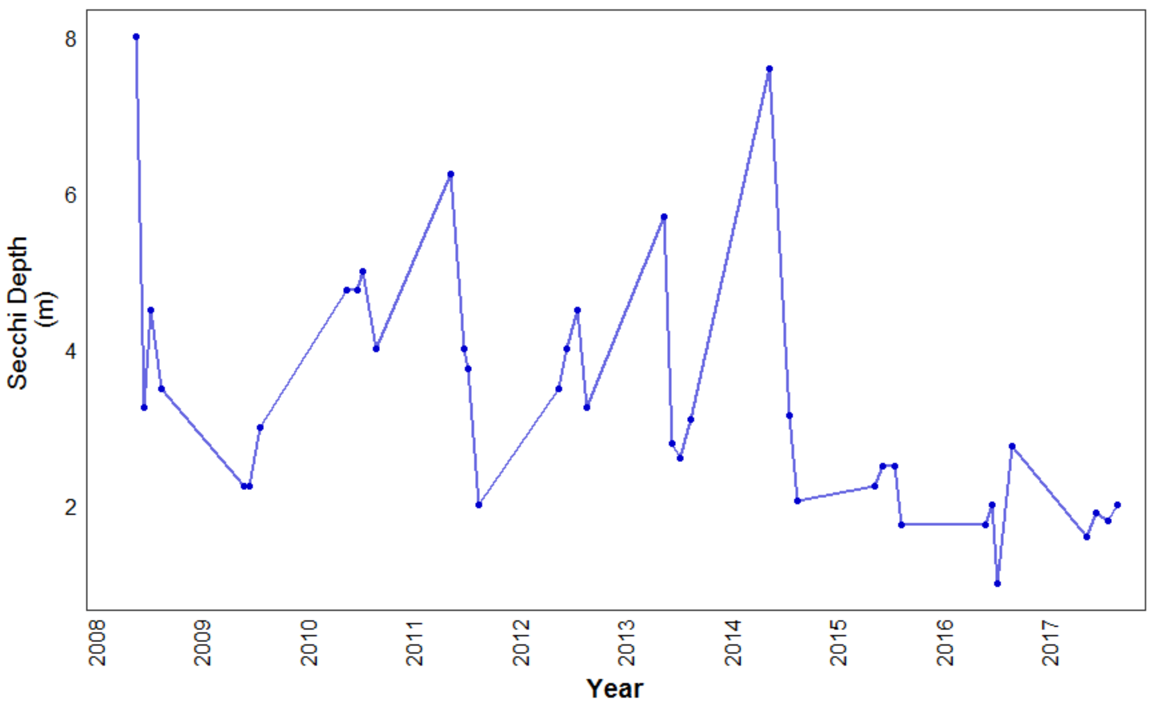


Figure 4-Monthly Secchi depth values measured between June and September over the long term sampling dates between 2008 and 2017 (n = 38). The value closest to the 15th day of the month was chosen to represent the monthly value in cases with multiple monthly samples.

Table 2- Results of Trend tests using monthly total phosphorus (TP), chlorophyll-*a* and Secchi depth data from June to September on Minnie Lake data.

Definition	Unit	Total Phosphorus (TP)	Chlorophyll-a	Total Dissolved Solids (TDS)	Secchi Depth
Statistical Method	-	Mann Kendall	Seasonal Kendall	Seasonal Kendall	Seasonal Kendall
The strength and direction (+ or -) of the trend between 0 and 1	Tau	-0.46	0.22	0.10	-0.53
The extent of the trend	Slope	-0.007	0.3	2.8	-0.3
The statistic used to find significance of the trend	Z	-4.5	1.7	1.3	-4.2
Number of samples included	n	47	39	32	38
The significance of the trend	*p*	6.52×10^{-6}*	0.096	0.20	3.36×10^{-5}*

*$p < 0.05$ is significant within 95%