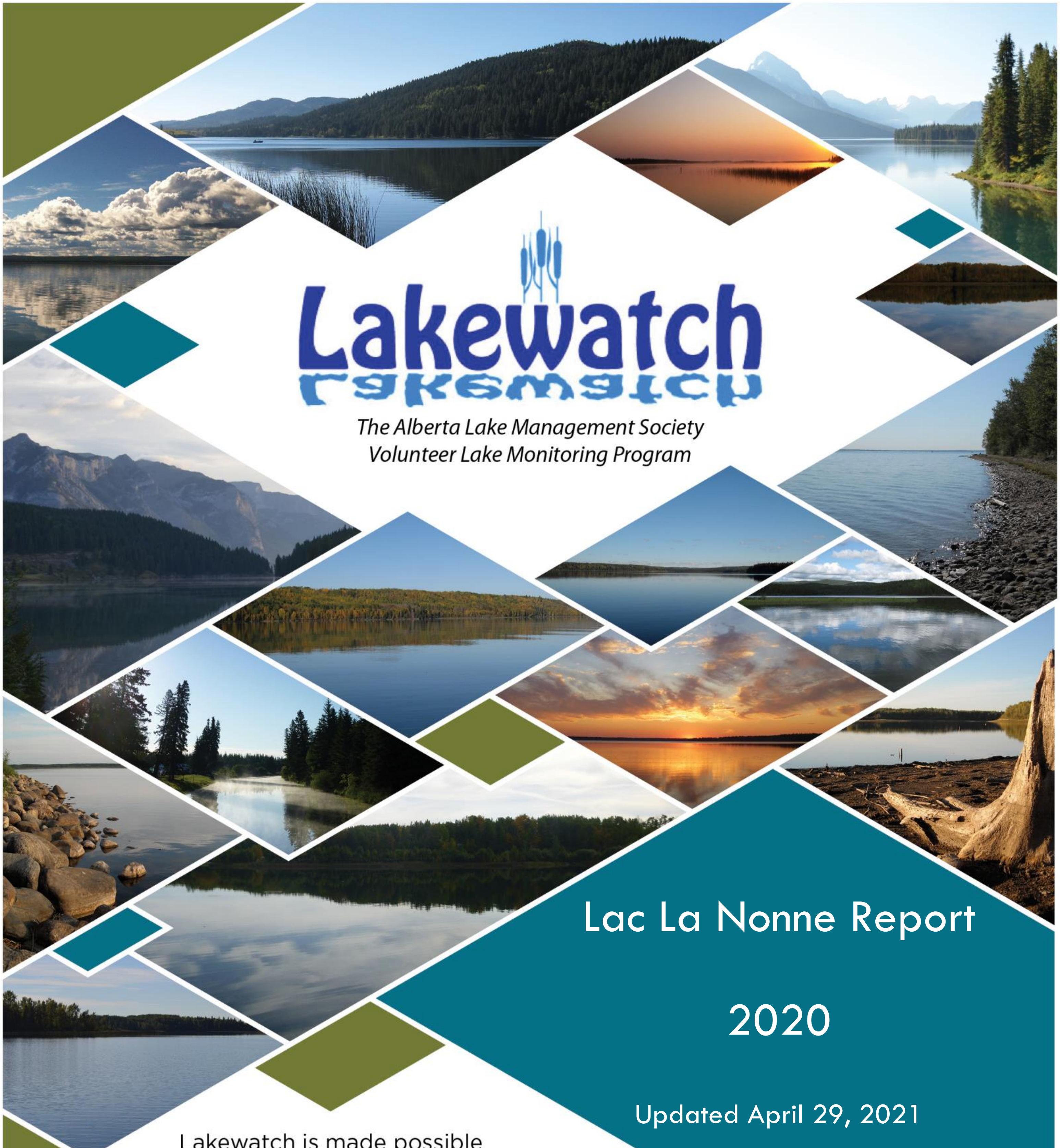

Lakewatch

The Alberta Lake Management Society
Volunteer Lake Monitoring Program

Lac La Nonne Report

2020

Updated April 29, 2021

Lakewatch is made possible with support from:

Alberta Environment and Parks
Pigeon Lake Watershed Association
Moose Lake Watershed Society
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 Rod Kause for his commitment to collecting data at Lac La Nonne. We would also like to thank Kyra Ford and Ryan Turner, who were summer technicians in 2020. Executive Director Bradley Peter and Program Manager Caleb Sinn were instrumental in planning and organizing the field program. This report was prepared by Caleb Sinn and Bradley Peter.

LAC LA NONNE

Lac La Nonne is a fairly large (11.8 km^2) and deep (maximum depth 19.8 m) lake located about 90 km northwest of Edmonton in the counties of Barrhead and Lac Ste. Anne.[1] The closest large population centre is the town of Barrhead located 20 km to the north. It is within the Athabasca River Watershed.

Lac La Nonne is a highly developed and popular recreational lake. It has one summer village, twelve residential subdivisions, five campgrounds/resorts, and is surrounded by agricultural land. A severe toxic cyanobacteria bloom in August 2002 prompted public concern over water quality and the formation of two local watershed stewardship groups, Lac La Nonne Enhancement and Protection Association and the Lac La Nonne Watershed Stewardship Society. They have been very active in implementing beneficial management practices, educating the watershed community, and organizing data collection.

Lac La Nonne Watershed is large (299 km^2) and includes Lake Nakamun and Majeau Lake. The lake area is 12.92 km^2, meaning that the lake to watershed area is 1:22. A map of the Lac La Nonne watershed area can be found at: https://alms.ca/wp-content/uploads/2016/12/Lac-La-Nonne.pdf.

In 2006, the Lac La Nonne Watershed Society undertook a State of the Watershed Report. This report summarizes available information for the historical and current condition of the watershed and makes recommendations for maintaining and improving lake and watershed health.[2]

Pelicans at Lac La Nonne, 2011.

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[1] Michell, P and E. Prepas. 1990. Atlas of Alberta Lakes, University of Alberta Press. Available at: http://sunsite.ualberta.ca/Projects/Alberta-Lakes/

[2] Aquality. 2006. Lac La Nonne State of the Watershed Report. Lac La Nonne Watershed Society. Available at: http://www.laclanonnewatershed.com/LLN_SoW_Report.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. 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 Bureau Veritas, 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, and spiny water flea. 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

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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 Lac La Nonne was 333 µg/L (Table 2), falling into the hypereutrophic, or very highly productive trophic classification. This value is the highest in the historical record for Lac La Nonne. TP was consistently high during every sampling event, ranging from 290 µg/L during the September 4th sampling event, to 380 during the July 17th sampling event (Figure 1).

Average chlorophyll-*a* concentration in 2020 was 74.8 µg/L (Table 2), falling into the hypereutrophic, or very highly productive trophic classification. This level is among the highest in the historical record (Table 2). Chlorophyll-*a* was lowest at the start of the season, with a minimum of 28.4 µg/L during the June 30th sampling event, then increasing to the maximum of 108.0 µg/L during the September 4th sampling event.

Finally, the average TKN concentration was 2.5 mg/L (Table 2) with concentrations ranging between 1.8 and 3.1 mg/L on each individual sampling event throughout the 2020 sampling season.

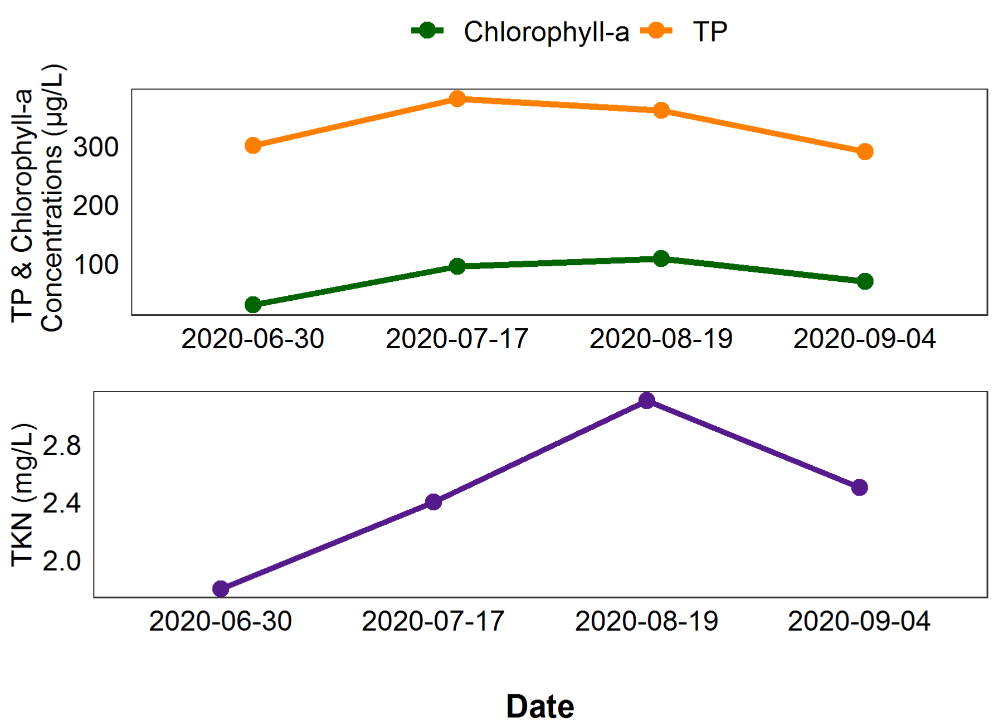


Figure 1. Total Phosphorus (TP), Total Kjeldahl Nitrogen (TKN), and Chlorophyll-*a* concentrations measured four times over the course of the summer at Lac La Nonne.

Average pH was measured as 8.63 in 2020, buffered by low alkalinity (160 mg/L $CaCO_3$) and bicarbonate (180 mg/L HCO_3). Aside from bicarbonate, the dominant ions were calcium and sodium, contributing to a moderate conductivity of 378 µS/cm (Figure 2, top; Table 2). Lac La Nonne was in the average range of ion levels compared to other LakeWatch lakes sampled in 2020, with the exception of relatively low levels of magnesium (Figure 2, bottom).

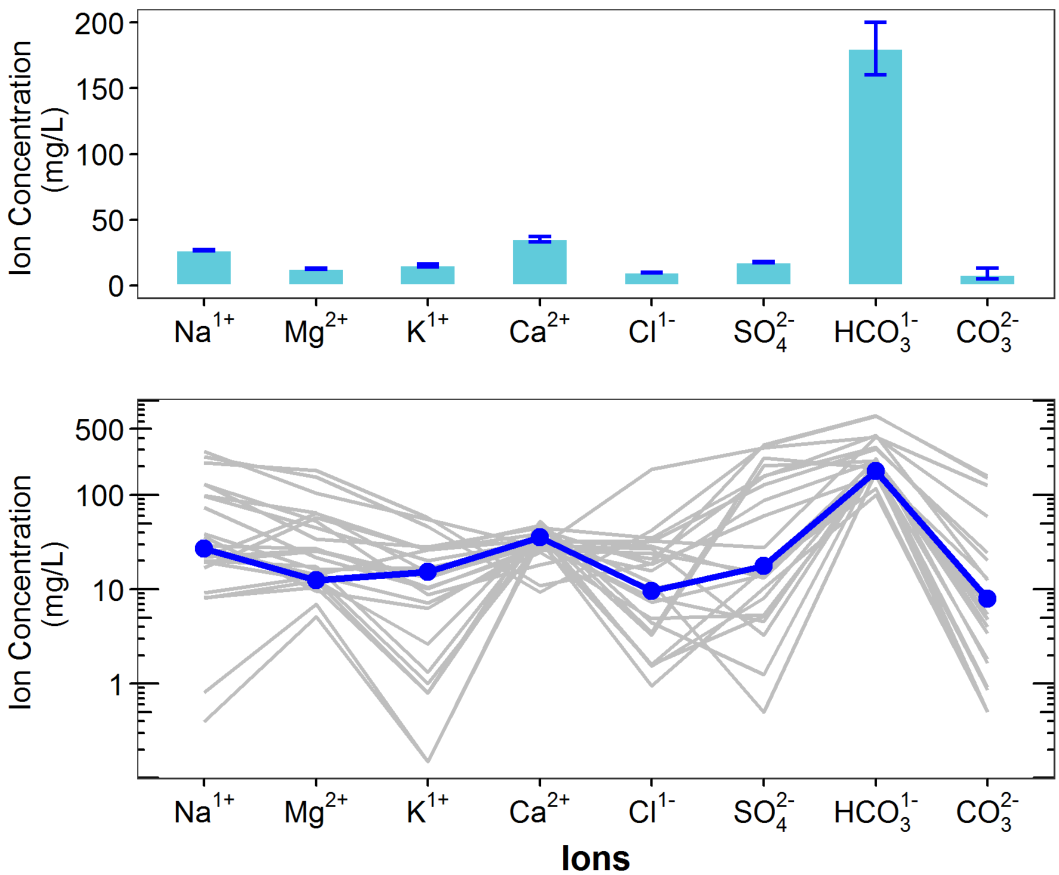


Figure 2. Average levels of cations (sodium = Na^{1+}, magnesium = Mg^{2+}, potassium = K^{1+}, calcium = Ca^{2+}) and anions (chloride = Cl^{1-}, sulphate = SO_4^{2-}, bicarbonate = HCO_3^{1-}, carbonate = CO_3^{2-}) from four measurements over the course of the summer at Lac La Nonne. Top) bars indicate range of values measured, and bottom) Schoeller diagram of average ion levels at Lac Nonne (blue line) compared to 25 lake basins (gray lines) sampled through the LakeWatch program in 2020 (note $\log_{10}$ scale on y-axis of bottom figure).

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 Lac La Nonne in 2020. Table 3 displays historical metal concentrations.

WATER CLARITY AND EUPHOTIC 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 euphotic depth of Lac La Nonne in 2020 was 3.74 m corresponding to an average Secchi depth of 1.87 m (Table 2). Euphotic depth was greatest at the beginning of the summer, and steadily decreased through to the August 19th sampling event, before increasing slightly again during the September 4th sampling event (Figure 3).

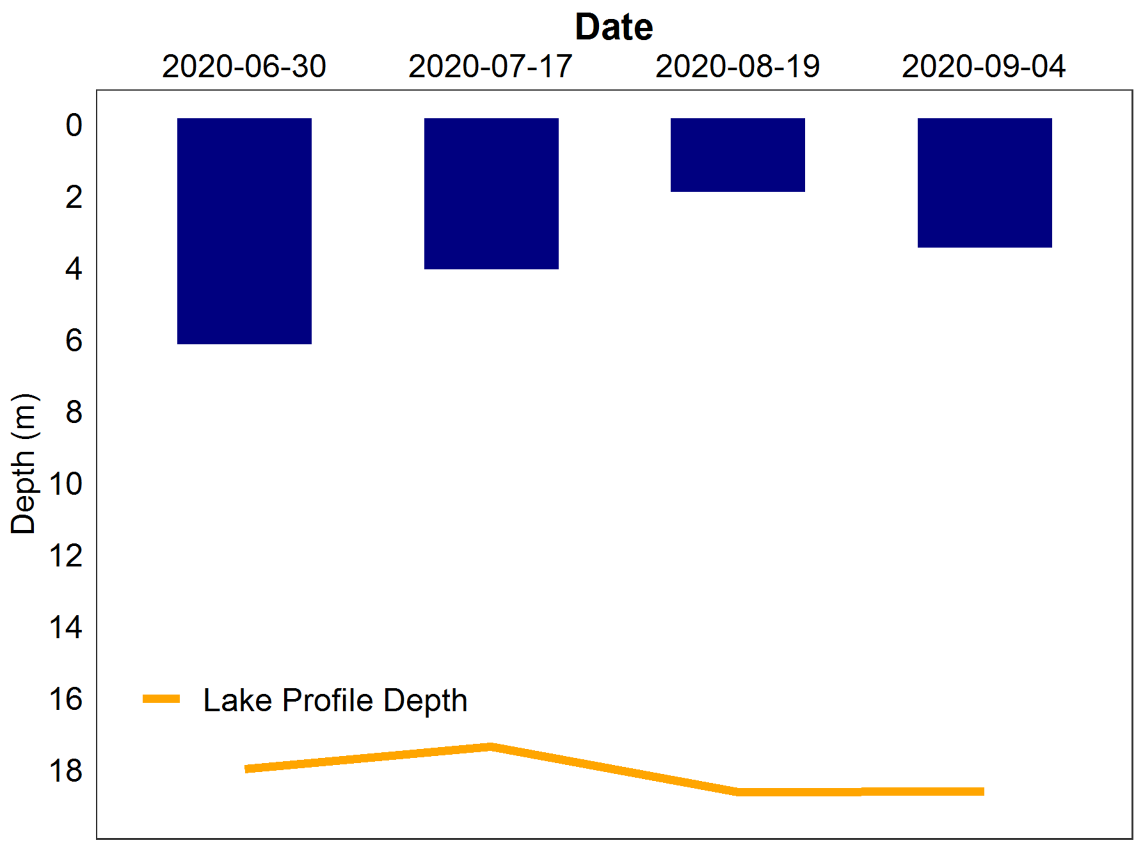


Figure 3. Secchi depth values measured four times over the course of the summer at Lac La Nonne in 2020.

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 Lac La Nonne varied throughout the summer, with a minimum temperature of 11.7°C at 18 m on June 30th, and a maximum temperature of 21.0°C measured at the surface August 19th (Figure 4a). The lake was stratified during all of the sampling trips, with variability in strength and depth of stratification. This indicates that the top and bottom of the water column mix little throughout the open water season. On August 19th, there appeared to be both a deep and shallow thermocline. This may occur on warm, calm days in mid-summer with relatively deep lakes. A deep thermocline on September 4th indicates sampling may have occurred during the beginning of Fall turnover.

Lac La Nonne remained well oxygenated through the upper layer of the water column over the June, July and August sampling events, measuring above the CCME guidelines of 6.5 mg/L dissolved oxygen (Figure 4b). The oxygen level fell below this level throughout the whole water column during the September 4th sampling event, and below 7.5 m depth during the June and July sampling events, and below 3.5 m depth on August 19th. The near surface oxygen levels on the August 19th sampling event also displayed supersaturation, as a result of high algae growth during that sampling event as indicated by the high chlorophyll-*a* levels (Figure 1), and low water clarity (Figure 2).

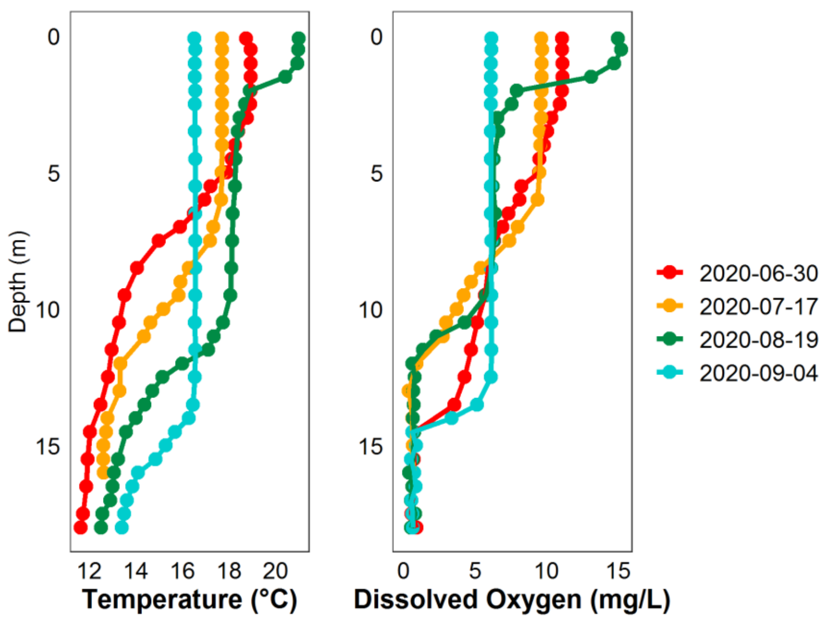


Figure 4. a) Temperature (°C) and b) dissolved oxygen (mg/L) profiles for Lac La Nonne measured four times over the course of the summer of 2020.

MICROCYSTIN

Microcystins are toxins produced by cyanobacteria (blue-green algae) which, can cause severe liver damage when ingested and skin irritation with prolonged contact. 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 fell below the recreational guideline of 20 µg/L at the locations and times sampled in Lac La Nonne in 2020. Microcystin concentrations were below the detection limit of 0.1 µg/L during the June 30th sampling event, then increased greatly by August 19th (Table 1). A value of 0.05 µg/L is used for the purpose of calculating average concentration in instances of no detection. A concentration of 5.15 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 Lac La Nonne in 2020.

Date	Microcystin Concentration (µg/L)
30-Jun-20	<0.10
17-Jul-20	0.39
19-Aug-20	5.15
4-Sep-20	3.81
Average	0.06

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 can change lake conditions which can then lead to toxic cyanobacteria blooms, decrease the amount of nutrients needed for fish and other native species, and cause millions of dollars in annual costs for repair and maintenance of water-operated infrastructure and facilities. Spiny water flea pose a concern for Alberta because they alter the abundance and diversity of native zooplankton as they are aggressive zooplankton predators. Through over-predation, they will impact higher trophic levels such as fish. They also disrupt fishing equipment by attaching in large numbers to fishing lines.

Monitoring involved sampling with a 63 µm plankton net at three sample sites to look for juvenile mussel veligers and spiny water flea in each lake sampled. In 2020, no mussels or spiny water flea were detected at Lac La Nonne.

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. Eurasian watermilfoil can look similar to the native Northern watermilfoil, thus genetic analysis is ideal for suspect watermilfoil species identification.

No suspect watermilfoil was observed or collected from Lac La Nonne in 2020.

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.

The current water level measurement record for Lac La Nonne began in 1972, which caught the lake in a relatively stable period for water level, which lasted until the late 1990s. From then, the levels steadily decreased in the early 2000s until the lowest level in the historical record was reached in 2010, nearly 1.5 m lower than the average level of the previous 3 decades (Figure 5). Since 2010, levels greatly increased again in the early 2010s, remained stable for a few years, then increased to the higher end of the historical range since 2018.

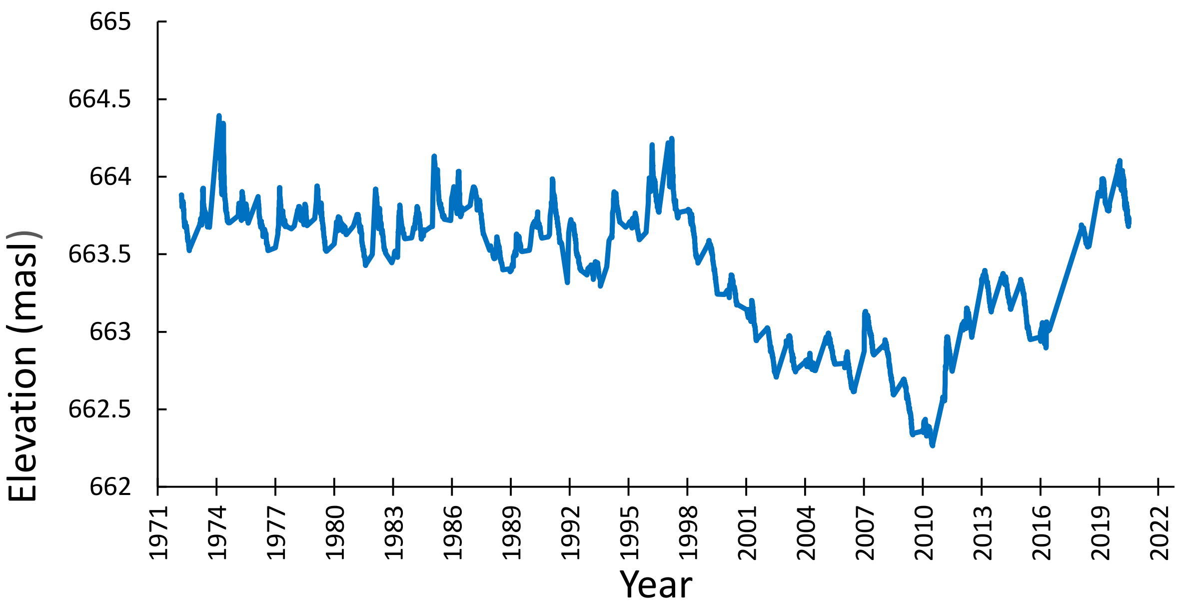


Figure 5. Water levels at Lac La Nonne measured in meters above sea level (masl) from 1972- 2020. Data retrieved from Environment Canada (1972 – 2019), and Alberta Environment and Parks (late 2019 – 2020).

Table 2a. Average Secchi depth and water chemistry values for Lac La Nonne. Historical values are given for reference.

Parameter	1983*	1988	1989	1990	2002*	2003	2004	2008
TP (µg/L)	280	168	176	252	167	149	149	155
TDP (µg/L)	191	104	128	/	98	101	111	95
Chlorophyll-*a* (µg/L)	108.0	55.5	28.1	120.7	43.0	28.3	45.7	35.8
Secchi depth (m)	0.60	1.91	2.32	1.47	0.70	2.10	2.42	1.80
TKN (mg/L)	2.6	2.0	1.7	/	3.4	1.6	1.9	1.8
NO_2-N and NO_3-N (µg/L)	1	20	18	10	3	24	42	12
NH_3-N (µg/L)	15	82	83	/	6	93	283	79
DOC (mg/L)	/	17	16	/	/	/	16	16
Ca (mg/L)	30	33	32	30	/	/	/	/
Mg (mg/L)	9	10	10	10	/	/	/	/
Na (mg/L)	17	17	17	15	/	21	22	23
K (mg/L)	9	10	10	10	/	11	12	12
SO_4^{2-} (mg/L)	12	13	14	11	/	13	14	8
Cl^- (mg/L)	2	3	3	3	/	4	5	5
CO_3 (mg/L)	10	14	7	25	/	10	/	14
HCO_3 (mg/L)	148	168	173	133	/	180	178	173
pH	8.70	8.38	8.37	9.33	/	8.77	8.11	8.65
Conductivity (µS/cm)	292	316	312	298	/	/	317	330
Hardness (mg/L)	112	123	119	117	/	125	102	120
TDS (mg/L)	162	176	176	170	/	189	174	184
Microcystin (µg/L)	/	/	/	/	/	/	/	/
Total Alkalinity (mg/L $CaCO_3$)	138	149	151	150	/	161	145	157

*1983 and 2002 data from single sampling event in August

Table 2b. Average historical Secchi depth and water chemistry values for Lac La Nonne. Historical values are given for reference.

Parameter	2011	2014	2015	2020
TP (µg/L)	213	219	204	333
TDP (µg/L)	157	36	152	300
Chlorophyll-*a* (µg/L)	30.4	62.8	24.8	74.8
Secchi depth (m)	1.98	1.35	2.84	1.87
TKN (mg/L)	1.8	2.1	1.8	2.5
NO_2-N and NO_3-N (µg/L)	7	228	40	9
NH_3-N (µg/L)	40	25	134	63
DOC (mg/L)	16	18	17	18
Ca (mg/L)	/	/	28	36
Mg (mg/L)	/	/	12	13
Na (mg/L)	24	27	26	27
K (mg/L)	12	15	14	15
SO_4^{2-} (mg/L)	7	14	16	18
Cl^- (mg/L)	6	7	7	10
CO_3 (mg/L)	8	20	6	8
HCO_3 (mg/L)	175	154	190	180
pH	8.77	8.99	8.57	8.63
Conductivity (µS/cm)	337	348	364	378
Hardness (mg/L)	111	122	122	140
TDS (mg/L)	180	214	204	218
Microcystin (µg/L)	0.79	1.69	3.22	2.35
Total Alkalinity (mg/L $CaCO_3$)	157	160	170	160

Table 3. Concentrations of metals measured in Lac La Nonne on in each sampling year since 2004. The CCME heavy metal Guidelines for the Protection of Freshwater Aquatic Life (unless otherwise indicated) are presented for reference. Values exceeding these guidelines are presented in red.

Metals (Total Recoverable)	**2004**	**2014**	**2015**	**Guidelines**
Aluminum µg/L	16.955	18.8	26.3333	100[a]
Antimony µg/L	3.0335	0.054	0.0587	/
Arsenic µg/L	1.52	0.969	0.9990	5
Barium µg/L	48.65	43.5	62.5333	/
Beryllium µg/L	0.00825	0.004	0.0040	100[c,d]
Bismuth µg/L	0.0005	0.0005	0.0052	/
Boron µg/L	56.7	50.2	66.2	1500
Cadmium µg/L	0.017	0.012	0.0013	0.26[b]
Chromium µg/L	0.24	0.45	0.27	/
Cobalt µg/L	0.09605	0.02	0.0370	1000[d]
Copper µg/L	0.53	0.26	0.3033	4[b]
Iron µg/L	5.25	18.1	19.9667	300
Lead µg/L	0.11155	0.041	0.0233	7[b]
Lithium µg/L	13.55	11.6	16.0333	2500[e]
Manganese µg/L	34.1	20.1	79.6	200[e]
Molybdenum µg/L	0.2355	0.109	0.1213	73[c]
Nickel µg/L	0.165	0.004	0.1827	150[b]
Selenium µg/L	0.8	0.1	0.0300	1
Silver µg/L	0.06512	0.001	0.0017	0.25
Strontium µg/L	153	169	179	/
Thallium µg/L	0.50075	0.0016	0.0013	0.8
Thorium µg/L	0.00215	0.00045	0.0021	/
Tin µg/L	0.051	0.016	0.0253	/
Titanium µg/L	0.97	1.44	2.0600	/
Uranium µg/L	0.164	0.106	0.1137	15
Vanadium µg/L	0.429	0.32	0.2333	100[d,e]
Zinc µg/L	7.35	0.9	0.3167	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

While historical water quality data exists at Lac La Nonne going back to 1983, the dataset does not meet the requirements of ALMS trend analysis due to a large data gap from 1990 to 2003. As such, 3 more years of data are required to assess trends at Lac La Nonne starting in 2003. All historical data is presented below as both line and box-and-whisker plot to visualize historical data at Lac La Nonne. Note that data from 1983 and 2002 are only based on a single sampling events in August, and the figures include data for months where multiple sampling events where performed. Detailed methods are available in the *ALMS Guide to Trend Analysis on Alberta Lakes.*

Definitions:

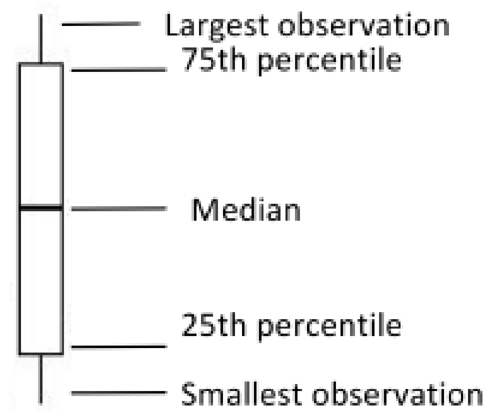
Median: the value in a range of ordered numbers that falls in the middle.

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)

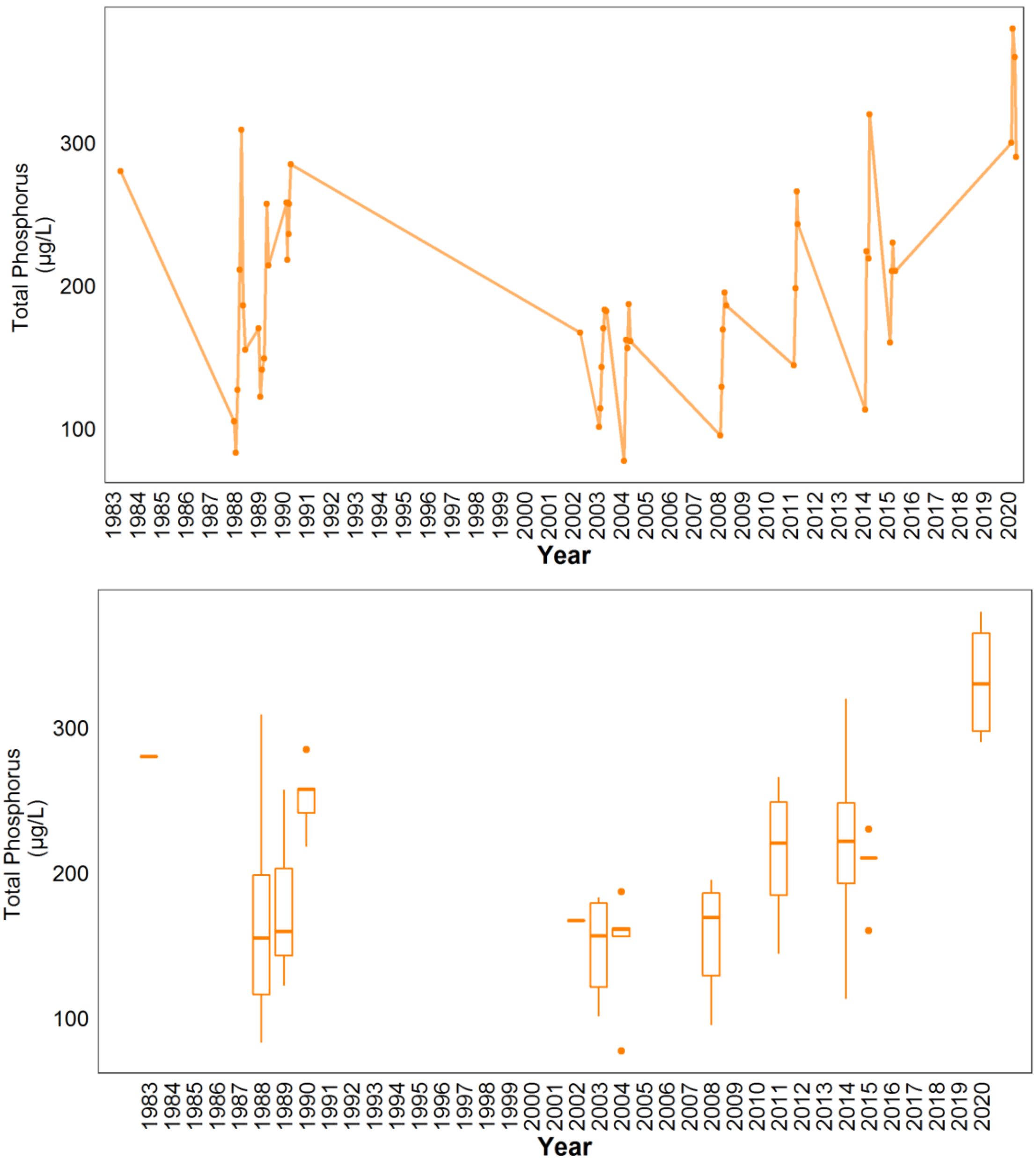


Figure 6. Monthly total phosphorus (TP) concentrations measured in the open water season over the long term sampling dates between 1983 and 2020 (n = 54).

Chlorophyll-*a*

When all data is examined, TP and Chlorophyll *a* did significantly correlate (r=0.59, p = 2.27 x 10^{-6}).

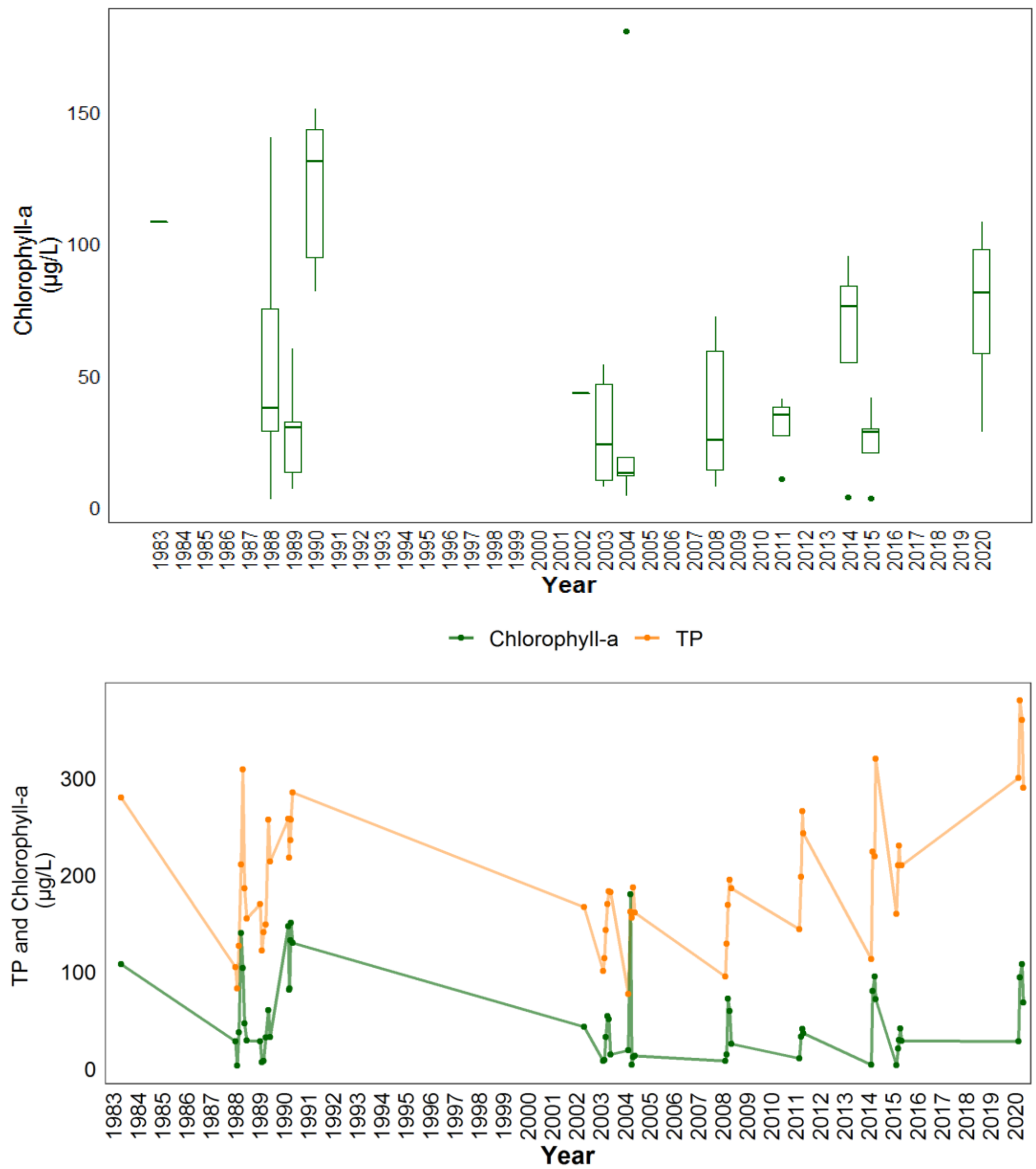
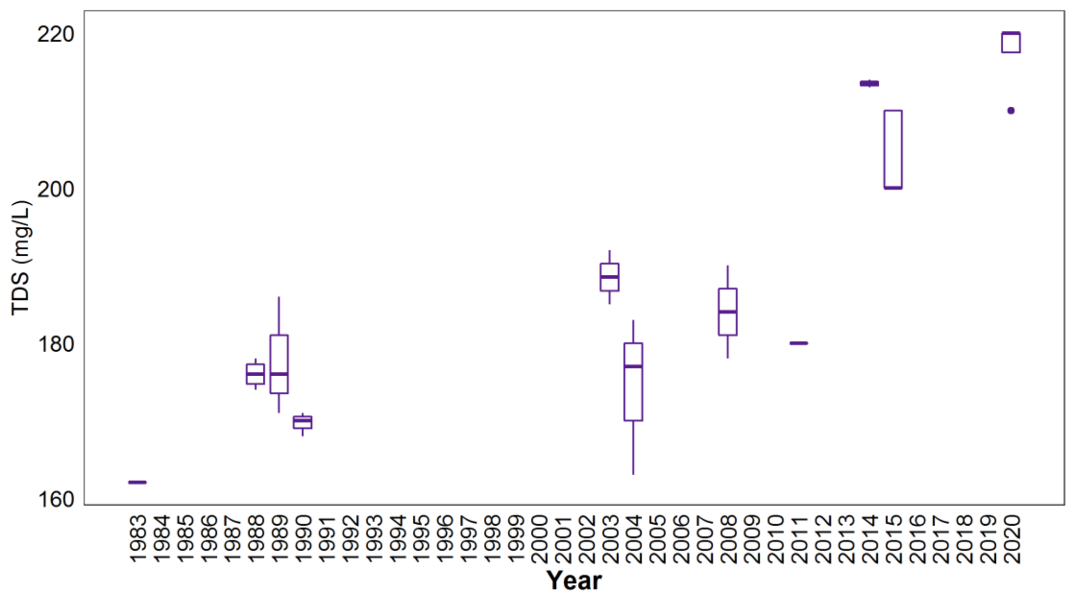


Figure 7. Monthly chlorophyll-*a* concentrations measured in the open water season over the long term sampling dates between 1983 and 2020 (n = 54).

Total Dissolved Solids (TDS)



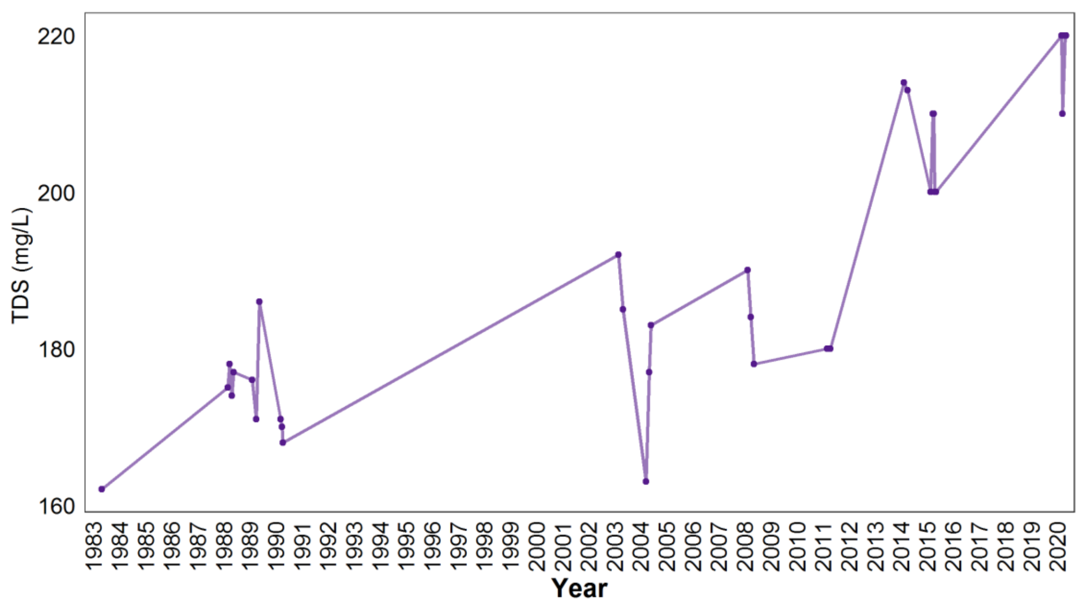


Figure 8. Monthly total dissolved solids (TDS) concentrations measured in the open water season over the long term sampling dates between 1983 and 2020 (n = 37).

Secchi Depth

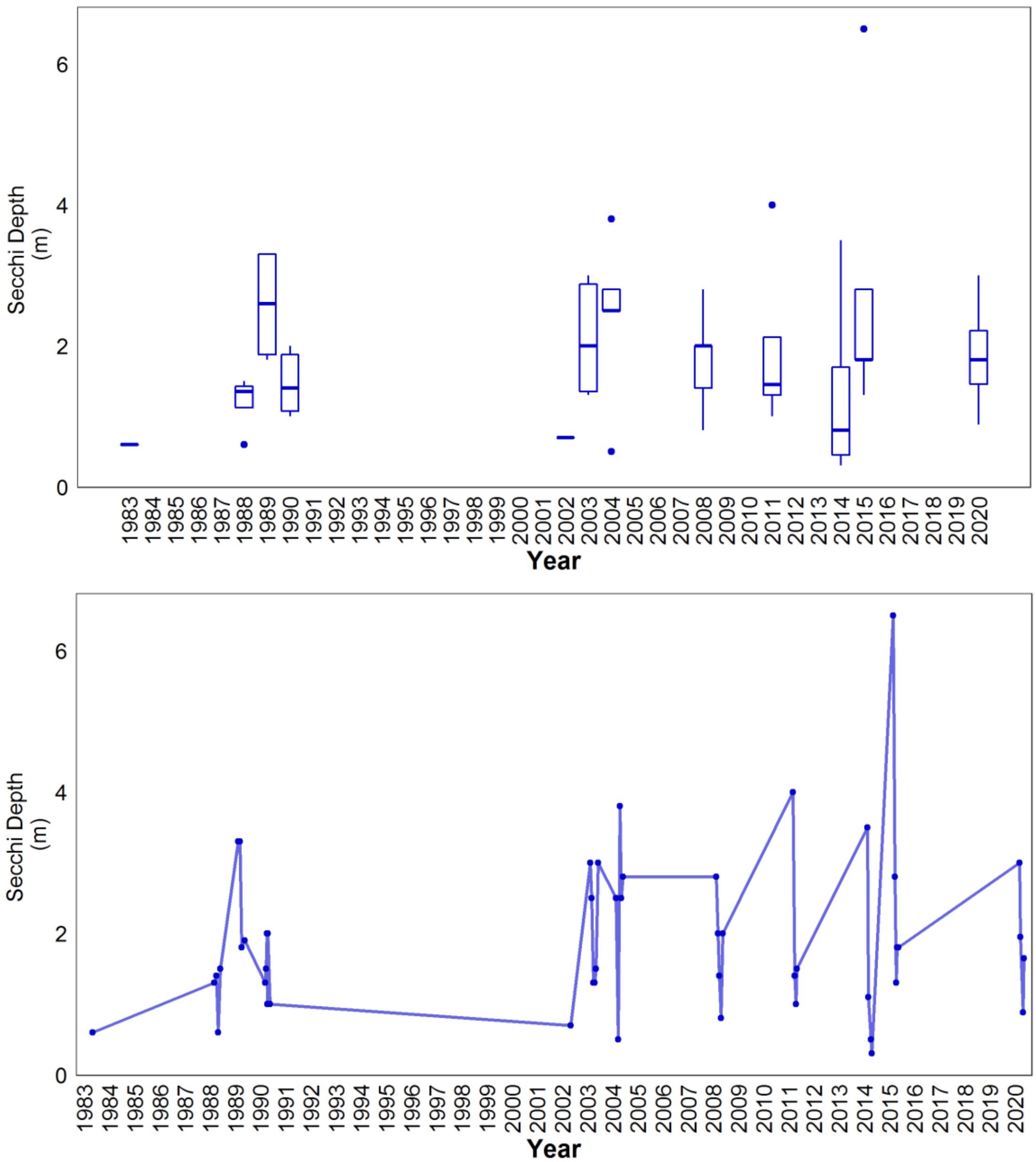


Figure 9. Monthly Secchi depth concentrations measured in the open water season over the long term sampling dates between 1983 and 2020 (n = 54).