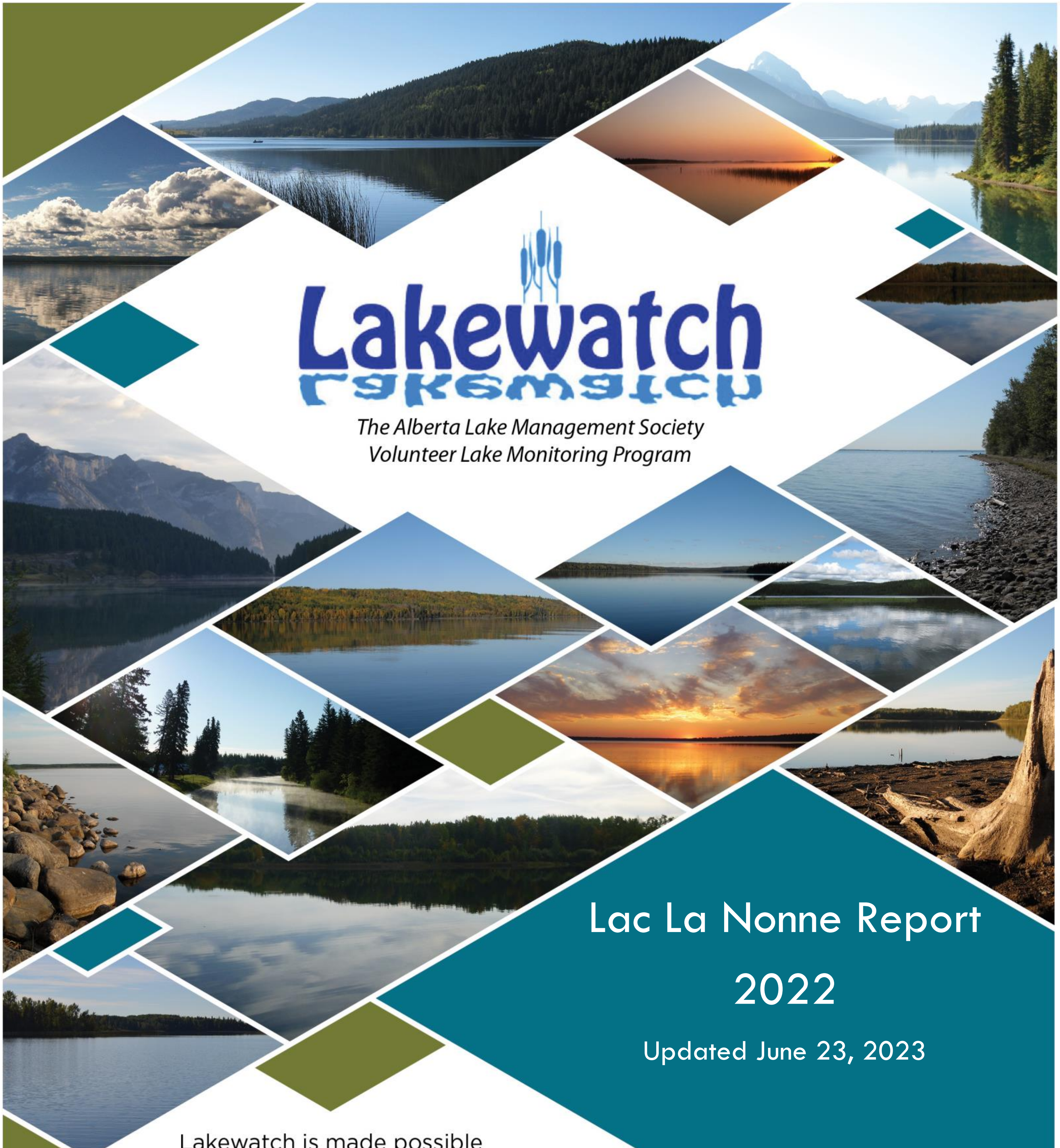

Lakewatch

The Alberta Lake Management Society
Volunteer Lake Monitoring Program

Lac La Nonne Report 2022

Updated June 23, 2023

Lakewatch is made possible with support from:

Alberta

Lac La Biche County
welcoming by nature.

LICA ENVIRONMENTAL STEWARDS

PIGEON LAKE WATERSHED ASSOCIATION

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, Nancy Kause, and Barry Brown for their commitment to collecting data at Lac La Nonne. We would also like to thank Kurstyn Perrin and Dominic Wong, who were summer technicians in 2022. 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

WATER CHEMISTRY

BEFORE READING THIS REPORT, CHECK OUT A BRIEF INTRODUCTION TO LIMNOLOGY AT ALMS.CA/REPORTS

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 275 µg/L (Table 2), falling into the hypereutrophic, or very highly productive trophic classification. This value falls on the higher end of all previously observed historical averages going back to 1983 (Table 2). TP ranged from a minimum of 240 µg/L on June 3rd and August 26th, to a maximum of 360 µg/L on September 23rd (Figure 1).

Average chlorophyll-*a* concentration in 2022 was 55 µg/L (Table 2), falling into the hypereutrophic, or very highly productive trophic classification. Chlorophyll-*a* was highest during the July 22nd sampling event at 109 µg/L, and lowest at 2.7 µg/L on June 3rd.

The average TKN concentration was 2.1 mg/L (Table 2), and displayed a low level during the June 3rd sampling event, relative to the consistent levels observed the rest of the summer (Figure 1).

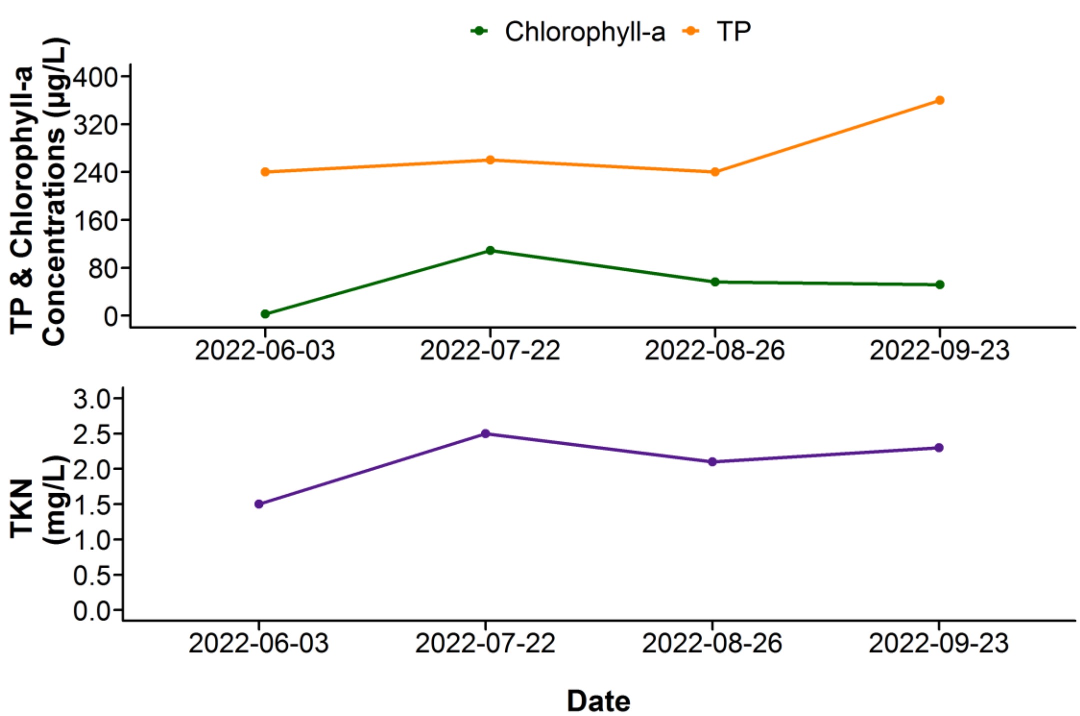


Figure 1. Total Phosphorus (TP), Total Kjeldahl Nitrogen (TKN), and Chlorophyll-*a* concentrations measured four times over the course of the summer at Lac La Nonne.

Average pH was measured as 8.64 in 2022, buffered by moderate alkalinity (180 mg/L $CaCO_3$) and bicarbonate (190 mg/L HCO_3). Aside from bicarbonate, sodium and calcium were higher than all other major ions, and together contributed to a moderate conductivity of 398 µS/cm (Figure 2, top; Table 2). Lac La Nonne is in the moderate to low end range of ion levels, compared to other LakeWatch lakes sampled in 2022, apart from calcium, being at a relatively higher level. (Figure 2, bottom).

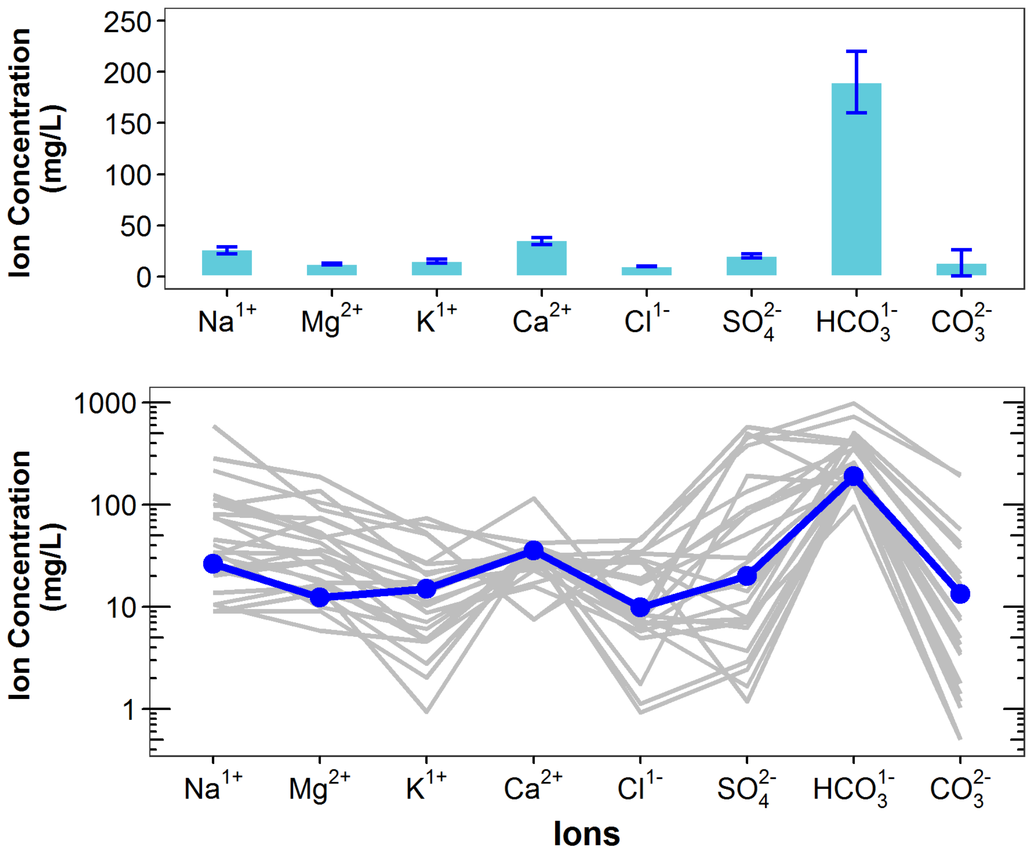


Figure 2. Average levels of cations (sodium = Na^{1+}, magnesium = Mg^{2+}, potassium = K^{1+}, calcium = Ca^{2+}) and anions (chloride = Cl^{1-}, sulphate = SO_4^{2-}, bicarbonate = HCO_3^{1-}, carbonate = CO_3^{2-}) from four measurements over the course of the summer at Lac La Nonne. Top) bars indicate range of values measured, and bottom) Schoeller diagram of average ion levels at Lac La Nonne (blue line) compared to 26 lake basins (gray lines) sampled through the LakeWatch program in 2022 (note $\log_{10}$ scale on y-axis of bottom figure).

METALS

Metals will naturally be present in aquatic environments due to in-lake processes or the erosion of rocks, or introduced to the environment from human activities such as urban, agricultural, or industrial developments. Many metals have a unique guideline as they may become toxic at higher concentrations. Where current metal data are not available, historical concentrations for 27 metals have been provided (Table 3).

Metals were not measured at Lac La Nonne in 2022, but historical levels are available in Table 3.

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 2022 was 4.78 m, corresponding to an average Secchi depth of 2.39 m (Table 2). Euphotic depth varied over the season, ranging from as deep as 11.10 m on June 3rd, to 2.20 m on September 23rd, which was a similar depth observed during the July and August sampling events (Figure 3).

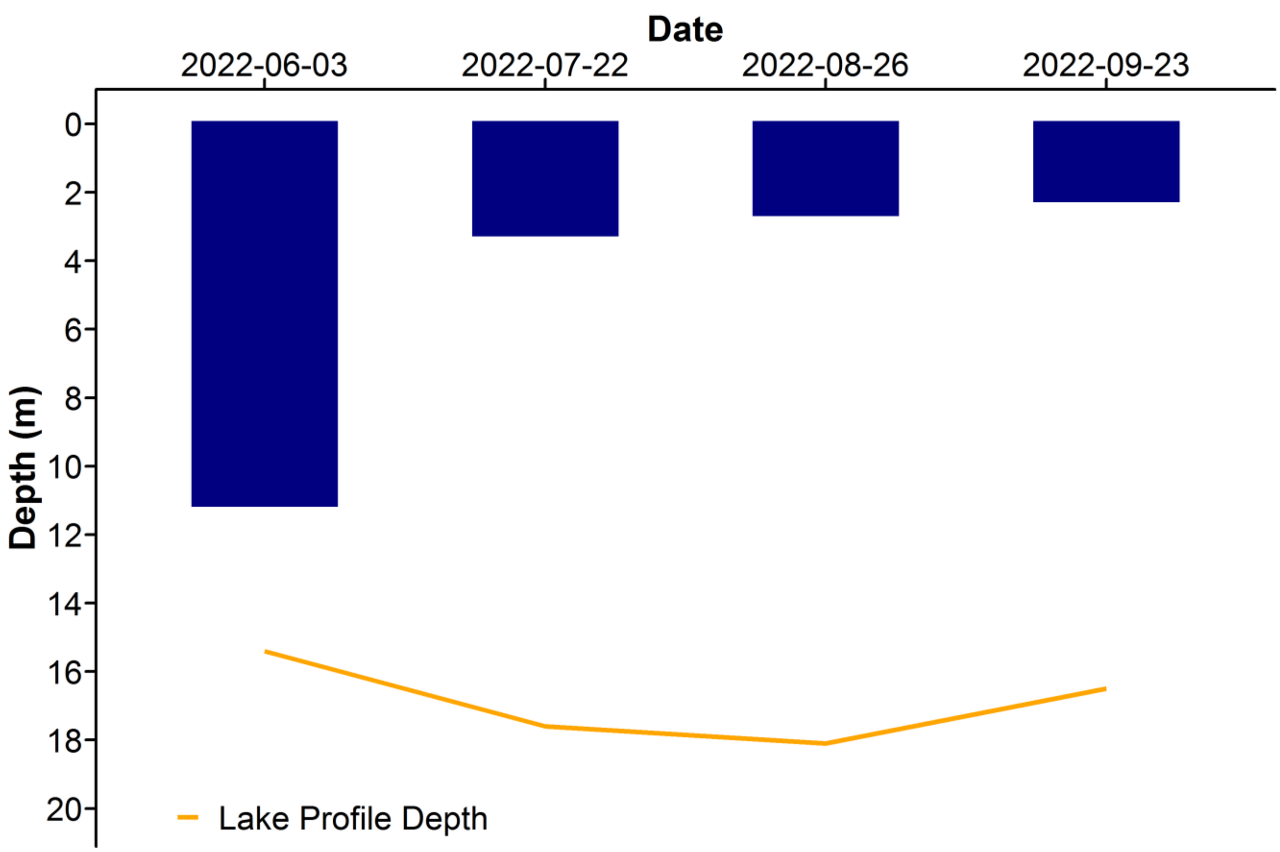


Figure 3. Euphotic depth values measured four times over the course of the summer at Lac La Nonne in 2022.

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.

Surface temperatures of Lac La Nonne varied throughout the summer, with the August 26th sampling date having the warmest temperature at 23.0°C (Figure 4a). The lake was weakly stratified during each sampling trip. The weak stratification and 9°C water temperatures near the bottom of the lake during the June 3rd sampling event indicate that the lake mixes completely following ice-off in the spring.

Lac La Nonne was well oxygenated in the surface waters on all sampling dates, measuring above the CCME guidelines of 6.5 mg/L dissolved oxygen (Figure 4b). High surface dissolved oxygen levels along with strong oxygen depletion below the depth of weak mixing was observed during the August 26th sampling event, indicating high surface algae and cyanobacteria abundance, also leading to anoxic conditions (<1.0 mg/L dissolved oxygen) in the majority of the water column.

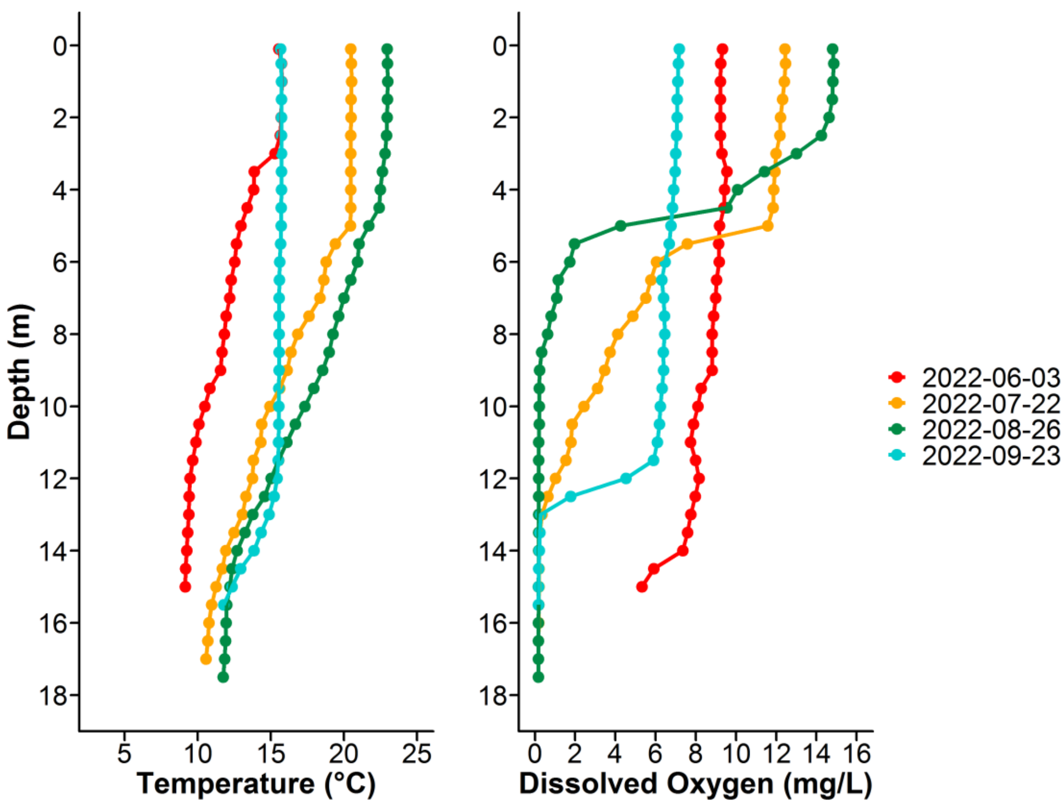


Figure 4. a) Temperature (°C) and b) dissolved oxygen (mg/L) profiles for Lac La Nonne measured four times over the course of the summer of 2022.

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 one of the most common cyanobacteria toxins. In Alberta, recreational guidelines for microcystin are set at 10 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 Lac La Nonne fell below the recreational guideline of 10 µg/L during every sampling event in 2022. In addition, microcystin levels from the June 3rd sampling event were below the laboratory detection limit of 0.10 µg/L. A value of 0.05 µg/L is assigned when a value is below detection, in order to calculate an average. The levels during the August and September sampling event indicate significant cyanobacteria abundance, and caution should be observed in areas of the lake where significant cyanobacteria accumulation occurs.

Table 1. Microcystin concentrations measured four times at Lac La Nonne in 2022.

Date	Microcystin Concentration (µg/L)
3-Jun-22	<0.1
22-Jul-22	0.53
26-Aug-22	6.58
23-Sep-22	8.28
Average	3.68

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 for aquatic invasive species involved sampling with a 63 µm plankton net at three sample sites. This monitoring is designed to detect juvenile Dreissenid mussel veligers and spiny water flea. In 2022, no mussels or spiny water flea were detected at Lac La Nonne.

Eurasian watermilfoil is a 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.

A watermilfoil specimen was collected from Lac La Nonne on June 2nd, and was confirmed to be the native Northern Watermilfoil.

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 at Lac La Nonne in 2022 were slightly above the historical average during the beginning of the year, and then decreased appreciably. Recent levels indicate the lake has returned to the levels that were observed between the 1970s and 1990s, following lower levels through 2000 to 2016.

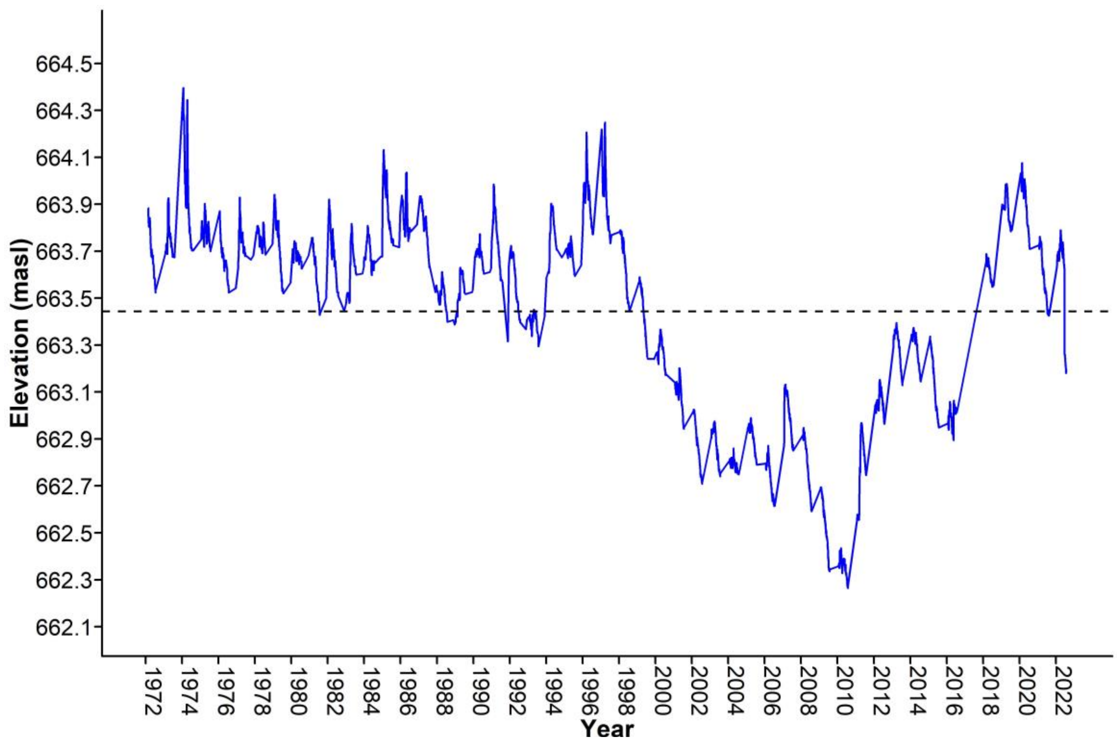


Figure 5. Water levels measured at Lac La Nonne in metres above sea level (masl) from 1972-2022. Data retrieved from Alberta Environment and Parks and/or Environment and Climate Change Canada. Black dashed line represents historical yearly average water level.

WEATHER & LAKE STRATIFICATION

Air temperature will directly impact lake temperatures, and result in different temperature layers (stratification) throughout the lake, depending on its depth. Wind will also impact the degree to which a lake mixes, and how it will stratify. The amount of precipitation that falls within a lake's watershed will have important implications, depending on the context of the watershed and the amount of precipitation that has fallen. Solar radiation represents the amount of energy that reaches the earth's surface, and has implications for lake temperature & productivity.

Lac La Nonne experienced a warmer, wetter, and slightly windier summer than normal (Figure 6). A long spell of warm and calm conditions leading up to the August sampling event likely led to high surface water temperatures, as well as stronger stratification relative to the other sampling events.

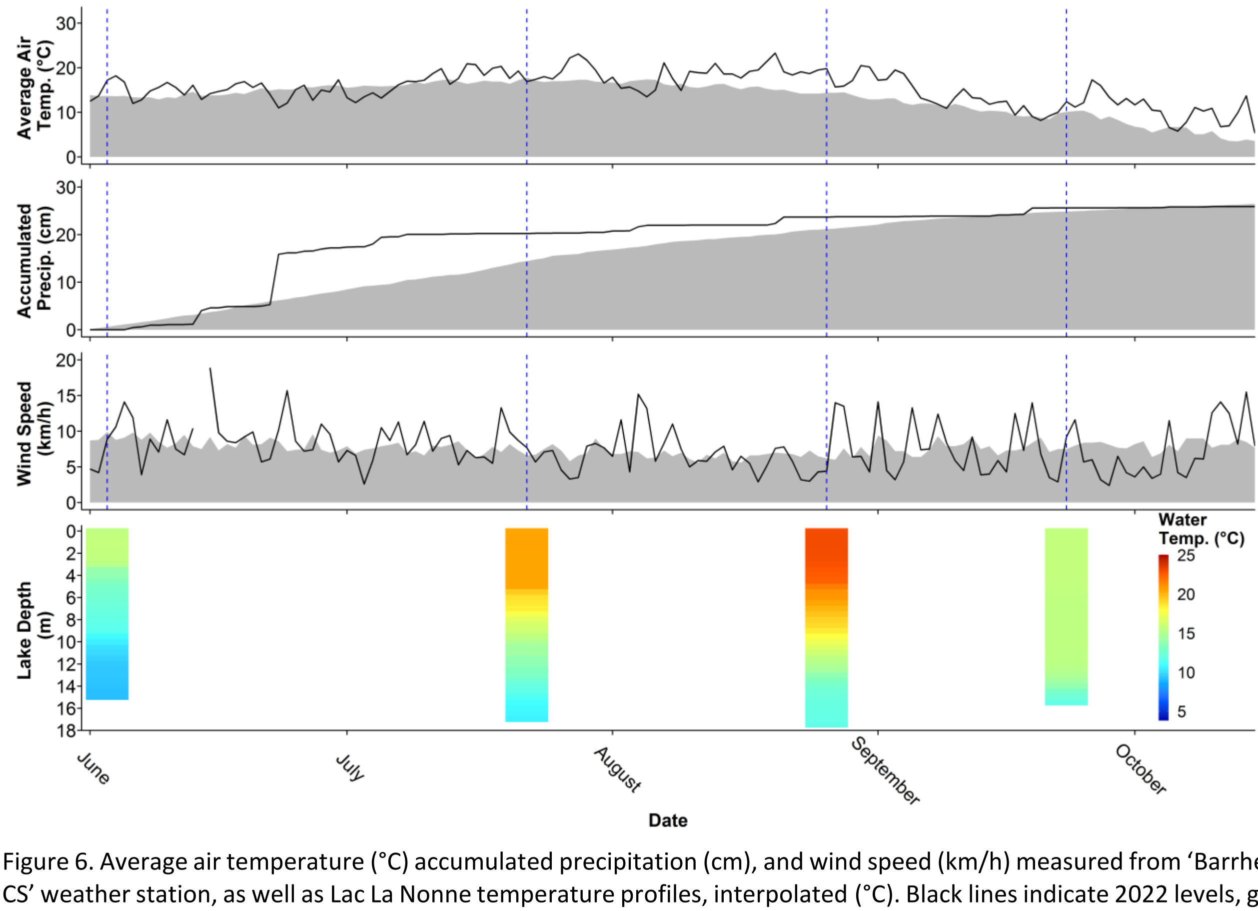


Figure 6. Average air temperature (°C) accumulated precipitation (cm), and wind speed (km/h) measured from 'Barrhead CS' weather station, as well as Lac La Nonne temperature profiles, interpolated (°C). Black lines indicate 2022 levels, gray indicates long-term normals, and blue lines indicate sampling dates for Lac La Nonne over the summer. Further information about the weather data provided is available in the LakeWatch 2022 Methods report. Weather data provided by Agriculture, Forestry and Rural Economic Development, Alberta Climate Information Service (ACIS) https://acis.alberta.ca (retrieved March 2023). *Note that solar radiation is unavailable for the 'Barrhead CS' weather station.

Table 2a. Average Secchi depth and water chemistry values for Lac La Nonne.

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
NO2 and NO3 (μg/L)	1	20	18	10	3	24	42	12
NH3 (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
SO42- (mg/L)	12	13	14	11	/	13	14	8
Cl- (mg/L)	2	3	3	3	/	4	5	5
CO3 (mg/L)	10	14	7	25	/	10	/	14
HCO3 (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 CaCO3)	138	149	151	150	/	161	145	157

*1983 and 2002 data from single sampling event in August

Table 2b. Average Secchi depth and water chemistry values for Lac La Nonne.

Parameter	2011	2014	2015	2020	2022
TP (µg/L)	213	219	204	333	275
TDP (µg/L)	157	36	152	300	228
Chlorophyll-*a* (µg/L)	30.4	62.8	24.8	74.8	55
Secchi depth (m)	1.98	1.35	2.84	1.87	2.39
TKN (mg/L)	1.8	2.1	1.8	2.5	2.1
NO_2-N and NO_3-N (µg/L)	7	228	40	9	11
NH_3-N (µg/L)	40	25	134	63	46
DOC (mg/L)	16	18	17	18	17
Ca (mg/L)	/	/	28	36	36
Mg (mg/L)	/	/	12	13	12
Na (mg/L)	24	27	26	27	26
K (mg/L)	12	15	14	15	15
SO_4^{2-} (mg/L)	7	14	16	18	20
Cl^- (mg/L)	6	7	7	10	10
CO_3 (mg/L)	8	20	6	8	13
HCO_3 (mg/L)	175	154	190	180	190
pH	8.77	8.99	8.57	8.63	8.64
Conductivity (µS/cm)	337	348	364	378	392
Hardness (mg/L)	111	122	122	140	140
TDS (mg/L)	180	214	204	218	228
Microcystin (µg/L)	0.79	1.69	3.22	2.35	3.86
Total Alkalinity (mg/L $CaCO_3$)	157	160	170	160	180

Table 3. Concentrations of metals measured in Lac La Nonne. The CCME heavy metal Guidelines for the Protection of Freshwater Aquatic Life (unless otherwise indicated) are presented for reference. Note that metal sample collection method changed in 2016 from composite to single surface grab at the profile location.

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	0.19[b]
Chromium μg/L	0.24	0.45	0.27	/
Cobalt μg/L	0.09605	0.02	0.0370	50,1000[c,d]
Copper μg/L	0.53	0.26	0.3033	2.80[b]
Iron μg/L	5.25	18.1	19.9667	300
Lead μg/L	0.11155	0.041	0.0233	4.10[b]
Lithium μg/L	13.55	11.6	16.0333	2500[d]
Manganese μg/L	34.1	20.1	79.6	170[e]
Molybdenum μg/L	0.2355	0.109	0.1213	73
Nickel μg/L	0.165	0.004	0.1827	111.2[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[c,d]
Zinc μg/L	7.35	0.9	0.3167	30[f]

Values represent means of total recoverable metal concentrations.
[a] Based on pH ≥ 6.5
[b] Based on 2015 avg. water hardness (as CaCO3) with CCME equation
[c] Based on CCME Guidelines for Agricultural use (Livestock).
[d] Based on CCME Guidelines for Agricultural Use (Irrigation).
[e] Based on CCME Manganese variable calculation (https://ccme.ca/en/chemical/129#_aql_fresh_concentration), using 2015 avg. water hardness (as CaCO3) and avg. pH
[f] Based on 2015 avg. water hardness (as CaCO3), avg. pH, and avg. DOC with CCME equation
A forward slash (/) indicates an absence of data or guideline

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 Lac La Nonne. In sum, a significant increasing trend was observed in TP, and no significant trends were detected for chlorophyll-*a* and Secchi depth. There is insufficient data to conduct trend analysis on TDS data. Secchi depth can be subjective and is sensitive to variation in weather; therefore, trend analysis must be interpreted with caution. Data is presented below as both line and box-and-whisker plots. Detailed methods are available in the *ALMS Guide to Trend Analysis on Alberta Lakes.*

Table 4. Summary table of trend analysis on Lac La Nonne data from 1988 to 2022.

Parameter	Date Range	Direction of Significant Trend
Total Phosphorus	1988-2022	Increasing
Chlorophyll-*a*	1988-2022	No Change
Total Dissolved Solids	*Insufficient Data*	*Insufficient Data*
Secchi Depth	1988-2022	No Change

Definitions:

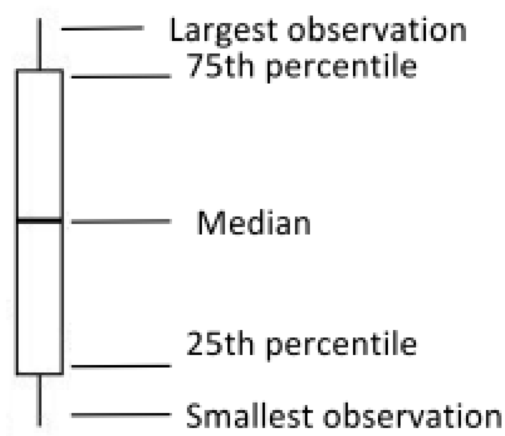
Median: the value in a range of ordered numbers that falls in the middle.

Trend: a general direction in which something is changing.

Monotonic trend: a gradual change in a single direction.

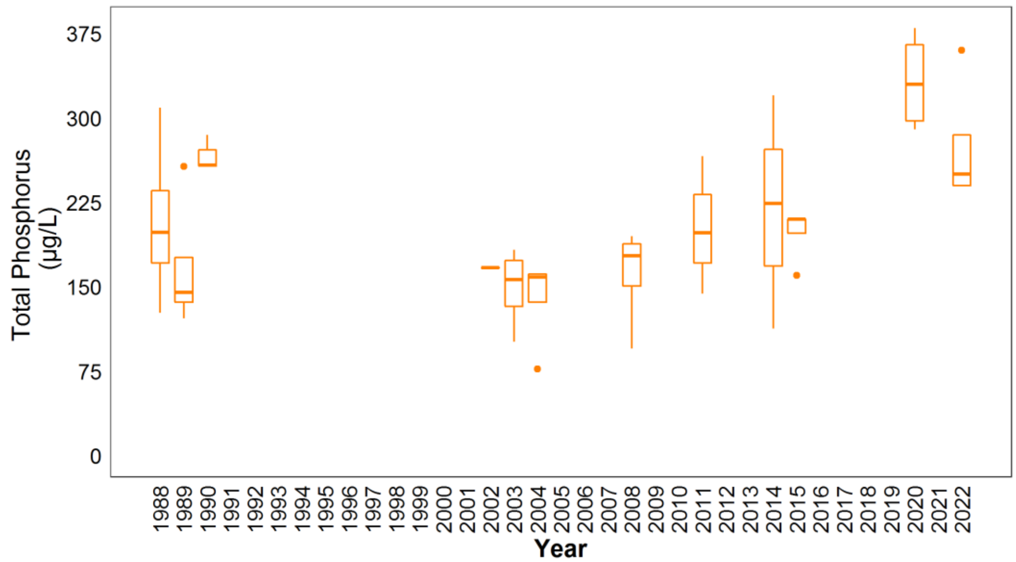
Statistically significant: The likelihood that a relationship between variables is caused by something other than random chance. This is indicated by a p-value of <0.05. Variability: the extent by which data is inconsistent or scattered.

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



Total Phosphorus (TP)

Trend analysis of TP over time showed that it has significantly increased in Lac La Nonne since 1988 (Tau = 0.40, p = <0.001).



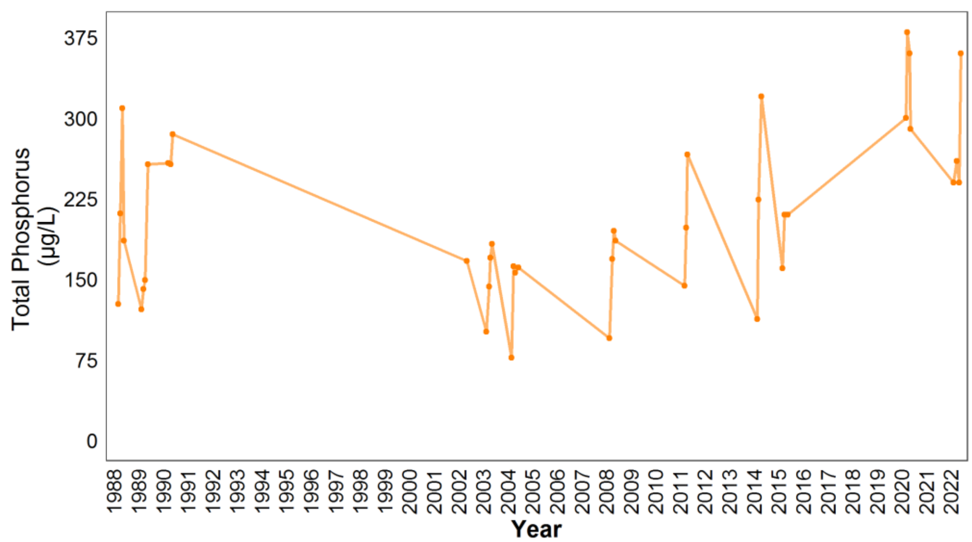
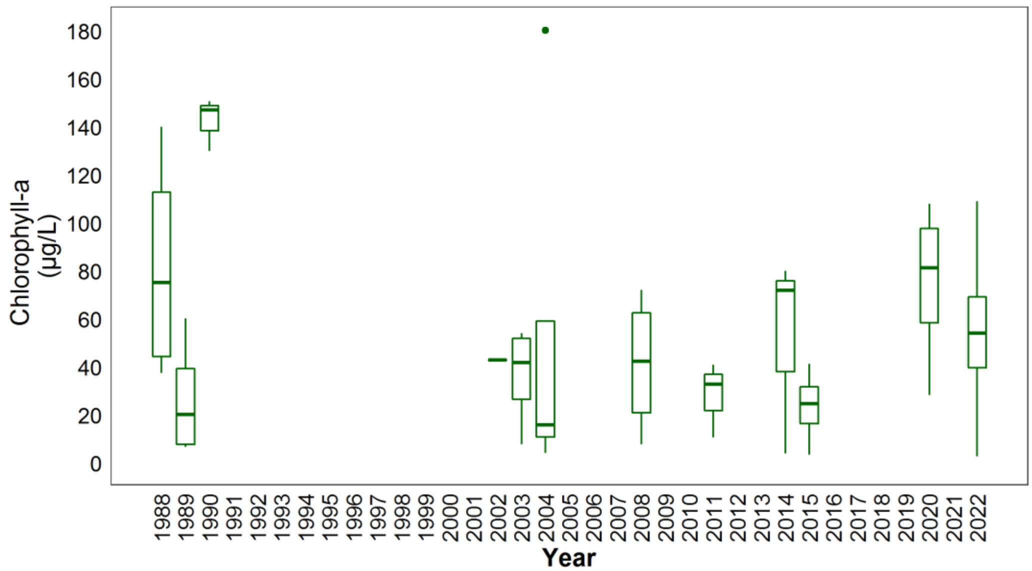


Figure 7. Monthly total phosphorus (TP) concentrations measured between June and September over the long term sampling dates between 1988 and 2022 (n = 42). The value closest to the 15th day of the month was chosen to represent the monthly value in cases with multiple monthly samples.

Chlorophyll-*a*

Chlorophyll-*a* has not significantly changed over time at Lac La Nonne (Tau = -0.05, *p* = 0.74).



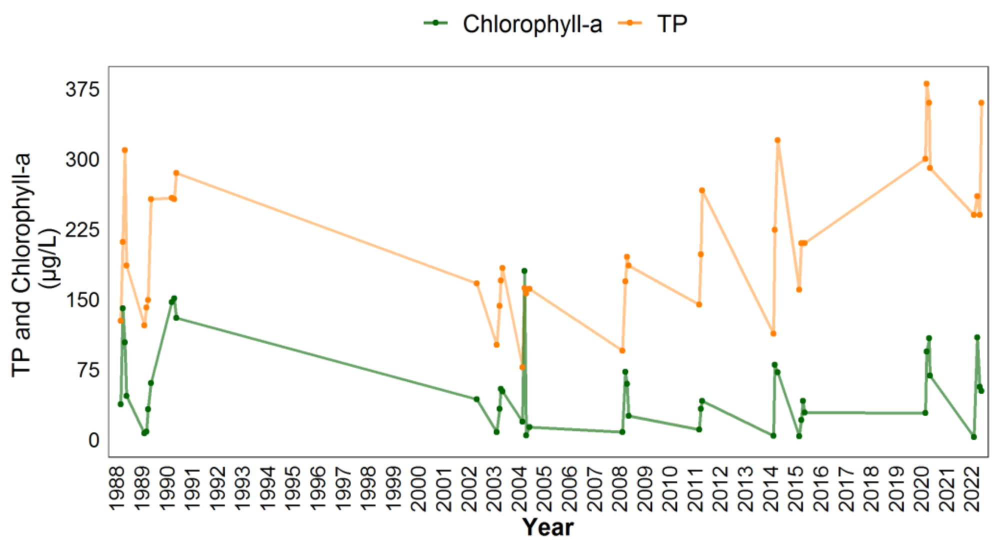


Figure 8. Monthly chlorophyll-*a* concentrations measured between June and September over the long term sampling dates between 1988 and 2022 (n = 42). The value closest to the 15th day of the month was chosen to represent the monthly value in cases with multiple monthly samples. Line graph is overlain by TP concentrations.

Total Dissolved Solids (TDS)

There is insufficient data to conduct trend analysis on TDS data at Lac La Nonne. However, the boxplot of TDS over time indicates that the median TDS level in 2022 is the highest in the historical record (Figure 9).

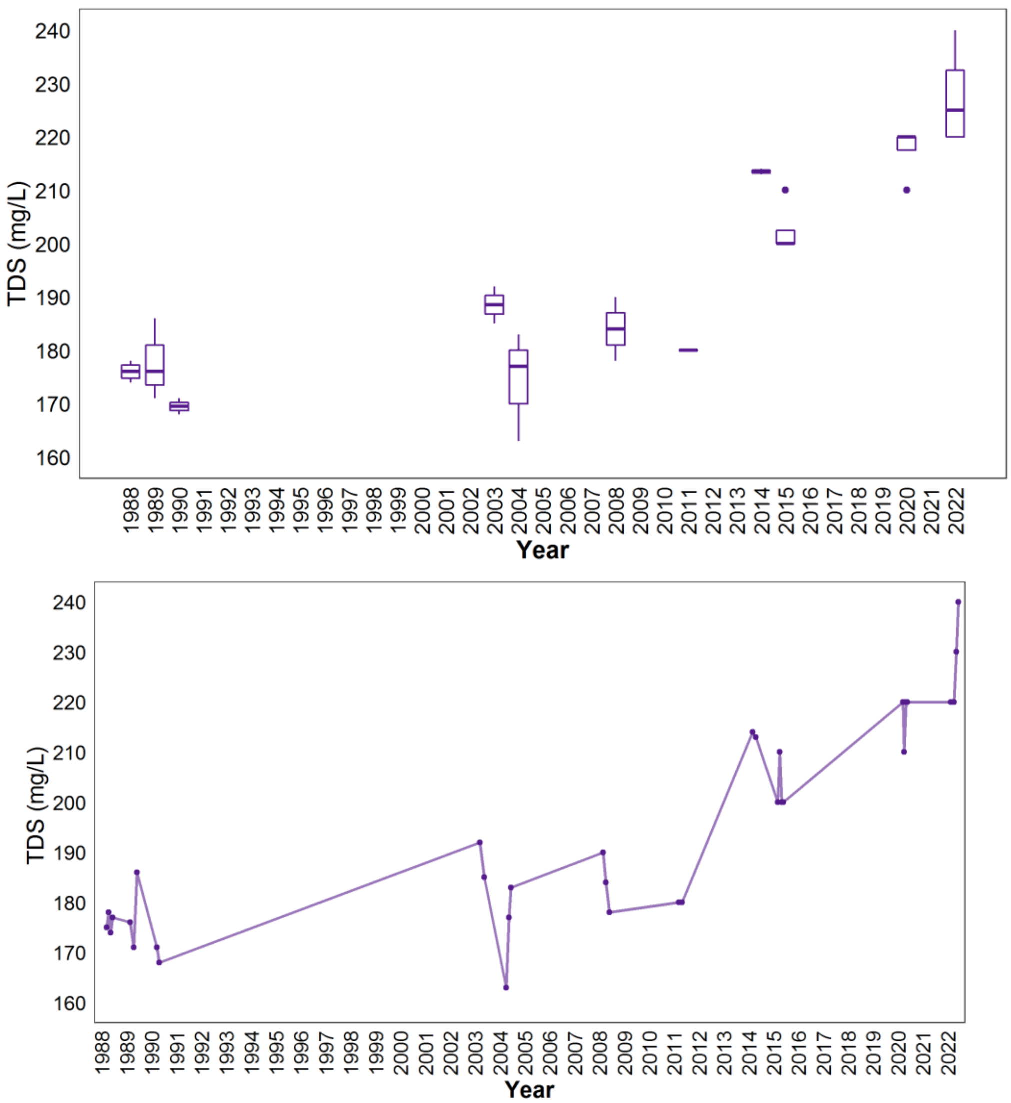
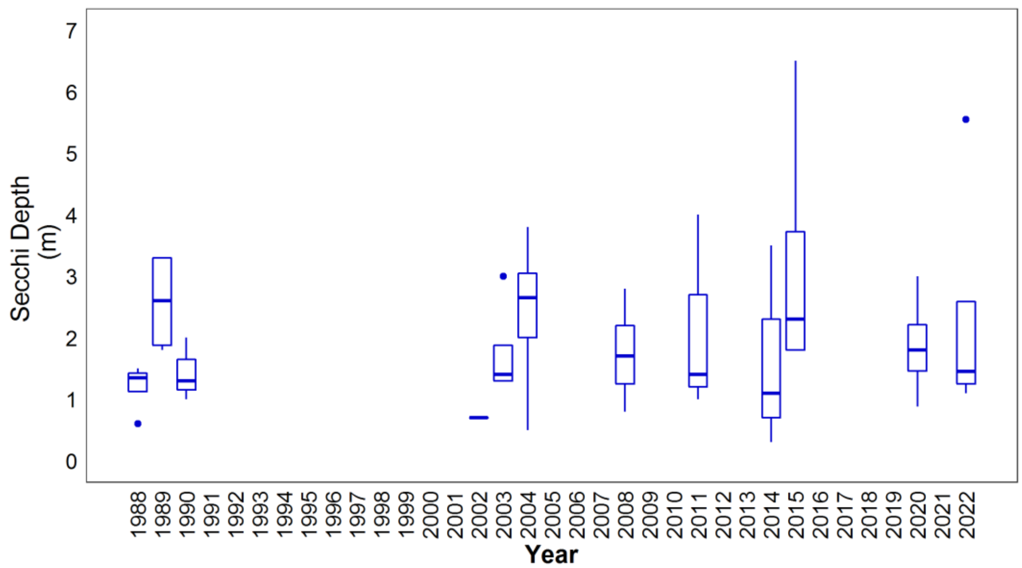


Figure 9. Monthly TDS values measured between June and September over the long term sampling dates between 1988 and 2022 (n = 33). The value closest to the 15th day of the month was chosen to represent the monthly value in cases with multiple monthly samples.

Secchi Depth

Secchi depth has not significantly changed in Lac La Nonne since 1988 (Tau = 0.14, *p* = 0.25).



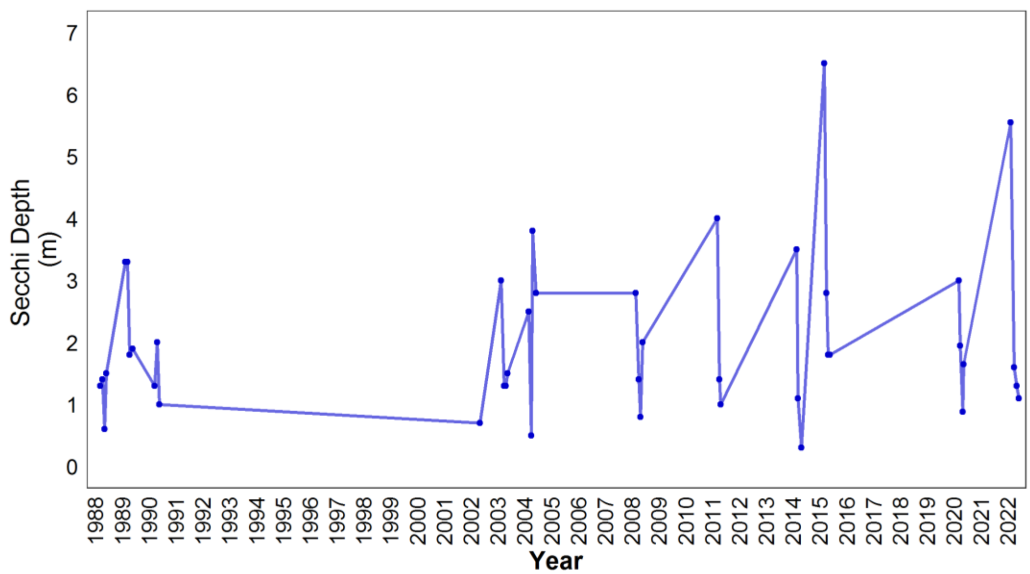


Figure 10. Monthly Secchi depth values measured between June and September over the long term sampling dates between 1988 and 2022 (n = 42). The value closest to the 15th day of the month was chosen to represent the monthly value in cases with multiple monthly samples.

Table 5. Results of trend tests using total phosphorus (TP), chlorophyll-*a*, total dissolved solids (TDS) and Secchi depth data from June to September, for sampled years from 1988-2022 on Lac La Nonne data. Note that there is insufficient data (*I.D.*) to conduct trend analysis on TDS data.

Definition	Unit	Total Phosphorus (TP)	Chlorophyll-a	Total Dissolved Solids (TDS)	Secchi Depth
Statistical Method	-	Seasonal Kendall	Seasonal Kendall	*I.D.*	Seasonal Kendall
The strength and direction (+ or -) of the trend between -1 and 1	Tau	0.40	-0.05	-	0.14
The extent of the trend	Slope (units per Year)	3.33	-0.12	-	0.01
The statistic used to find significance of the trend	Z	3.32	-0.33	-	1.16
Number of samples included	n	42	42	-	42
The significance of the trend	*p*	8.86×10^{-4}*	0.74	-	0.25

*$p < 0.05$ is significant within 95%