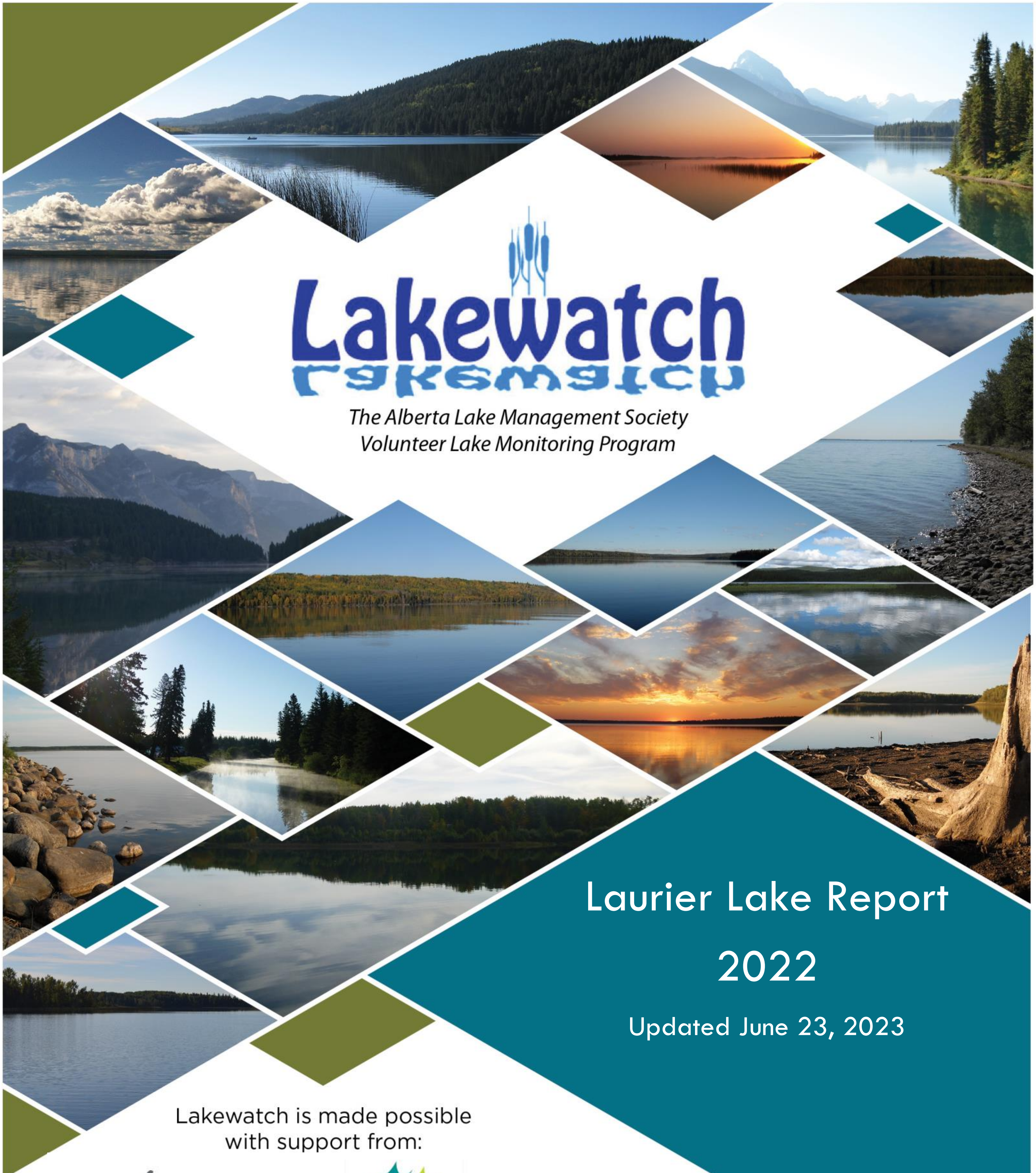


Lakewatch

The Alberta Lake Management Society
Volunteer Lake Monitoring Program

Laurier Lake 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.

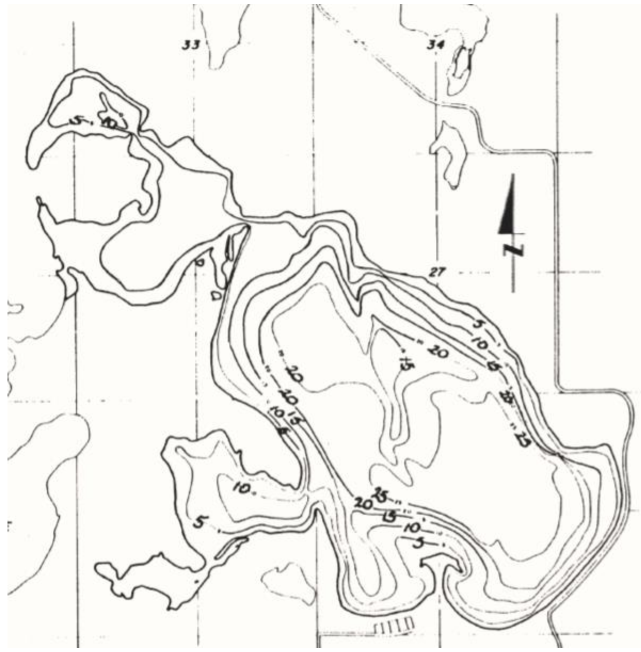
If you require data from this report, please contact ALMS for the raw data files.

ACKNOWLEDGEMENTS

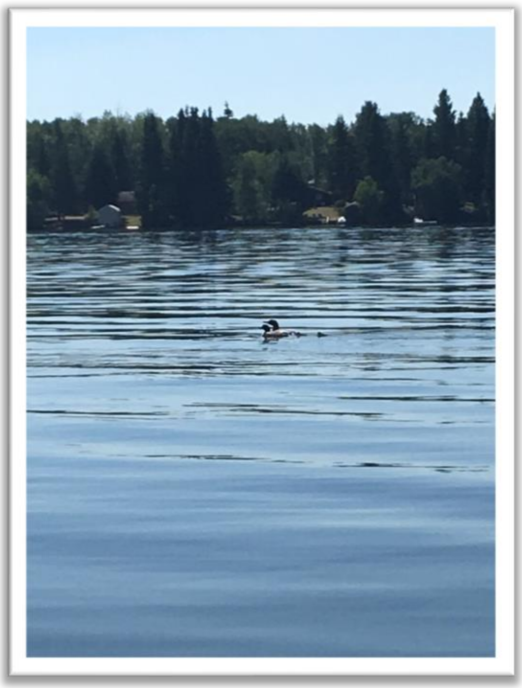
The LakeWatch program is made possible through the dedication of its volunteers. A special thanks to Shawn Jacula for his commitment to collecting data at Laurier Lake. We would also like to thank Kurstyn Perrin and Dominic Wong, who were summer technicians in 2022. Executive Director Bradley Peter and Program Manager Caleb Sinn were instrumental in planning and organizing the field program. This report was prepared by Caleb Sinn and Bradley Peter.

LAURIER LAKE

Laurier Lake is one of the four lakes which are part of Whitney Lakes Provincial Park that were left behind 10,000 years ago when glaciers carved a hummocky terrain of kettles, eskers, and lake basins. Archaeological evidence indicates that the area was inhabited 7000 years ago, with Europeans arriving in 1754 by way of the nearby North Saskatchewan River. The Whitney Lakes Provincial Park adjacent to Laurier Lake was established in 1982. It boasts a diverse setting of jack pine (*Pinus banksiana*) meadows, aspen (*Populus* spp.) groves, willow (*Salix* spp.) thickets, marshes, fens, and mixed wood forests.



Bathymetric map of Laurier Lake circa 1856 (Angler's Atlas).



Loons on Laurier Lake, 2017 (photo by Elashia Young).

As many as 148 bird species have been observed in the park with an excellent viewing point on the west side of Laurier Lake. The land surrounding Laurier Lake includes a mixture of recreational cottage development, cleared agricultural land, and natural deciduous forest. Protected Crown Land makes up the north shore of the lake and the remainder is privately owned. The lake is enjoyed through recreational activities including hiking, wildlife viewing, and water-based recreation such as wind surfing, waterskiing, sailing, swimming, and fishing. Yellow perch (*Perca flavescens*) and northern pike (*Esox lucius*) are the sport fish of Laurier Lake. Fish stocking occurred in 1953 with sport and forage fish transferred from Moose Lake to Laurier Lake. The lake has not been managed for commercial or domestic fisheries.

The watershed area for Laurier Lake is 196 km^2 and the lake area is 6.57 km^2. The lake to watershed ratio of Laurier Lake is 1:30. A map of the Laurier Lake watershed area can be found at http://alms.ca/wp-content/uploads/2016/12/Laurier.pdf.

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 Laurier Lake was 91 µg/L (Table 2), falling into the eutrophic, or very productive trophic classification. This value falls is the second highest observed average since sampling began in 1997. TP ranged from a minimum of 62 µg/L on the September 15th sampling trip, to a maximum of 110 µg/L on July 22nd (Figure 1).

Average chlorophyll-*a* concentration in 2022 was 66.7 µg/L (Table 2), falling into the hypereutrophic, or very highly productive trophic classification. Chlorophyll-*a* was lowest during the July sampling event at 32 µg/L and peaked at 118 µg/L on August 17th.

The average TKN concentration was 2.6 mg/L (Table 2), and displayed little seasonal variation (Figure 1).

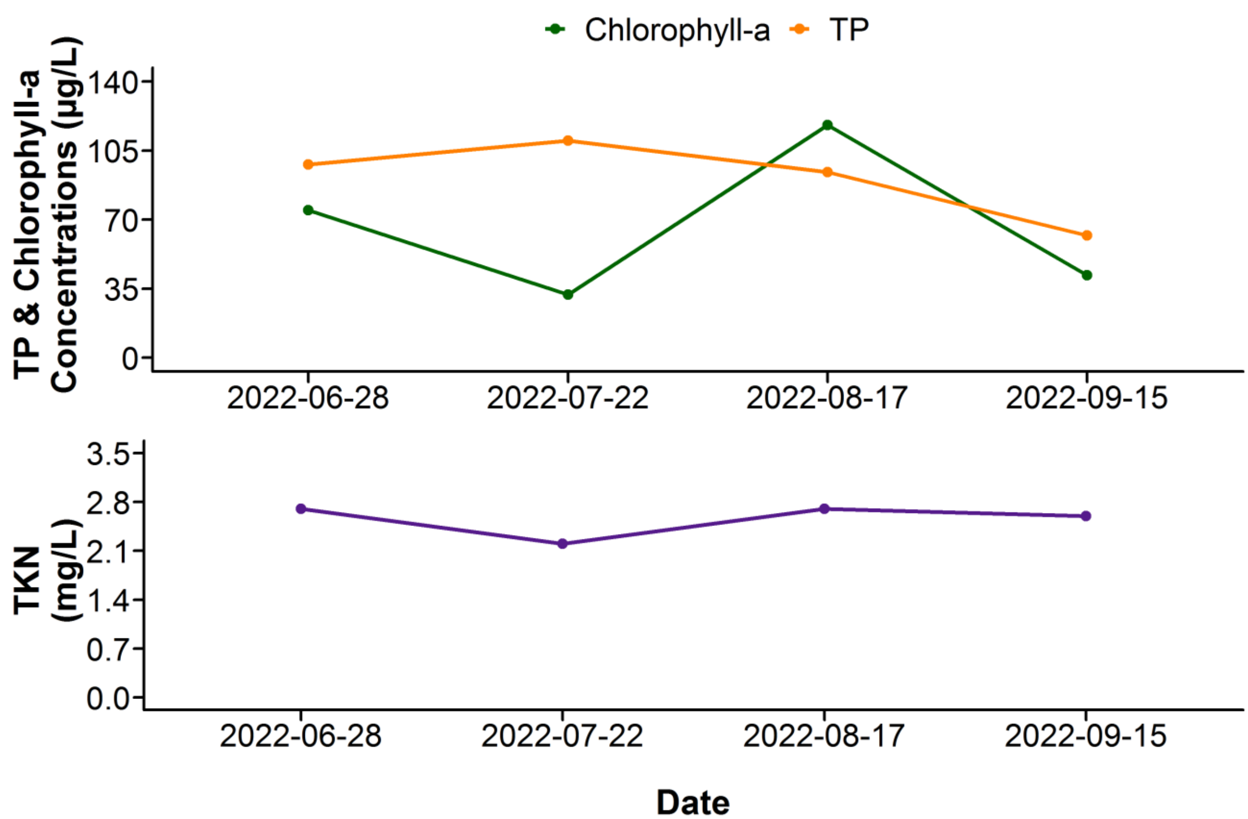


Figure 1. Total Phosphorus (TP), Total Kjeldahl Nitrogen (TKN), and Chlorophyll-*a* concentrations measured four times over the course of the summer at Laurier Lake.

Average pH was measured as 8.81 in 2022, buffered by high alkalinity (425 mg/L $CaCO_3$) and bicarbonate (438 mg/L HCO_3). Aside from bicarbonate, sodium and sulphate were higher than all other major ions, and together contributed to a moderate conductivity of 908 µS/cm (Figure 2, top; Table 2). Laurier Lake is in the moderate to high end range of ion levels, compared to other LakeWatch lakes sampled in 2022.

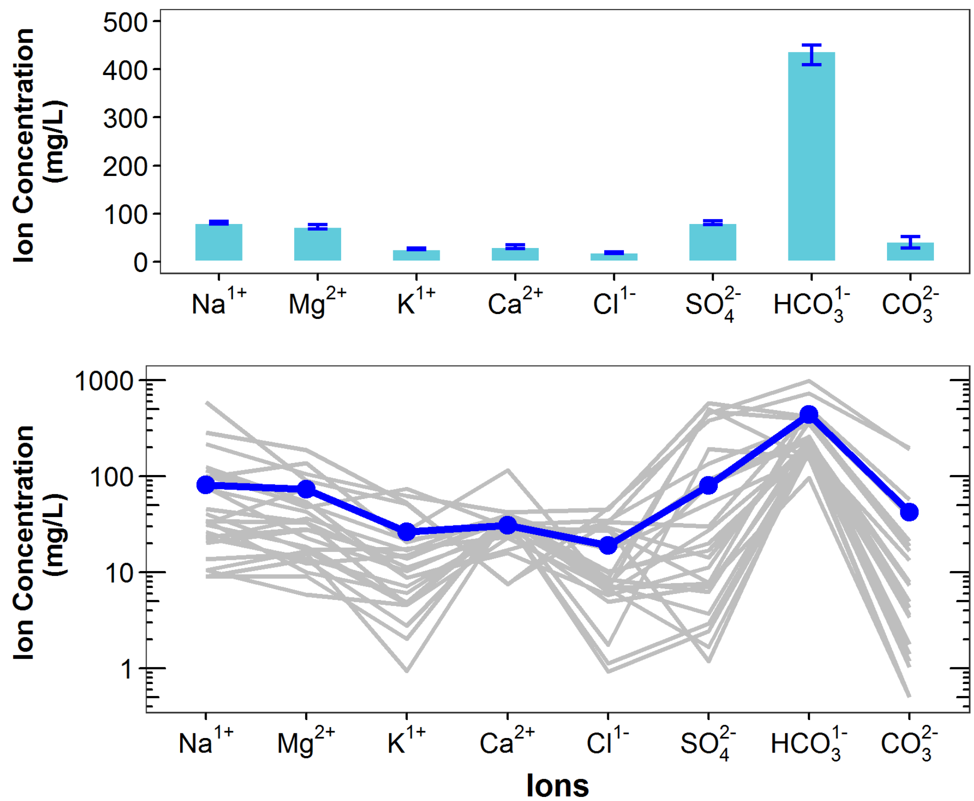


Figure 2. Average levels of cations (sodium = Na^{1+}, magnesium = Mg^{2+}, potassium = K^{1+}, calcium = Ca^{2+}) and anions (chloride = Cl^{1-}, sulphate = SO_4^{2-}, bicarbonate = HCO_3^{1-}, carbonate = CO_3^{2-}) from four measurements over the course of the summer at Laurier Lake. Top) bars indicate range of values measured, and bottom) Schoeller diagram of average ion levels at Laurier Lake (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 measured at Laurier Lake in 2022, and no metal exceeds CCME guidelines (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 Laurier Lake in 2022 was 2.76 m, corresponding to an average Secchi depth of 1.38 m (Table 2). Euphotic depth varied over the season, ranging from as deep 3.90 m on July 22nd, to a minimum of 1.10 m on August 17th (Figure 3). The highest chlorophyll-*a* observation occurred at the same time as the lowest Secchi disk depth measurement, suggesting chlorophyll-*a* was likely impairing water clarity on that date.

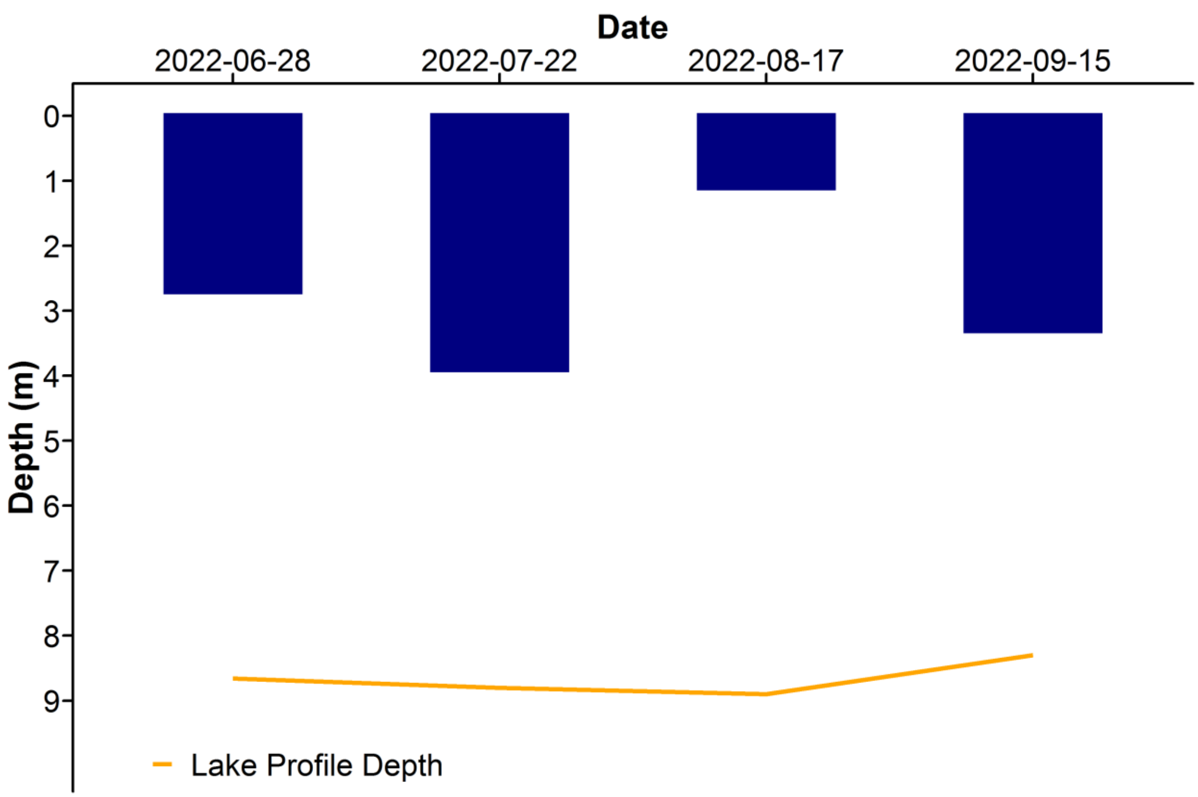


Figure 3. Euphotic depth values measured four times over the course of the summer at Laurier Lake in 2022.

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 Laurier Lake varied throughout the summer, with the August 18th sampling date having the warmest temperatures (Figure 4a). Slight thermal stratification was observed near the bottom of the lake on the July 22nd sampling trip.

Oxygen concentrations varied greatly throughout the summer at Laurier Lake. In June and August, the surface waters were highly saturated with oxygen, measuring > 10 mg/L. These concentrations declined sharply with depth, suggesting high amounts of photosynthetic activity at the surface likely contributed to these high oxygen values. In July, oxygen concentrations declined sharply at the bottom thermocline, suggesting a lack of lake mixing below that depth may have contributed to the decline in oxygen concentrations. In September, the entire water column appeared well mixed and above the Canadian Council for Ministers of the Environment Guideline of 6.5 mg/L for the protection of aquatic life.

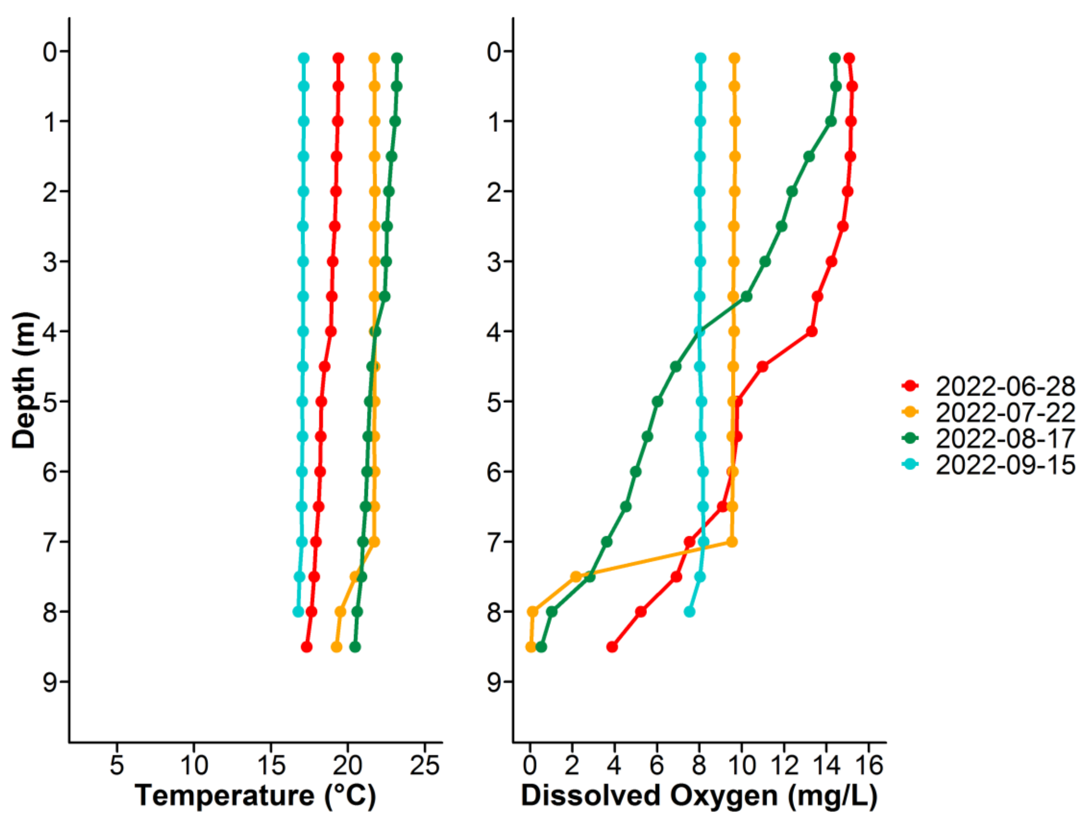


Figure 4. a) Temperature (°C) and b) dissolved oxygen (mg/L) profiles for Laurier Lake measured four times over the course of the summer of 2022.

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.

Composite microcystin levels in Laurier Lake fell below the recreational guideline of 10 μg/L during every sampling event in 2022. However, high microcystin values have been observed from grab samples taken directly from cyanobacteria blooms in Laurier Lake.[1] Caution should always be observed when recreating near cyanobacteria.

Table 1. Microcystin concentrations measured four times at Laurier Lake in 2022.

Date	**Microcystin Concentration (μg/L)**
28-Jun-22	0.24
22-Jul-22	2.44
17-Aug-22	2.96
15-Sep-22	3.03
Average	2.17

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 Laurier Lake.

[1] Sinn, C. Peter, B. Laurier Lake 2019. LakeWatch Reports. (2019). www.alms.ca/reports.

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.

No suspect watermilfoil was observed or collected from Laurier Lake in 2022.

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 Protected Areas.

Water levels at Laurier Lake have increased sharply in the past decade. Water levels in 2022 showed some decline compared to the previous historical maximum observed in 2017 (567.4259 masl), though remain on the high end of observations recorded since 1968.

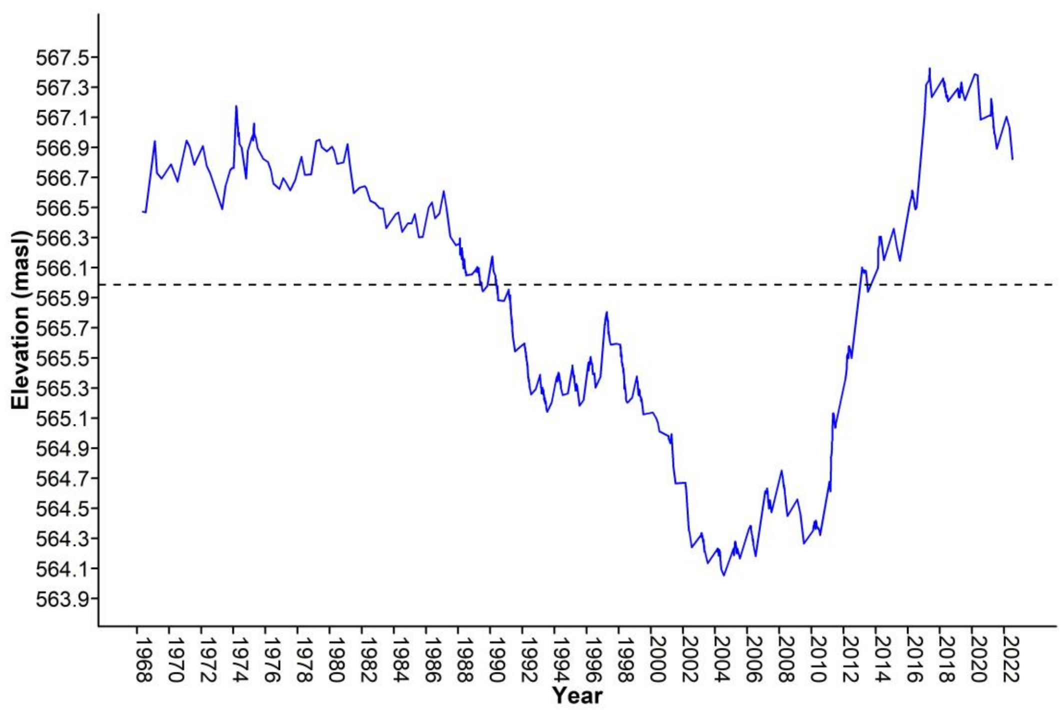


Figure 5. Water levels measured at Laurier Lake in metres above sea level (masl) from 1968-2022. Data retrieved from Alberta Environment and Protected Areas and/or Environment and Climate Change Canada. Black dashed line represents historical yearly average water level.

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.

Laurier Lake experienced a warmer, and windier summer with more accumulated precipitation than normal (Figure 6). Higher accumulated precipitation than normal is likely contributing both to Laurier Lake's high water levels as well as elevated nutrient concentrations as nutrients are washed into the lake from watershed sources.

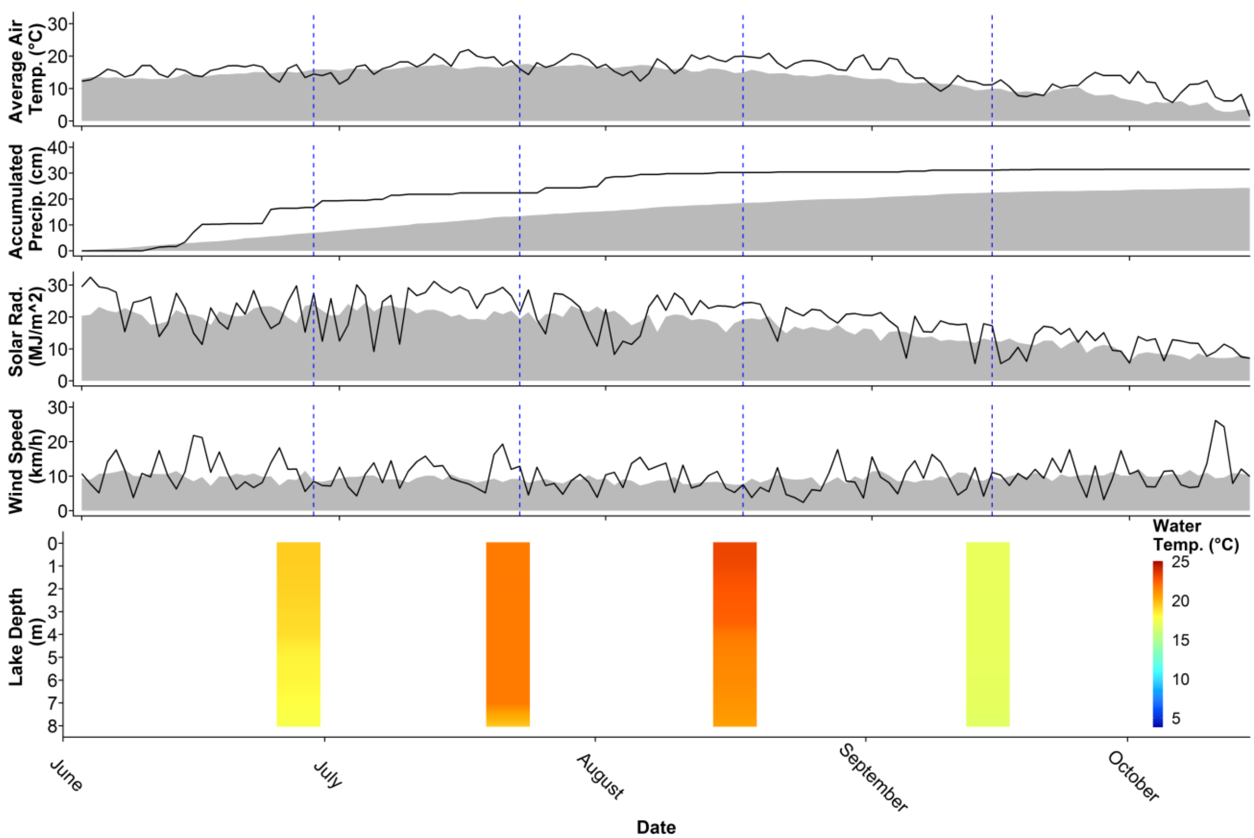


Figure 6. Average air temperature (°C) and wind speed (km/h) measured from Lindbergh AGDM weather station, as well as Laurier Lake temperature profiles, interpolated (°C). Black lines indicate 2022 levels, gray indicates long-term normals, and blue lines indicate sampling dates for Laurier Lake over 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).

Table 2a. Average Secchi depth and water chemistry values for Laurier Lake.

Parameter	1997	1998	2000	2003	2004	2007	2008	2009	2010
TP (µg/L)	32	48	36	27	33	42	51	50	38
TDP (µg/L)	/	/	/	15	18	22	19	20	16
Chlorophyll-a (µg/L)	5.3	9	5.5	2.6	4.9	4.3	11.9	9.1	7
Secchi depth (m)	4.6	1.32	1.83	4.38	3.18	2.42	1.34	2.05	1.8
TKN (mg/L)	/	/	/	2.4	2.6	2.2	2.7	2.8	2.6
NO2 and NO3 (µg/L)	/	/	50	211	7	5	6	6	10
NH3 (µg/L)	/	/	/	41	74	46	39	39	33
DOC (mg/L)	/	/	/	/	44	38	38	39	37
Ca (mg/L)	20	21	13	/	/	/	/	/	/
Mg (mg/L)	73	81	83	/	/	/	/	/	/
Na (mg/L)	85	92	98	128	130	123	121	132	136
K (mg/L)	24	25	25	31	34	33	32	38	34
SO42- (mg/L)	62	66	72	99	104	112	121	136	149
Cl- (mg/L)	12	13	15	18	20	20	20	21	23
CO3 (mg/L)	39.1	62.5	66	112	83.7	86	84.7	70	85
HCO3 (mg/L)	493	468	469	522	601	536	544	582	568
pH	8.77	8.87	8.95	9.24	9.06	9.11	9.03	9	9.1
Conductivity (µS/cm)	919	957	929	/	1197	1163	1197	1247	1257
Hardness (mg/L)	351	387	376	462	459	443	419	393	436
TDS (mg/L)	562	598	602	764	784	750	754	784	817
Microcystin (µg/L)	/	/	/	/	/	0.53	0.24	0.39	0.17
Total Alkalinity (mg/L CaCO3)	470	488	493	615	633	583	588	594	608

*1983 and 2002 data from single sampling event in August

Table 2b. Average Secchi depth and water chemistry values for Laurier Lake.

Parameter	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**	**2018**	**2019**	**2022**
TP (µg/L)	46	36	73	48	39	45	53	94	81	91
TDP (µg/L)	21	19	31	26	13	13	12	17	14	36
Chlorophyll-*a* (µg/L)	3.8	5.9	14.3	19.6	7.8	36.4	39.6	58.3	43.5	66.7
Secchi depth (m)	4.04	3.14	1.74	1.44	2.68	1.98	1.42	1.7	1.67	1.43
TKN (mg/L)	2.5	2.2	2.3	2.2	2.2	2.4	2.5	2.9	2.4	2.6
NO_2-N and NO_3-N (µg/L)	7	3	2	24	5	5	3	11	18	10
NH_3-N (µg/L)	50	33	26	33	74	105	66	96	128	48
DOC (mg/L)	37	32	34	35	33	27	28	30	31	30
Ca (mg/L)	/	/	/	/	26	28	30	32	30	30
Mg (mg/L)	/	/	/	/	87	89	77	75	70	72
Na (mg/L)	120	102	101	108	98	97	87	86	80	80
K (mg/L)	33	31	35	33	30	32	29	27	25	26
SO_4^{2-} (mg/L)	128	118	107	103	120	110	91	89	104	80
Cl^- (mg/L)	21	19	17	18	20	19	17	18	19	19
CO_3 (mg/L)	66.8	45	55.6	63.7	51.8	52.5	42.2	47.4	49.7	42
HCO_3 (mg/L)	536	547	500	485	536	508	474	470	447	438
pH	9.04	8.84	8.88	8.9	8.85	8.9	8.86	8.87	8.85	8.81
Conductivity (µS/cm)	1177	1144	1099	1100	1100	1100	966	970	973	908
Hardness (mg/L)	451	399	401	353	422	435	394	390	363	372
TDS (mg/L)	751	691	669	710	698	682	612	612	603	570
Microcystin (µg/L)	/	0.47	/	3.51	0.49	0.93	2.29	2.68	2.21	2.17
Total Alkalinity (mg/L $CaCO_3$)	551	524	503	504	524	505	458	462	453	425

Table 3a. Concentrations of metals measured in Laurier Lake. 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)	2007	2008	2010	2011	2012	2013	Guidelines
Aluminum µg/L	29.4	9.69	20.65	17.2	7.61	7.265	100[a]
Antimony µg/L	0.137	0.117	0.131	0.1245	0.115	0.0931	/
Arsenic µg/L	2.6	3	3.185	2.825	2.435	2.35	5
Barium µg/L	20.2	16.95	17.8	19.15	29.6	35.8	/
Beryllium µg/L	<0.003	<0.003	0.002	0.003	0.010	0.002	100[c,d]
Bismuth µg/L	<0.005	0.005	0.002	0.003	0.007	0.001	/
Boron µg/L	175.5	182	188.5	189	221.5	163	1500
Cadmium µg/L	0.008	0.004	0.004	0.003	0.003	0.002	0.37[b]
Chromium µg/L	0.611	0.560	0.441	0.465	0.296	0.526	/
Cobalt µg/L	0.099	0.058	0.071	0.081	0.059	0.048	50,1000[c,d]
Copper µg/L	0.61	0.56	0.28	2.90	0.68	0.37	4[b]
Iron µg/L	37.1	15.8	16.855	21.05	9.5	17.15	300
Lead µg/L	0.06	0.02	0.02	0.06	0.02	0.03	7[b]
Lithium µg/L	102.9	100.2	114	114.5	111.5	87.05	2500[d]
Manganese µg/L	5.2	8.0	4.1	8.3	13.0	19.9	140[e]
Molybdenum µg/L	0.66	0.59	0.86	0.78	0.59	0.46	73
Nickel µg/L	0.28	0.13	0.13	0.2	0	0.22	150[b]
Selenium µg/L	0.55	0.37	0.42	0.31	0.3	0.24	1
Silver µg/L	<0.003	0.009	0.001	0.043	0.002	0.025	0.25
Strontium µg/L	84.5	62.9	58.85	72.35	114.5	134	/
Thallium µg/L	<0.001	0.002	0.001	0.001	<0.001	<0.001	0.8
Thorium µg/L	<0.01	0.02	0.01	0.04	0.01	0.01	/
Tin µg/L	<0.06	<0.03	0.02	0.02	0.03	0.02	/
Titanium µg/L	1.24	1.36	1.38	0.75	0.69	1.4	/
Uranium µg/L	0.81	0.81	1.09	0.88	0.68	0.68	15
Vanadium µg/L	0.74	0.51	0.81	0.56	0.43	0.33	100[c,d]
Zinc µg/L	1.53	0.92	0.33	1.09	1.03	0.62	30[f]

Values represent means of total recoverable metal concentrations.

[a] Based on pH ≥ 6.5

[b] Based on 2022 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 2022 avg. water hardness (as CaCO3) and avg. pH

[f] Based on 2022 avg. water hardness (as CaCO3), avg. pH, and avg. DOC with CCME equation

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

Table 3b. Concentrations of metals measured in Laurier Lake. 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)	2014	2015	2016	2017	2018	2019	2022	Guidelines
Aluminum μg/L	16.05	10.05	3.5	6.8	3.9	28.8	7.6	100[a]
Antimony μg/L	0.094	0.1415	0.093	0.074	0.08	0.062	0.068	/
Arsenic μg/L	2.165	3.89	1.93	2.56	2.13	2.14	2.27	5
Barium μg/L	37.85	23.225	39.9	43.8	53.6	47.2	45.4	/
Beryllium μg/L	0.004	0.004	0.004	0.006	<0.001	0.0015	0.0015	100[c,d]
Bismuth μg/L	0.001	0.015	<0.001	0.006	0	0.0015	0.0015	/
Boron μg/L	171	280	171	170	140	129	155	1500
Cadmium μg/L	0.002	0.002	0.001	0.025	0.01	0.005	0.005	0.37[b]
Chromium μg/L	0.695	0.185	0.060	0.250	0.1	0.05	0.05	/
Cobalt μg/L	0.026	0.071	0.020	0.083	0.06	0.054	0.07	50,1000[c,d]
Copper μg/L	0.24	1.09	0.78	0.91	0.11	0.15	0.16	4[b]
Iron μg/L	13.4	14	8.3	8.3	12	12.1	11.6	300
Lead μg/L	0.01	0.04	0.01	0.01	0.01	0.031	0.02	7[b]
Lithium μg/L	75.8	149.35	94.3	89.5	75	73.4	74.1	2500[d]
Manganese μg/L	20.3	12.6	20.6	13.3	35.3	10.6	9.36	140[e]
Molybdenum μg/L	0.32	0.78	0.4	0.3	0.33	0.45	0.751	73
Nickel μg/L	<0.001	0.16	0.03	1.64	0.22	0.17	0.36	150 [b]
Selenium μg/L	0.49	0.11	0.57	0.5	0.6	0.4	0.1	1
Silver μg/L	0.018	0.002	0.001	0.003	<0.001	0.002	0.0005	0.25
Strontium μg/L	145	89.2	166	178	210	196	191	/
Thallium μg/L	0.003	0.022	<0.001	0.005	<0.001	0.001	0.001	0.8
Thorium μg/L	<0.01	0.03	0.01	0.014	<0.01	0.012	0.002	/
Tin μg/L	0.01	0.02	0.01	0.15	0.06	0.03	0.03	/
Titanium μg/L	1.94	2.01	1.4	1.31	1.38	1.64	0.33	/
Uranium μg/L	0.55	2.77	0.61	0.5	0.46	0.574	0.532	15
Vanadium μg/L	0.44	0.85	0.26	0.31	0.27	0.109	0.354	100[c,d]
Zinc μg/L	1.1	1.25	1.1	2.1	1.1	0.8	0.8	30 [f]

Values represent means of total recoverable metal concentrations.

[a] Based on pH ≥ 6.5

[b] Based on 2022 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 2022 avg. water hardness (as CaCO3) and avg. pH

[f] Based on 2022 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 Laurier Lake. In sum, significant increasing trends were observed in TP and chlorophyll-*a*, while significant decreasing trends were observed in TDS and Secchi depth. 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 Laurier Lake data from 1997 to 2022.

Parameter	Date Range	Direction of Significant Trend
Total Phosphorus	1997-2022	Increasing
Chlorophyll-*a*	1997-2022	Increasing
Total Dissolved Solids	1997-2022	Decreasing
Secchi Depth	1997-2022	Decreasing

Definitions:

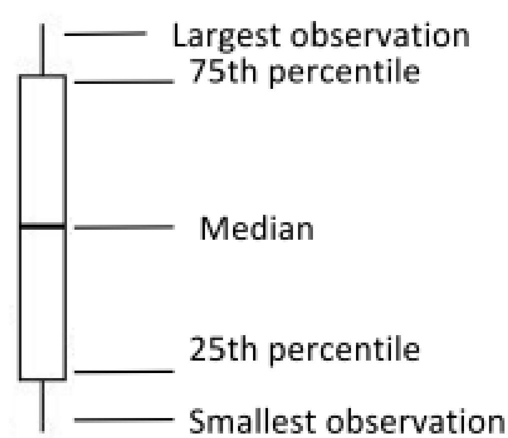
Median: the value in a range of ordered numbers that falls in the middle.

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 Laurier Lake since 1997 (Tau = 0.49, *p* = <0.001).

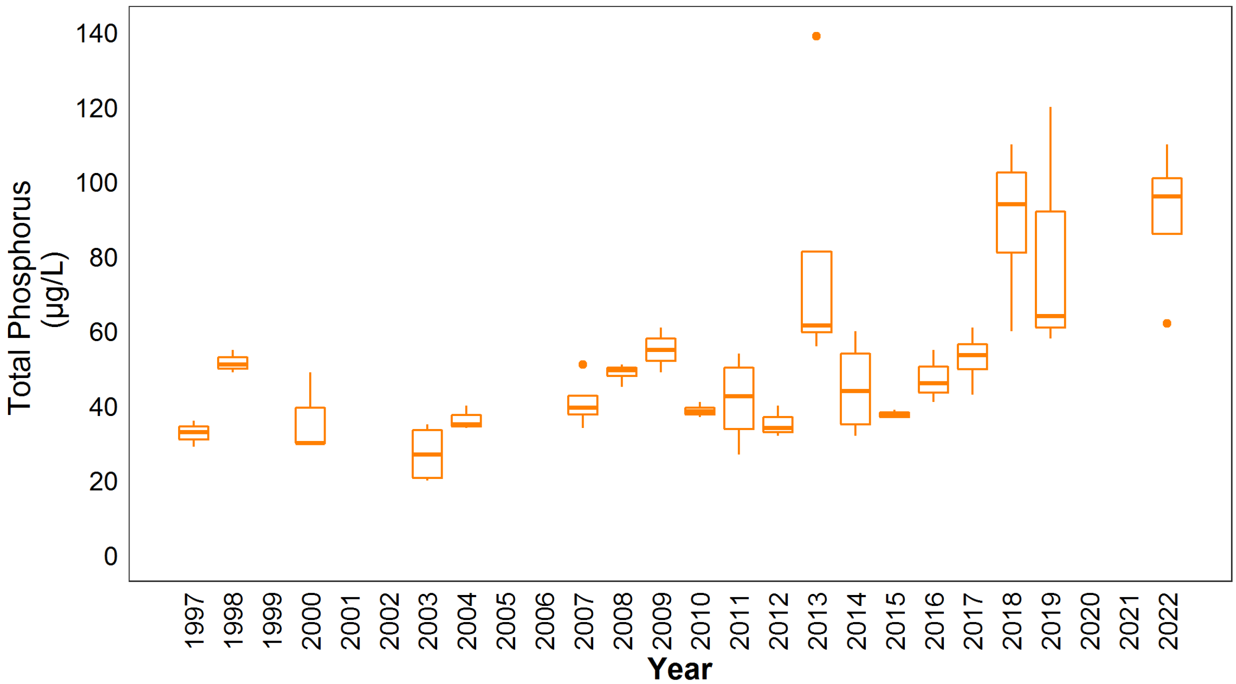
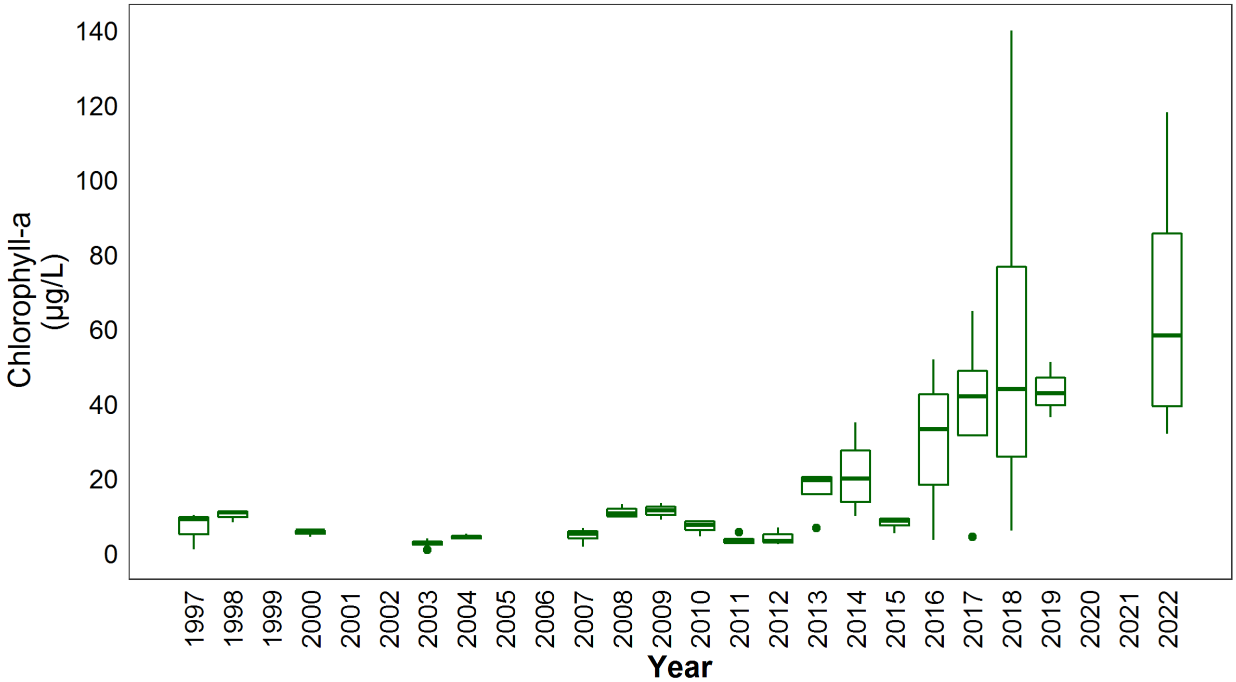


Figure 7. Monthly total phosphorus (TP) concentrations measured between June and September over the long term sampling dates between 1997 and 2022 (n = 68). The value closest to the 15th day of the month was chosen to represent the monthly value in cases with multiple monthly samples.

Chlorophyll-*a*

Chlorophyll-*a* has significantly increased over time at Laurier Lake (Tau = 1.38, p = <0.001). Chlorophyll-*a* trends were not significantly correlated with total phosphorus trends over time (r = 0.11, p = 0.88).



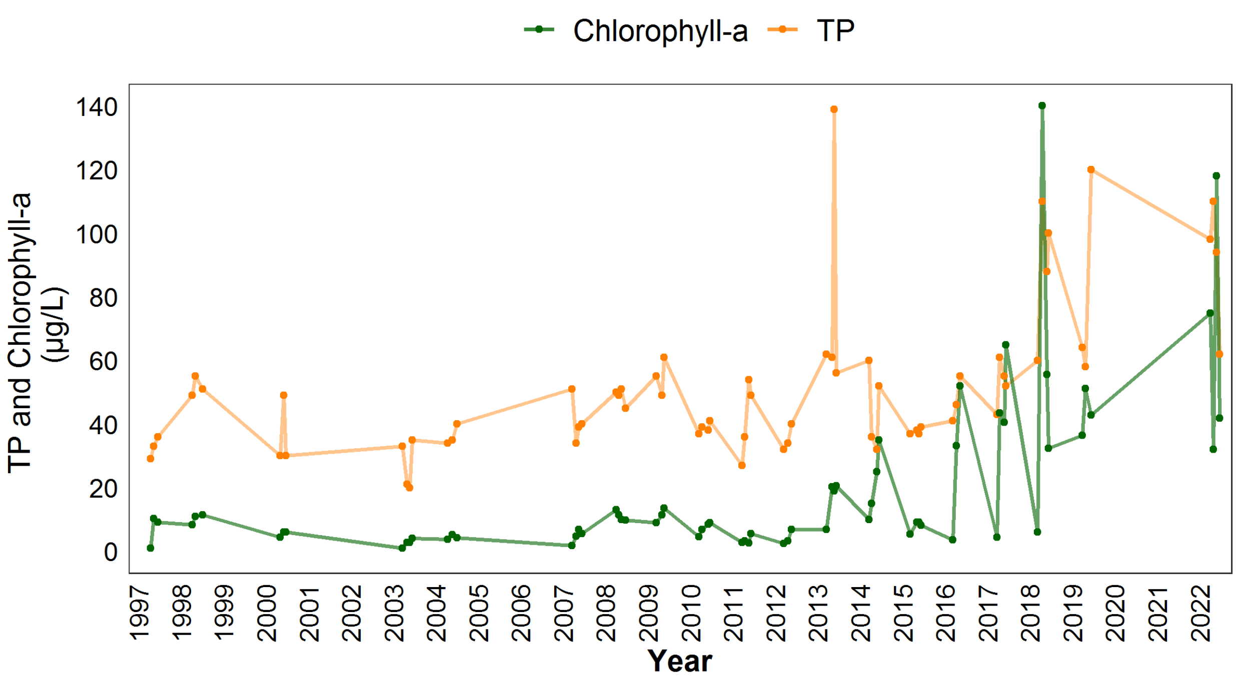
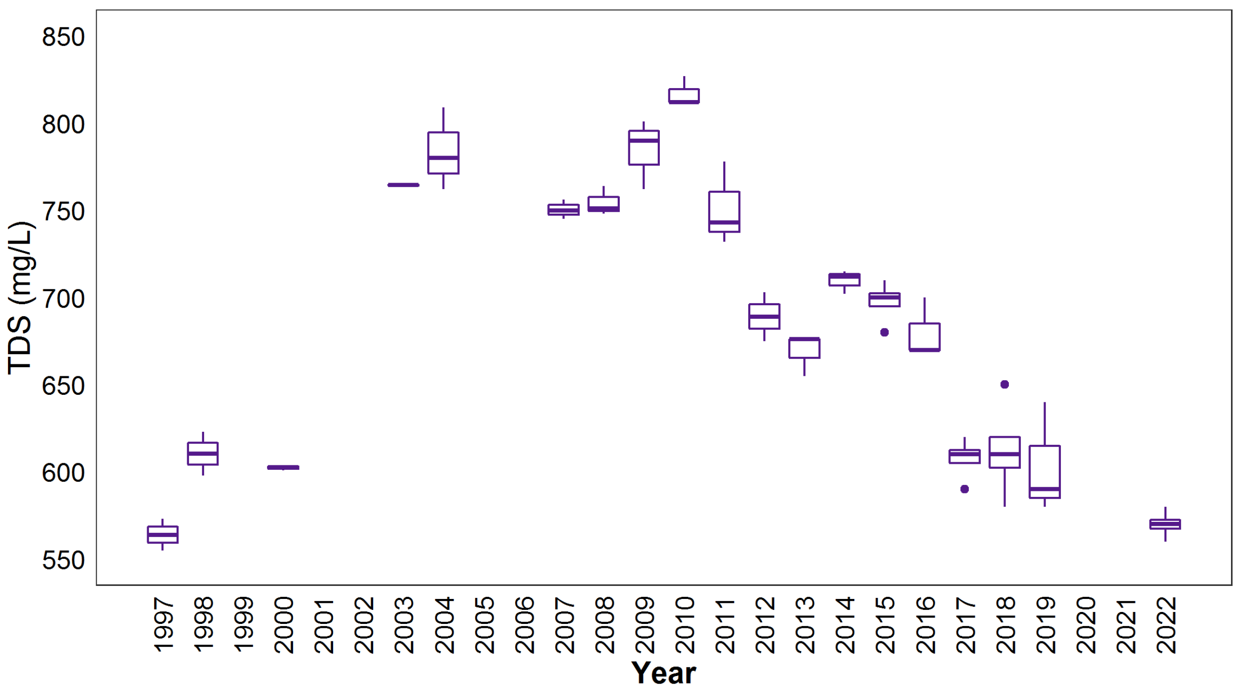


Figure 8. Monthly chlorophyll-*a* concentrations measured between June and September over the long term sampling dates between 1997 to 2022 (n = 68). The value closest to the 15th day of the month was chosen to represent the monthly value in cases with multiple monthly samples. Line graph is overlain by TP concentrations.

Total Dissolved Solids (TDS)

Trend analysis showed a significant decreasing trend in TDS between 1997 and 2022 (Tau = -0.44, p = <0.001) in Laurier Lake. Visually, levels appear to be returning to levels previously measured in the late 1990s, but a steady decrease beginning in the early 2010s following an increase after the late 1990s is driving the trend (Figure 9). Changes in TDS are likely related to appreciable changes in water levels within the lake (Figure 5).



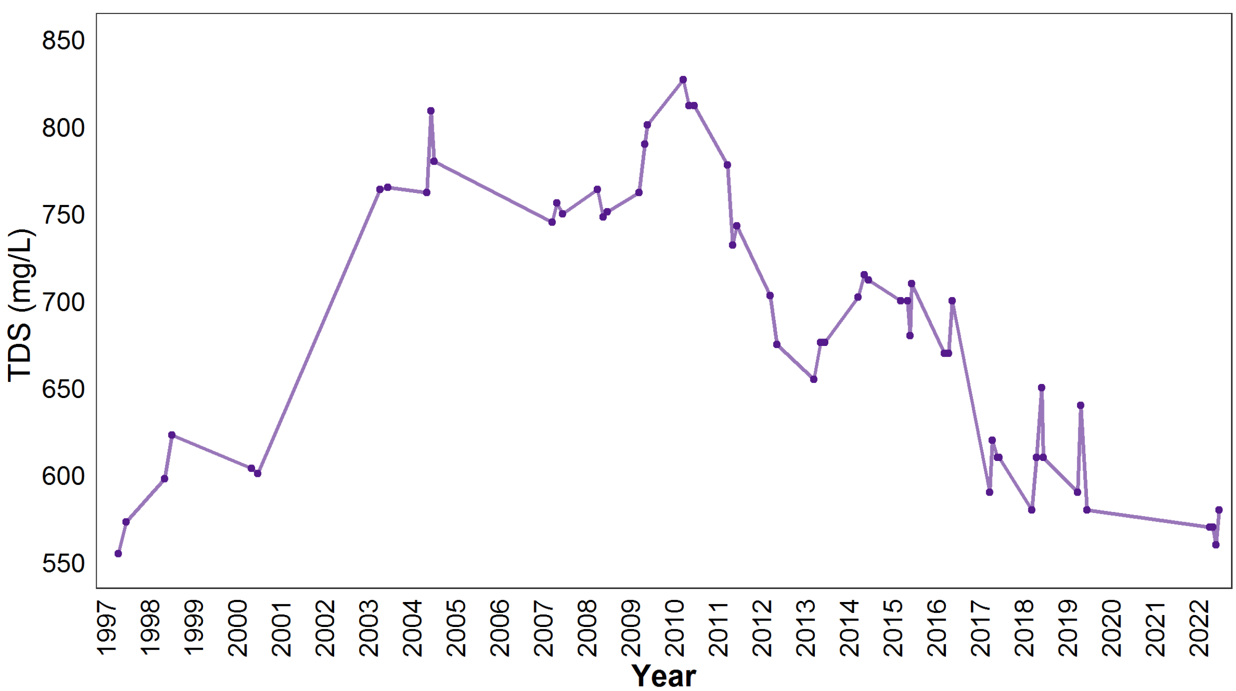


Figure 9. Monthly TDS values measured between June and September over the long term sampling dates between 1997 and 2022 (n = 56). The value closest to the 15th day of the month was chosen to represent the monthly value in cases with multiple monthly samples.

Due to the significant decreasing trend of TDS in Laurier Lake, exploring the specific major ions which may be driving this trend is important to determine. Of the major ions with enough data to conduct trend analysis on, sodium and alkalinity demonstrate significant negative (decreasing) trends. Visual inspection of the trend graphs suggests that other major ions including potassium and sulphate are experiencing declines in the recent decade (Figure 10).

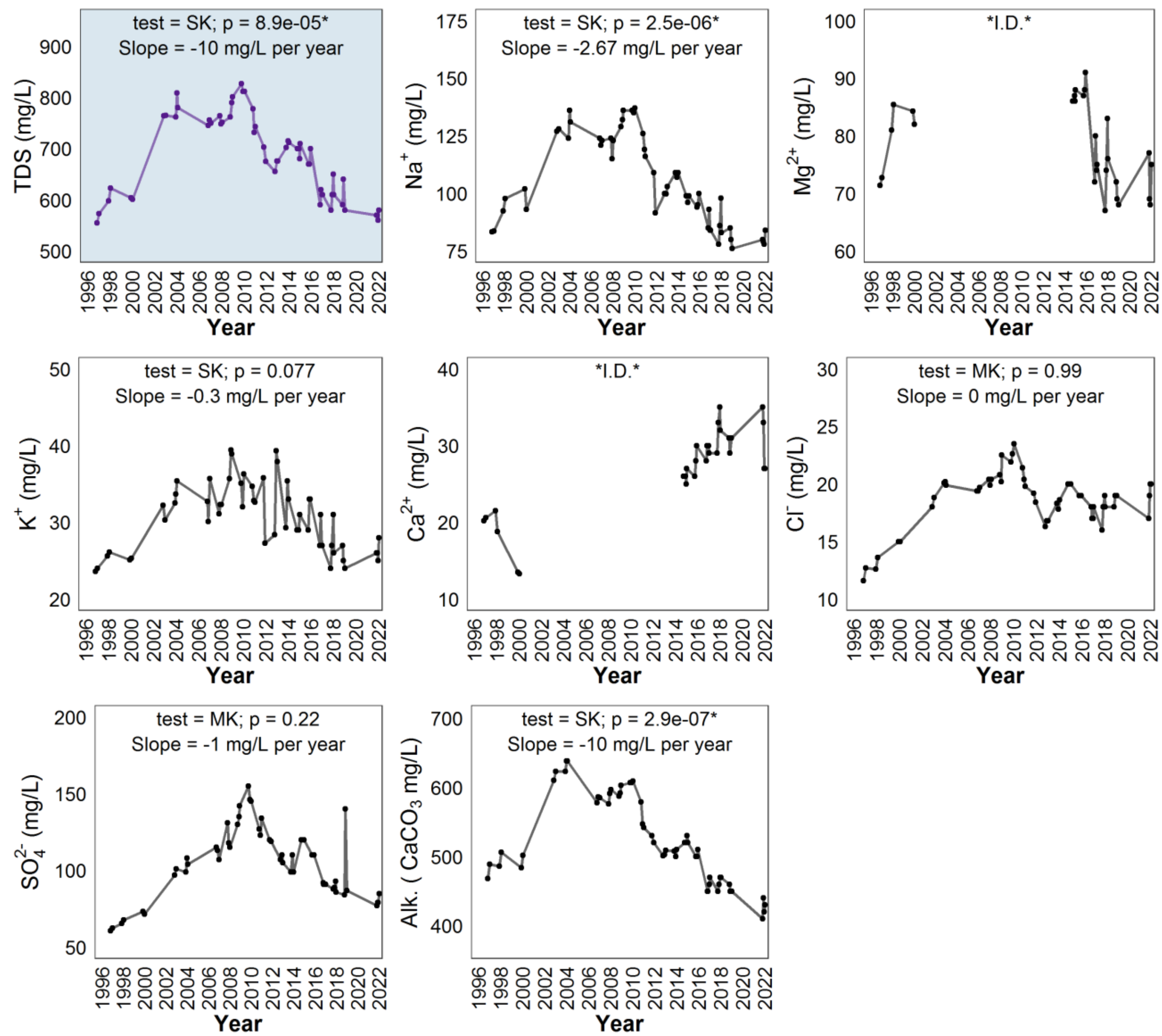
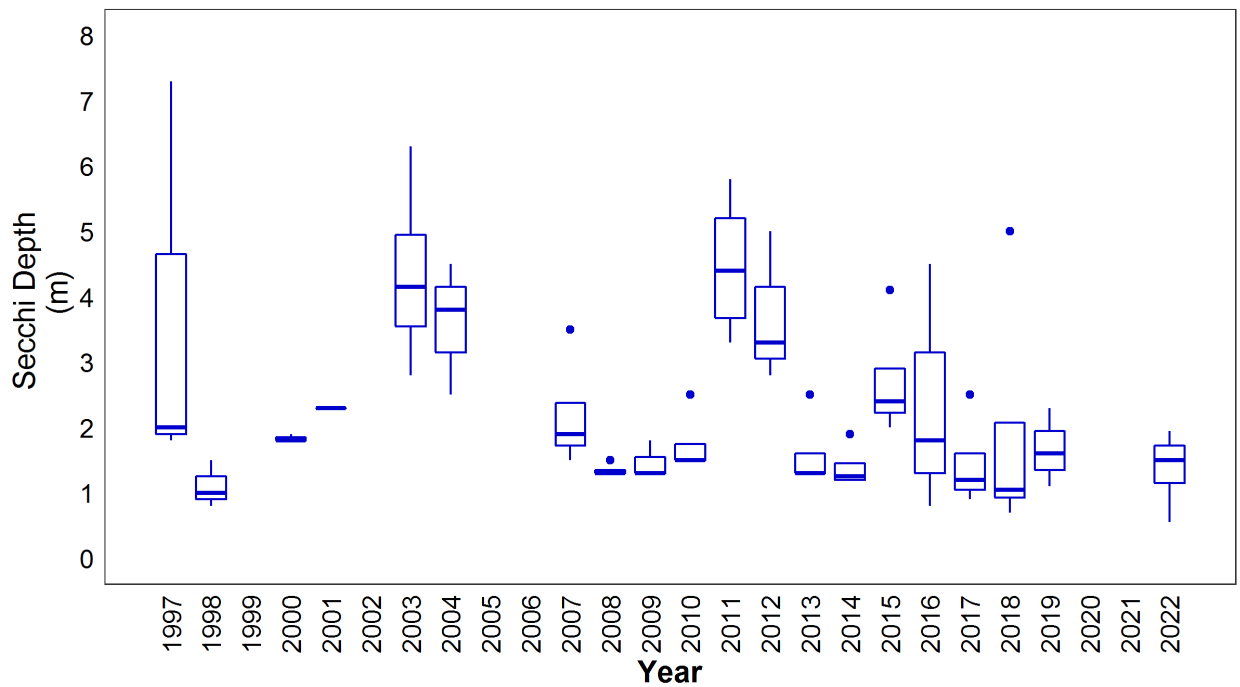


Figure 10. Concentrations of TDS (top left, blue panel), major ions (sodium = Na^+, magnesium = Mg^{2+}, potassium = K^+, calcium = Ca^{2+}, chloride = Cl^-, sulphate = SO_4^{2-}), and total alkalinity (Alk., as mg/L $CaCO_3$) measured monthly between June and September on sampling dates between 1997 and 2022. Also represented is the monotonic trend results for each parameter; test used (MK = Mann Kendall, SK = Seasonal Kendall), significance of test (p; assessed as significance when $p < 0.05$, marked with '*' if significant), and the slope of the trend. Test selection follows method outline in the *ALMS Guide to Trend Analysis on Alberta Lakes.* Note that some ions had insufficient data (*I.D.*) therefore trends were not calculated. 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 significantly decreased (become less clear) in Laurier Lake since 1997 (Tau = -0.26, *p* = 0.003).



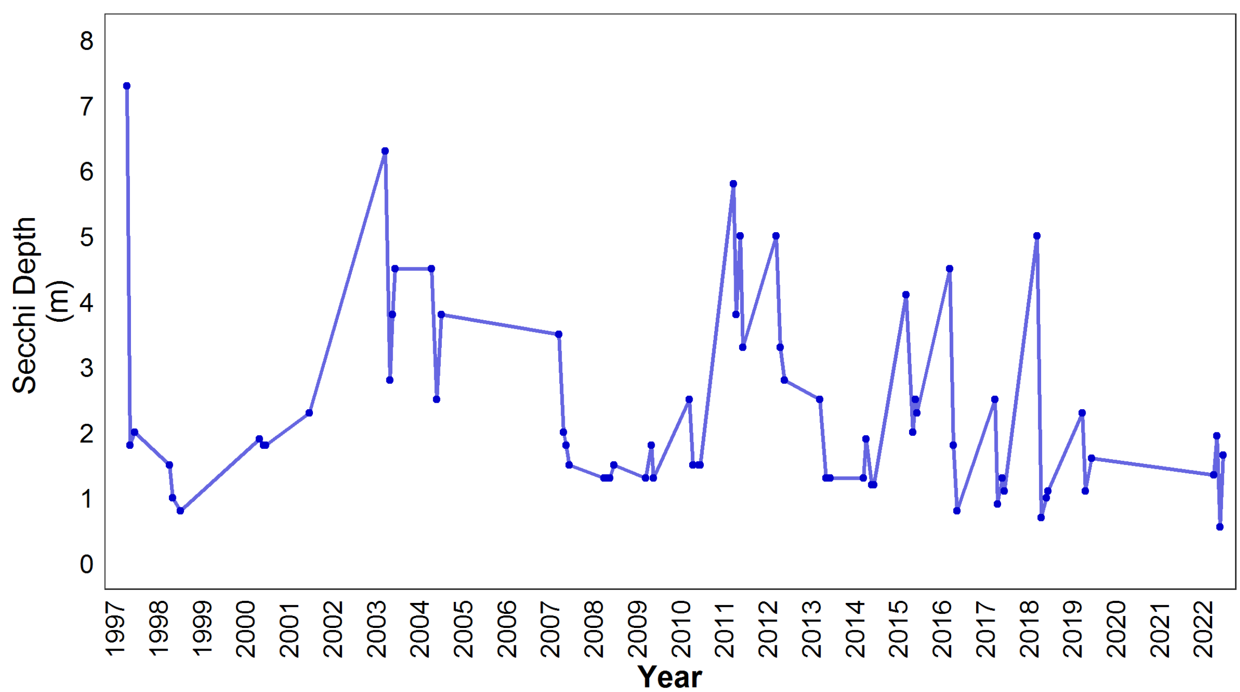


Figure 11. Monthly Secchi depth values measured between June and September over the long term sampling dates between 1997 and 2022 (n = 69). The value closest to the 15th day of the month was chosen to represent the monthly value in cases with multiple monthly samples.

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 1997-2022 on Laurier 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	0.49	0.49	-0.44	-0.26
The extent of the trend	Slope (units per Year)	1.44	1.38	-10.00	-0.04
The statistic used to find significance of the trend	Z	5.47	5.54	-3.92	-2.97
Number of samples included	n	68	68	56	69
The significance of the trend	*p*	4.44×10^{-8}*	2.97×10^{-8}*	8.94×10^{-5}*	3.03×10^{3}*

*$p < 0.05$ is significant within 95%