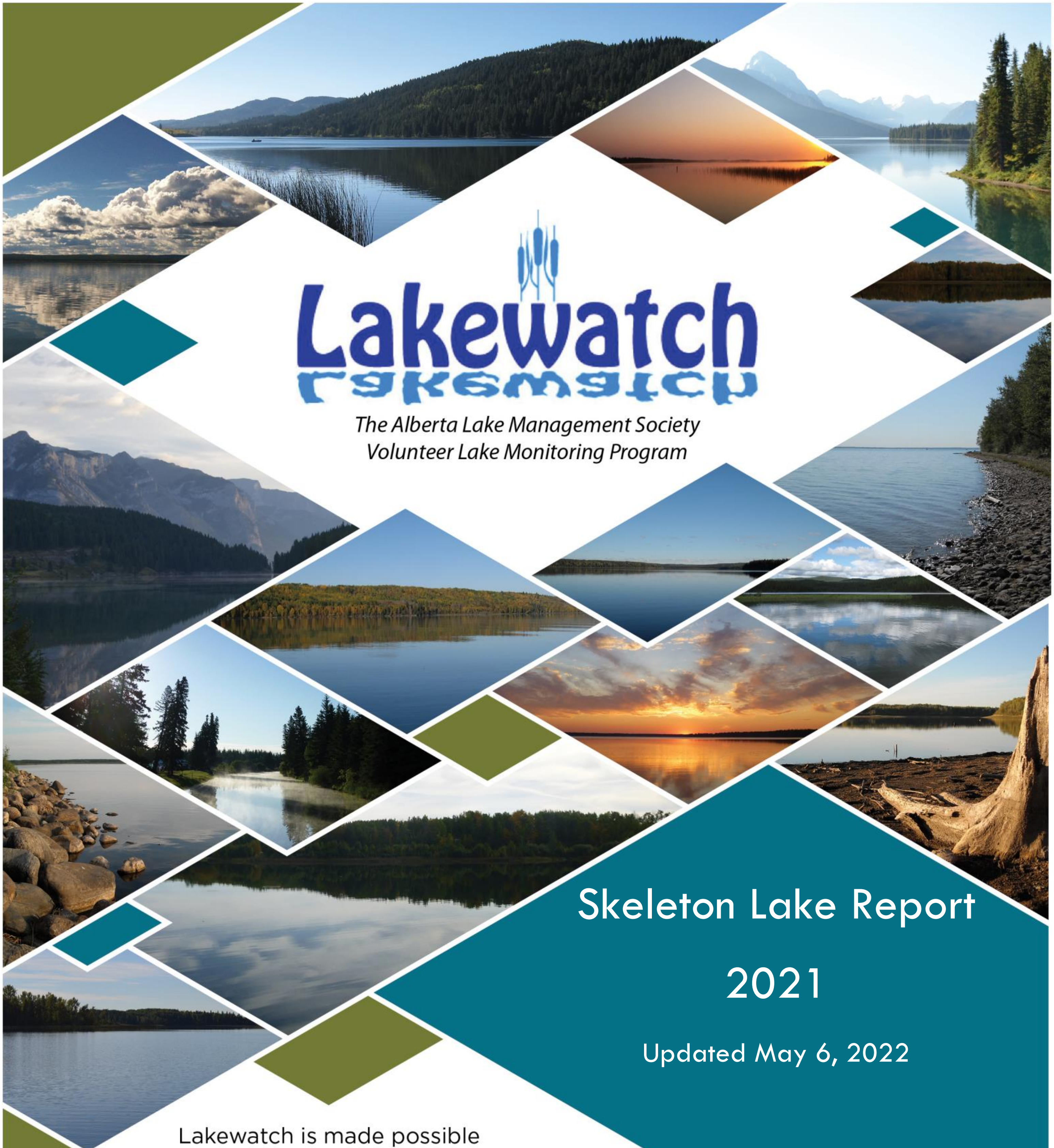

Lakewatch

The Alberta Lake Management Society
Volunteer Lake Monitoring Program

Skeleton Lake Report

2021

Updated May 6, 2022

Lakewatch is made possible
with support from:

Alberta
LICA Environmental Stewards
Pigeon Lake Watershed Association
MD61 Wainwright
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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

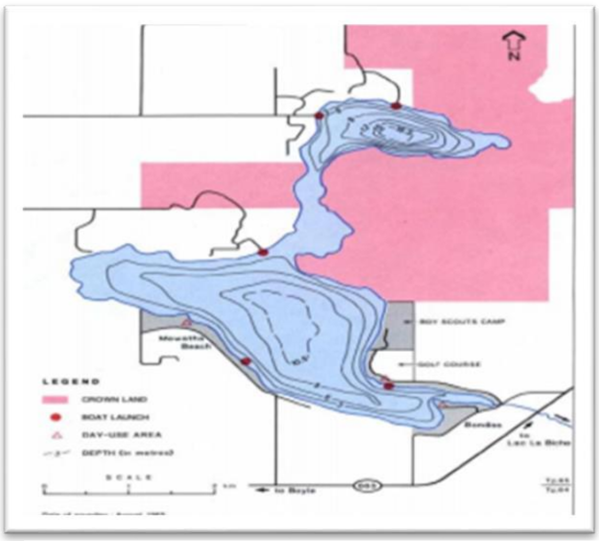
The LakeWatch program is made possible through the dedication of its volunteers. A special thanks to Orest Kitt and Rick Tiedemann for their commitment to collecting data at Skeleton Lake. We would also like to thank Keri Malanchuk and Brittany Onysyk, who were summer technicians in 2021. Executive Director 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.

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

SKELETON LAKE

Skeleton Lake is located in the western portion of the Beaver River watershed. The lake's name is a translation of the Cree Cîpay Sâkâhikan, which means "place of the skeletons". It is thought that a Cree chief is buried along the shores of the lake.[1] The lake is located within the County of Athabasca, 160 km northeast of the city of Edmonton and 6.5 km northeast of the village of Boyle. Skeleton Lake has an extensively developed shoreline with the summer villages of Mewatha and Bondiss on the southern shore of the lake and additional cottage developments on the north shore.

Skeleton Lake, North Basin — photo by Elashia Young 2017



Bathymetric map of Skeleton Lake (Alberta Environment)

Skeleton Lake used to be the main source of drinking water for the Town of Boyle, but has received its drinking water from the Athabasca River since 2007. The watershed is located in the Dry Mixedwood subregion of the Boreal Mixedwood natural region.[2] Several small intermittent streams flow into the lake and drain a watershed that is four times the size of the lake.[3] The outlet is a small creek located at the southeast end of the lake, and drains eastward into Amisk Lake. Beaver dams, however, often block the outlet. Tree cover in the watershed is primarily trembling aspen and secondarily white spruce, balsam poplar, and white birch. Peatlands are also significant, and most agricultural activities in the watershed take place in the southern and northwestern sections.

The LakeWatch program samples the north and south basins separately.

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[1] Aubrey, M. K. 2006. Concise place names of Alberta. Retrieved from http://www.albertasource.ca/placenames/resources/searchcontent.php?book=1

[2] Strong, W.L. and K.R. Leggat. 1981. Ecoregions of Alberta. Alta. En. Nat. Resour., Resour. Eval. Plan. Div., Edmonton.

[3] Mitchell, P. and E. Prepas. 1990. Atlas of Alberta Lakes, University of Alberta Press. Retrieved from http://sunsite.ualberta.ca/projects/alberta-lakes/

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.

North Basin:

The average total phosphorus (TP) concentration for the East Basin was 72 µg/L (Table 3), falling into the eutrophic, or high productivity trophic classification. This value is higher than any other historical average. TP ranged from a minimum of 44 µg/L on the August 19th sampling event, and was highest during the July 7th sampling event at 99 µg/L (Figure 1, top). The average total Kjeldahl nitrogen (TKN) concentration was 2.3 mg/L (Table 2) and varied through the season between 1.0 – 2.6 mg/L (Figure 1, top).

Average chlorophyll-*a* concentration in 2021 was 48.2 µg/L (Table 2), falling into the hypereutrophic, or very highly productive trophic classification. This is the highest average in the historical record, nearly double the next highest level (Table 3). Chlorophyll-*a* was lowest during the June 9th sampling event at 26.4 µg/L, and was slightly highest during the September 22nd sampling event at 68.6 µg/L (Figure 1, top).

Average pH was measured as 8.63 in 2021, buffered by moderate alkalinity (218 mg/L $CaCO_3$) and bicarbonate (245 mg/L HCO_3). Aside from bicarbonate, only calcium and magnesium were appreciably higher than all other major ions, and together contributed to a moderate conductivity of 440 µS/cm (Figure 2, top; Table 3). Compared to the South Basin, the North Basin had higher variability of bicarbonate values through the season. The North Basin of Skeleton Lake displays moderate ion levels compared to lakes sampled through the LakeWatch program in 2021 (Figure 2, top).

South Basin:

The average TP concentration for the South Basin was 45 µg/L (Table 3), falling into the eutrophic, or high productivity trophic classification. This value falls within the range of historical averages. TP ranged from a minimum of 14 µg/L on the June 14th sampling event, and was highest during the July 19th sampling event at 88 µg/L (Figure 1, bottom). The average TKN concentration was 1.3 mg/L (Table 3) and was relatively stable through the season, varying between 1.2 – 1.4 mg/L (Figure 1, bottom).

Average chlorophyll-*a* concentrations in 2021 was 17.7 µg/L (Table 3), falling into the eutrophic, or highly productive trophic classification. Chlorophyll-*a* was lowest during the June 14th sampling event at 6.3 µg/L, and was highest during the August 28th sampling event at 26.7 µg/L (Figure 1, bottom).

Average pH was measured as 8.51 in 2021, buffered by moderate alkalinity (228 mg/L $CaCO_3$) and bicarbonate (268 mg/L HCO_3). Aside from bicarbonate, calcium, magnesium and sodium were slightly higher than all other major ions, and together contributed to a moderate conductivity of 450 µS/cm (Figure 2, bottom; Table 3). The South Basin of Skeleton Lake displays moderate ion levels compared to lakes sampled through the LakeWatch program in 2021 (Figure 2, bottom).

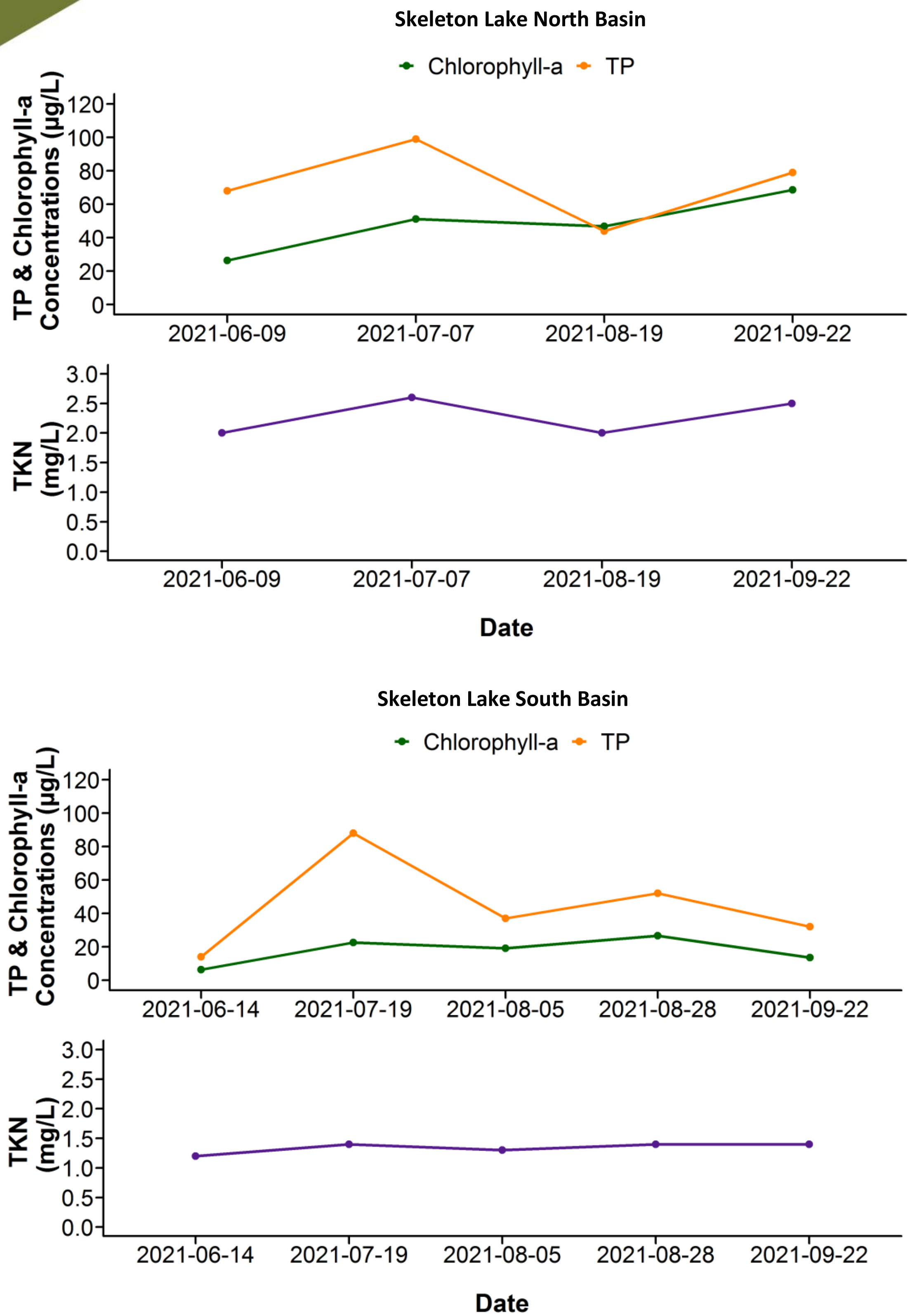
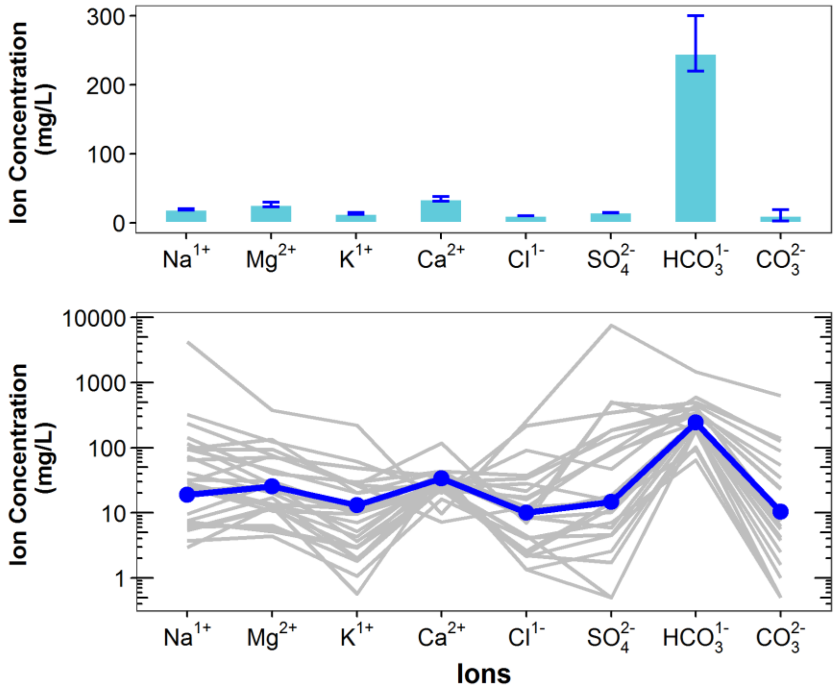


Figure 1. Total Phosphorus (TP), Total Kjeldahl Nitrogen (TKN), and chlorophyll-*a* concentrations measured over the course of the summer at Skeleton Lake North Basin (top) and Skeleton Lake South Basin (bottom) in the summer of 2021.

Skeleton Lake North Basin



Skeleton Lake South Basin

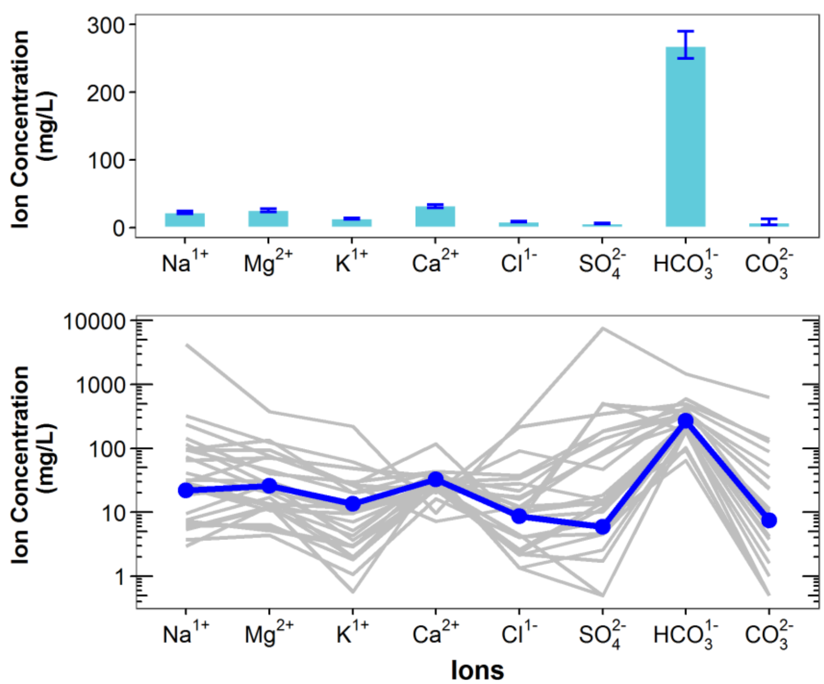


Figure 2. Average levels of cations (sodium = Na^{1+}, magnesium = Mg^{2+}, potassium = K^{1+}, calcium = Ca^{2+}) and anions (chloride = Cl^{1-}, sulphate = SO_4^{2-}, bicarbonate = HCO_3^{1-}, carbonate = CO_3^{2-}) from measurements taken over the course of the summer at Skeleton Lake North Basin (top pair of figures), and Skeleton Lake South Basin (bottom pair of figures). Top) bars indicate range of values measured, and bottom) Schoeller diagram of average ion levels at Skeleton Lake (blue line) compared to 26 lake basins (gray lines) sampled through the LakeWatch program in 2021 (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 (Tables 5 & 6).

Metals were measured in both basins of Skeleton Lake in 2021, during the August 19th and August 5th sampling events. No metals exceeded the CCME guidelines for the protection of aquatic life in either basin (Tables 5 and 6).

WATER CLARITY AND EUPHOTIC DEPTH

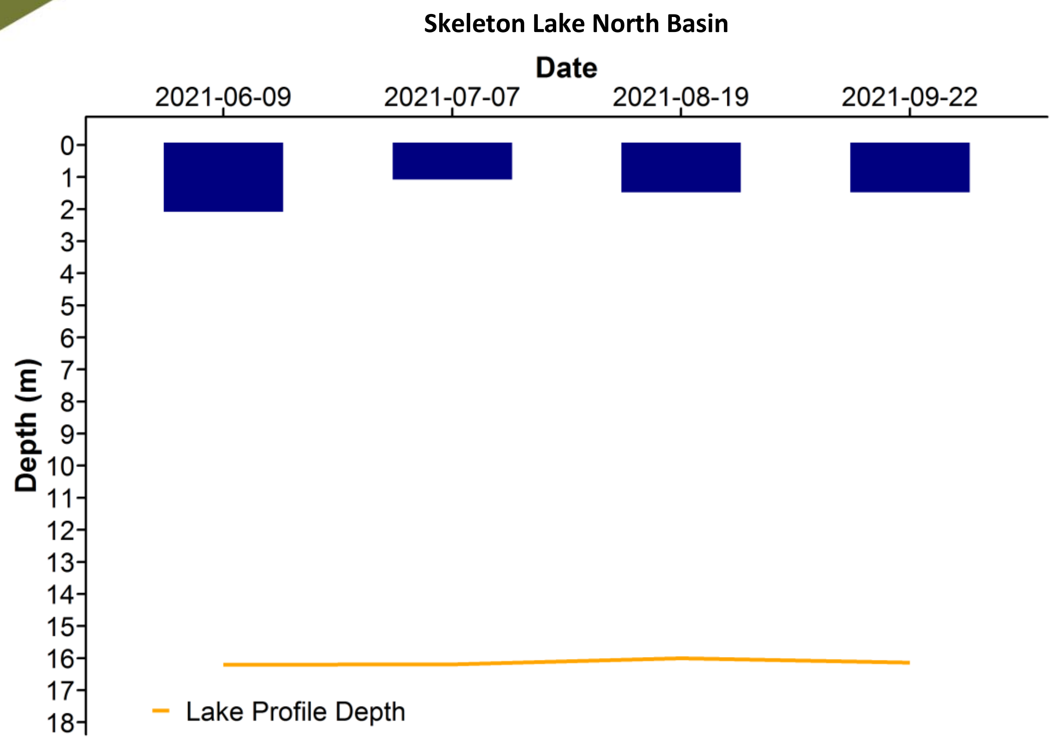
Water clarity is influenced by suspended materials, both living and dead, as well as dissolved colored compounds in the water column. During the melting of snow and ice in spring, lake water can become turbid (cloudy) from silt transported into the lake. Lake water usually clears in late spring, but 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.

North Basin:

The average euphotic depth of the North Basin in 2021 was 1.44 m, corresponding to an average Secchi depth of 0.72 m (Table 2). Euphotic depth was consistently low over the season, ranging from as deep as 2.0 m on June 9th, to as shallow as 1.0 m on July 7th (Figure 3, top). Relative to the depth of the lake, the water clarity for Skeleton Lake North basin is low. This is likely due to increased growth of a cyanobacteria in the genus *Planktothrix*, as indicated by chlorophyll-*a* levels, as well as elevated microcystin levels (Table 1a).

South Basin:

The average euphotic depth of the West Basin in 2021 was 5.74 m, corresponding to an average Secchi depth of 2.87 m (Table 3). Euphotic depth varied over the season, ranging from as deep as 8.14 m on June 14th to as shallow as 3.00 m on August 28th (Figure 3, bottom). The relatively lower water clarity measured during the August 28th sampling event is likely due to slightly increased algal growth, as indicated by the chlorophyll-*a* levels in Figure 1, bottom.



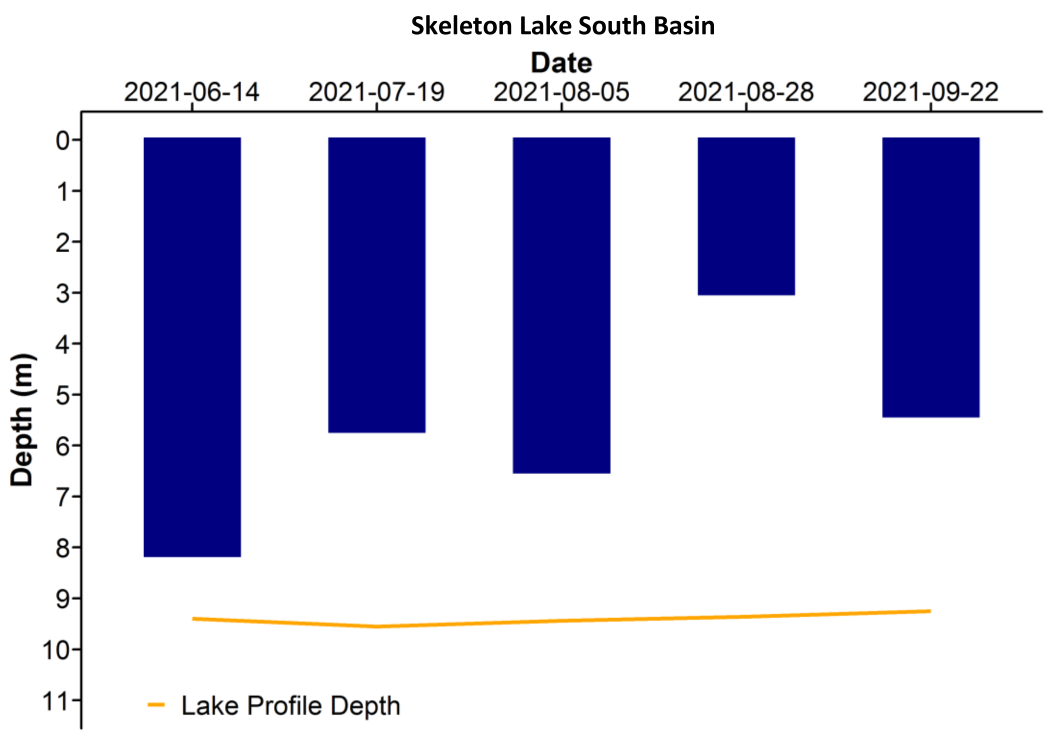


Figure 3. Euphotic depth values measured over the course of the summer at Skeleton Lake North Basin (top) and Skeleton Lake South Basin (bottom) in the summer of 2021.

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.

North Basin:

Water temperatures in the North Basin varied throughout the summer, with a maximum temperature of 21.5°C measured at the surface on July 7th, and a minimum temperature of 5.5°C measured near the bottom at 16 m on June 9th (Figure 4a, top). The temperature profiles indicate that the lake was strongly stratified for the extent of the sampling season, with the thermocline between 4 – 9 m deep, depending on the sampling date, and with the depth of thermocline increasing from June to September. This indicates the lake does not mix completely during the summer season. The bottom of the lake warmed slightly between the June and September sampling events, by about 1.2°C.

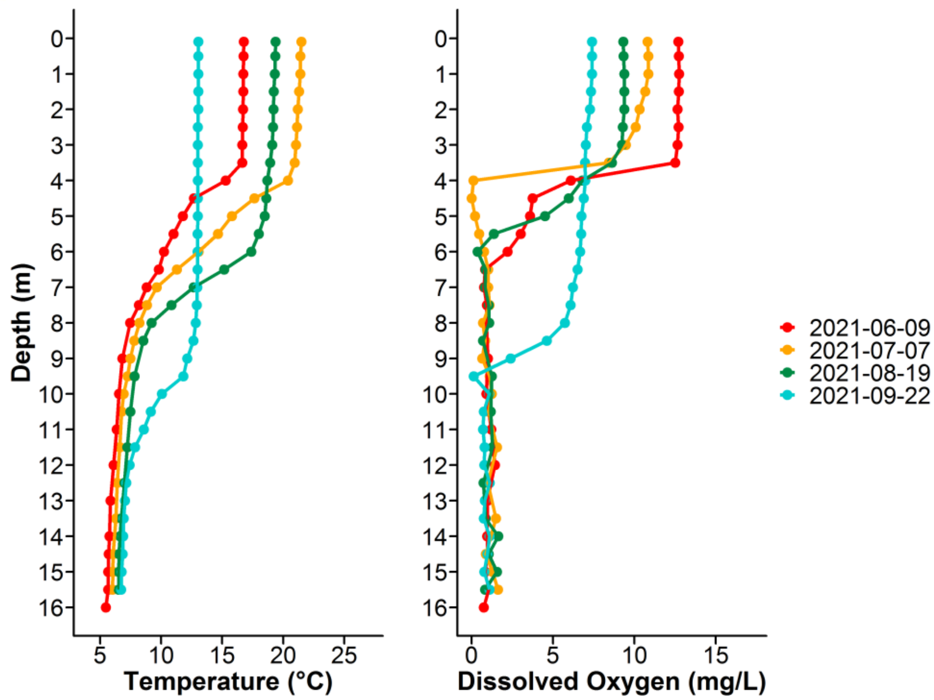
The North Basin remained well oxygenated at the surface and in most of the water column throughout the summer, measuring above the CCME guidelines of 6.5 mg/L dissolved oxygen (Figure 4b, top). During each sampling event, oxygen rapidly dropped to anoxic levels (dissolved oxygen <1 mg/L) at the depth of the thermocline. On some dates, this drop happened extremely fast – for example, dissolved oxygen dropped from 8.44 mg/L to 0.12 mg/L between 3.5 m and 4 m.

South Basin:

Water temperatures in the West Basin varied throughout the summer, with a maximum temperature of 22.8°C measured at the surface on August 5th, and a minimum temperature of 12.1°C measured near the bottom at 8.5 m on June 14th. (Figure 4a, bottom). The temperature profiles indicate that the lake does mix completely, and that the lake was appreciably warmer in July and August compared to June and September. Weak stratification is evident during the June 14th, July 19th, and August 5th sampling events, with the depth of the thermocline likely being mediated by the interaction between varying air temperature and wind conditions in this time (Figure 6b).

The South Basin remained well oxygenated at the surface and throughout most of the water column through the summer, measuring above the CCME guidelines of 6.5 mg/L dissolved oxygen (Figure 4b, bottom). However, dissolved oxygen levels during the July 19th sampling event were relatively low, at approximately 6.6 mg/L from the surface to 7.5 m, below which the levels were less than 6.5 mg/L, and proceeded to anoxia (dissolved oxygen <1 mg/L) below 8.5 m. This may have been caused by significant smoky conditions, which would have inhibited algal production of oxygen in the surface waters due to reduced light, as evident by the reduced solar radiation in this time period (Figure 6b). Oxygen levels decreased appreciably with depth during the sampling events where weak stratification was observed (June 14th and August 5th; Figure 4b, bottom).

Skeleton Lake North Basin



Skeleton Lake South Basin

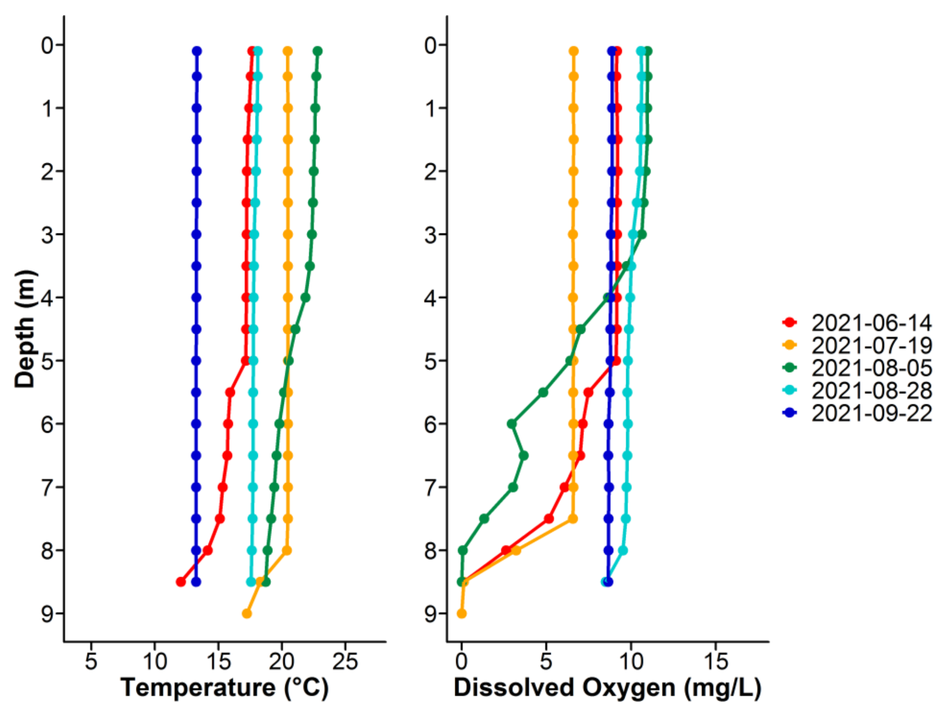


Figure 4. a) Temperature (°C) and b) dissolved oxygen (mg/L) profiles for Skeleton Lake measured over the course of the summer at Skeleton Lake North Basin (top) and Skeleton Lake South Basin (bottom) in the summer of 2021

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 Skeleton Lake North Basin exceeded the recreational guideline of 10 μg/L during the July 7th and September 22nd sampling events in 2021 (Table 1). Although the levels during June and August fell below the guideline, levels were still appreciably high. In recent years, a toxic species of cyanobacteria of the genus *Planktothrix* has been observed in Skeleton Lake North – this is likely creating high levels of microcystin.

Microcystin levels from all sampling events in the South Basin fell below the recreational guideline (Table 2). During the June 14th sampling event, the microcystin level was below the laboratory detection limit of 0.10 μg/L. A value of 0.05 μg/L is assigned to this date in order to calculate an average. Caution should always be observed when recreating around cyanobacteria.

Table 1. Microcystin concentrations measured four times at Skeleton Lake North Basin in 2021.

Date	**Microcystin Concentration (μg/L)**
9-Jun-21	6.00
7-Jul-21	10.54
19-Aug-21	9.23
22-Sep-21	11.42
Average	9.30

Table 2. Microcystin concentrations measured five times at Skeleton Lake South Basin in 2021.

Date	Microcystin Concentration (μg/L)
14-Jun-21	<0.10
19-Jul-21	0.14
5-Aug-21	0.41
28-Aug-21	0.69
22-Sep-21	0.21
Average	0.30

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 2021, no mussels or spiny water flea were detected at either basin of Skeleton Lake.

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 Skeleton Lake North Basin during the July 7th sampling event, and also at Skeleton Lake South Basin during the August 28th sampling event. Both specimens were 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.

Historically, the North and South basins were connected by open water. For some time, the narrows between the two basins were un-navigable due to extensive aquatic plant growth in the shallow water. However, in 2020 the narrows were navigable with the presence of open water between the two basins.

Water levels in Skeleton Lake South have been monitored since 1965. There was a significant decrease in water levels in the late 1980s and early 1990s (Figure 5a). Levels then recovered to the initial historical range for a brief time in the late 1990s before plummeting to lowest levels on record in 2016. Water levels recovered slightly in 2020 and declined again in 2021.

Water levels in Skeleton Lake North have been monitored from 2012 to 2020, and have remained relatively stable until 2020, where levels increased by about 1 m, but then dropped slightly in 2021 (Figure 5b).

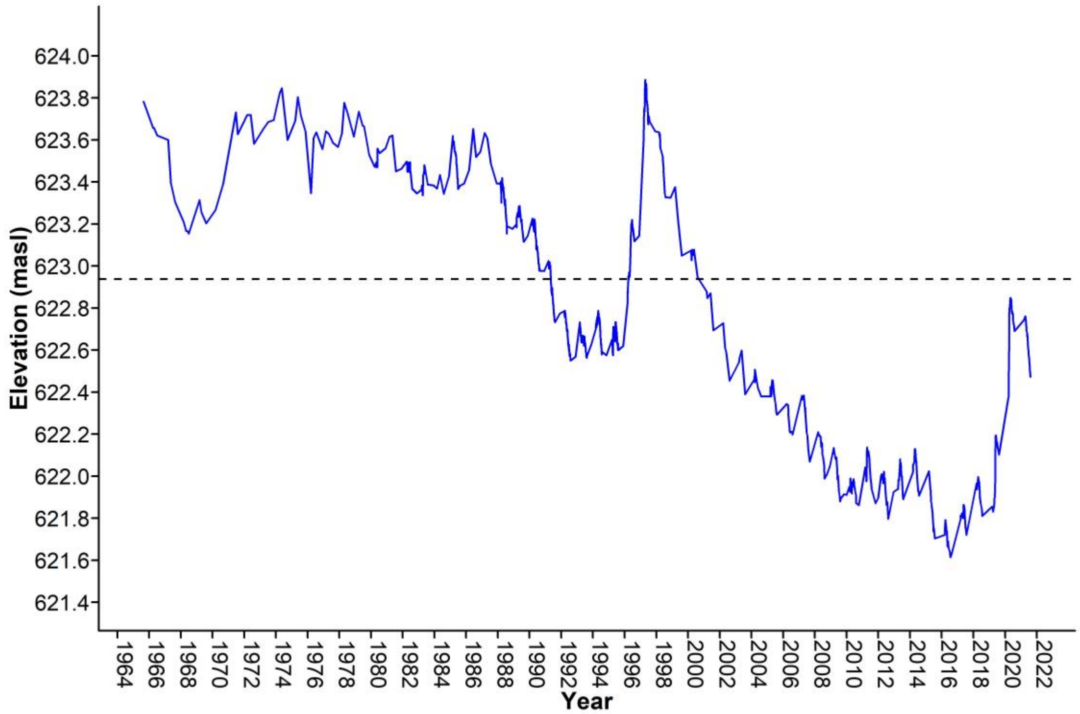


Figure 5a. Water levels measured at Skeleton Lake South Basin in metres above sea level (masl) from 1965-2021. Data retrieved from Alberta Environment and Parks. Black dashed line represents historical yearly average water level.

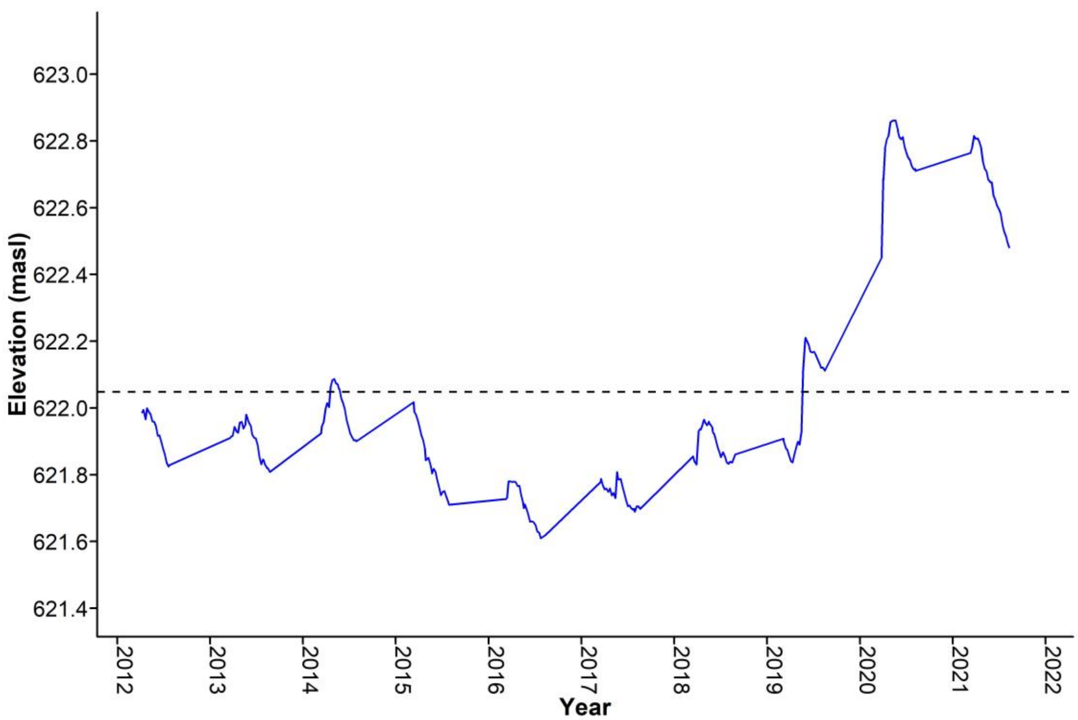


Figure 5b. Water levels measured at Skeleton Lake North Basin in metres above sea level (masl) from 2012-2021. Data retrieved from Environment Canada. Black dashed line represents historical yearly average water level.

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.

Skeleton Lake North Basin experienced a warmer, drier, windier summer with slightly more solar radiation compared to normal (Figure 6a). A few warm spells prior to the July 7th sampling likely resulted in very high near-surface water temperatures.

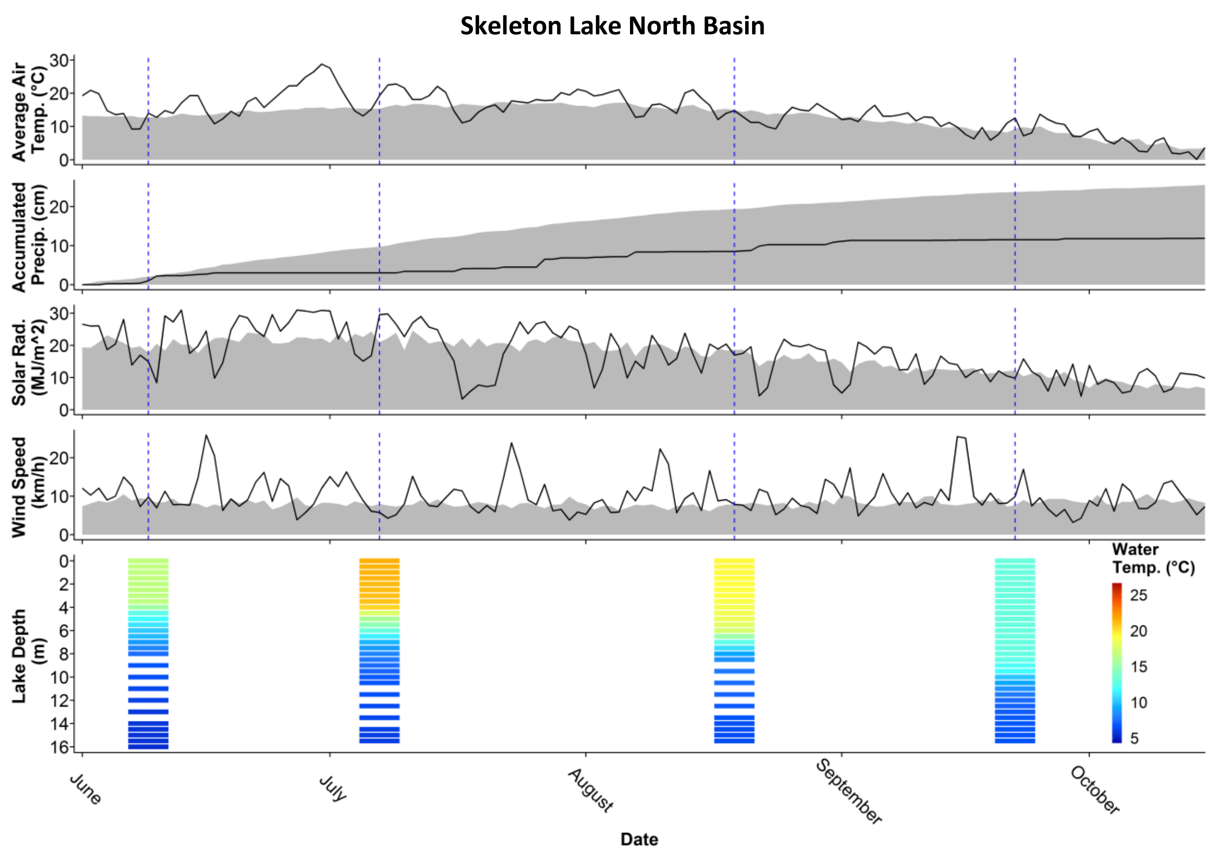


Figure 6a. Average air temperature (°C) and accumulated precipitation (cm), wind speed (km/h), solar radiation (MJ/m^2) measured from Atmore AGDM, with Skeleton Lake North Basin temperature profiles (°C) at the bottom. Black lines indicate 2021 levels, gray indicates long-term normals, and blue lines indicate sampling dates for Skeleton Lake North Basin over the summer. Further information about the weather data provided is available in the LakeWatch 2021 Methods report. Weather data provided by Agriculture, Forestry and Rural Economic Development, Alberta Climate Information Service (ACIS) https://acis.alberta.ca (retrieved April 2022).

Skeleton Lake South Basin experienced a warmer, drier, windier summer with slightly less solar radiation compared to normal (Figure 6b). Relatively hot conditions leading up to the July 19th and August 5th sampling events led to relatively high whole-lake and near-surface temperatures. The lake cooled by nearly 4.5°C between the August 28th and September 22nd sampling events and did not re-stratify, likely due to consistent windy conditions and cooling air temperatures.

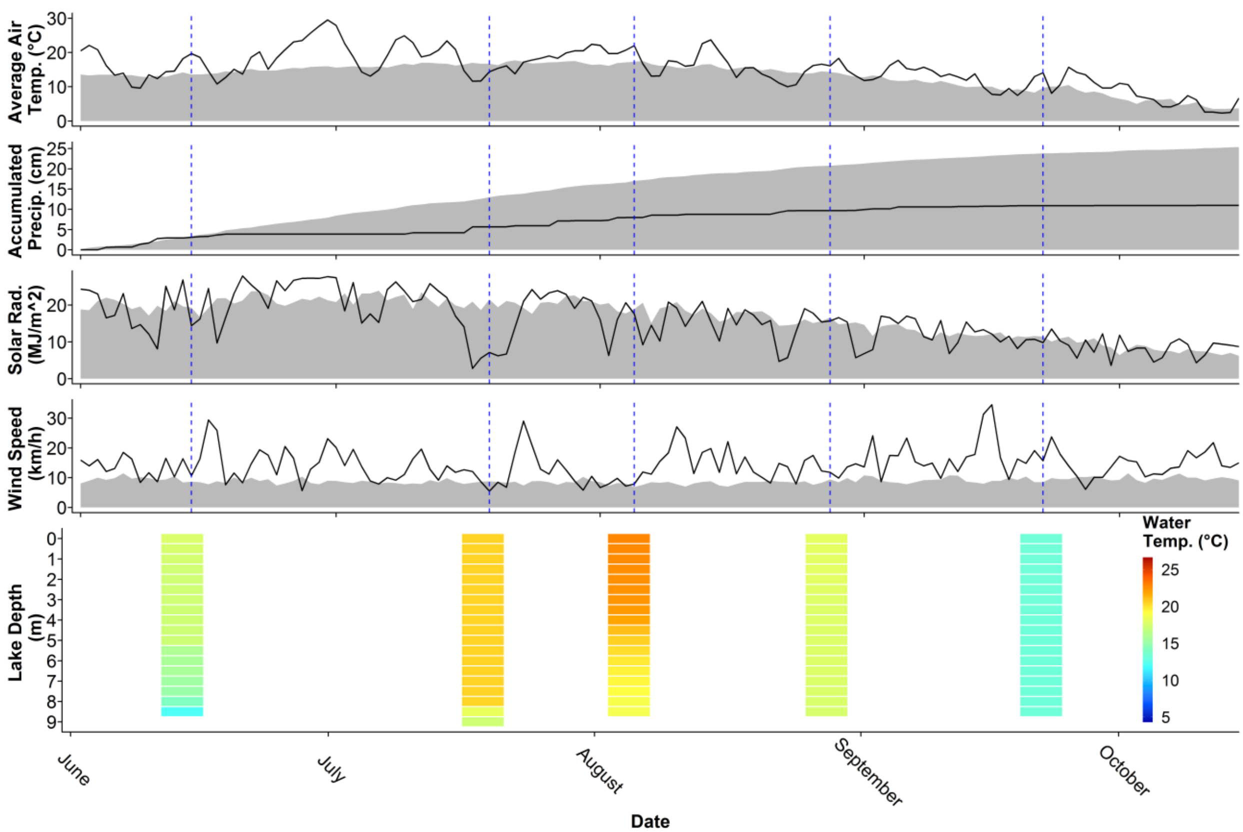


Figure 6b. Average air temperature (°C) and accumulated precipitation (cm), wind speed (km/h), solar radiation (MJ/m^2) measured from Kinikinik AGCM, with Skeleton Lake South Basin temperature profiles (°C) at the bottom. Black lines indicate 2021 levels, gray indicates long-term normals, and blue lines indicate sampling dates for Skeleton Lake West Basin over the summer. Further information about the weather data provided is available in the LakeWatch 2021 Methods report. Weather data provided by Agriculture, Forestry and Rural Economic Development, Alberta Climate Information Service (ACIS) https://acis.alberta.ca (retrieved April 2022).

Table 3a. Average Secchi depth and water chemistry values for Skeleton Lake North Basin. Historical values are given for reference. Number of sample trips are inconsistent between years.

Parameter	1985	1986	2005	2010	2011	2012	2013	2014	2015
TP (µg/L)	24	36	33	48	45	36	48	25	26
TDP (µg/L)	8	11	11	16	12	14	28	11	11
Chlorophyll-*a* (µg/L)	9.2	10.7	11.0	8.6	17.2	8.6	7.6	5.8	7.5
Secchi depth (m)	/	/	2.63	1.75	1.40	2.45	2.35	2.81	2.00
TKN (mg/L)	1.2	1.1	1.3	1.6	1.4	1.5	1.5	1.2	1.5
NO_2-N and NO_3-N (µg/L)	2	4	3	4	6	3	3	22	2
NH_3-N (µg/L)	21	33	13	83	24	21	23	33	25
DOC (mg/L)	15	15	17	19	14	18	18	19	17
Ca (mg/L)	23	24	21	23	22	25	24	31	25
Mg (mg/L)	19	19	24	26	27	25	27	21	26
Na (mg/L)	13	14	18	19	20	18	19	21	20
K (mg/L)	8	8	11	11	12	12	14	12	13
SO_4^{2-} (mg/L)	3	3	5	6	2	4	8	2	8
Cl^- (mg/L)	2	1	3	3	4	6	5	6	7
CO_3 (mg/L)	4	11	12	10	12	9	17	10	11
HCO_3 (mg/L)	198	194	204	218	229	226	213	236	228
pH	8.53	8.58	8.79	8.71	8.72	8.67	8.86	8.58	8.70
Conductivity (µS/cm)	318	324	335	372	388	388	390	390	402
Hardness (mg/L)	135	138	150	164	165	166	171	165	170
TDS (mg/L)	172	175	193	205	210	210	217	215	222
Microcystin (µg/L)	/	/	0.08	0.14	0.23	0.17	0.13	0.08	0.08
Total Alkalinity (mg/L $CaCO_3$)	170	172	187	195	208	200	204	193	204

Table 3b. Average Secchi depth and water chemistry values for Skeleton Lake North Basin. Historical values are given for reference. Number of sample trips are inconsistent between years.

Parameter	2016	2017	2018	2019	2020	2021
TP (µg/L)	28	31	32	42	43	72
TDP (µg/L)	9	8	8	5	11	10
Chlorophyll-*a* (µg/L)	9.2	11.2	19.6	27.3	18.8	48.2
Secchi depth (m)	1.40	1.88	1.03	0.90	0.98	0.72
TKN (mg/L)	1.5	1.6	1.6	1.9	2.2	2.3
NO_2-N and NO_3-N (µg/L)	3	2	4	2	3	5
NH_3-N (µg/L)	25	28	20	36	83	26
DOC (mg/L)	18	17	19	19	20	18
Ca (mg/L)	24	25	24	23	32	34
Mg (mg/L)	28	28	26	27	26	26
Na (mg/L)	21	21	20	21	20	19
K (mg/L)	14	13	13	13	13	13
SO_4^{2-} (mg/L)	8	8	9	10	17	15
Cl^- (mg/L)	7	7	8	9	10	10
CO_3 (mg/L)	10	18	14	13	5	10
HCO_3 (mg/L)	226	206	208	215	232	245
pH	8.70	8.83	8.79	8.83	8.44	8.63
Conductivity (µS/cm)	392	390	390	393	415	440
Hardness (mg/L)	174	176	164	168	185	188
TDS (mg/L)	224	222	216	223	238	250
Microcystin (µg/L)	0.20	0.08	0.13	2.63	4.40	9.30
Total Alkalinity (mg/L $CaCO_3$)	200	198	192	195	198	218

Table 4a. Average Secchi depth and water chemistry values for Skeleton Lake South Basin. Historical values are given for reference. Number of sample trips are inconsistent between years.

Parameter	1985	1986	2005	2006	2008	2009	2010	2011	2012
TP (µg/L)	31	47	29	40	45	40	59	45	40
TDP (µg/L)	8	11	8	13	13	14	15	12	12
Chlorophyll-*a* (µg/L)	14.8	24.2	12.1	15.0	19.3	12.4	22.3	17.2	17.3
Secchi depth (m)	2.00	1.60	2.28	1.60	1.65	1.63	1.40	1.40	1.81
TKN (mg/L)	1.1	1.3	1.2	1.2	1.3	1.1	1.6	1.4	1.4
NO_2-N and NO_3-N (µg/L)	2	3	6	14	13	13	25	6	4
NH_3-N (µg/L)	14	37	13	27	19	27	22	24	21
DOC (mg/L)	14	15	14	15	17	15	16	14	14
Ca (mg/L)	26	25	23	26	23	24	21	22	26
Mg (mg/L)	19	19	23	23	27	24	25	27	26
Na (mg/L)	14	14	19	20	20	21	22	20	21
K (mg/L)	9	9	11	12	12	13	12	12	13
SO_4^{2-} (mg/L)	3	3	3	4	3	5	3	2	2
Cl^- (mg/L)	2	1	3	3	4	4	5	4	5
CO_3 (mg/L)	5	9	6	10	9	10	9	12	9
HCO_3 (mg/L)	208	192	226	233	224	231	229	229	247
pH	8.53	8.72	8.66	8.71	8.73	8.76	8.80	8.72	8.64
Conductivity (µS/cm)	333	327	360	389	374	381	391	388	406
Hardness (mg/L)	143	140	152	158	168	159	157	165	170
TDS (mg/L)	181	178	204	214	211	218	214	210	222
Microcystin (µg/L)	/	/	0.15	0.18	0.24	0.34	0.31	0.23	0.22
Total Alkalinity (mg/L $CaCO_3$)	178	175	203	210	205	211	210	208	218

Table 4b. Average Secchi depth and water chemistry values for Skeleton Lake South Basin. Historical values are given for reference. Number of sample trips are inconsistent between years.

Parameter	2013	2014	2015	2017	2018	2019	2020	2021
TP (µg/L)	40	51	27	39	40	15	29	45
TDP (µg/L)	20	59	9	7	7	6	5	13
Chlorophyll-*a* (µg/L)	12.12	29.8	14.1	27.3	31.6	6.3	21.4	17.7
Secchi depth (m)	1.59	1.56	2.50	1.40	1.18	2.45	1.52	2.87
TKN (mg/L)	1.3	1.4	1.4	1.5	1.5	1.1	1.5	1.3
NO_2-N and NO_3-N (µg/L)	3	38	2	2	4	2	2	7
NH_3-N (µg/L)	21	56	25	32	34	8	24	39
DOC (mg/L)	14	17	16	15	15	16	15	15
Ca (mg/L)	25	21	24	24	24	24	29	32
Mg (mg/L)	26	26	26	30	27	28	26	26
Na (mg/L)	22	24	21	25	25	25	22	22
K (mg/L)	18	14	13	15	14	14	14	14
SO_4^{2-} (mg/L)	5	2	2	2	3	3	5	6
Cl^- (mg/L)	4	5	6	6	7	7	8	9
CO_3 (mg/L)	16	22	13	17	13	11	5	7
HCO_3 (mg/L)	228	255	243	236	242	250	230	268
pH	8.75	8.80	8.72	8.79	8.71	8.73	8.49	8.51
Conductivity (µS/cm)	410	398	413	422	420	435	420	450
Hardness (mg/L)	168	159	167	184	172	175	180	188
TDS (mg/L)	230	233	227	240	238	240	225	252
Microcystin (µg/L)	0.24	0.40	0.37	0.50	0.79	0.13	0.31	0.30
Total Alkalinity (mg/L $CaCO_3$)	214	209	220	222	220	230	195	228

Table 5a. Concentrations of metals measured in Skeleton Lake North Basin. 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)	2010	2011	2012	2013	2014	2015	Guidelines
Aluminum μg/L	26.04	13.9	14.75	11.735	10.75	16.2	100[a]
Antimony μg/L	0.03635	0.02885	0.0307	0.0326	0.032	0.0315	/
Arsenic μg/L	0.8565	0.8685	0.574	0.8165	0.7735	0.828	5
Barium μg/L	48.95	50.85	51.1	49.05	48.5	53.75	/
Beryllium μg/L	0.00585	0.0052	0.00645	0.0015	0.004	0.004	100[c,d]
Bismuth μg/L	0.00195	0.00215	0.0321	0.0143	0.00225	0.00925	/
Boron μg/L	122.5	105.5	104.85	93.5	97.05	94.3	1500
Cadmium μg/L	0.0057	0.001	0.001	0.001	0.002	0.002	0.27[b]
Chromium μg/L	0.242	0.0765	0.1535	0.28	0.105	0.075	/
Cobalt μg/L	0.01845	0.01115	0.00955	0.02615	0.007	0.0185	50,1000[c,d]
Copper μg/L	0.1633	0.154	0.3698	0.1402	0.13	0.175	4[b]
Iron μg/L	7.73	3.59	7.2	21.95	2.875	7.5	300
Lead μg/L	0.0151	0.0137	0.01055	0.0168	0.0135	0.0275	7[b]
Lithium μg/L	31.7	33	28.1	26.65	27.95	28.7	2500[d]
Manganese μg/L	35.4	43.9	29	16.05	12.55	31.55	190[e]
Molybdenum μg/L	0.0627	0.05335	0.02955	0.03915	0.037	0.041	73
Nickel μg/L	0.0025	0.0025	0.0025	0.05425	0.004	0.004	150[b]
Selenium μg/L	0.05	0.096	0.05	0.082	0.03	0.03	1
Silver μg/L	0.0013	0.003175	0.00153	0.007125	0.001	0.001	0.25
Strontium μg/L	176	187	166	180	180	194.5	/
Thallium μg/L	0.00073	0.0006	0.00123	0.0004	0.0005	0.0104	0.8
Thorium μg/L	0.00803	0.00625	0.0313	0.01075	0.0012	0.00045	/
Tin μg/L	0.015	0.015	0.38175	0.0377	0.0065	0.026	/
Titanium μg/L	0.336	0.676	0.2735	0.7785	0.2025	0.73	/
Uranium μg/L	0.1965	0.202	0.18	0.1995	0.211	0.205	15
Vanadium μg/L	0.214	0.1855	0.2035	0.1865	0.19	0.19	100[c,d]
Zinc μg/L	0.3085	0.41	0.4175	0.2805	0.55	0.25	30[f]

Values represent means of total recoverable metal concentrations.

[a] Based on pH ≥ 6.5

[b] Based on 2021 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 2021 avg. water hardness (as CaCO3) and avg. pH

[f] Based on 2021 avg. water hardness (as CaCO3), avg. pH, and avg. DOC with CCME equation

[g] Did not exceed guideline due to effect of relatively lower pH value in 2014 on Manganese variable calculation.

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

Table 5b. Concentrations of metals measured in Skeleton Lake North Basin. 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)	2016	2017	2018	2019	2020	2021	Guidelines
Aluminum µg/L	6.6	4.5	2.8	7.9	3.4	9.1	100[a]
Antimony µg/L	0.03	0.028	0.03	0.0029	0.039	0.031	/
Arsenic µg/L	0.745	0.77	0.84	0.85	0.94	0.92	5
Barium µg/L	50.9	49.5	49.7	51.6	57.1	66.5	/
Beryllium µg/L	0.004	0.0015	0	0.0015	0.0015	0.0015	100[c,d]
Bismuth µg/L	5.00E-04	0.0015	0	0.0015	0.0015	0.004	/
Boron µg/L	103	96.5	94.6	93	88.9	97.7	1500
Cadmium µg/L	0.001	0.005	0.01	0.005	0.005	0.005	0.27[b]
Chromium µg/L	0.015	0.05	0.1	0.05	0.05	0.05	/
Cobalt µg/L	0.001	0.039	0.02	0.041	0.04	0.065	50,1000[c,d]
Copper µg/L	0.32	0.27	0.1	0.04	0.04	0.13	4[b]
Iron µg/L	3.8	3	2.3	16	9.9	5.4	300
Lead µg/L	0.007	0.014	0.01	0.009	0.005	0.014	7[b]
Lithium µg/L	32.7	31.6	29.6	27.2	25.7	30.8	2500[d]
Manganese µg/L	26	7.66	6.74	43.6	43.7	48.2	190[e]
Molybdenum µg/L	0.026	0.038	0.04	0.052	0.081	0.049	73
Nickel µg/L	0.004	0.08	0.08	0.11	0.13	0.18	150[b]
Selenium µg/L	0.2	0.1	0.2	0.4	0.3	0.3	1
Silver µg/L	0.001	0.0005	0	0.0005	0.0005	0.0005	0.25
Strontium µg/L	193	183	197	204	202	226	/
Thallium µg/L	0.00045	0.001	0	0.001	0.001	0.001	0.8
Thorium µg/L	0.00045	0.001	0	0.001	0.002	0.003	/
Tin µg/L	0.023	0.03	0.06	0.03	0.03	0.03	/
Titanium µg/L	0.26	0.2	0.29	0.4	0.42	0.75	/
Uranium µg/L	0.201	0.22	0.23	0.211	0.217	0.189	15
Vanadium µg/L	0.14	0.171	0.14	0.171	0.221	0.103	100[c,d]
Zinc µg/L	0.3	0.4	0.2	0.4	0.4	1.2	30[f]

Values represent means of total recoverable metal concentrations.

[a] Based on pH ≥ 6.5

[b] Based on 2021 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 2021 avg. water hardness (as CaCO3) and avg. pH

[f] Based on 2021 avg. water hardness (as CaCO3), avg. pH, and avg. DOC with CCME equation

[g] Did not exceed guideline due to effect of relatively lower pH value in 2014 on Manganese variable calculation.

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

Table 6a. Concentrations of metals measured in Skeleton Lake South Basin. 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)	2008	2009	2010	2011	2012	2013	Guidelines
Aluminum μg/L	24.1	12.8	22.95	23.2	7.88	12.655	100[a]
Antimony μg/L	0.033	0.032	0.03335	0.0326	0.0236	0.02795	/
Arsenic μg/L	1.01	0.983	1.065	0.948	0.367	1.0065	5
Barium μg/L	55.8	57.3	55.55	56.2	44	57.7	/
Beryllium μg/L	0.0045	<0.003	0.0015	0.0048	0.0015	0.0015	100[c,d]
Bismuth μg/L	0.0036	0.004	0.002	0.0014	0.0057	0.0038	/
Boron μg/L	102.5	109.6	97	106	87.2	100.9	1500
Cadmium μg/L	<0.002	0.0023	0.00695	0.0045	0.0035	0.0024	0.27[b]
Chromium μg/L	0.115	0.188	0.1395	0.15	0.106	0.196	/
Cobalt μg/L	0.023	0.0203	0.01325	0.0171	0.0084	0.0285	50,1000[c,d]
Copper μg/L	0.171	0.27	0.1303	0.181	0.508	0.1805	4[b]
Iron μg/L	49.2	70.4	41	53.4	48.5	40.2	300
Lead μg/L	0.0285	0.0283	0.02505	0.0327	0.0126	0.02665	7[b]
Lithium μg/L	30.6	36.1	28.05	33.2	21.9	29.15	2500[d]
Manganese μg/L	44.5	62.1	49.75	58.1	40.3	50.15	240[e]
Molybdenum μg/L	0.103	0.114	0.09395	0.103	0.0643	0.0823	73
Nickel μg/L	<0.005	0.204	0.0025	0.0025	0.0025	0.16175	150[b]
Selenium μg/L	0.144	0.12	0.076	0.138	0.05	0.05	1
Silver μg/L	0.0036	0.0069	0.00255	0.00025	0.0022	0.02725	0.25
Strontium μg/L	185	185	188	186	134	197.5	/
Thallium μg/L	0.00115	0.00185	0.001	0.001	0.00015	0.000365	0.8
Thorium μg/L	0.0093	0.0017	0.0096	0.0066	0.0084	0.00655	/
Tin μg/L	0.0483	<0.03	0.03015	0.015	0.0327	0.015	/
Titanium μg/L	1.21	0.762	0.904	1.1	0.26	1.43	/
Uranium μg/L	0.121	0.11	0.1145	0.12	0.0612	0.09055	15
Vanadium μg/L	0.207	0.208	0.2095	0.217	0.101	0.145	100[c,d]
Zinc μg/L	0.373	0.996	0.5025	0.399	0.361	0.346	30[f]

Values represent means of total recoverable metal concentrations.
[a] Based on pH ≥ 6.5
[b] Based on 2021 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 2021 avg. water hardness (as CaCO3) and avg. pH
[f] Based on 2021 avg. water hardness (as CaCO3), avg. pH, and avg. DOC with CCME equation
[g] Did not exceed guideline due to effect of relatively lower pH value in 2014 on Manganese variable calculation.
A forward slash (/) indicates an absence of data or guidelines

Table 6b. Concentrations of metals measured in Skeleton Lake South Basin. 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	2017	2018	2020	2021	Guidelines
Aluminum µg/L	24.1	18.5	21.5	1.8	0.5	100[a]
Antimony µg/L	0.033	0.0455	0.04	0.03	4.4	/
Arsenic µg/L	1.01	1.36	1.04	1.03	0.039	5
Barium µg/L	55.8	45.8	56.1	55.3	1.18	/
Beryllium µg/L	0.0045	0.004	0.0015	0	60.3	100[c,d]
Bismuth µg/L	0.0036	0.0005	0.0015	0	0.0015	/
Boron µg/L	102.5	94.75	105	106	0.006	1500
Cadmium µg/L	<0.002	0.008	0.005	0.005	93	0.27[b]
Chromium µg/L	0.115	0.215	0.05	0.05	0.01	/
Cobalt µg/L	0.023	0.022	0.042	0.02	0.05	50,1000[c,d]
Copper µg/L	0.171	0.535	0.46	0.08	0.028	4[b]
Iron µg/L	49.2	13.45	28.4	18.2	0.38	300
Lead µg/L	0.0285	0.0265	0.029	0	15.5	7[b]
Lithium µg/L	30.6	39.7	33.8	32	0.054	2500[d]
Manganese µg/L	44.5	34.15	44.3	23.5	28.5	240[e]
Molybdenum µg/L	0.103	0.087	0.097	0.09	12.6	73
Nickel µg/L	<0.005	0.0595	0.18	0.09	0.178	150[b]
Selenium µg/L	0.144	0.07	0.1	0.1	0.18	1
Silver µg/L	0.0036	0.001	0.002	0	0.2	0.25
Strontium µg/L	185	208.5	190	211	0.0005	/
Thallium µg/L	0.00115	0.00068	0.001	0	210	0.8
Thorium µg/L	0.0093	0.00563	0.001	0	0.01	/
Tin µg/L	0.0483	0.0195	0.03	0.03	0.005	/
Titanium µg/L	1.21	0.985	1	0.88	0.03	/
Uranium µg/L	0.121	0.196	0.105	0.1	0.64	15
Vanadium µg/L	0.207	0.265	0.225	0.09	0.103	100[c,d]
Zinc µg/L	0.373	1.3	2.7	0.5	0.14	30[f]

Values represent means of total recoverable metal concentrations.
[a] Based on pH ≥ 6.5
[b] Based on 2021 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 2021 avg. water hardness (as CaCO3) and avg. pH
[f] Based on 2021 avg. water hardness (as CaCO3), avg. pH, and avg. DOC with CCME equation
[g] Did not exceed guideline due to effect of relatively lower pH value in 2014 on Manganese variable calculation.
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 both the north and south basins of Skeleton Lake. Both basins were first sampled through LakeWatch in 2005 and last sampled in 2021 – this date range has been used for the trend analysis. However, the north basin was not sampled from 2006 through 2009, leaving a four year gap in the data. While trend analysis is still possible given this gap, inferences made from the data are less reliable. Data is presented below for the different parameters in each lake as both line and box-and-whisker plots. Detailed methods are available in the *ALMS Guide to Trend Analysis on Alberta Lakes.*

In the north basin, chlorophyll-*a* and TDS have significantly increased over the sampling period, and Secchi depth has significantly decreased. There has been not a significant trend detected for TP in the north basin.

In the south basin, TDS has significantly increased over the sampling period, and TP significantly decreased during the sampling period. No significant trends were detected for chlorophyll-*a* and Secchi depth.

Table 7a. Summary table of trend analysis on Skeleton Lake North data from 2005 to 2021.

Parameter	Date Range	Direction of Significant Trend
Total Phosphorus	2005-2021	No Change
Chlorophyll-*a*	2005-2021	Increasing
Total Dissolved Solids	2005-2021	Increasing
Secchi Depth	2005-2021	Decreasing

Table 7b. Summary table of trend analysis on Skeleton Lake South data from 2005 to 2021.

Parameter	Date Range	Direction of Significant Trend
Total Phosphorus	2005-2021	Decreasing
Chlorophyll-*a*	2005-2021	No Change
Total Dissolved Solids	2005-2021	Increasing
Secchi Depth	2005-2021	No Change

Definitions:

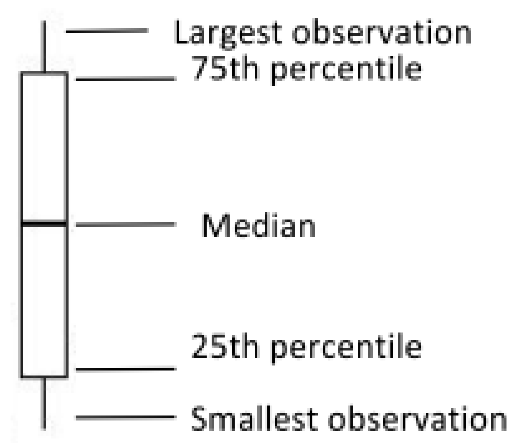
Median: the value in a range of ordered numbers that falls in the middle.

Trend: a general direction in which something is changing.

Monotonic trend: a gradual change in a single direction.

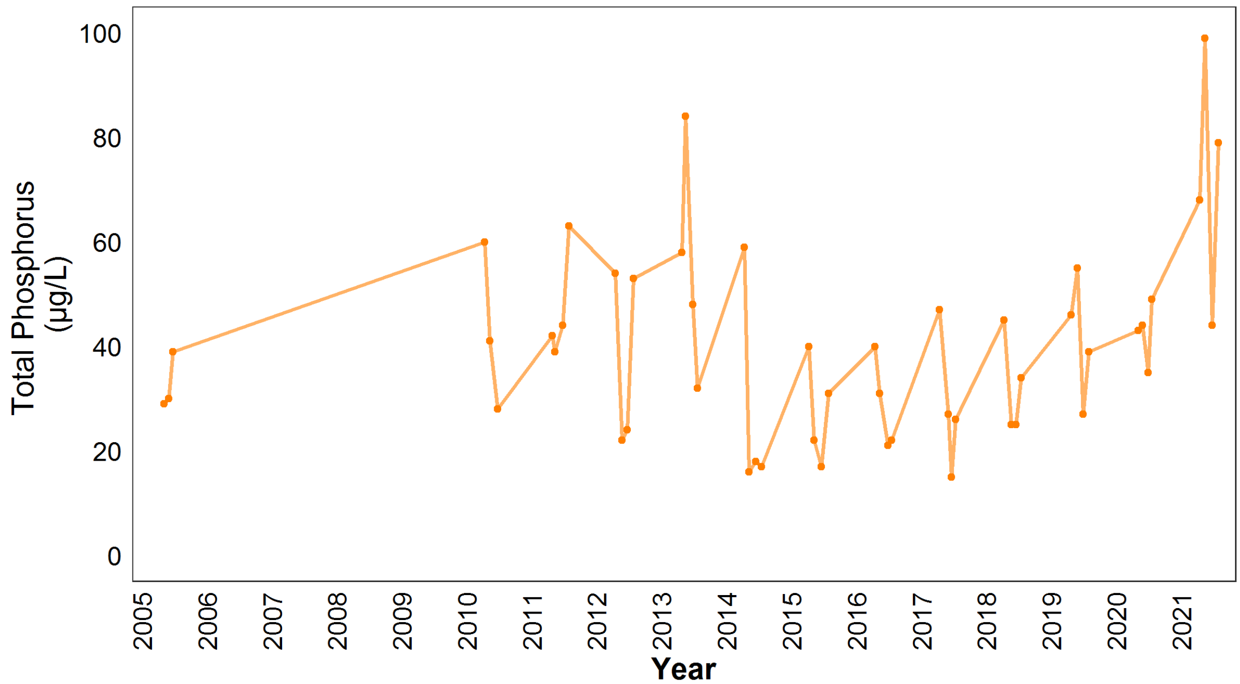
Statistically significant: The likelihood that a relationship between variables is caused by something other than random chance. This is indicated by a p-value of <0.05. Variability: the extent by which data is inconsistent or scattered.

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) – North Basin

TP has not significantly changed in Skeleton Lake North since 2005 (Tau = 0.11, *p* = 0.33). However, increasing levels since 2014 are evident when visualizing the data (Figure 7).



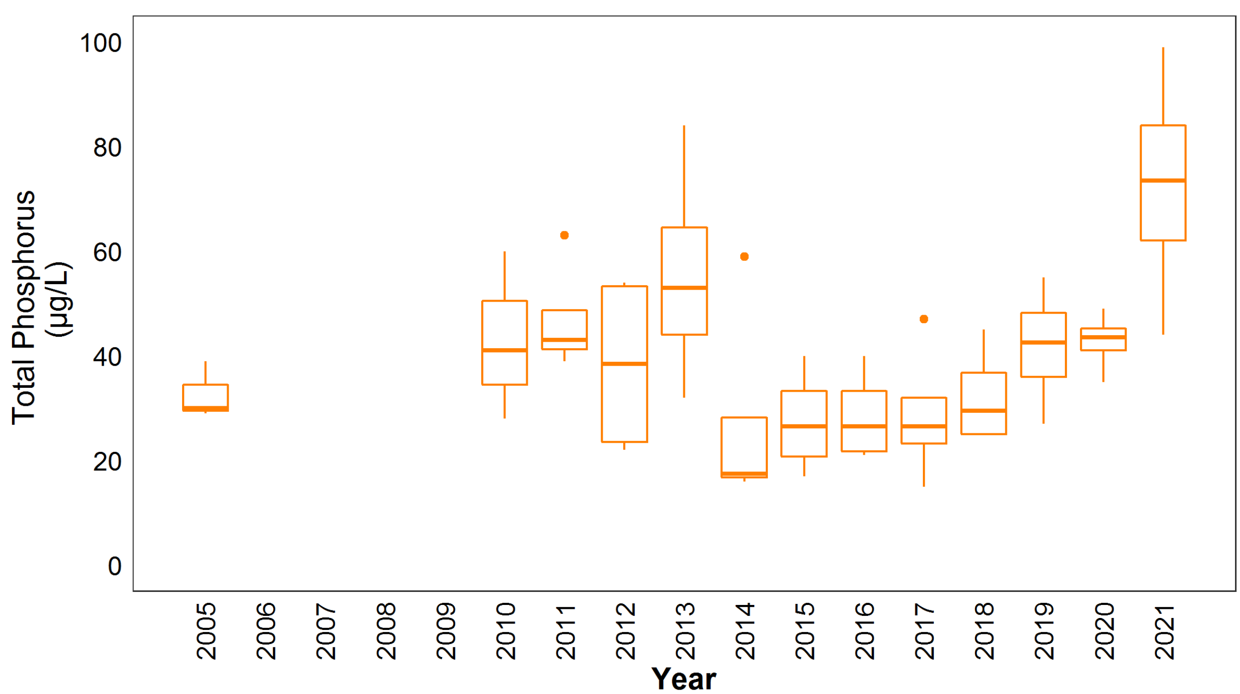
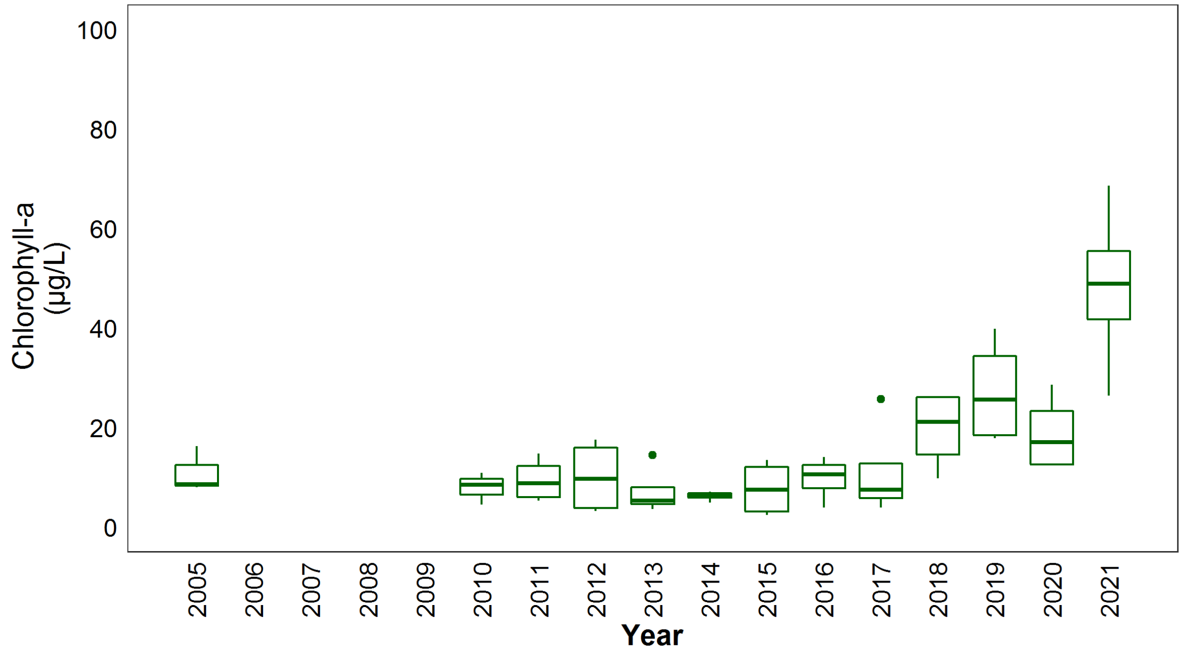


Figure 7. Monthly total phosphorus (TP) concentrations at Skeleton Lake North measured between June and September over the long term sampling dates between 2005 and 2021 (n = 50). The value closest to the 15th day of the month was chosen to represent the monthly value in cases with multiple monthly samples.

Chlorophyll-*a* – North Basin

Chlorophyll-*a* has significantly increased in Skeleton Lake North since 2005 (Tau = 0.42, p = <0.001) (Figure 2a). Chlorophyll-*a* and Total Phosophorus concentrations are significantly correlated over time ($r = 0.56$, $p = 2.34 \times 10^{-5}$).



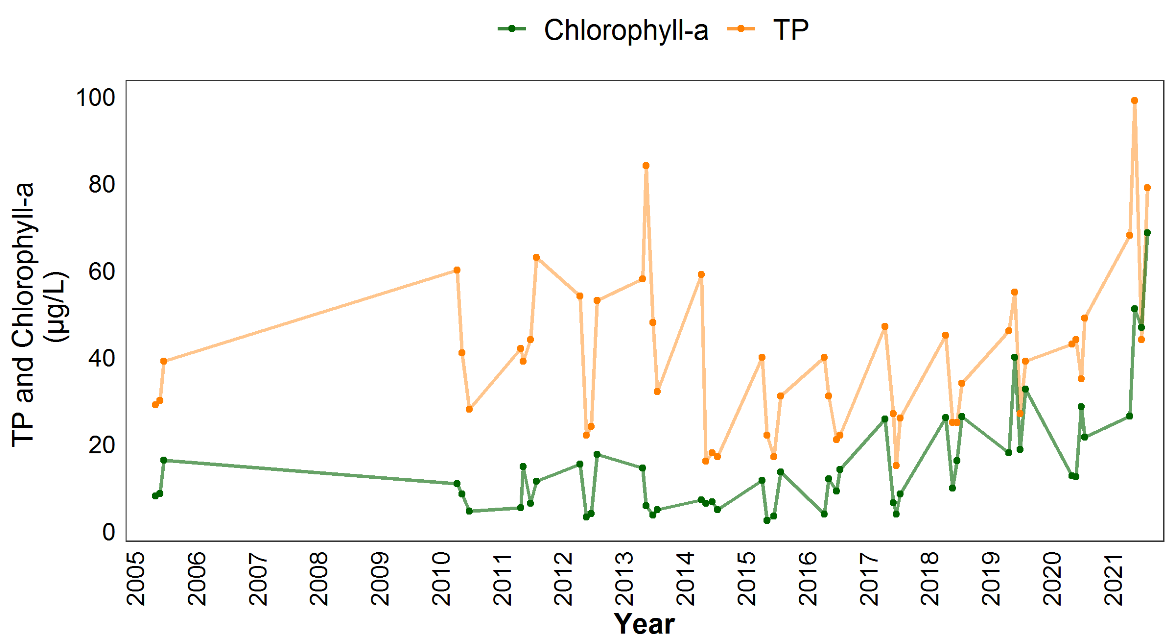
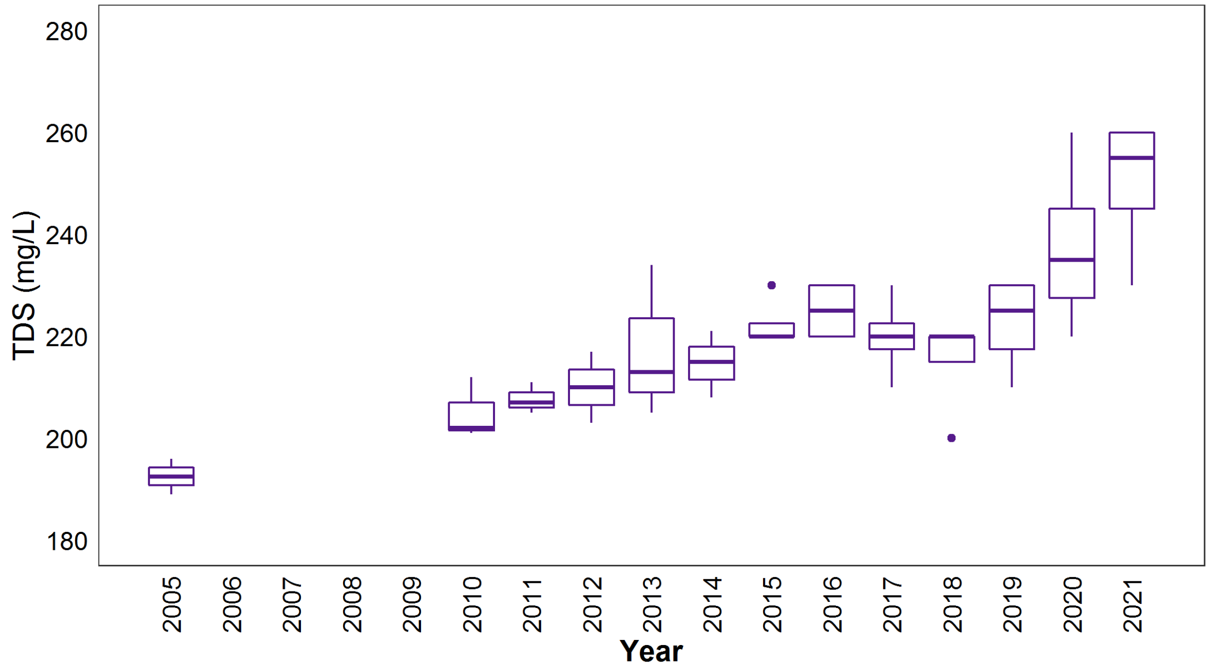


Figure 8. Monthly chlorophyll-*a* concentrations measured in Skeleton Lake North between June and September over the long term sampling dates between 2005 and 2021 (n = 50). The value closest to the 15th day of the month was chosen to represent the monthly value in cases with multiple monthly samples. Line graph is overlain by TP concentrations.

Total Dissolved Solids (TDS) - North Basin

Trend analysis showed a significant increasing trend in TDS since 2005 in Skeleton Lake North (Tau = 0.57, $p < 0.001$).



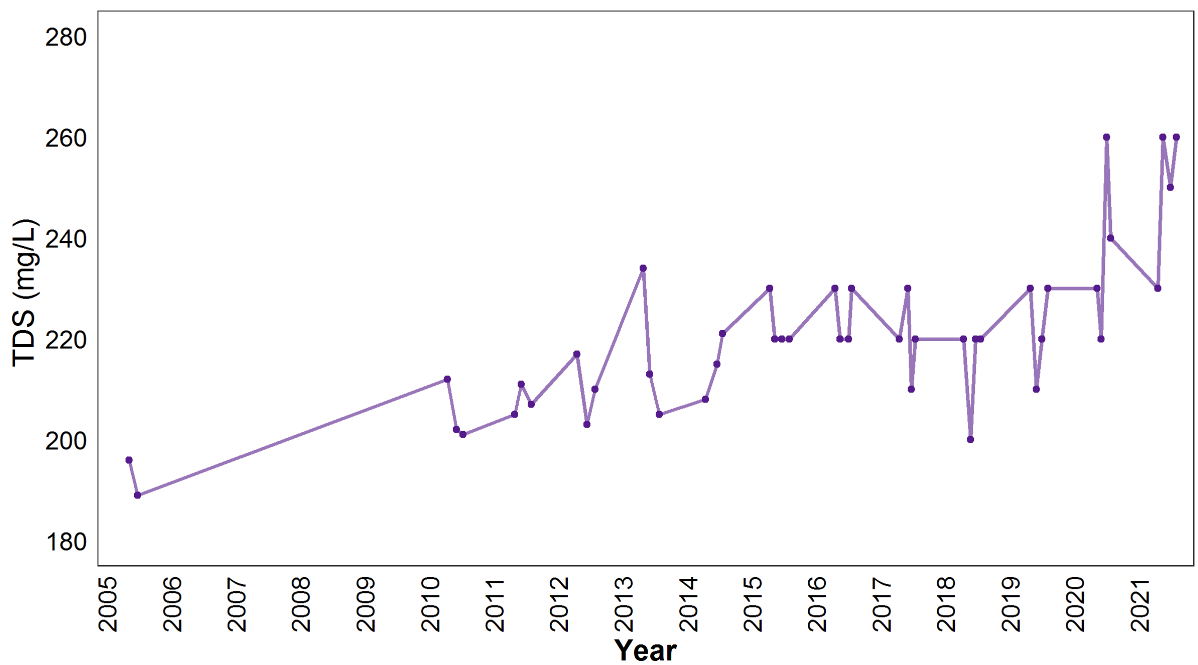


Figure 9. Monthly TDS values measured at Skeleton Lake North between June and September over the long term sampling dates between 2005 and 2021 (n = 45). The value closest to the 15th day of the month was chosen to represent the monthly value in cases with multiple monthly samples.

Due to the significant increasing trend of TDS in Skeleton Lake North, exploring the specific major ions which may be driving this trend is important to determine. Trend analysis of major ions at Skeleton Lake North, indicates that sulphate and chloride are likely the key parameters that are driving the increase in TDS (Figure 9). These two parameters display the greatest magnitude of change over time (slopes), while also displaying statistically significant increasing trends ($p < 0.05$). However, the magnitude of the slopes indicates that other parameters may also be contributing to the increasing TDS levels, and it's possible that calcium or magnesium might be important contributors to the increasing trend as well, but insufficient data prevents trends analysis of these parameters.

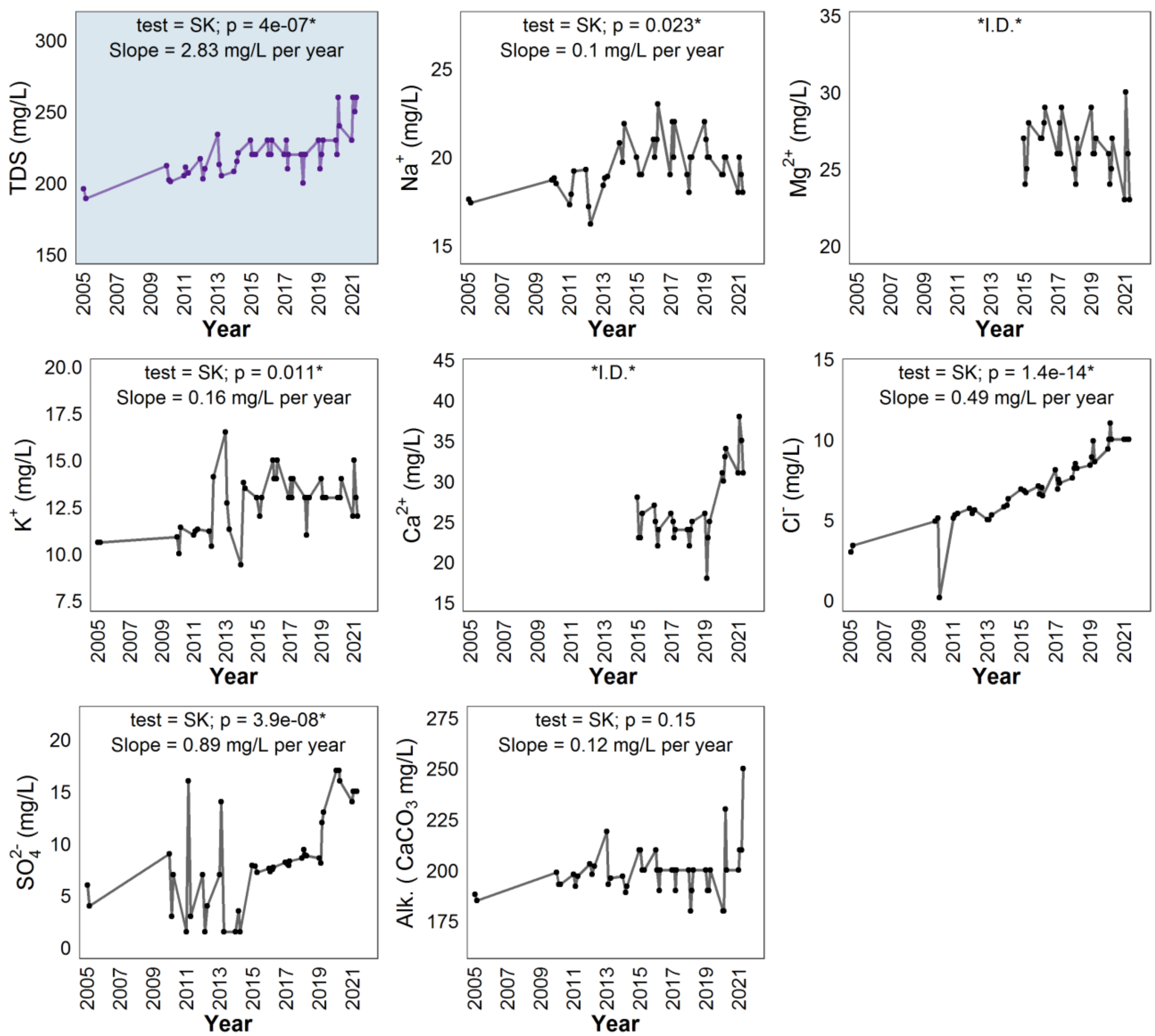
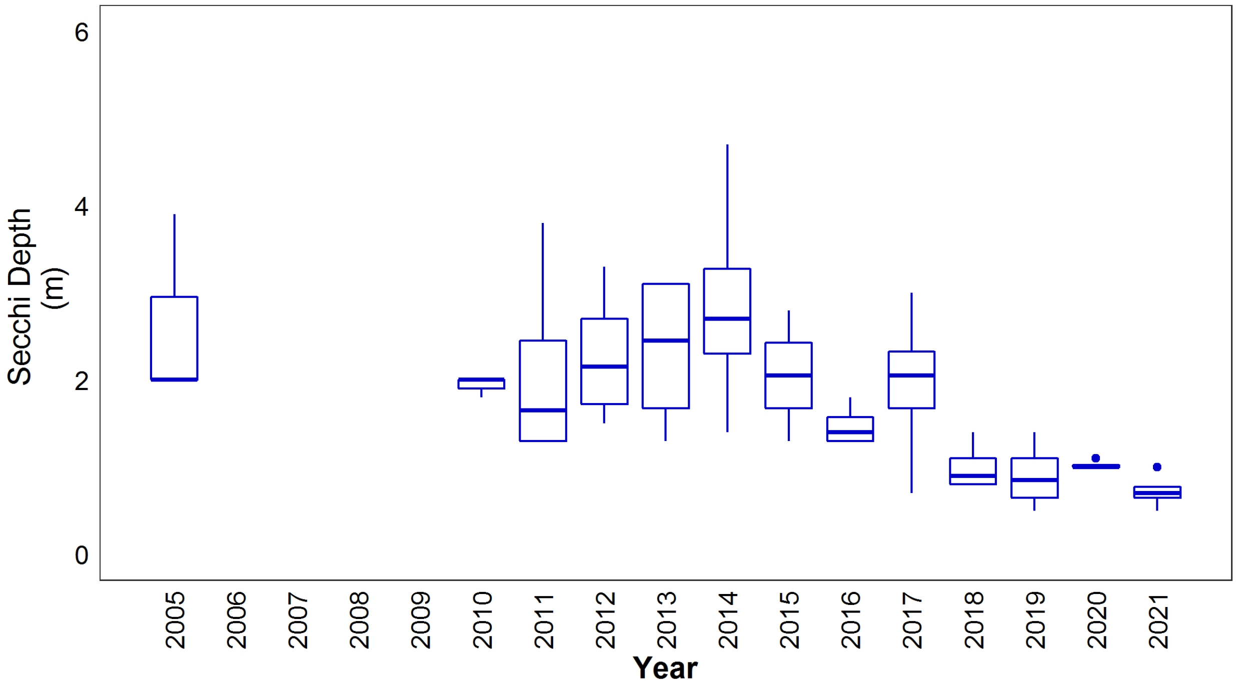


Figure 10. Concentrations of TDS (top left, blue panel), major ions (sodium = Na^+, magnesium = Mg^{2+}, potassium = K^+, calcium = Ca^{2+}, chloride = Cl^-, sulphate = SO_4^{2-}), and total alkalinity (Alk., as mg/L $CaCO_3$) measured monthly between June and September on sampling dates between 2005 and 2021. 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 - North Basin

Water clarity measured as Secchi depth in Skeleton Lake North has undergone a statistically significant decrease since 2005 (Tau =-0.49, $p < 0.001$). The most recent four years have had both the lowest Secchi depth medians since 2005, and also some of the least variance (Figure 11).



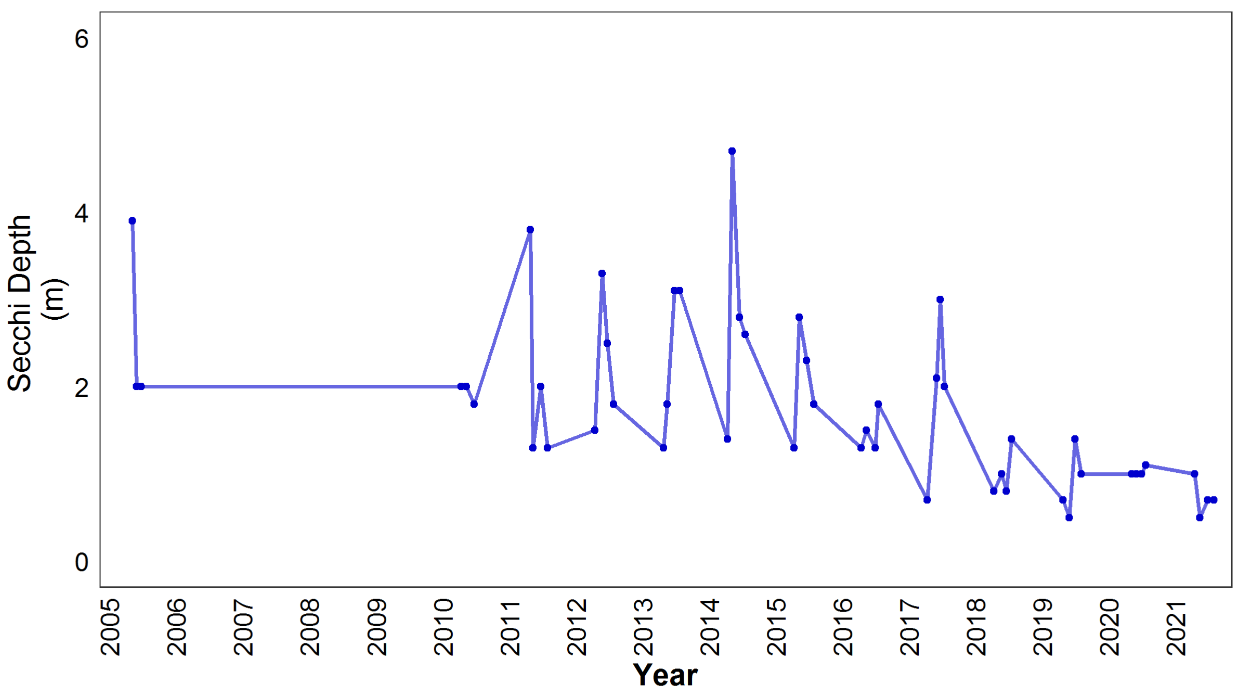


Figure 11. Monthly Secchi depth values measured at Skeleton Lake North between June and September over the long term sampling dates between 2005 and 2021 (n = 50). The value closest to the 15^{th} day of the month was chosen to represent the monthly value in cases with multiple monthly samples.

Total Phosphorus (TP) – South Basin

TP has significantly decreased in Skeleton Lake South since 2005 (Tau = -0.24, *p* = 0.021). Some TP data from 2014 were removed from the dataset as the samples exceeded laboratory hold times and were not considered reliable (see Skeleton Lake 2014 LakeWatch report for more details). Also note that 2019 data is only from June and July.

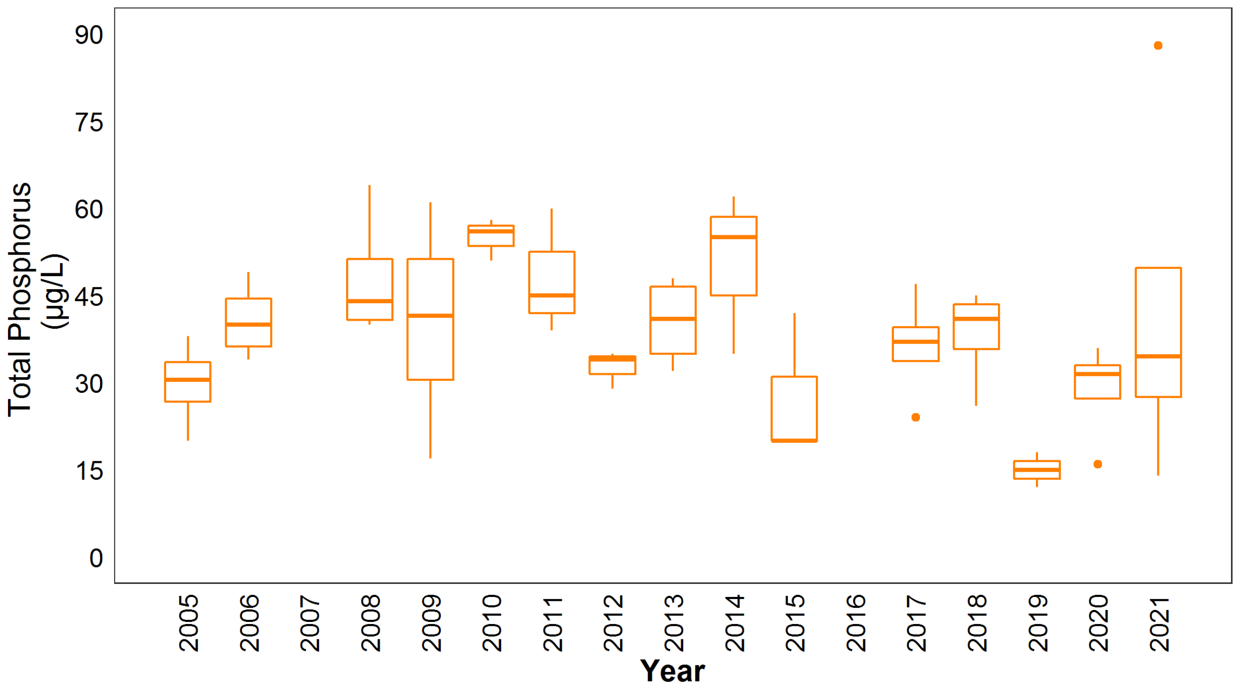
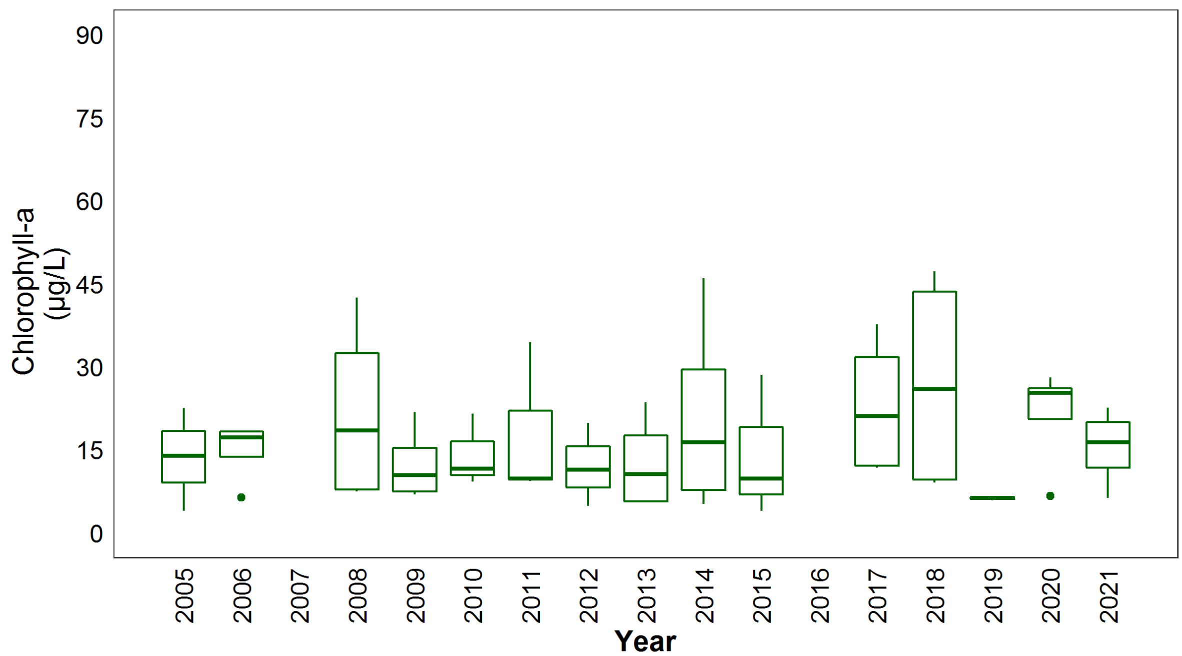


Figure 12. Monthly total phosphorus (TP) concentrations measured at Skeleton Lake South between June and September over the long term sampling dates between 2005 and 2021 (n = 53). The value closest to the 15th day of the month was chosen to represent the monthly value in cases with multiple monthly samples.

Chlorophyll-*a* – South Basin

Chlorophyll-*a* has not significantly changed in Skeleton Lake South since 2005 (Tau = 0.15, p = 0.18). Note that 2019 data is only from June and July. Chlorophyll-*a* and Total Phosophorus concentrations are significantly correlated over time (r = 0.49, p = 0.0002).



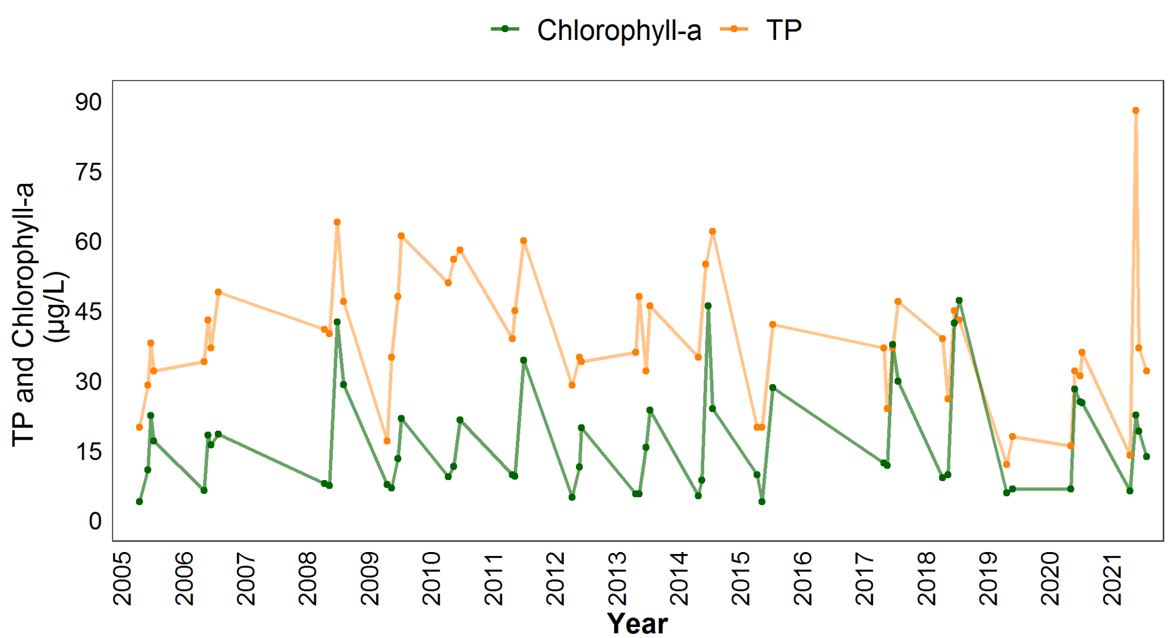
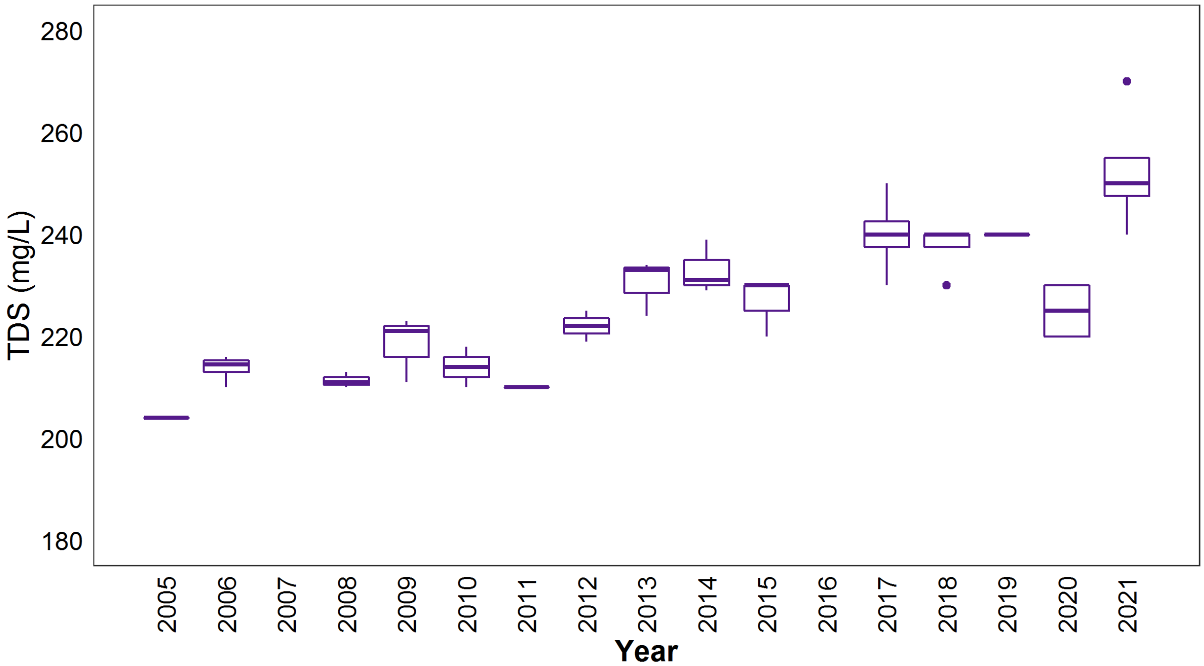


Figure 13. Monthly chlorophyll-*a* concentrations measured in Skeleton Lake South between June and September over the long term sampling dates between 2005 and 2021 (n = 54). The value closest to the 15th day of the month was chosen to represent the monthly value in cases with multiple monthly samples. Line graph is overlain by TP concentrations.

Total Dissolved Solids (TDS) - South Basin

Trend analysis showed a significant increasing trend in TDS since 2005 in Skeleton Lake South (Tau = 0.67, $p < 0.001$). This could be attributed to decreasing water levels. Note that 2019 data is only from June and July.



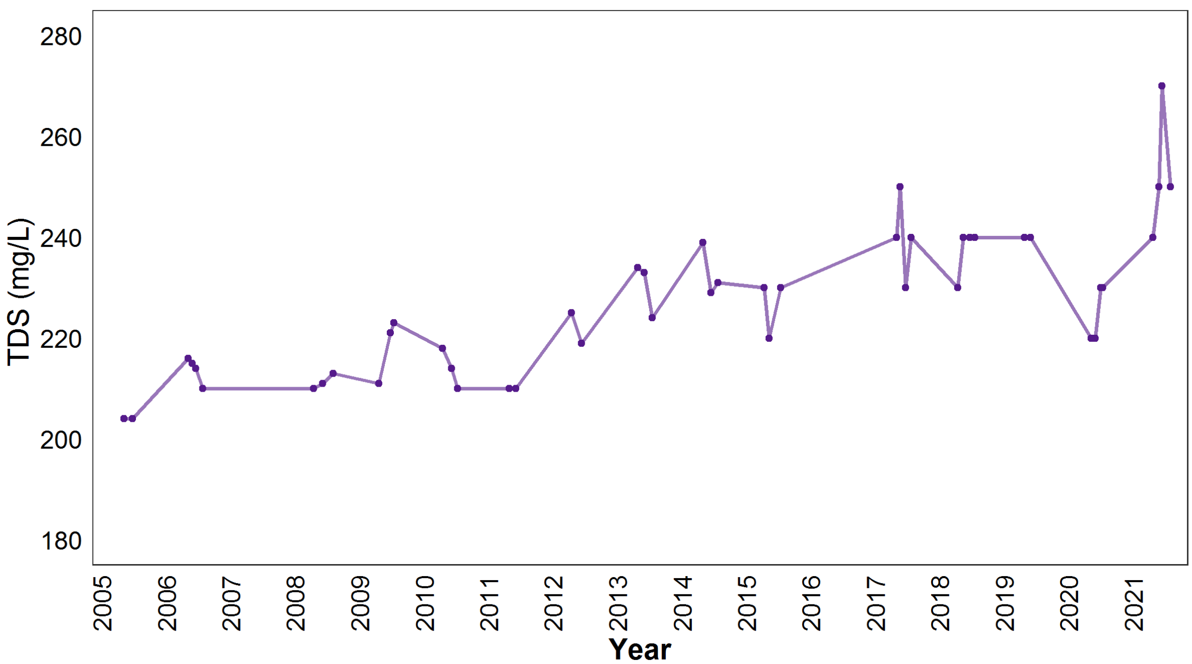


Figure 14. Monthly TDS values measured in Skeleton Lake South between June and September over the long term sampling dates between 2005 and 2021 (n = 46). The value closest to the 15th day of the month was chosen to represent the monthly value in cases with multiple monthly samples.

Due to the significant increasing trend of TDS in Skeleton Lake South, exploring the specific major ions which may be driving this trend is important to determine. Trend analysis of major ions at Skeleton Lake South indicates that all ions with sufficient data display significant increasing trends over time, but that alkalinity (bicarbonate and carbonate) is the main parameter driving the increase in TDS over time. In addition, both alkalinity and chloride follow the trajectory of TDS the closest, relative to the other parameters visualized. It is possible that recent increases in TDS are also related to increases in calcium, a parameter with insufficient historical data for trend analysis, but one that displays an appreciable increase between 2019 and 2021.

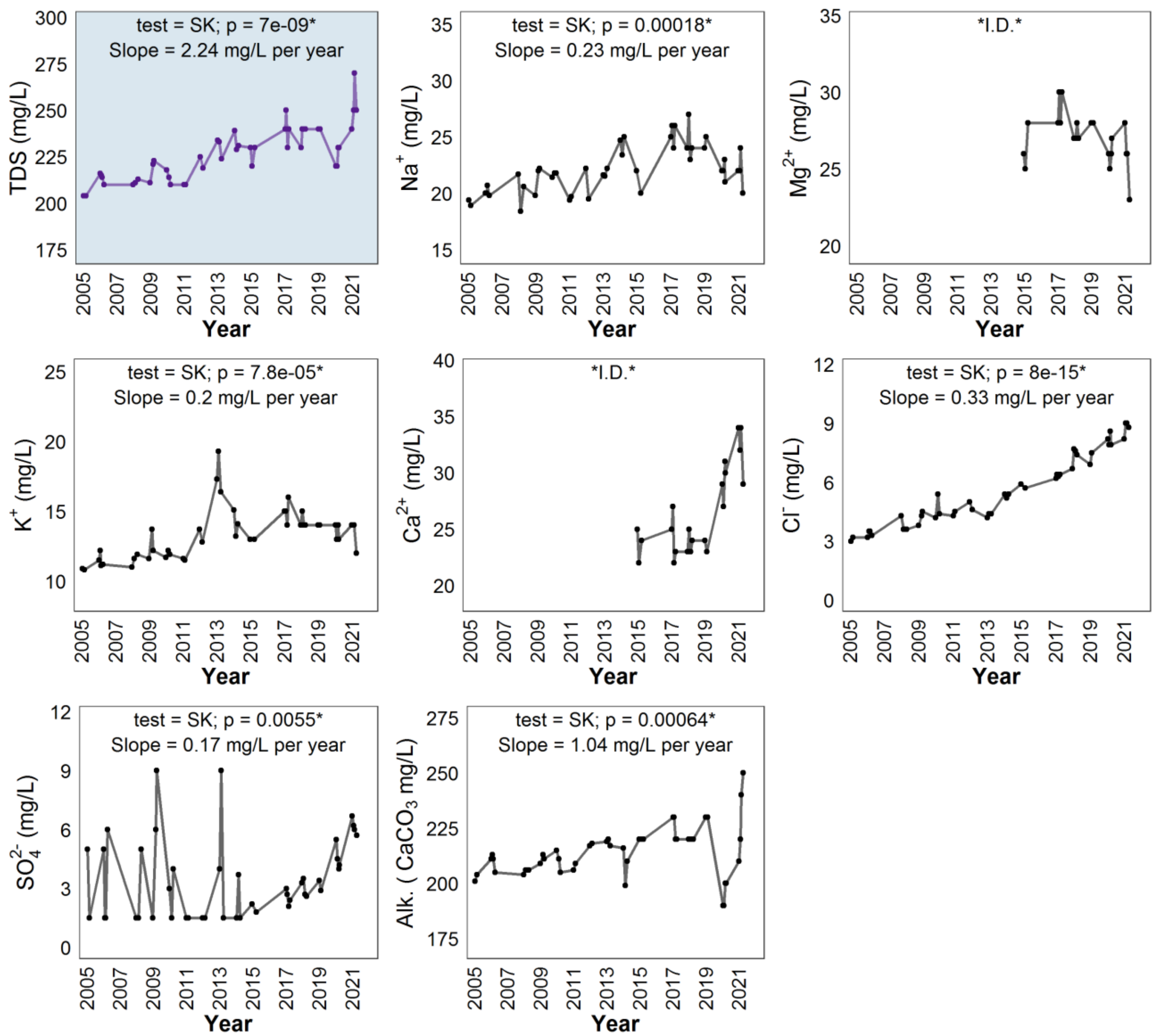
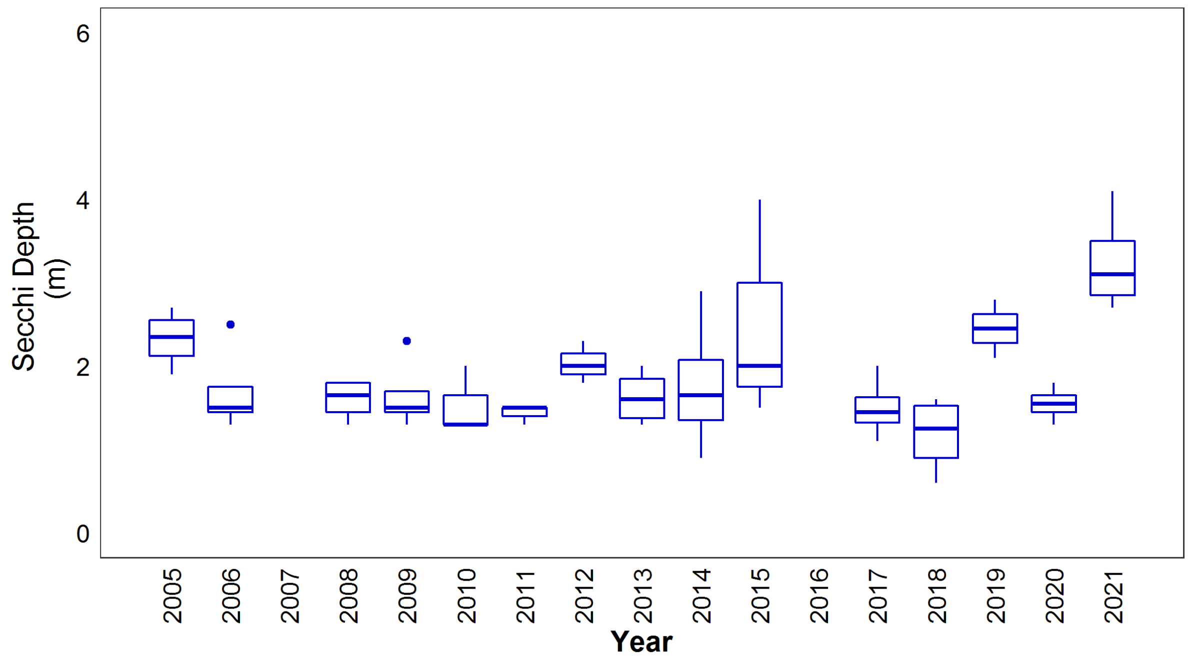


Figure 15. Concentrations of TDS (top left, blue panel), major ions (sodium = Na^+, magnesium = Mg^{2+}, potassium = K^+, calcium = Ca^{2+}, chloride = Cl^-, sulphate = SO_4^{2-}), and total alkalinity (Alk., as mg/L $CaCO_3$) measured monthly between June and September on sampling dates between 2005 and 2021. 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 - South Basin

Water clarity measured as Secchi depth in Skeleton Lake South has not significantly changed since 2005, (Tau $=-1.68 \times 10^{-3}$, $p = 0.93$). Note that 2019 data is only from June and July.



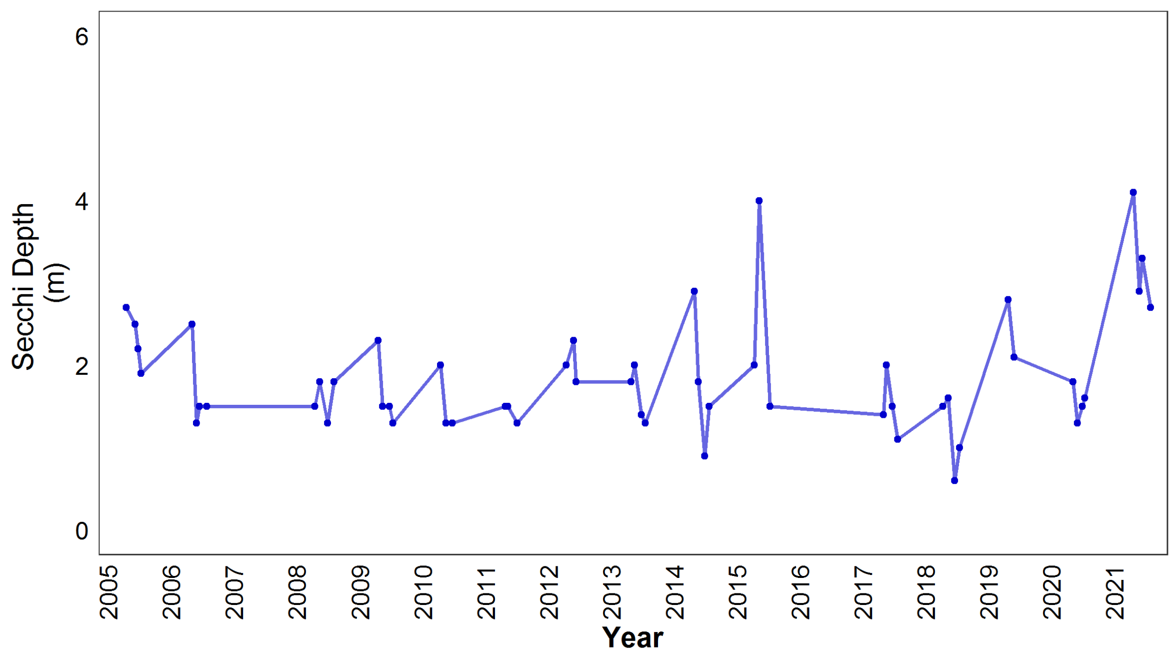


Figure 16. Monthly Secchi depth values measured in Skeleton Lake South between June and September over the long term sampling dates between 2005 and 2020 (n = 50). The value closest to the 15th day of the month was chosen to represent the monthly value in cases with multiple monthly samples.

Table 8a. North Basin: Results of Seasonal Kendall trend tests using monthly total phosphorus (TP), chlorophyll-*a*, total dissolved solids (TDS) and Secchi depth data from June to September on Skeleton Lake North 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	0.11	0.42	0.57	-0.49
The extent of the trend	Slope (units per Year)	0.73	1.41	2.83	-0.13
The statistic used to find significance of the trend	Z	0.96	3.82	5.07	-4.62
Number of samples included	n	50	50	45	50
The significance of the trend	*p*	0.33	1.33×10^{-4}*	4.04×10^{-7}*	3.82×10^{-6}*

$^*p < 0.05$ is significant within 95%

Table 8b. South Basin: Results of Seasonal Kendall trend tests using monthly total phosphorus (TP), chlorophyll-*a*, total dissolved solids (TDS) and Secchi depth data from June to September on Skeleton Lake South 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	-0.24	0.15	0.67	-1.68×10^{-3}
The extent of the trend	Slope (units per Year)	-0.75	0.17	2.24	0
The statistic used to find significance of the trend	Z	-2.31	1.33	5.79	0.09
Number of samples included	n	53	54	46	54
The significance of the trend	*p*	0.021*	0.18	6.97×10^{-9}*	0.93

*$p < 0.05$ is significant within 95%