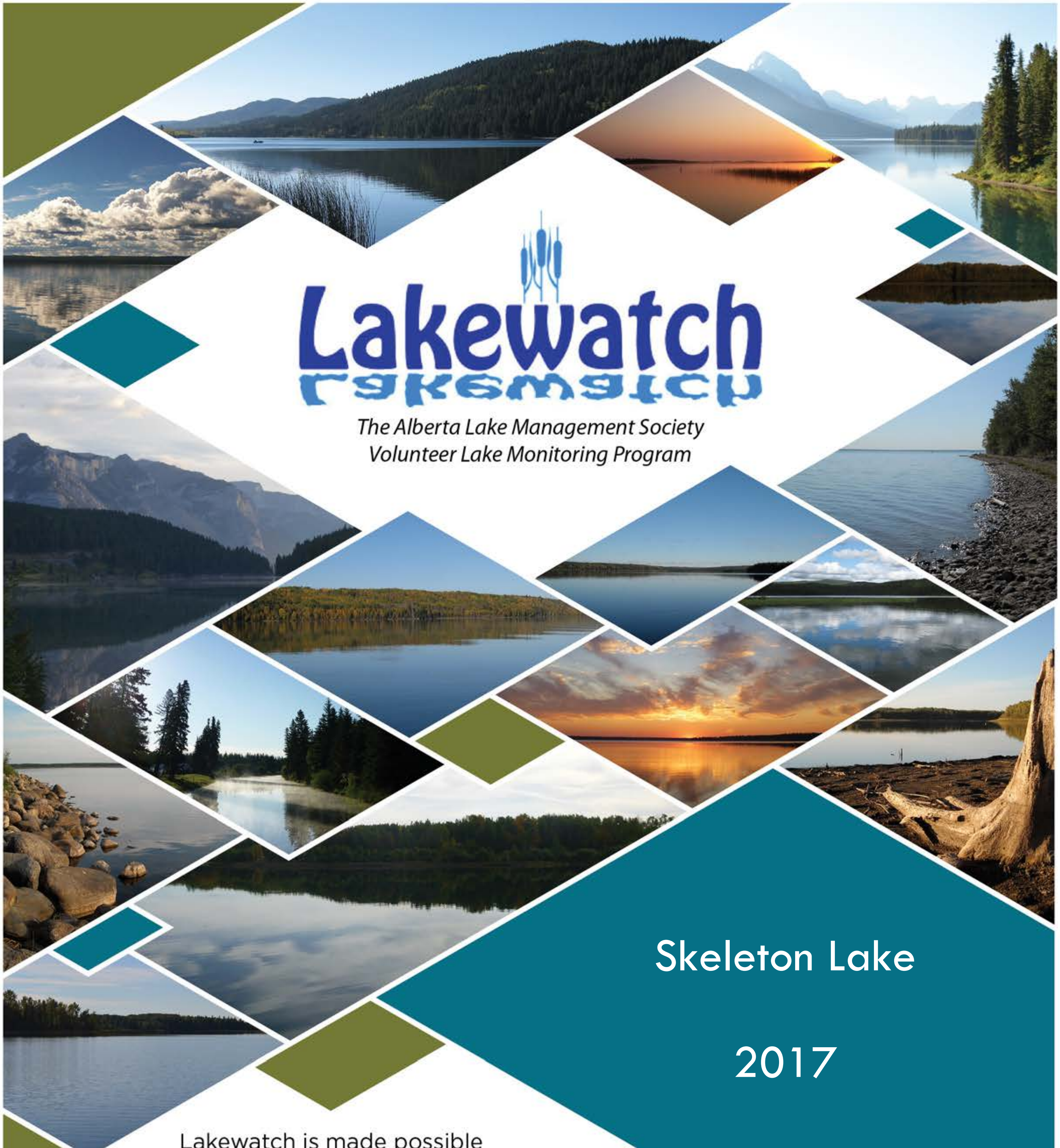


Lakewatch

The Alberta Lake Management Society
Volunteer Lake Monitoring Program

Skeleton Lake

2017

Lakewatch is made possible with support from:

Cargill Helping the world thrive
Jackfish Lake
Pigeon Lake Watershed Association
LICA Lakeland Industry & Community Association
Red Deer River Watershed Alliance
Beaver River Watershed Alliance
Alberta Environment and Parks

ALBERTA LAKE MANAGEMENT SOCIETY'S LAKEWATCH PROGRAM

LakeWatch has several important objectives, one of which is to collect and interpret water quality data on Alberta Lakes. Equally important is educating lake users about their aquatic environment, encouraging public involvement in lake management, and facilitating cooperation and partnerships between government, industry, the scientific community and lake users. LakeWatch Reports are designed to summarize basic lake data in understandable terms for a lay audience and are not meant to be a complete synopsis of information about specific lakes. Additional information is available for many lakes that have been included in LakeWatch and readers requiring more information are encouraged to seek those sources.
ALMS would like to thank all who express interest in Alberta's aquatic environments and particularly those who have participated in the LakeWatch program. These people prove that ecological apathy can be overcome and give us hope that our water resources will not be the limiting factor in the health of our environment.

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

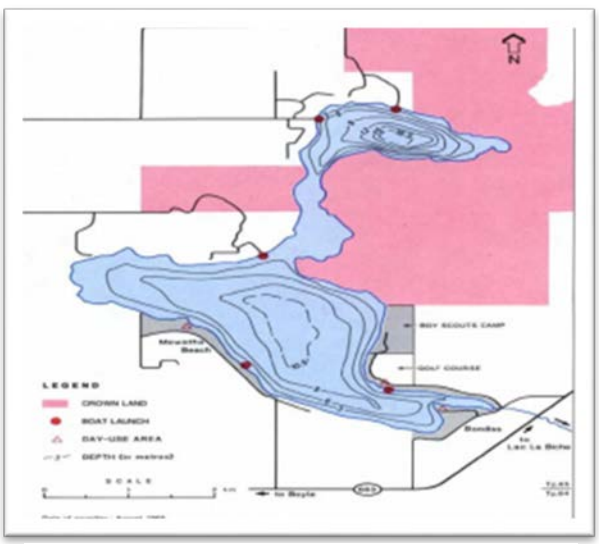
ACKNOWLEDGEMENTS

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

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—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.

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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/

METHODS

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

Composite samples: At 10-sites across the lake, water is collected from the euphotic zone and combined across sites into one composite sample. This water is collected for analysis of water chemistry, chlorophyll-a, nutrients and microcystin. Quality control (QC) data for total phosphorus was taken as a duplicate true split on one sampling date. ALMS uses the following accredited labs for analysis: Routine water chemistry and nutrients are analyzed by Maxxam Analytics, chlorophyll-*a* and metals are analyzed by Alberta Innovates Technology Futures (AITF), and microcystin is analyzed by the Alberta Centre for Toxicology (ACTF). In lakes where mercury samples are taken, they are analyzed by the Biogeochemical Analytical Service Laboratory (BASL).

Invasive Species: Monitoring for invasive quagga and zebra mussels involved two components: monitoring for juvenile mussel veligers using a 63 µm plankton net at three sample sites and monitoring for attached adult mussels using substrates installed at each lake.

Data Storage and Analysis: Data is stored in the Water Data System (WDS), a module of the Environmental Management System (EMS) run by Alberta Environment and Parks (AEP). Data goes through a complete validation process by ALMS and AEP. Users should use caution when comparing historical data, as sampling and laboratory techniques have changed over time (e.g. detection limits). For more information on data storage, see AEP Surface Water Quality Data Reports at aep.alberta.ca/water.

Data analysis is done using the program R.[1] Data is reconfigured using packages tidyr [2] and dplyr [3] and figures are produced using the package ggplot2 [4]. Trophic status for each lake is classified based on lake water characteristics using values from Nurnberg (1996)[5]. The Canadian Council for Ministers of the Environment (CCME) guidelines for the Protection of Aquatic Life are used to compare heavy metals and dissolved oxygen measurements. Pearson's Correlation tests are used to examine relationships between TP, chlorophyll-*a,* TKN and Secchi depth, providing a correlation coefficient (r) to show the strength (0-1) and a p-value to assess significance of the relationship. For lakes with >10 years of long term data, trend analysis is done with non-parametric methods. The seasonal Kendall test estimates the presence of monotonic (unidirectional) trends across individual seasons (months) and is summed to give an overall trend over time. For lakes that had multiple samplings in a single month, the value closest to the middle of the month was used in analysis.

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[1] R Core Team (2016). R: A language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria. URL https://www.R-project.org/.
[2] Wickman, H. and Henry, L. (2017). tidyr: Easily Tidy Data with 'spread ( )' and 'gather ( )' Functions. R package version 0.7.2. https://CRAN.R-project.org/package=tidyr.
[3] Wickman, H., Francois, R., Henry, L. and Muller, K. (2017). dplyr: A Grammar of Data Manipulation. R package version 0.7.4. http://CRAN.R-project.org/package=dplyr.
[4] Wickham, H. (2009). ggplot2: Elegant Graphics for Data Analysis. Springer-Verlag New York.
[5] Nurnberg, G.K. (1996). Trophic state of clear and colored, soft- and hardwater lakes with special consideration of nutrients, anoxia, phytoplankton and fish. Lake and Reservoir Management 12: 432-447.

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

WATER CHEMISTRY

ALMS measures a suite of water chemistry parameters. Phosphorus, nitrogen, and chlorophyll-a are important because they are indicators of eutrophication, or excess nutrients, which can lead to harmful algal/cyanobacteria blooms. One direct measure of harmful cyanobacteria blooms are Microcystins, a common group of toxins produced by cyanobacteria. See Table 2 for a complete list of parameters.

Nutrient and water chemistry values in Skeleton Lake will differ between the North basin and the South basin due to differences and size and depth. The differences in size and depth significantly impact how the basins mix throughout the summer, and this difference is reflected in how the parameters change throughout the season.

The average total phosphorus (TP) concentration for Skeleton Lake North was 31.4 µg/L (Table 2), and for Skeleton Lake South was 38.6 µg/L, with both basins falling into the eutrophic trophic classification. TP in the north basin decreased and in the south basin increased over the course of the sampling season (Figure 1).

Average chlorophyll-*a* concentrations in 2017 for Skeleton Lake North was 11.2 µg/L and for Skeleton Lake South was 27.3 µg/L (Table 2). This puts the north basin in the eutrophic classification and the south basin in the hypereutrophic classification. Chlorophyll-*a* concentrations remained constant over the course of the summer. In Skeleton Lake North, chlorophyll-*a* decreased over the course of the sampling season, and was significantly correlated with TP ($r = 0.98$, $p = 0.003$). In the south basin, chlorophyll-*a* peaked on August 28, measuring 44.8 µg/L (Figure 1).

The average total Kjeldahl nitrogen (TKN) concentration of the north basin was 1.6 mg/L and the TKN concentration of the south basin was 1.5 mg/L. TKN was correlated with chlorophyll-*a* concentrations in Skeleton Lake North ($r = 0.91$, $p = 0.03$) and Skeleton Lake South ($r = 0.89$, $p = 0.04$).

Average pH of Skeleton North was 8.83 in 2017, buffered by moderate alkalinity (198 mg/L $CaCO_3$) and bicarbonate (206 mg/L HCO_3). Calcium and magnesium were the dominant ions contributing to a low conductivity of 390 µS/cm (Table 2).

Average pH of Skeleton South was 8.79 in 2017, buffered by moderate alkalinity (222 mg/L $CaCO_3$) and bicarbonate (236 mg/L HCO_3). Magnesium and sodium were the dominant ions contributing to a low conductivity of 422 µS/cm (Table 2).

METALS

Samples were analyzed for metals (Table 3). In total, 27 metals were sampled for. It should be noted that many metals are naturally present in aquatic environments due to the weathering of rocks and may only become toxic at higher levels.

Metals were measured once at both Skeleton Lake North and South on August 14. In 2017, all measured values fell within their respective guidelines (Table 3).

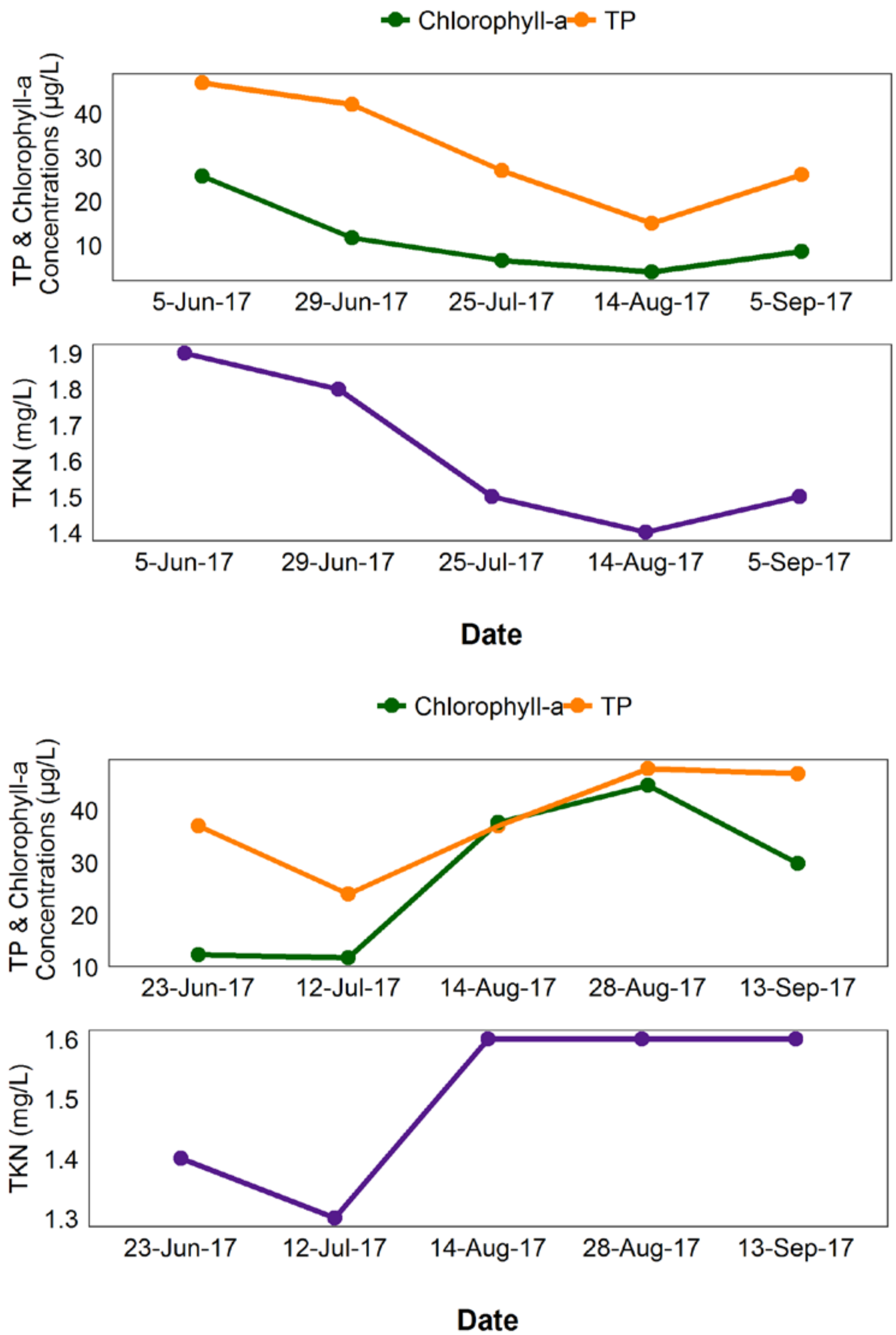


Figure 1- Total Phosphorus (TP), Total Kjeldahl Nitrogen (TKN), and Chlorophyll-*a* concentrations measured five times over the course of the summer at Skeleton Lake North (top) and Skeleton Lake South (bottom).

WATER CLARITY AND SECCHI DEPTH

Water clarity is influenced by suspended materials, both living and dead, as well as dissolved colored compounds in the water column. During the melting of snow and ice in spring, lake water can become turbid (cloudy) from silt transported into the lake. Lake water usually clears in late spring but then becomes more turbid with increased algal growth as the summer progresses. The easiest and most widely used measure of lake water clarity is the Secchi depth. Two times the Secchi depth equals the euphotic depth – the depth to which there is enough light for photosynthesis.

The average Secchi depth of Skeleton Lake North in 2017 was 1.88 m and Skeleton Lake South was 1.40 m (Table 2). Water clarity measured as Secchi depth was lowest on June 5 in the north basin and increased over the course of the sampling season. Secchi depth in the south basin stayed within 1 and 2 m in 2017 (Figure 2).

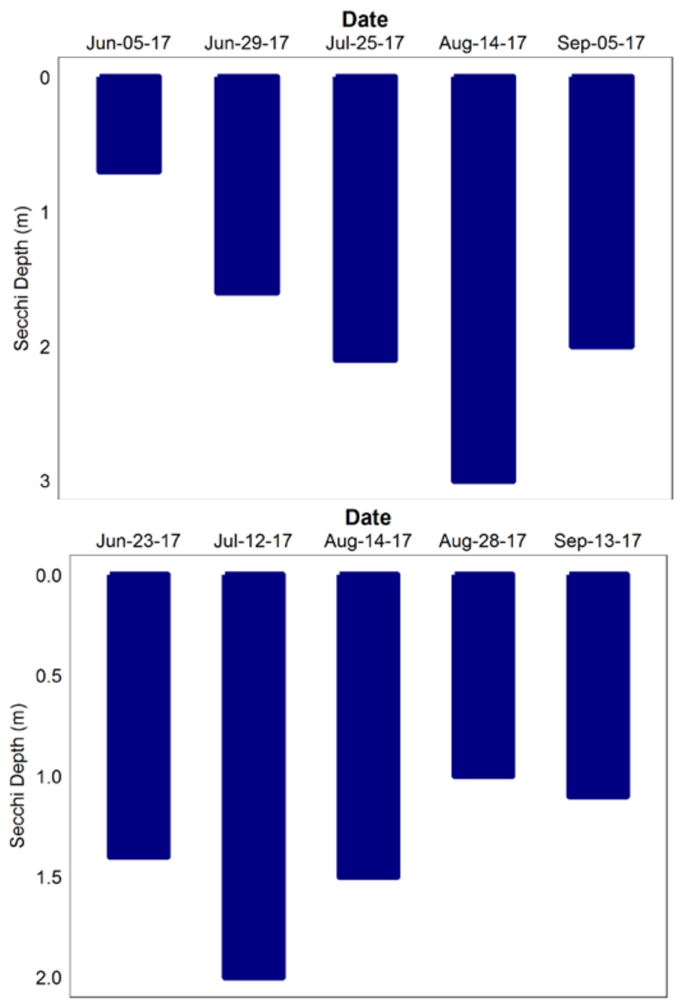


Figure 2 – Secchi depth values measured five times over the course of the summer at Skeleton Lake North (top) and Skeleton Lake South (bottom) in 2017.

WATER TEMPERATURE AND DISSOLVED OXYGEN

Water temperature and dissolved oxygen profiles in the water column can provide information on water quality and fish habitat. The depth of the thermocline is important in determining the depth to which dissolved oxygen from the surface can be mixed. Please refer to the end of this report for descriptions of technical terms.

Skeleton Lake North:

Temperatures of Skeleton Lake North varied throughout the summer, with a maximum temperature of 20.5 °C measured at the surface on August 14 (Figure 3a). The lake was strongly stratified for the extent of the sampling season, with the thermocline deepening as the lake warmed.

Skeleton Lake North remained well oxygenated at the surface throughout the summer, measuring above the CCME guidelines of 6.5 mg/L for the Protection of Aquatic Life (Figure 3b). During thermal stratification, oxygen levels reached anoxia near the bottom due to separation from atmospheric oxygen that is circulated at the lake's surface. On August 14, a spike in oxygen occurred at 7 m depth. This could have been caused by a metalimnetic bloom of algae that grow at lower light conditions.

Skeleton Lake South:

Temperatures of Skeleton Lake South varied throughout the summer, with a maximum temperature of 21.8 °C measured at the surface on July 12 (Figure 3a). The lake was well mixed for the sampling season although weak stratification was observed on July 12.

Skeleton Lake South remained well oxygenated at the surface throughout the summer, measuring above the CCME guidelines of 6.5 mg/L for the Protection of Aquatic Life (Figure 3b). During thermal stratification, oxygen levels reached anoxia near the bottom due to separation from oxygen that is circulated at the lake surface. Oxygen levels declined near the bottom in August, likely due to decomposition. The entire water column was well oxygenated in June and September.

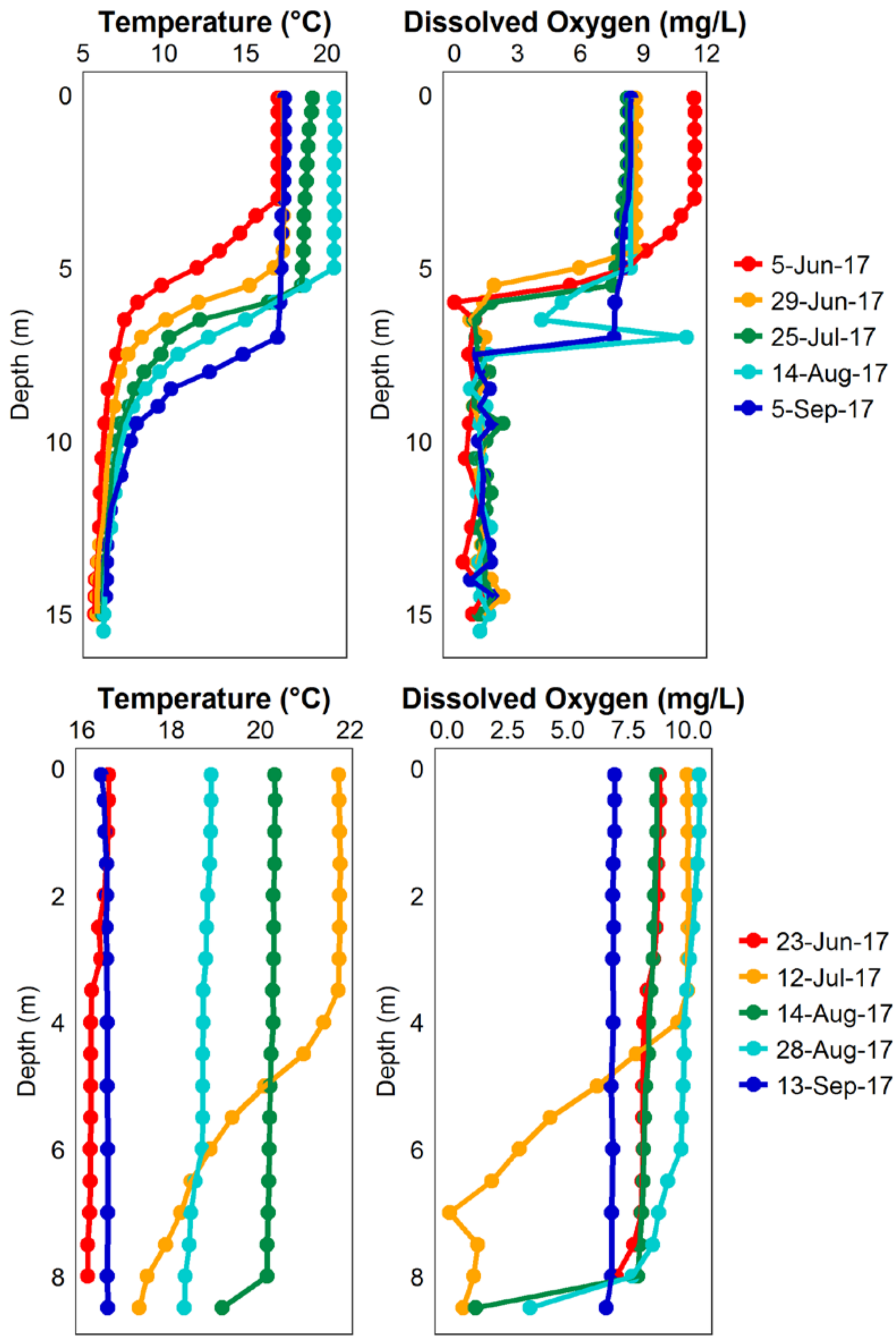


Figure 3 – a) Temperature (°C) and b) dissolved oxygen (mg/L) profiles for Skeleton Lake North (top) and Skeleton Lake South (bottom) measured five times over the course of the summer of 2017.

MICROCYSTIN

Microcystins are toxins produced by cyanobacteria (blue-green algae) which, when ingested, can cause severe liver damage. Microcystins are produced by many species of cyanobacteria which are common to Alberta's Lakes, and are thought to be the one of the most common cyanobacteria toxins. In Alberta, recreational guidelines for microcystin are set at 20 μg/L. Blue-green algae advisories are managed by Alberta Health Services. Recreating in algal blooms, even if microcystin concentrations are not above guidelines, is not recommended.

Microcystin levels in Skeleton Lake fell below the recreational guideline for the entire sampling period of 2017 (Table 1). Microcystin was below the detection limit on three trips to Skeleton Lake North (Table 1A).

Table 1 – A) Microcystin concentrations measured five times at Skeleton Lake North in 2017.

Date	Microcystin Concentration (μg/L)
Jun-05-17	<0.1
Jun-29-17	0.1
Jul-25-17	0.13
Aug-14-17	<0.1
Sep-05-17	<0.1
Average	0.08

Table 1 – B) Microcystin concentrations measured five times at Skeleton Lake South in 2017.

Date	Microcystin Concentration (μg/L)
Jun-23-17	0.34
Jul-12-17	0.14
Aug-14-17	0.4
Aug-28-17	0.78
Sep-13-17	0.85
Average	0.50

INVASIVE SPECIES MONITORING

Dreissenid mussels pose a significant concern for Alberta because they impair the function of water conveyance infrastructure and adversely impact the aquatic environment. These invasive mussels have been linked to creating toxic algae blooms, decreasing the amount of nutrients needed for fish and other native species, and causing millions of dollars in annual costs for repair and maintenance of water-operated infrastructure and facilities.

Monitoring involved two components: monitoring for juvenile mussel veligers using a plankton net and monitoring for attached adult mussels using substrates installed in each lake. In 2017, no mussels were detected in Skeleton Lake.

WATER LEVELS

There are many factors influencing water quantity. Some of these factors include the size of the lake's drainage basin, precipitation, evaporation, water consumption, ground water influences, and the efficiency of the outlet channel structure at removing water from the lake. Requests for water quantity monitoring should go through Alberta Environment and Parks Monitoring and Science division.

Water levels in Skeleton Lake North have been monitored since 2012 and has remained relatively stable (Figure 4a). In 2015, the north basin decreased to 621.0 m asl, about a 1 m decrease from the previous year.

Water levels in Skeleton Lake South have been monitored since 1965 and has been decreasing since the late 1990s (Figure 4b). Decreasing water levels in Skeleton Lake have separated the two basins.

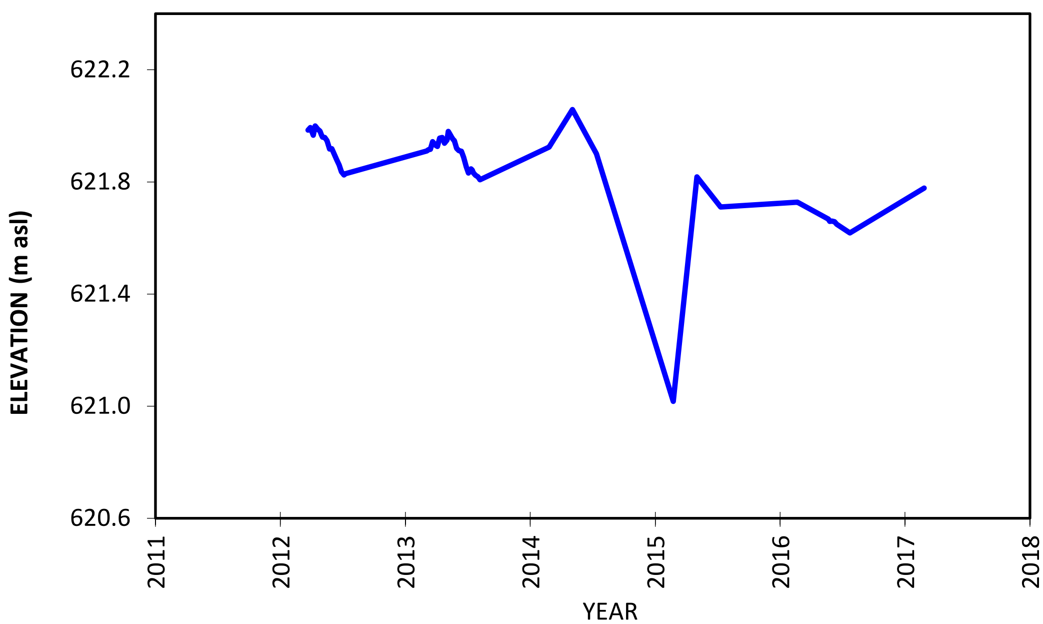


Figure 4a- Water levels measured in metres above sea level (asl) from 2012-2017 from the North basin of Skeleton Lake. Data retrieved from Alberta Environment.

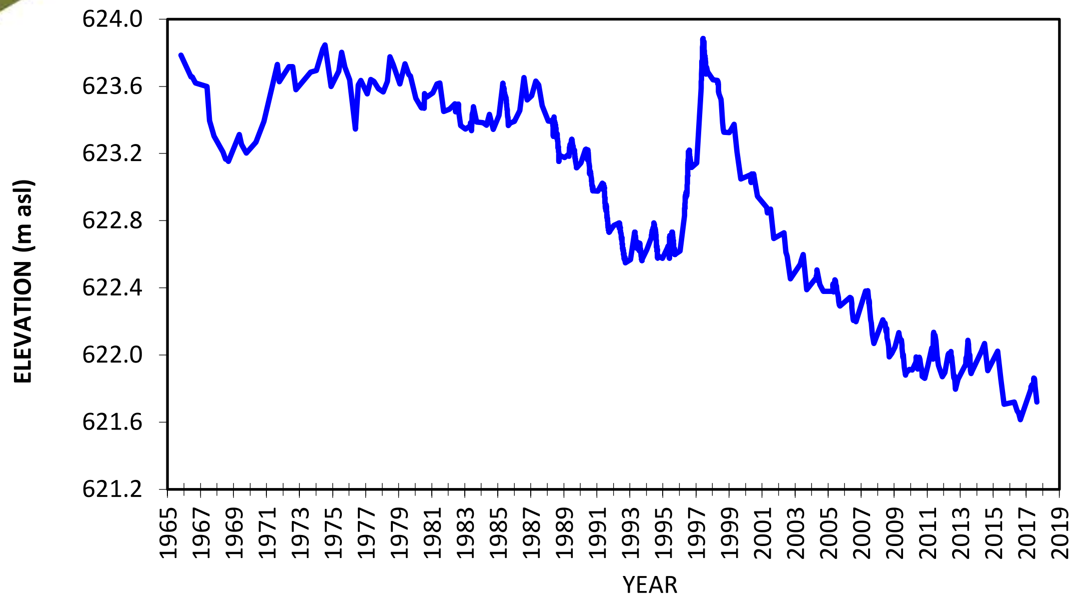


Figure 4b- Water levels measured in metres above sea level (m asl) from 1965 to 2017 from the South basin of Skeleton Lake. Data retrieved from Alberta Environment.

Table 2: Average Secchi depth and water chemistry values for Skeleton Lake North.

Parameter	1985	1986	2005	2010	2011	2012	2013	2014	2015	2016	2017
TP (µg/L)	24.3	36.3	32.7	47.8	44.5	36.0	47.6	25.2	26	28	31.4
TDP (µg/L)	7.8	10.7	11.0	16.0	11.8	14.4	28.2	10.6	11	9	7.6
Chlorophyll-*a* (µg/L)	9.2	10.7	11.0	8.6	17.2	8.6	7.56	5.76	7.46	9.2	11.2
Secchi depth (m)	/	/	2.63	1.75	1.40	2.45	2.35	2.81	2.00	1.4	1.88
TKN (mg/L)	1.2	1.1	1.3	1.6	1.4	1.5	1.5	1.2	1.5	1.5	1.6
NO_2-N and NO_3-N (µg/L)	2.25	3.67	3.00	4.40	6.00	2.50	2.5	22	2.3	2.5	2.32
NH_3-N (µg/L)	21.2	32.5	12.7	82.8	24.3	21.2	23.2	33.4	25	25	27.6
DOC (mg/L)	14.8	14.6	16.6	18.6	14.3	17.8	18.2	18.97	17	18.4	16.6
Ca (mg/L)	23.3	24.3	21.3	23.0	22.1	25.1	24.17	31	25	24.2	25
Mg (mg/L)	18.7	18.8	23.5	25.9	26.7	25.0	26.9	21.23	26	27.6	27.6
Na (mg/L)	13.3	13.5	17.5	18.7	19.6	17.6	18.7	20.8	20	21.2	20.8
K (mg/L)	8.43	8.45	10.60	10.77	11.60	11.90	13.5	12.24	13	14.2	13.4
SO_4^{2-} (mg/L)	2.5	2.5	5.0	6.3	1.5	4.2	7.5	2.17	7.6	7.6	8.1
Cl^- (mg/L)	1.5	1.3	3.2	3.4	4.4	5.6	5.1	6	6.8	6.82	7.4
CO_3 (mg/L)	4.1	10.8	12.0	9.7	11.8	8.7	17.4	9.78	11	9.96	18
HCO_3 (mg/L)	198.08	194.43	204.00	217.67	229.25	226.40	212.8	235.6	228	226	206
pH	8.53	8.58	8.79	8.71	8.72	8.67	8.86	8.578	8.70	8.70	8.83
Conductivity (µS/cm)	318.3	323.7	334.5	372.3	388.0	388.4	390.4	390	402	392	390
Hardness (mg/L)	134.8	138.0	150.0	164.0	165.0	165.7	171	165	170	174	176
TDS (mg/L)	172.2	174.5	192.5	205.0	210.0	210.0	217.3	214.6667	222	224	222
Microcystin (µg/L)	/	/	0.078	0.142	0.230	0.169	0.129	0.08	0.08	0.198	0.08
Total Alkalinity (mg/L $CaCO_3$)	169.8	171.5	186.5	195.0	208.0	200.0	204	192.6	204	200	198

Table 2: Average Secchi depth and water chemistry values for Skeleton Lake South.

Parameter	1985	1986	2005	2006	2008	2009	2010	2011	2012	2013	2014	2015*	2017
TP (µg/L)	31.4	46.7	28.8	39.8	45.4	40.3	58.8	44.5	40.3	39.6	50.7	27	38.6
TDP (µg/L)	7.8	10.7	8.4	12.6	13.4	13.5	14.8	11.8	11.8	20.2	59.0	9.0	6.62
Chlorophyll-*a* (µg/L)	14.8	24.2	12.1	15.0	19.3	12.4	22.3	17.2	17.3	12.12	29.8	14.1	27.3
Secchi depth (m)	2.00	1.60	2.28	1.60	1.65	1.63	1.40	1.40	1.81	1.59	1.56	2.50	1.4
TKN (mg/L)	1.1	1.3	1.2	1.2	1.3	1.1	1.6	1.4	1.4	1.3	1.4	1.4	1.5
NO_2-N and NO_3-N (µg/L)	2.1	2.8	6.0	14.0	12.7	12.5	24.8	6.0	3.5	2.5	38.0	2.0	2.26
NH_3-N (µg/L)	13.6	37.2	12.8	27.0	19.2	26.8	22.0	24.3	21.0	21	55.6	25	31.8
DOC (mg/L)	13.6	14.6	14.4	14.9	16.5	14.6	15.8	14.3	14.2	14.3	17.4	16	15.2
Ca (mg/L)	26.3	25.0	23.4	25.5	22.8	23.6	21.3	22.1	25.8	25	21.3	24	24.2
Mg (mg/L)	19.0	19.0	23.4	23.0	26.9	24.4	25.1	26.7	25.7	25.6	25.8	26	29.8
Na (mg/L)	13.6	13.8	19.2	20.1	20.2	21.3	21.7	19.6	20.9	21.77	24.4	21	25.4
K (mg/L)	8.59	8.64	10.85	11.50	11.50	12.50	11.93	11.60	13.25	17.7	14.1	13	15
SO_4^{2-} (mg/L)	2.5	2.5	3.0	3.7	3.0	5.0	2.9	1.5	1.5	4.83	2.2	2.0	2.46
Cl^- (mg/L)	1.8	1.4	3.1	3.4	3.8	4.2	4.7	4.4	4.8	4.33	5.3	5.8	6.24
CO_3 (mg/L)	4.6	9.0	5.7	9.7	8.8	10.1	9.0	11.8	9.4	16	21.88	13	17.02
HCO_3 (mg/L)	208.40	191.62	226.00	232.50	223.67	231.33	229.33	229.25	246.75	227.8	255.2	243	236
pH	8.53	8.72	8.66	8.71	8.73	8.76	8.80	8.72	8.64	8.75	8.8	8.72	8.79
Conductivity (µS/cm)	333.4	327.2	360.0	389.3	374.3	381.3	390.7	388.0	405.8	410.2	398.0	413	422
Hardness (mg/L)	143.4	140.4	152.0	158.3	168.0	159.0	156.7	165.0	170.0	168	159	167	184
TDS (mg/L)	181.1	178.1	204.0	213.8	211.3	218.3	214.0	210.0	222.0	230.3	233	227	240
Microcystin (µg/L)	/	/	0.148	0.178	0.240	0.340	0.306	0.230	0.218	0.2356	0.402	0.370	0.50
Total Alkalinity (mg/L $CaCO_3$)	178.2	175.2	202.5	210.0	205.3	211.0	210.3	208.0	218.0	213.6	209.2	220	222

Table 3: Concentrations of metals measured in Skeleton Lake North. The CCME heavy metal Guidelines for the Protection of Freshwater Aquatic Life (unless otherwise indicated) are presented for reference.

Metals (Total Recoverable)	2010	2011	2012	2013	2014	2015	2016	2017 North	Guidelines
Aluminum µg/L	26.04	13.9	14.75	11.735	10.75	16.2	6.6	4.5	100[a]
Antimony µg/L	0.03635	0.02885	0.0307	0.0326	0.032	0.0315	0.03	0.028	/
Arsenic µg/L	0.8565	0.8685	0.574	0.8165	0.7735	0.828	0.745	0.77	5
Barium µg/L	48.95	50.85	51.1	49.05	48.5	53.75	50.9	49.5	/
Beryllium µg/L	0.00585	0.0052	0.00645	0.0015	0.004	0.004	0.004	0.0015	100[c,d]
Bismuth µg/L	0.00195	0.00215	0.0321	0.0143	0.00225	0.00925	5.00E-04	0.0015	/
Boron µg/L	122.5	105.5	104.85	93.5	97.05	94.3	103	96.5	1500
Cadmium µg/L	0.0057	0.001	0.001	0.001	0.002	0.002	0.001	0.005	0.26[b]
Chromium µg/L	0.242	0.0765	0.1535	0.28	0.105	0.075	0.015	0.05	/
Cobalt µg/L	0.01845	0.01115	0.00955	0.02615	0.007	0.0185	0.001	0.039	1000[d]
Copper µg/L	0.1633	0.154	0.3698	0.1402	0.13	0.175	0.32	0.27	4[b]
Iron µg/L	7.73	3.59	7.2	21.95	2.875	7.5	3.8	3	300
Lead µg/L	0.0151	0.0137	0.01055	0.0168	0.0135	0.0275	0.007	0.014	7[b]
Lithium µg/L	31.7	33	28.1	26.65	27.95	28.7	32.7	31.6	2500[e]
Manganese µg/L	35.4	43.9	29	16.05	12.55	31.55	26	7.66	200[e]
Molybdenum µg/L	0.0627	0.05335	0.02955	0.03915	0.037	0.041	0.026	0.038	73[c]
Nickel µg/L	0.0025	0.0025	0.0025	0.05425	0.004	0.004	0.004	0.08	150[b]
Selenium µg/L	0.05	0.096	0.05	0.082	0.03	0.03	0.2	0.1	1
Silver µg/L	0.0013	0.003175	0.001525	0.007125	0.001	0.001	0.001	5.00E-04	0.25
Strontium µg/L	176	187	166	180	180	194.5	193	183	/
Thallium µg/L	0.000725	0.0006	0.001225	0.0004	0.00045	0.0104	0.00045	0.001	0.8
Thorium µg/L	0.008025	0.00625	0.0313	0.01075	0.001175	0.00045	0.00045	0.001	/
Tin µg/L	0.015	0.015	0.38175	0.0377	0.0065	0.026	0.023	0.03	/
Titanium µg/L	0.336	0.676	0.2735	0.7785	0.2025	0.73	0.26	0.2	/
Uranium µg/L	0.1965	0.202	0.18	0.1995	0.211	0.205	0.201	0.22	15
Vanadium µg/L	0.214	0.1855	0.2035	0.1865	0.19	0.19	0.14	0.171	100[d,e]
Zinc µg/L	0.3085	0.41	0.4175	0.2805	0.55	0.25	0.3	0.4	30

Values represent means of total recoverable metal concentrations.

[a] Based on pH ≥ 6.5

[b] Based on water hardness > 180mg/L (as $CaCO_3$)

[c] CCME interim value.

[d] Based on CCME Guidelines for Agricultural use (Livestock Watering).

[e] Based on CCME Guidelines for Agricultural Use (Irrigation).

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

Table 3: Concentrations of metals measured in Skeleton Lake South. The CCME heavy metal Guidelines for the Protection of Freshwater Aquatic Life (unless otherwise indicated) are presented for reference.

Metals (Total Recoverable)	2008	2009	2010	2011	2012	2013	2014	2017	Guidelines
Aluminum µg/L	24.1	12.8	22.95	23.2	7.88	12.655	18.5	21.5	100[a]
Antimony µg/L	0.033	0.032	0.03335	0.0326	0.0236	0.02795	0.0455	0.04	/
Arsenic µg/L	1.01	0.983	1.065	0.948	0.367	1.0065	1.36	1.04	5
Barium µg/L	55.8	57.3	55.55	56.2	44	57.7	45.8	56.1	/
Beryllium µg/L	0.0045	<0.003	0.0015	0.0048	0.0015	0.0015	0.004	0.0015	100[c,d]
Bismuth µg/L	0.0036	0.004	0.002	0.0014	0.0057	0.0038	0.0005	0.0015	/
Boron µg/L	102.5	109.6	97	106	87.2	100.9	94.75	105	1500
Cadmium µg/L	<0.002	0.0023	0.00695	0.0045	0.0035	0.0024	0.008	0.005	0.26[b]
Chromium µg/L	0.115	0.188	0.1395	0.15	0.106	0.196	0.215	0.05	/
Cobalt µg/L	0.023	0.0203	0.01325	0.0171	0.0084	0.0285	0.022	0.042	1000[d]
Copper µg/L	0.171	0.27	0.1303	0.181	0.508	0.1805	0.535	0.46	4[b]
Iron µg/L	49.2	70.4	41	53.4	48.5	40.2	13.45	28.4	300
Lead µg/L	0.0285	0.0283	0.02505	0.0327	0.0126	0.02665	0.0265	0.029	7[b]
Lithium µg/L	30.6	36.1	28.05	33.2	21.9	29.15	39.7	33.8	2500[e]
Manganese µg/L	44.5	62.1	49.75	58.1	40.3	50.15	34.15	44.3	200[e]
Molybdenum µg/L	0.103	0.114	0.09395	0.103	0.0643	0.0823	0.087	0.097	73[c]
Nickel µg/L	<0.005	0.204	0.0025	0.0025	0.0025	0.16175	0.0595	0.18	150[b]
Selenium µg/L	0.144	0.12	0.076	0.138	0.05	0.05	0.07	0.1	1
Silver µg/L	0.0036	0.0069	0.00255	0.00025	0.0022	0.02725	0.001	0.002	0.25
Strontium µg/L	185	185	188	186	134	197.5	208.5	190	/
Thallium µg/L	0.00115	0.00185	0.001	0.001	0.00015	0.000365	0.00068	0.001	0.8
Thorium µg/L	0.0093	0.0017	0.0096	0.0066	0.0084	0.00655	0.00563	0.001	/
Tin µg/L	0.0483	<0.03	0.03015	0.015	0.0327	0.015	0.0195	0.03	/
Titanium µg/L	1.21	0.762	0.904	1.1	0.26	1.43	0.985	1	/
Uranium µg/L	0.121	0.11	0.1145	0.12	0.0612	0.09055	0.196	0.105	15
Vanadium µg/L	0.207	0.208	0.2095	0.217	0.101	0.145	0.265	0.225	100[d,e]
Zinc µg/L	0.373	0.996	0.5025	0.399	0.361	0.346	1.3	2.7	30

Values represent means of total recoverable metal concentrations.
[a] Based on pH ≥ 6.5
[b] Based on water hardness > 180mg/L (as $CaCO_3$)
[c] CCME interim value.
[d] Based on CCME Guidelines for Agricultural use (Livestock Watering).
[e] Based on CCME Guidelines for Agricultural Use (Irrigation).
A forward slash (/) indicates an absence of data or guidelines.

LONG TERM TRENDS- SKELTON LAKE SOUTH

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 the south basin of Skeleton Lake. In sum, non-significant increases were observed in chlorophyll-*a* and non-significant decreasing trends were observed in TP and Secchi depth. Secchi depth can be subjective and is sensitive to variation in weather - trend analysis must be interpreted with caution. Significant increases were observed in TDS. Data is presented below as both a line graph (all data points used in analysis) and a box-and-whisker plot. Detailed methods are available in the *ALMS Guide to Trend Analysis on Alberta Lakes.*

Table 1: Summary table of trend analysis on Skeleton Lake South data from 2005 to 2017.

Parameter	Date Range	Trend	Probability
Total Phosphorus	2005-2017	Decreasing	Non-significant
Chlorophyll-*a*	2005-2017	Increasing	Non-significant
Total Dissolved Solids	2005-2017	Increasing	Significant
Secchi Depth	2005-2017	Decreasing	Non-significant

Definitions:

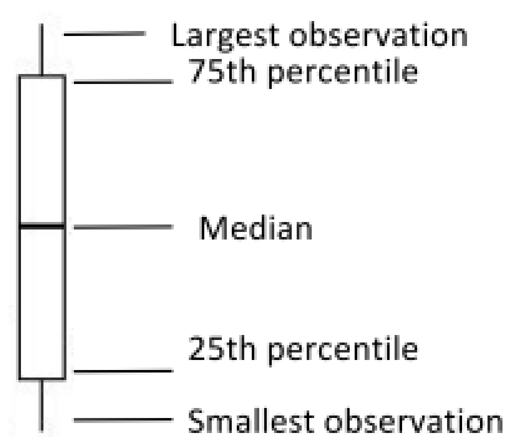
Median: the value in a range of ordered numbers that falls in the middle.

Trend: a general direction in which something is changing.

Monotonic trend: a gradual change in a single direction.

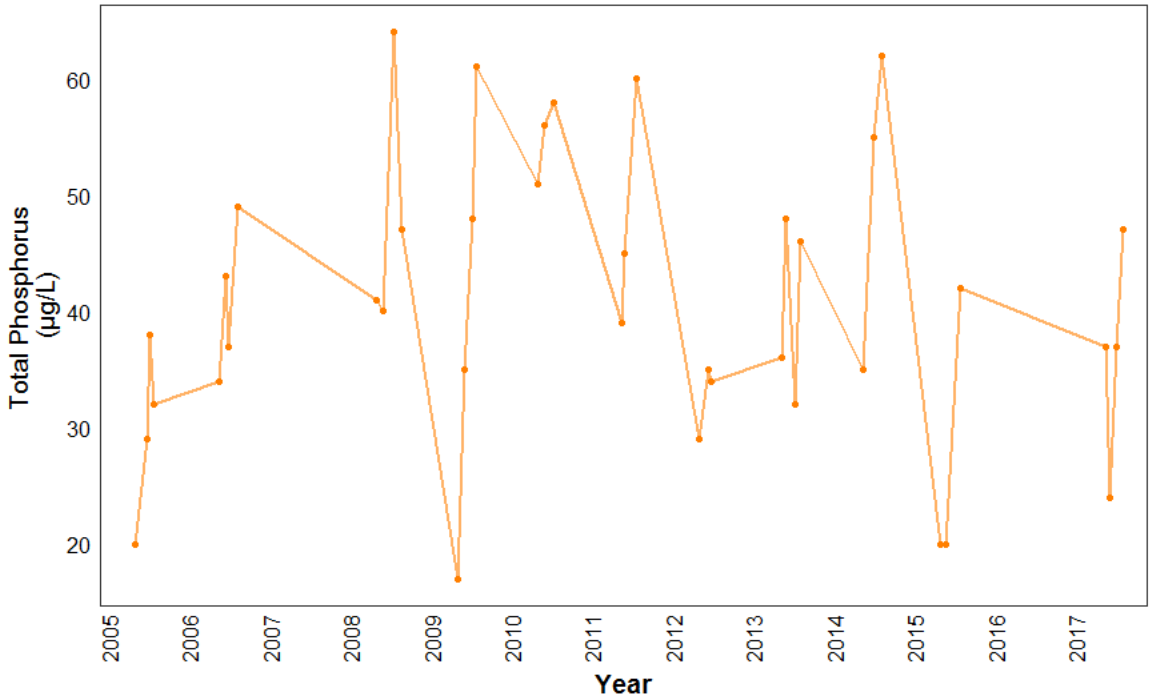
Statistically significant: The likelihood that a relationship between variables is caused by something other than random chance. This is indicated by a p-value of <0.05. Variability: the extent by which data is inconsistent or scattered.

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



Total Phosphorus (TP)

TP has not significantly increased or decreased in Skeleton Lake South since sampling began in 2005 (Tau = -0.05, p = 0.68).



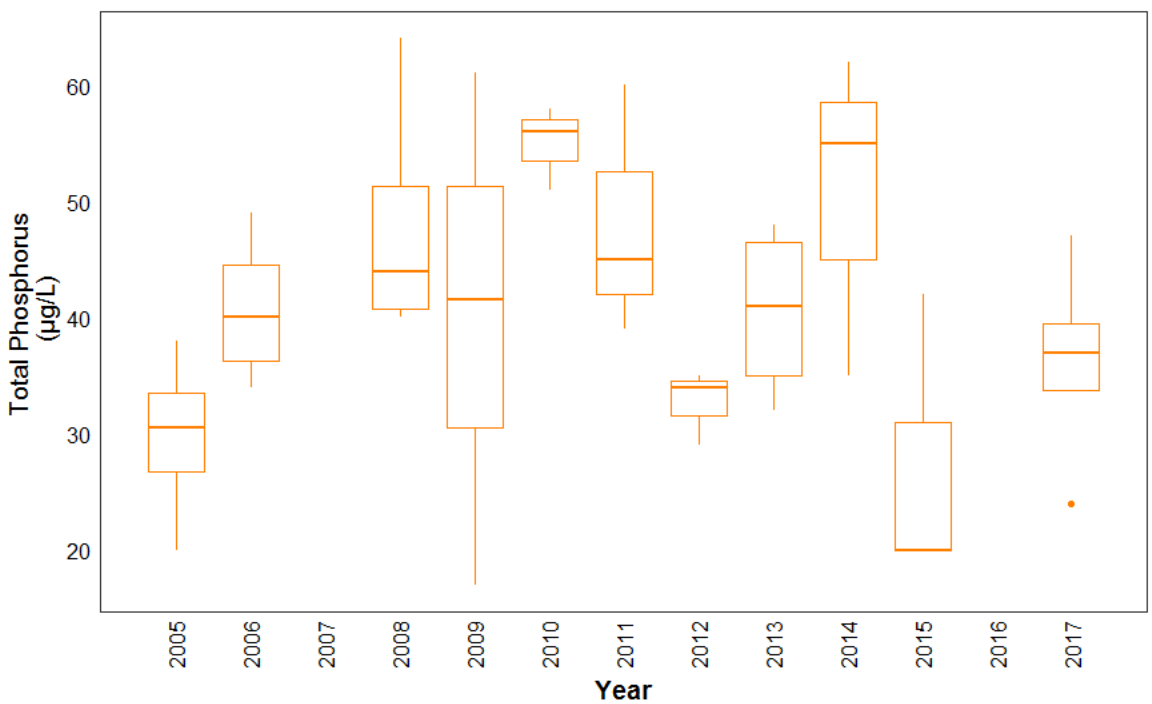


Figure 1- Monthly total phosphorus (TP) concentrations measured between June and September over the long term sampling dates between 2005 and 2017 (n = 39). The value closest to the 15th day of the month was chosen to represent the monthly value in cases with multiple monthly samples.

Chlorophyll-*a*

Chlorophyll-*a* has not significantly increased or decreased since sampling began on Skeleton Lake South in 2005 (Tau = 0.22, p=0.14).

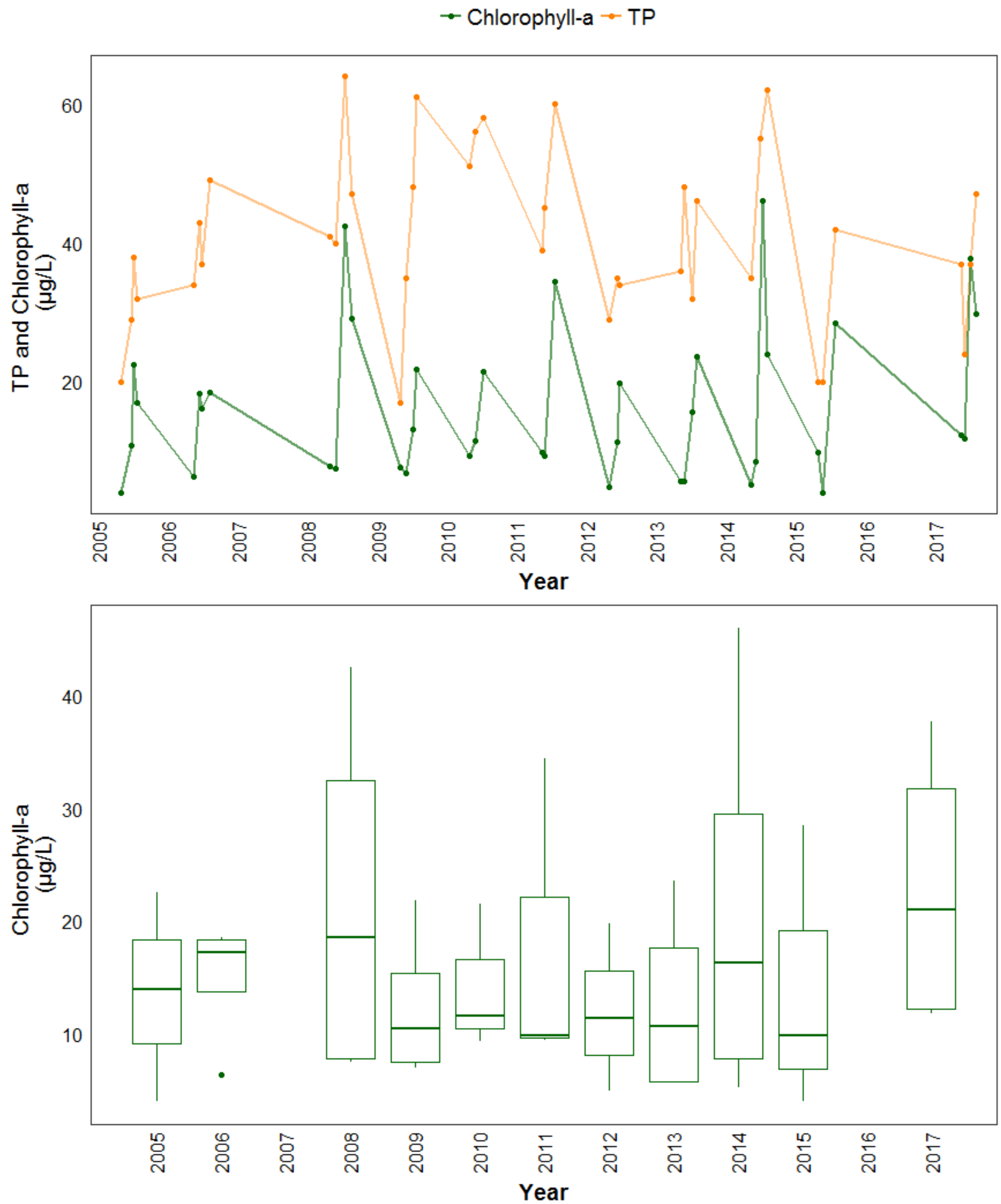
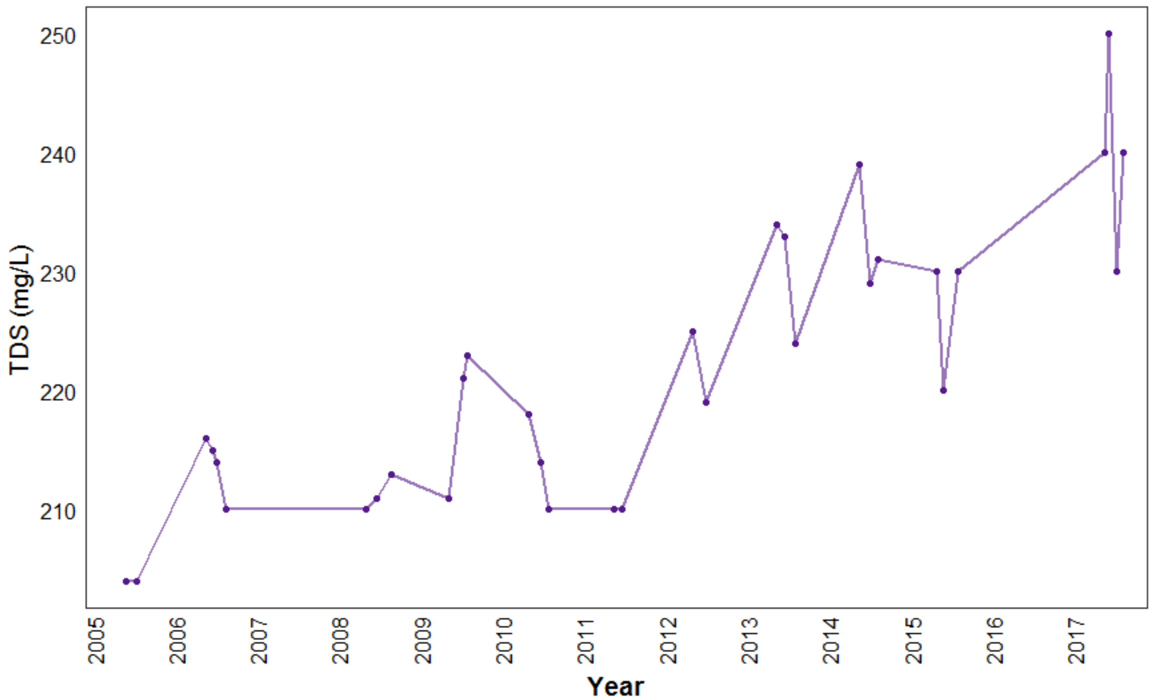


Figure 2-Monthly chlorophyll-*a* concentrations measured between June and September over the long term sampling dates between 2005 and 2017 (n = 40). The value closest to the 15[th] day of the month was chosen to represent the monthly value in cases with multiple monthly samples. Line graph is overlain by TP concentrations.

Total Dissolved Solids (TDS)

Trend analysis showed an increasing trend in TDS since 2005 in Skeleton Lake South (Tau = 0.70, $p < 0.001$). This could be attributed to decreasing water levels.



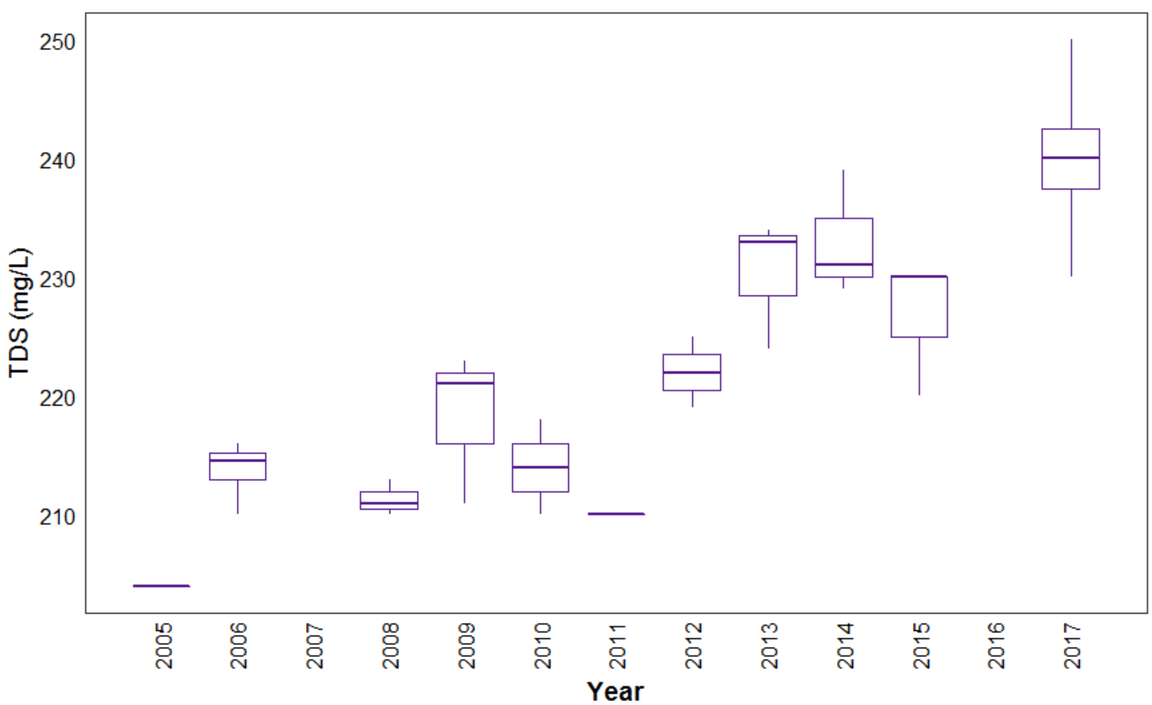


Figure 3- Monthly TDS values measured between June and September over the long term sampling dates between 2005 and 2017 (n = 32). The value closest to the 15th day of the month was chosen to represent the monthly value in cases with multiple monthly samples.

Secchi Depth

Water clarity measured as Secchi depth has not changed significantly in Skeleton Lake South since 2005 (Tau =-0.16, p = 0.27).

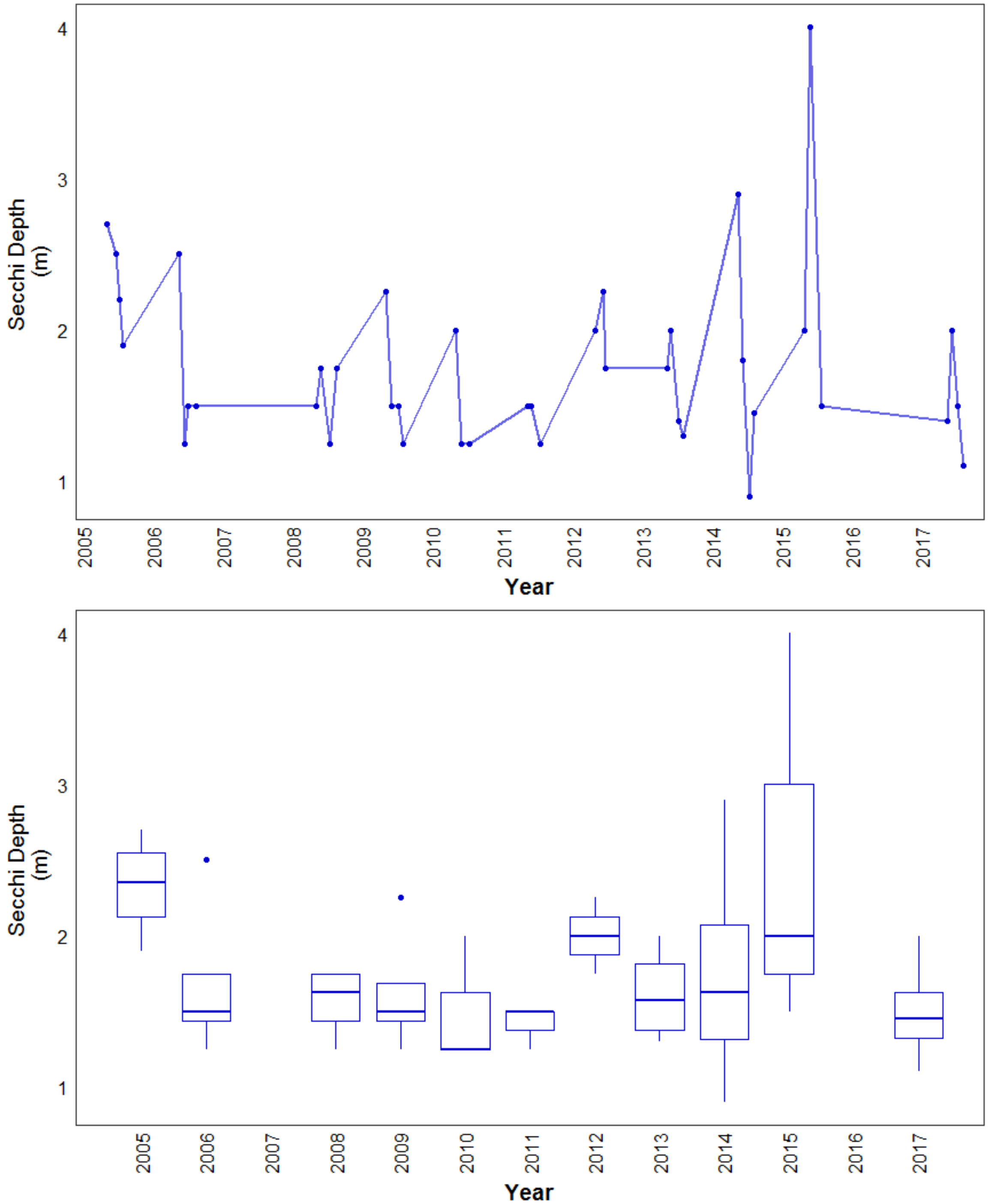


Figure 4- Monthly Secchi depth values measured between June and September over the long term sampling dates between 2005 and 2017 (n = 40). The value closest to the 15th day of the month was chosen to represent the monthly value in cases with multiple monthly samples.

Table 2- Results of trend tests using monthly total phosphorus (TP), chlorophyll-*a*, 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	-0.050	0.22	0.70	-0.16
The extent of the trend	Slope	-0.20	0.40	2.67	-0.025
The statistic used to find significance of the trend	Z	-0.41	1.49	4.82	-1.11
Number of samples included	n	39	40	32	40
The significance of the trend	*p*	0.68	0.14	1.46×10^{-6}*	0.27

*$p < 0.05$ is significant within 95%