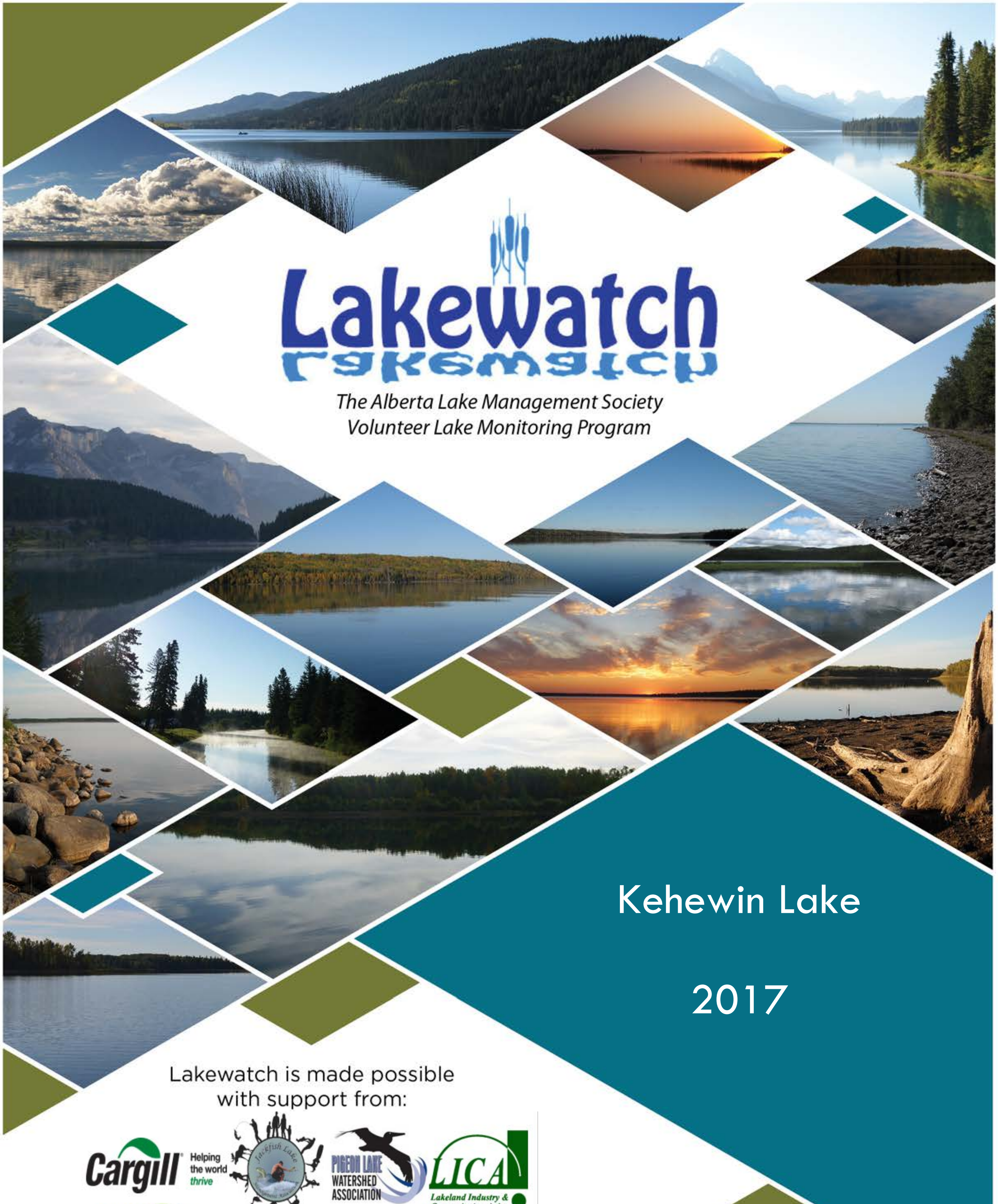


Lakewatch

The Alberta Lake Management Society
Volunteer Lake Monitoring Program

Kehewin 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 Monty Moore and Paul Kip for the time and energy put into sampling Kehewin 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.

KEHEWIN LAKE

Kehewin Lake is a long, beautiful lake located on Highway 41 north of Elk Point. The lake is surrounded by rolling pasture and hay lands. Kehewin Lake has two recreational facilities: one located on the southeast shore just off Highway 41, and the other located on the southwest shore.

A calm evening on Kehewin Lake—photo by Elashia Young 2017

Alternate spellings for Kehewin Lake are found in various literatures – spellings even differ on the two highway signs for the lake. “Kehew” is a Cree word meaning eagle, suggesting that “Kehewin” is the most appropriate spelling[1]. Kehewin Lake is named after the Indian Chief who signed treaty No.6 for The Kehewin Indian Reserve No.123 in 1876[2]. The Kehewin Indian Reserve is 8212.2 ha to the north of the lake, with 863 residents of 1,581 members in October 2002. The reserve is in the county of Bonnyville, but most of the lake is within the County of St. Paul. Kehewin Lake is very shallow in the north and south portions. The lake is situated within the Beaver River drainage basin, which is in the Moose Lake watershed, in the westernmost part of the Churchill River system. The outflow of Kehewin Lake drains into Bangs Lake to the north via Kehewin Creek, then joins with Yelling Creek and flows into Thin Lake, finally draining into Moose Lake via Thin Lake River. Agriculture in Kehewin’s drainage basin is limited to pasture and hay fields. The drainage basin overlies geological formations that are rich in heavy oils, thus oil extraction is common in the area. Kehewin Lake lies in a large melt-water channel predominated by glacial till and alluvial deposits[1]. It is surrounded by rough, broken land with steep slopes dominated by aspen (Populus spp.). Extensive marshes on the north and south ends of the lake provide excellent habitat for waterfowl.

Marsh vegetation includes reed grass (Calamagrostis spp.), bulrush (Scirpus spp.), sedge (Carex spp.), cattail (Typha latifolia), and arrowhead (Sagittaria cuneata). Common submerged and floating aquatic plants include water smartweed (Polygomum natans), coontail (Ceratophyllum demersum), Richardson’s pondweed (Potamogeton richardsonii), northern watermilfoil (Myriophyllum exalbescens), sago pondweed (Potamogeton pectinatus), large-sheath pondweed (Potamogeton vaginatus), and duckweed (Lemna spp.)[2].

As a popular sport fishing lake, Kehewin Lake is noted for its large northern pike.[2]

[1]Ken Dion. (2002). Personal Communication.
[2]Mitchell, P. and E. Prepas. (1990). Atlas of Alberta Lakes, University of Alberta Press.

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. Mann Kendall tests are used with non-normal data to assess unidirectional trends over time in a dataset (a non-parametric linear regression). This test allows for missing values, making it a robust test to use on water quality data (Helsel and Hirsch 2002).

[1] R Core Team (2016). R: A language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria. URL https://www.R-project.org/.

[2] Wickman, H. and Henry, L. (2017). tidyr: Easily Tidy Data with 'spread ( )' and 'gather ( )' Functions. R package version 0.7.2. https://CRAN.R-project.org/package=tidyr.

[3] Wickman, H., Francois, R., Henry, L. and Muller, K. (2017). dplyr: A Grammar of Data Manipulation. R package version 0.7.4. http://CRAN.R-project.org/package=dplyr.

[4] Wickham, H. (2009). ggplot2: Elegant Graphics for Data Analysis. Springer-Verlag New York.

[5] Nurnberg, G.K. (1996). Trophic state of clear and colored, soft- and hardwater lakes with special consideration of nutrients, anoxia, phytoplankton and fish. Lake and Reservoir Management 12: 432-447.

Before reading this report, check out [A Brief Introduction to Limnology] at alms.ca/reports

WATER CHEMISTRY

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

The average total phosphorus (TP) concentration for Kehewin Lake was 121 µg/L (Table 2), falling into the hypereutrophic, or very productive, trophic classification. TP increased in July, and was then constant for the rest of the sampling season (Figure 1).

Average chlorophyll-*a* concentrations in 2017 was 85.7 µg/L (Table 2), also putting Kehewin Lake into the hypereutrophic classification. This is the second highest average chlorophyll-*a* average in historical records at Kehewin Lake. Chlorophyll-*a* concentrations spiked on July 27, reaching a maximum concentration of 192 µg/L.

Finally, average total Kjeldahl nitrogen (TKN) concentration was 1.975 mg/L (Table 2), and the maximum concentration was measured on July 27. TKN and chlorophyll-*a* trends were significantly correlated ($r = 0.99$, $p = 0.00014$).

Average pH was measured as 8.63 in 2017, buffered by moderate alkalinity (222.5 mg/L $CaCO_3$) and bicarbonate (242.5 mg/L HCO_3). Sodium and magnesium were the dominant ions contributing to a moderate conductivity of 513 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 Kehewin Lake at the surface on September 7. In 2017, all measured values fell within their respective guidelines (Table 3).

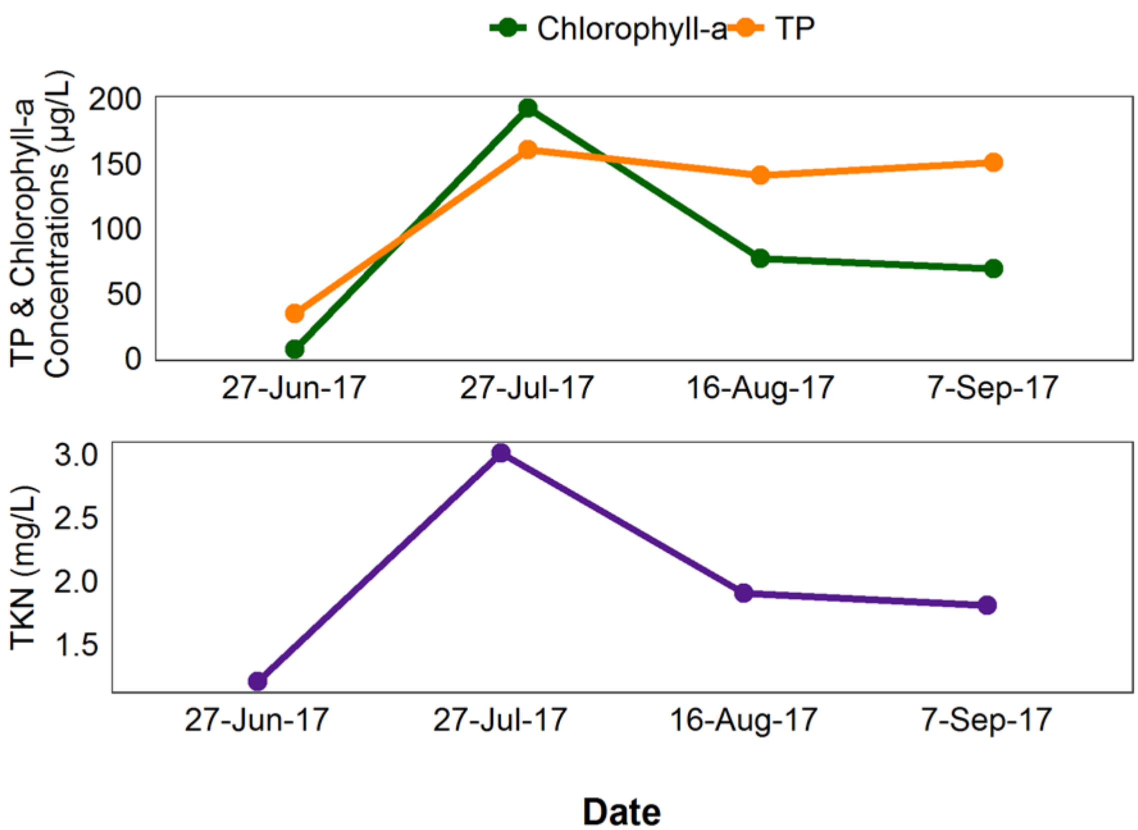


Figure 1- Total Phosphorus (TP), Total Kjeldahl Nitrogen (TKN), and Chlorophyll-*a* concentrations measured four times over the course of the summer at Kehewin Lake.

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 Kehewin Lake in 2017 was 1.65 m (Table 2). Water clarity measured as Secchi depth was lowest on July 27, when chlorophyll-*a* levels were highest. The decreasing water clarity could be associated with increasing algal biomass in the warmer months of the summer.

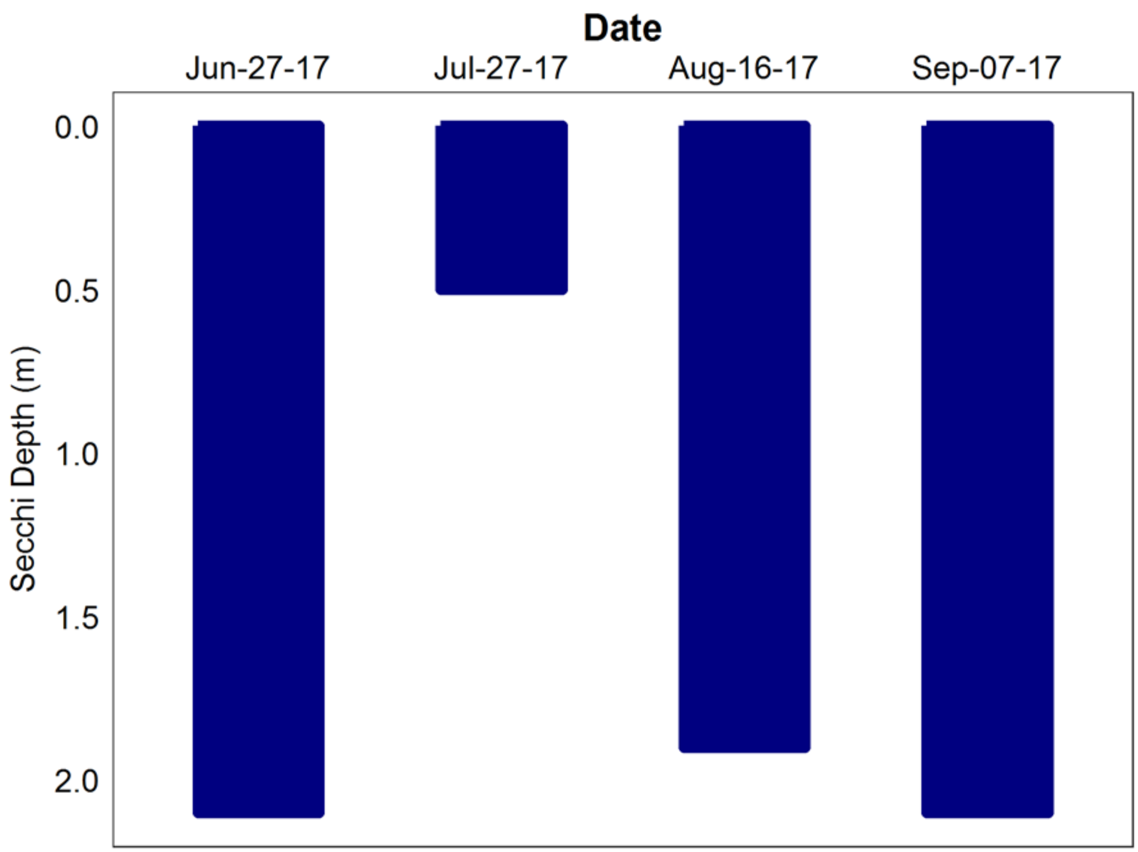


Figure 2 – Secchi depth values measured four times over the course of the summer at Kehewin Lake in 2017.

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.

Temperatures of Kehewin Lake varied throughout the summer, with a maximum temperature of 21.2 °C measured at the surface on July 27 (Figure 3a). The lake was well mixed for most of the summer, with weak stratification occurring during the warmest visit in July.

Kehewin Lake 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 decreased near the bottom due to separation rom atmospheric oxygen that is circulated at the lake's surface.

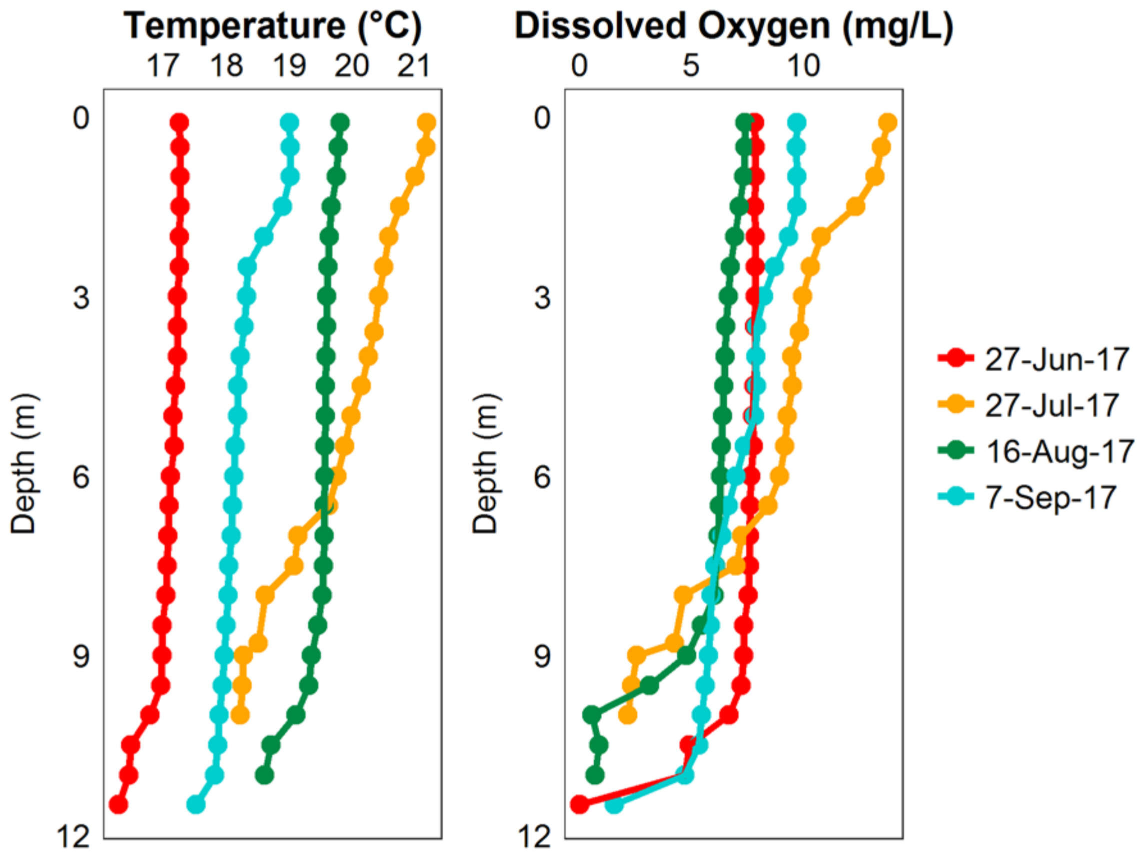


Figure 3 – a) Temperature (°C) and b) dissolved oxygen (mg/L) profiles for Kehewin Lake measured four times over the course of the summer of 2017.

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 Kehewin Lake fell below the recreational guideline for the entire sampling period of 2017 (Table 1).

Table 1 – Microcystin concentrations measured four times at Kehewin Lake in 2017.

Date	Microcystin Concentration (μg/L)
Jun-27-17	0.12
Jul-27-17	3.64
Aug-16-17	2.07
Sep-07-17	3.08
Average	2.23

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. No mussels have been detected in Kehewin 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 Kehewin Lake have fluctuated since Alberta Environment began monitoring the lake in 1967. Since 2010, lake levels have been increasing, but have remained within historical levels. A minimum water level of 538.9 m was measured in 1993, and a maximum water level of 540.35 m was measured in 1997.

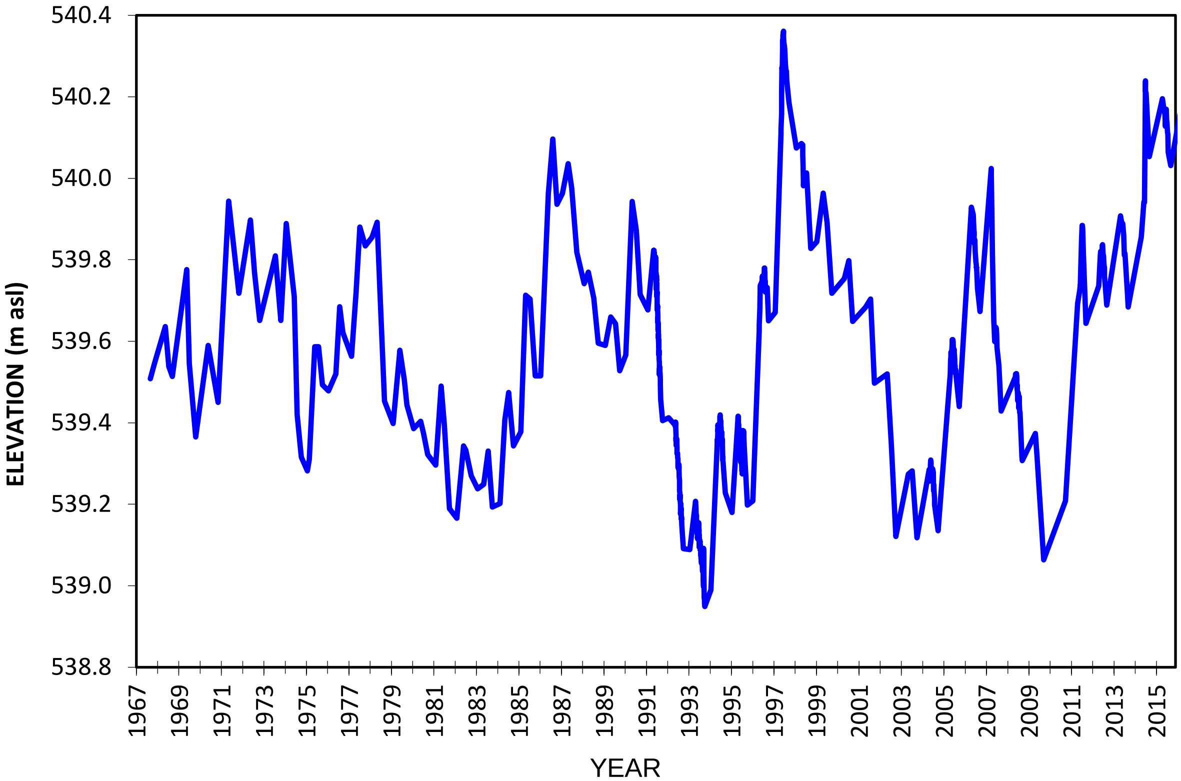


Figure 4- Water levels measured in meters above sea level (m asl) from 1967-2016 at Kehewin Lake. Data retrieved from Alberta Environment and Parks.

Table 2: Average Secchi depth and water chemistry values for Kehewin Lake. Historical values are given for reference.

Parameter	2002	2003	2004	2004	2005	2007	2008	2009	2011	2013	2017
TP (µg/L)	106	105	36	123	98	170.8	162.3	130	117	89.3	121
TDP (µg/L)	65	62	31	67	33	116.3	126.7	52.5	45.3	17.3	35.5
Chlorophyll-*a* (µg/L)	30	49	1.3	45	40	50.7	19.58	32.9	131.9	38.4	85.7
Secchi depth (m)	2.1	1.9	/	1.9	1.9	1.1	2.9	1.13	1.5	1.1	1.65
TKN (mg/L)	1.400	1.382	1.300	1.474	1.386	1.877	1.620	1.800	2.070	1.650	1.98
NO_2-N and NO_3-N (µg/L)	20	19	270	35	14	101	19	5	7.5	2.5	6.4
NH_3-N (µg/L)	149	69	67	65	15	89	261	23.5	90.3	35.3	66.25
DOC (mg/L)	/	/	/	/	/	13.6	13.9	13.9	14.45	17.15	14.5
Ca (mg/L)	25	26	29	24	26	24.2	25.2	25.3	22.2	24.8	29.25
Mg (mg/L)	29	29	33	25	30	28.3	26.8	29	28.1	27.45	32.5
Na (mg/L)	32	35	39	36	35	36.2	34.1	35.4	34.5	37.3	40.5
K (mg/L)	14	12	14	12	13	13.1	13.5	11.9	13.05	16.45	15.5
SO_4^{2-} (mg/L)	20	27	33	28	26	22.7	26	17	14	20	27.75
Cl^- (mg/L)	16	16	18	17	17	18.9	19.2	19.7	20.65	20.8	25.25
CO_3 (mg/L)	6.2	14	6.7	14	17	14	20	21	19.75	22.67	12.06
HCO_3 (mg/L)	189	245	284	238	234	226.3	228.5	228	221	222	242.5
pH	8.5	8.7	8.4	8.7	8.8	8.7	8.9	8.93	8.99	8.95	8.63
Conductivity (µS/cm)	/	/	/	/	/	481	499	485	480	513	513
Hardness (mg/L)		184		166	191	177	173	/	171	175	207.5
TDS (mg/L)	/	/	/	/	/	269.3	277.5	272	262	280	310
Microcystin (µg/L)	/	/	/	/	0.28	0.54	0.56	/	0.16	0.4	2.23
Total Alkalinity (mg/L $CaCO_3$)	165	224	243	218	220	209	221	222	215	220.3	222.5

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

Metals (Total Recoverable)	**2003**	**2004**	**2005**	**2007**	**2008**	**2009**	**2011**	**2013**	**2017**	**Guidelines**
Aluminum μg/L	24	13	8.8	23.4	12.3	13.2	11.8	5.21	9.2	100[a]
Antimony μg/L	0.072	0.1	0.105	0.09	0.088	0.092	0.0812	0.0683	0.065	/
Arsenic μg/L	2.1	2	1.84	2.17	2.5	2.84	2.14	1.76	2.38	5
Barium μg/L	54	56	58	50.9	51.7	52.3	55.5	51.7	52.9	/
Beryllium μg/L	0.037	0.0015	0.0015	<0.003	<0.003	/	0.0015	0.0034	0.0015	100[c,d]
Bismuth μg/L	0.0037	0.0005	0.054	0.002	<0.001	0.0273	0.0005	0.0005	0.0015	/
Boron μg/L	84	87	81	79	89	88	100	95.4	93.2	1500
Cadmium μg/L	0.02	0.0016	0.0043	0.017	0.0071	0.0137	0.0064	0.0022	0.005	0.26[b]
Chromium μg/L	0.18	0.25	0.21	0.244	0.324	0.261	0.269	0.161	0.05	/
Cobalt μg/L	0.04	0.037	0.04	0.056	0.0379	0.0525	0.0532	0.0432	0.049	1000[d]
Copper μg/L	0.43	0.52	0.47	1.31	0.675	0.439	0.351	0.261	0.17	4[b]
Iron μg/L	27	7.7	3.4	19.2	10.55	9.3	24.6	24.3	17	300
Lead μg/L	0.11	0.042	0.354	0.07	0.0467	0.0708	0.0275	0.0022	0.007	7[b]
Lithium μg/L	26	29	26	26.5	27.3	29.3	36.8	31.2	29.4	2500[e]
Manganese μg/L	30	26	32	23.9	25.6	32.5	14.5	12.9	28.9	200[e]
Molybdenum μg/L	0.8	0.83	0.82	0.77	0.748	0.767	0.647	0.49	0.633	73[c]
Nickel μg/L	0.15	0.16	0.18	0.27	0.373	0.182	0.283	0.358	0.44	150[b]
Selenium μg/L	0.42	0.05	0.2	0.35	0.183	0.214	0.327	0.221	0.4	1
Silver μg/L	/	/	/	0.005	<0.0005	0.00115	0.00025	0.0213	0.002	0.25
Strontium μg/L	229	235	226	214	208	222	226	217	230	/
Thallium μg/L	0.093	0.001	0.022	0.002	0.0005	0.0131	0.0006	0.00015	0.004	0.8
Thorium μg/L	0.012	0.004	0.06	0.005	0.0014	0.0033	0.0105	0.00015	0.02	/
Tin μg/L	0.05	0.026	0.015	<0.03	<0.03	0.0358	0.015	0.015	0.03	/
Titanium μg/L	1.23	1.33	0.98	1.8	0.878	1.42	0.777	0.983	1.55	/
Uranium μg/L	0.57	0.6	0.64	0.56	0.617	0.678	0.6	0.489	0.545	15
Vanadium μg/L	0.66	0.56	0.4	0.45	0.426	0.458	0.369	0.24	0.369	100[d,e]
Zinc μg/L	2	11.8	2.8	1.03	0.646	0.148	0.386	0.274	0.1	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

Trend analysis was conducted on the parameters total phosphorus (TP), chlorophyll-*a* and Secchi depth to look for changes over time in Kehewin Lake. In sum, non-significant increases were observed in chlorophyll-*a,* TP and TDS, and non-significant decreasing trends were observed in Secchi depth. Secchi depth can be subjective and is sensitive to variation in weather - trend analysis must be interpreted with caution. Data is presented below as both a line graph (all data points) 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 Kehewin Lake data from 2003 to 2017.

Parameter	Date Range	Trend	Probability
Total Phosphorus	2003-2017	Increasing	Non-significant
Chlorophyll-a	2003-2017	Increasing	Non-significant
Total Dissolved Solids	2003-2017	Increasing	Non-significant
Secchi Depth	2003-2017	Decreasing	Non-significant

Definitions:

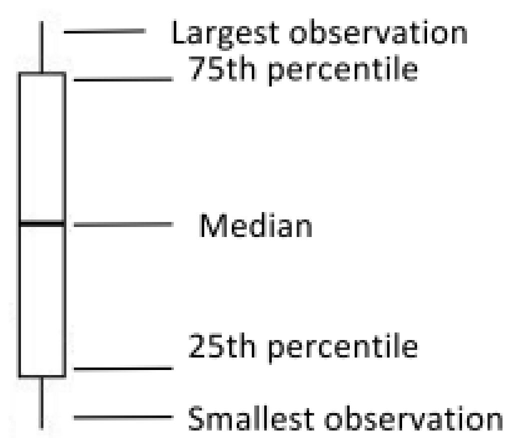
Median: the value in a range of ordered numbers that falls in the middle.

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 changed over the course of data collection at Kehewin Lake (Tau = 0.064, p = 0.62).

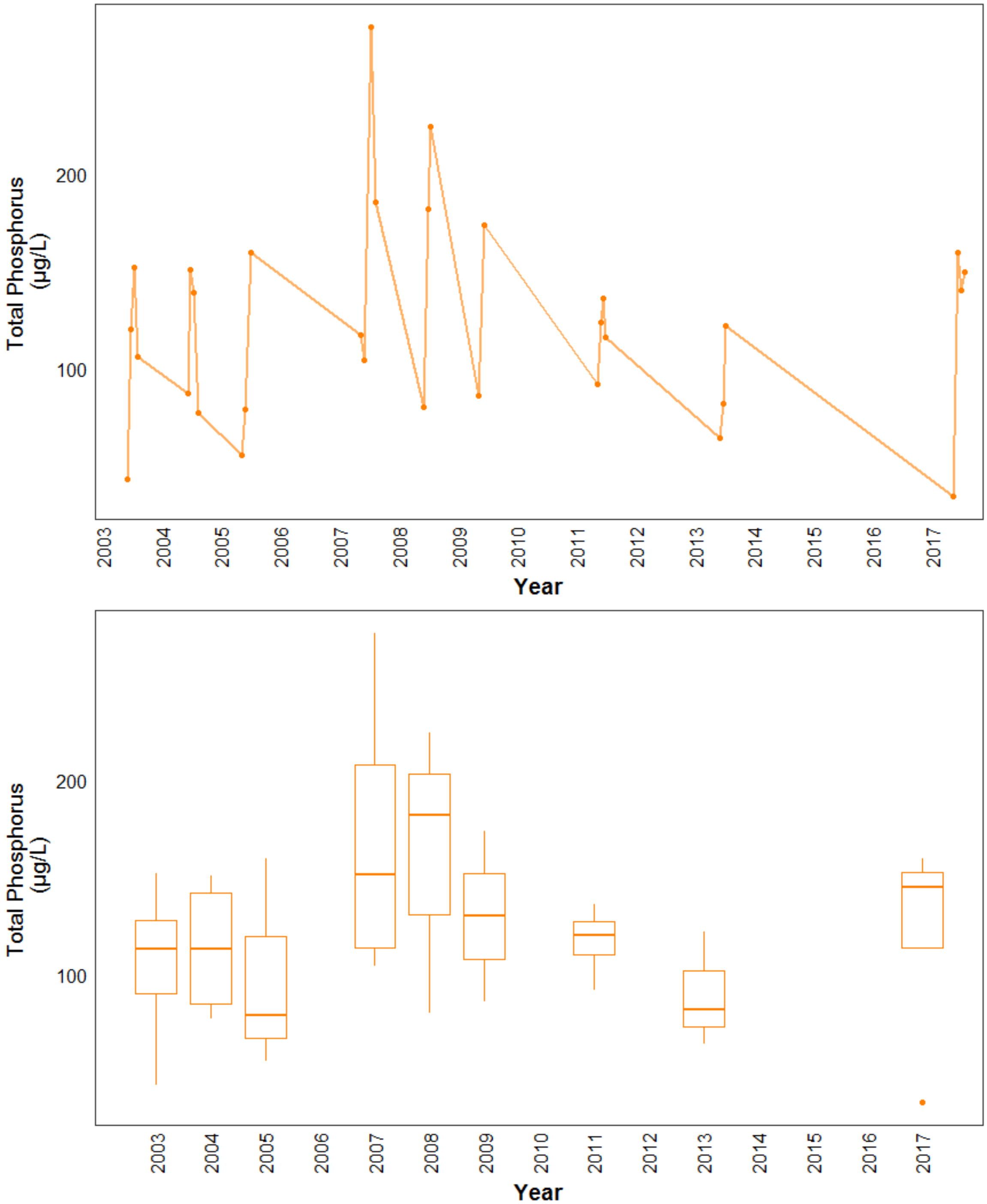


Figure 1- Total phosphorus (TP) concentrations measured between June and September over the long term sampling dates between 2003 and 2017 (n = 31). The value closest to the 15th day of the month was chosen to represent the monthly value in cases with multiple monthly samples.

Chlorophyll-*a*

Chlorophyll-*a* has not significantly changed over the course of data collection at Kehewin Lake (Tau = 0.09, p = 0.5). Chlorophyll-*a* trends follow TP trends with correlation over time (r = 0.52, p = 0.02).

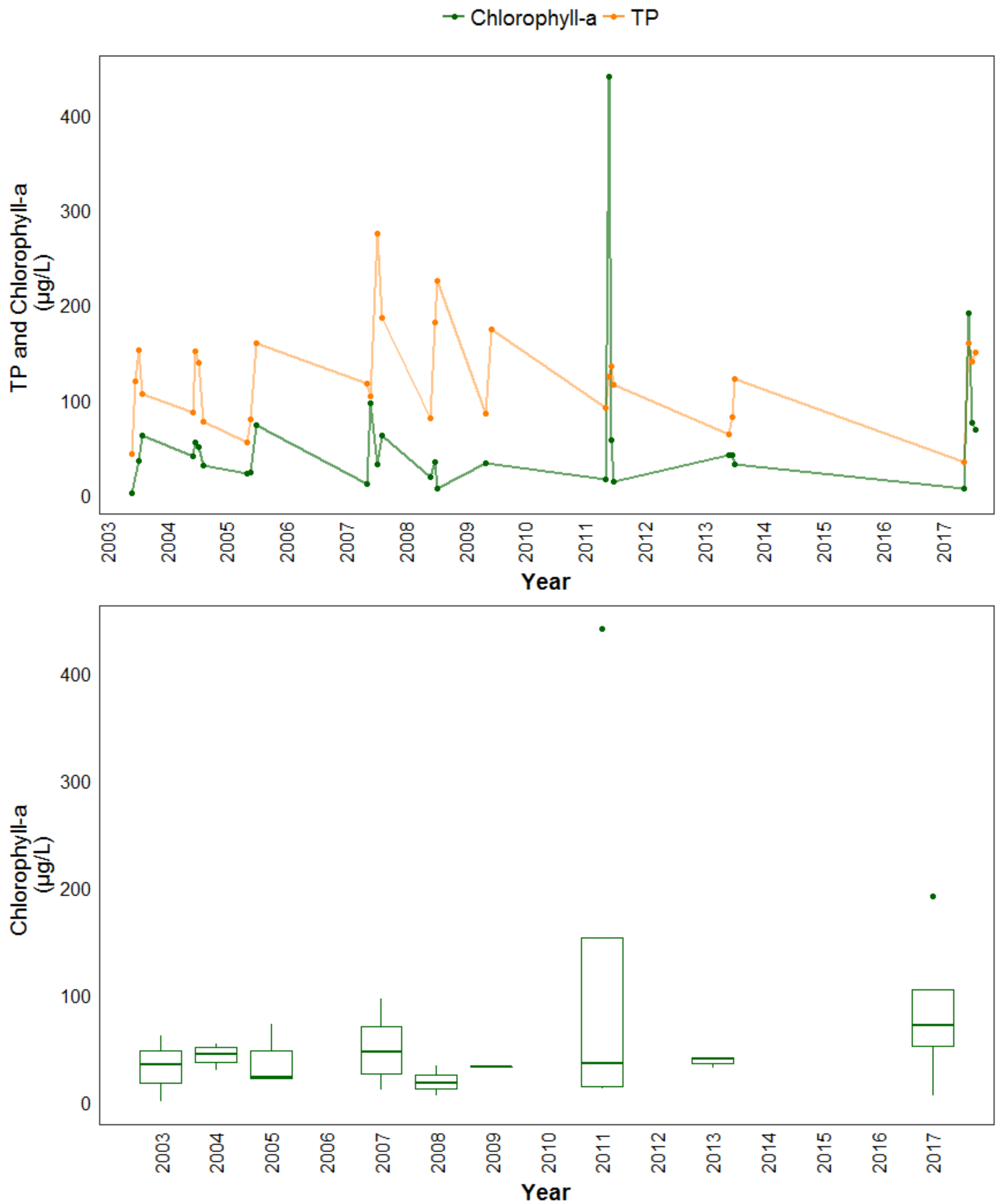


Figure 2-Chlorophyll-*a* concentrations measured between June and September over the long term sampling dates between 2003 and 2017 (n = 29).

Total Dissolved Solids (TDS)

TDS concentrations have not significantly changed over the course of data collection at Kehewin Lake (Tau = 0.16, *p* = 0.32).

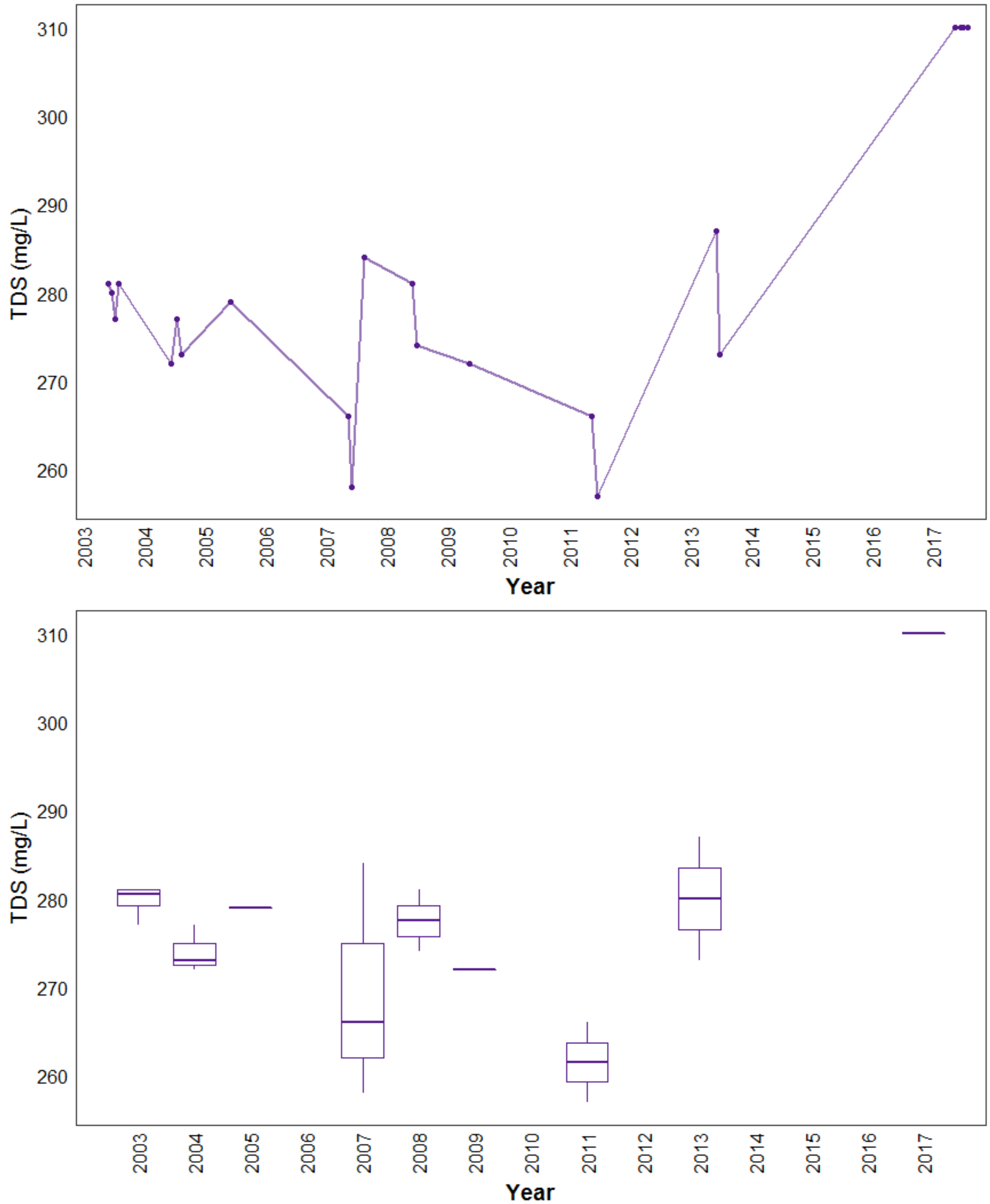


Figure 3- TDS measured between June and September over the long term sampling dates between 2003 and 2017 (n = 22).

Secchi Depth

Secchi depth has not significantly changed over the course of data collection at Kehewin Lake (Tau = -0.16, p = 0.19).

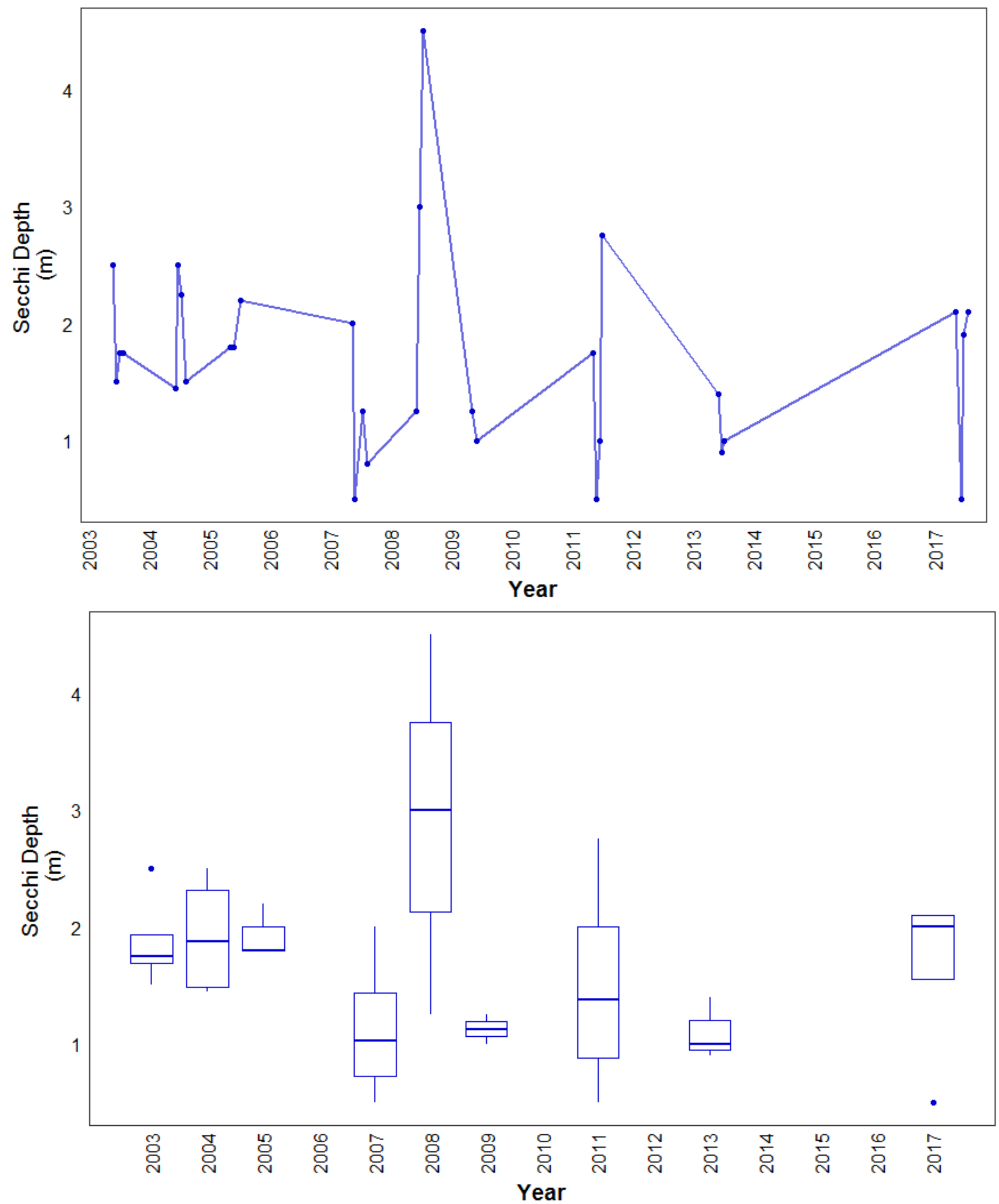


Figure 4- Secchi depth values measured between June and September over the long term sampling dates between 2003 and 2017 (n = 31).

Table 2- Results of Mann-Kendall and Seasonal Kendall Trend tests using monthly total phosphorus (TP), chlorophyll-*a*, total dissolved solids (TDS) and Secchi depth data from June to September on Kehewin Lake data.

Definition	Unit	Total Phosphorus (TP)	Chlorophyll-a	Total Dissolved Solids (TDS)	Secchi Depth
Statistical Method	-	Mann Kendall	Mann Kendall	Mann Kendall	Mann Kendall
The strength and direction (+ or -) of the trend between -1 and 1	Tau	0.064	0.090	0.16	-0.16
The extent of the trend	Slope	0.003	0.003	0.002	-0.0001
The statistic used to find significance of the trend	Z	0.49	0.67	0.99	-1.29
Number of samples included	n	31	29	22	31
The significance of the trend	*p*	0.62	0.50	0.32	0.19