



LakeKeepers

Winter
LakeKeepers
2019-2020



ALBERTA
ecotrust

ALBERTA LAKE MANAGEMENT SOCIETY'S OBJECTIVES

The Alberta Lake Management Society (ALMS) has several 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.

ALMS would like to thank all who express interest in Alberta's aquatic environments and particularly those who have participated in the Winter LakeKeepers program. These leaders in stewardship give us hope that our water resources will not be the limiting factor in the health of our environment.

ACKNOWLEDGEMENTS

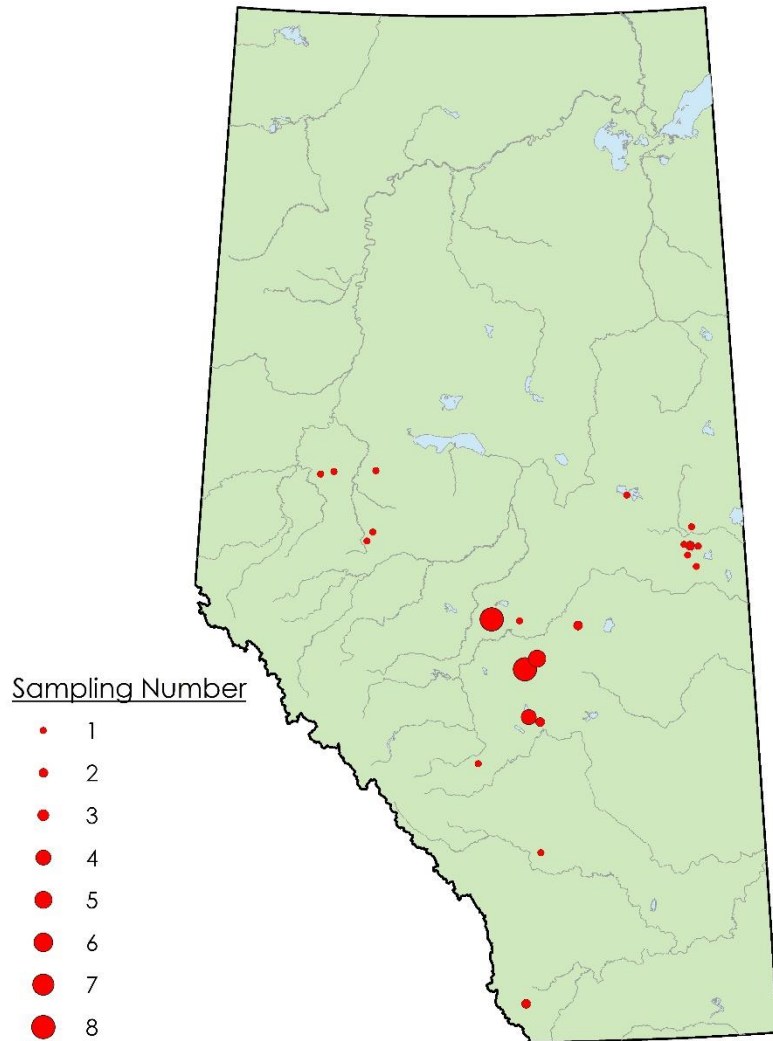
The Winter LakeKeepers project was made possible with support from Alberta EcoTrust.

We would like to thank the all the volunteers and watershed stewardship groups who made this program happen. We would also like to thank the Mighty Peace Watershed Alliance for their assistance with coordinating volunteers and sample shipment.

This report has been prepared by Caleb Sinn and Bradley Peter.

Report last updated: February 1st, 2021

Executive Summary



Map 1. Geographic spread of lakes sampled as part of the Winter LakeKeepers 2019-2020 season. The size of the dot indicates the number of samples taken from the lake, both in terms of locations and number of times location was sampled through the winter of 2019-2020.

Following the successful pilot of Winter LakeKeepers in February – March 2019, the Alberta Lake Management Society (ALMS) delivered a subsequent Winter LakeKeepers season from December 2019 – March 2020.

As in the pilot year, many ice angler volunteers participated. Also in the 2019 – 2020 season, the program was widely adopted by Watershed Planning and Advisory Councils (WPACs), and Watershed Stewardship Groups (WSGs). 2019 – 2020 was the first season that the Winter LakeKeepers program included multiple sampling events at specific sites on lakes, as well as multiple sampling sites per lake.

Due to the amount of data collected in the 2019 – 2020 season, lakes have been compared by major watershed groupings. A summary of total phosphorus and hypoxia data is provided in the appendix.

Overall, 28 locations were sampled on 22 different lakes, ranging from lakes in the Oldman watershed in the south, to lakes up in the Peace watershed in northern Alberta (Map 1). 44 sampling events took place, from as early as December 27th, 2019, to as late as March 29th, 2020. This is a large increase from the pilot season, where only 10 lakes were sampled for a total of 11 sampling events.

25 volunteers took part in Winter LakeKeepers 2019-2020, more than doubling the 10 volunteers who participated in the pilot season.

A variety of winter lake conditions were captured throughout the province, and seasonal trends of dissolved oxygen and total phosphorus were detected. In order to explore winter lake water quality trends further, greater sampling frequency spread throughout the winter is needed in future Winter LakeKeeper seasons, along with the collection of additional parameters.

Methods



Volunteers from the Wabamun Watershed Management Council sampling Wabamun Lake, December 2019.

Prior to sampling, volunteers were provided with an ice-safety manual, and then were required to take a quiz on ice safety. Volunteers needed to score 100% before their first sampling event, with unlimited attempts to do so. Volunteers also were required to sign an informed consent form.

Volunteers were also provided with a training manual (available at www.alms.ca/winter-lakekeepers). Lakes were to be sampled one or more times during the ice-on period, coinciding with Alberta's ice fishing season (December 1st – March 31st).

Volunteers chose their own locations for sampling, generally based on their desired location for ice fishing, or location near their lakeside residence. Unlike other ALMS summer programs, this meant Winter LakeKeepers sampling did not occur at the deepest point in the lake.

Volunteers were provided with field sheets, a YSI ProODO dissolved oxygen and temperature meter, and a nutrient sample bottle with preservative. The sampling kits also included gloves to protect volunteers from cold water and the sulfuric acid preservative. Including a hot water bottle ensured the nutrient sample and probe did not freeze.

Profile measurements for dissolved oxygen and temperature were taken every meter starting at 1m, until lake bottom. A nutrient grab sample was collected just below the surface of the ice, at 0.1m depth. The sample was then preserved with the 2mL vial of sulfuric acid, and was submitted for total phosphorus analysis. ALMS coordinated delivery of the nutrients to an analytical laboratory, and then also coordinated shipment of the sampling kits.

Data collected from the sites was compiled, then formatted for upload to the Gordon Foundation's DataStream (<https://gordonfoundation.ca/initiatives/datastream>), and for ALMS data visualization and reporting. Data analysis is done using the program R.¹ Data was reconfigured using packages tidy² and dplyr³, figures were produced using the package ggplot2⁴, and tables were produced using the package formattable⁵. Trophic status for each lake is classified based on lake water characteristics using values from Nurnberg (1996)⁶.

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). tidy: Easily Tidy Data with 'spread ()' and 'gather ()' Functions. R package version 0.7.2. <https://CRAN.R-project.org/package=tidy>.

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 Ren, K. and Russell, K. (2016). formattable: Create 'Formattable' Data Structures. R package version 0.2.0.1. <https://CRAN.R-project.org/package=formattable>.

⁶Nurnberg, 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.

Results



Volunteer Vien Lam sampling at Spring Lake, January 2020.

Given the higher number of samples taken at certain sites, certain trends in water chemistry were recognized.

As expected, the dissolved oxygen levels in all lakes sampled were higher at the surface, and decreased towards lake bottom. For all lakes with sampling events spread throughout the winter, later season sampling events had lower water column dissolved oxygen values than earlier season sampling events. This trend is most obvious at Pigeon Lake, Grandview and Lacombe Lake (Figure 8), all sites on Wabamun Lake (Figure 5), Wizard Lake, Jubilee Park (Figure 6), and Half Moon Lake (Figure 7). This trend is also evident when investigating the percentage of water column hypoxia, or dissolved oxygen of less than 6.5 mg/L (Appendix Tables 1 & 2). The level of hypoxia is based on Alberta's chronic dissolved oxygen guideline for aquatic life⁷, and The Canadian Council for Ministers of the Environment (CCME) guidelines for the protection of aquatic life in cold water for life stages other than early life stages⁸. Trends in dissolved oxygen were not observed at the watershed scale.

Trends with water temperature data were more variable, however the majority of lakes with sampling events spread throughout the winter were slightly warmer in mid depths toward the end of the season than in the early season. Regardless of seasonality, temperature profiles ranged between 0-5°C, and were for the most part warmer at the bottom of the lake than at the surface, as expected given maximum water density at about 4°C.

A wide range of air temperatures were recorded. The warmest temperature of 7°C was recorded at Pigeon Lake, Grandview on February 28th, 2020, and the coolest temperature of -27°C was recorded was at Lac La Biche on January 13th, 2020. The average air temperature recorded was -5°C.

⁷ Shaw, J. (1997). Alberta water quality guideline for the protection of freshwater aquatic life: Dissolved oxygen. Standards and Guidelines Branch, Alberta Environmental Protection, Edmonton, Alberta.

⁸ Canadian Council of Ministers of the Environment (1999). Canadian water quality guidelines for the protection of aquatic life: Dissolved oxygen (freshwater). Canadian environmental quality guidelines, Canadian Council of Ministers of the Environment, Winnipeg, Manitoba.

Results

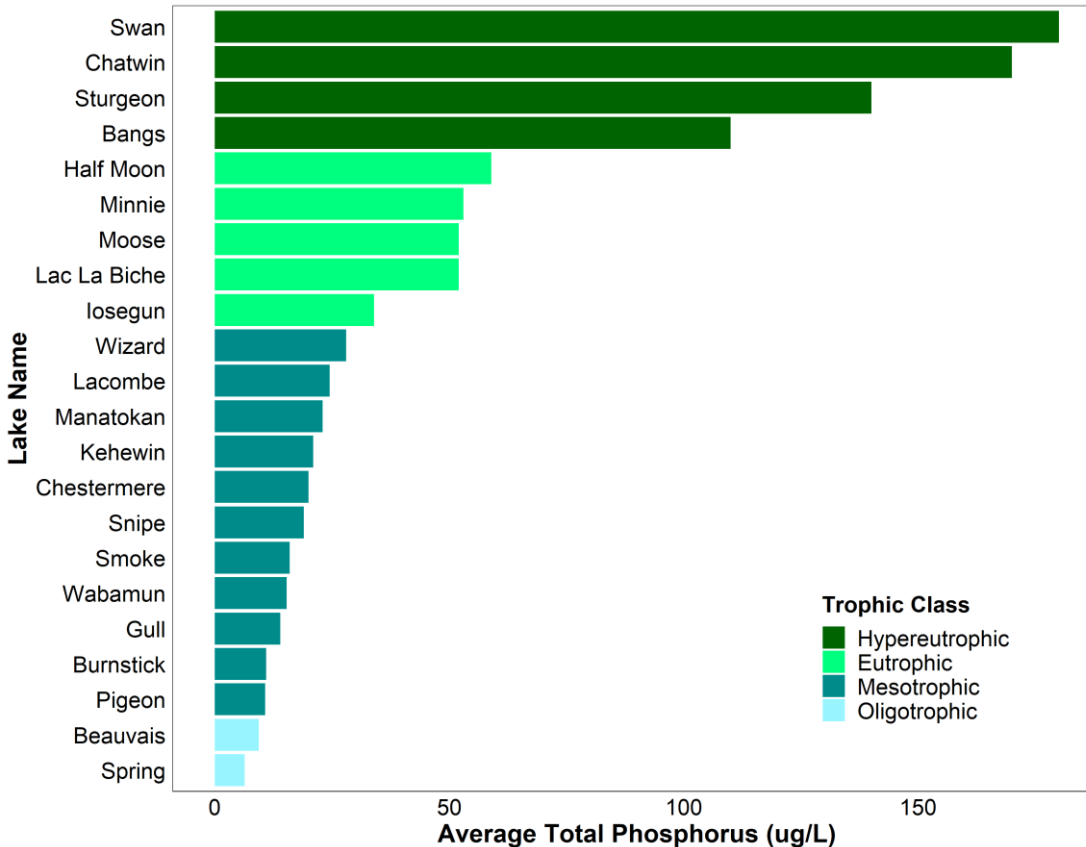


Figure 1. Average total phosphorus (ug/L) from lakes sampled in Winter LakeKeepers 2019-2020. Average total phosphorus represents the average from across sample dates, if lakes had multiple sample events, and across sample locations, if lakes had multiple sampled locations. Samples were taken at 0.1m, right below the ice, between December 2019 and March 2020.

A wide range of ice thickness was also recorded. The thickest ice of 77cm was recorded at Gull Lake on February 12th, 2020, and the thinnest ice of 24cm was recorded at Wabamun Lake, Sundance on December 31st, 2019. The average ice thickness was 53cm.

Recordings of depth of snow cover also varied. The greatest depth of snow cover of 41cm was recorded at Snipe Lake on February 15th, 2020, and the smallest snow depth of 1cm was recorded at Wabamun Lake, Seba beach on December 31st, 2019. The average snow depth was 16cm.

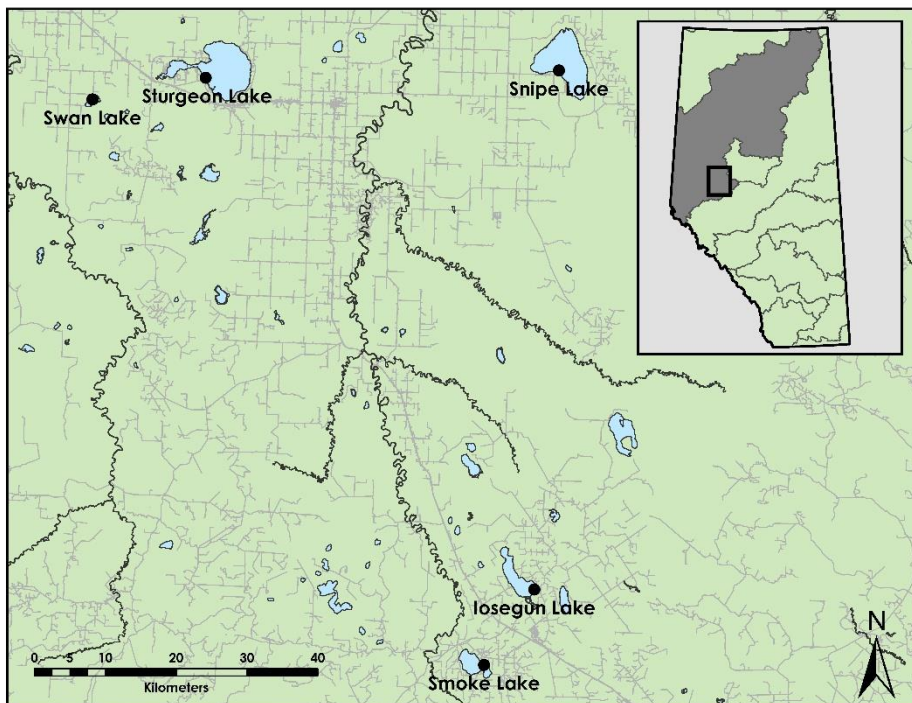
Average total phosphorus (TP) values ranged from oligotrophic to hypereutrophic classifications, with most lakes falling into the mesotrophic, or moderate productivity classification. The maximum value of average TP was at Swan Lake, at 180 ug/L, and the lowest was at Spring Lake, at 6.4 ug/L.

Average lake TP from the 2019 – 2020 Winter LakeKeepers season were slightly lower, or comparable, to recent summer average lake TP, with the exception of Sturgeon Lake (Appendix Table 3). This follows the trend from the 2018 – 2019 Winter LakeKeepers season that lakes usually have lower levels of TP in the winter, with some exceptions.

TP values for lakes with sampling events spread throughout the winter appeared to have the trend of increasing from early in the season to later in the season. In order to investigate this trend further, more lakes with more sampling events spread throughout the winter season is needed. Finally, TP values were higher in the northern watersheds (Peace, Beaver, Athabasca) than in the southern watersheds.

Peace River Watershed

Five lakes were sampled within the Peace River watershed in Winter LakeKeepers 2019 – 2020, which was the second highest number of lakes sampled in any watershed (Map 1). Lakes were sampled once each, between mid-February and mid-March. The lakes varied with their oxygen profiles, notably with Smoke, Snipe and Sturgeon Lakes being fairly well oxygenated, Iosegun only having one reading at 1m depth, and Swan Lake having low oxygen throughout it's 3m column (Figure 2). Total phosphorus was fairly high in lakes sampled within the Peace River watershed, with three out of five lakes being either eutrophic or hypereutrophic, or having levels of greater than 30 ug/L or 100 ug/L, respectively (Figure 1, Table 1). Lakes had above average snow levels, compared to lakes sampled in other watersheds, with Snipe Lake having the most of any lake in the 2019 – 2020 season at 41 cm (Table 1).



Map 2. Sampling locations for Winter LakeKeepers 2019-2020, in the Peace River watershed. Peace River watershed highlighted in Alberta inset map.

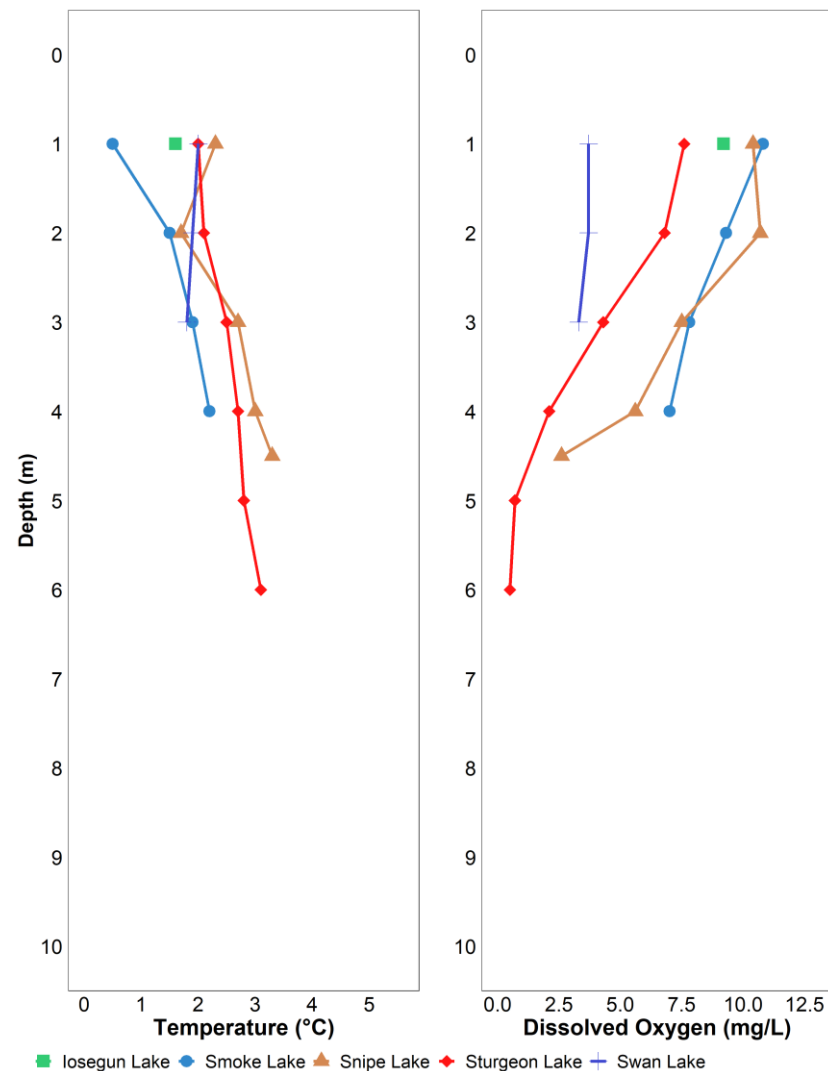


Figure 2. Temperature (°C) and dissolved oxygen (mg/L) measurements recorded at lakes in the Peace River watershed in Winter 2019-2020. Measurements were taken every meter starting at 1 meter from water surface, until lake bottom.

Peace River Watershed

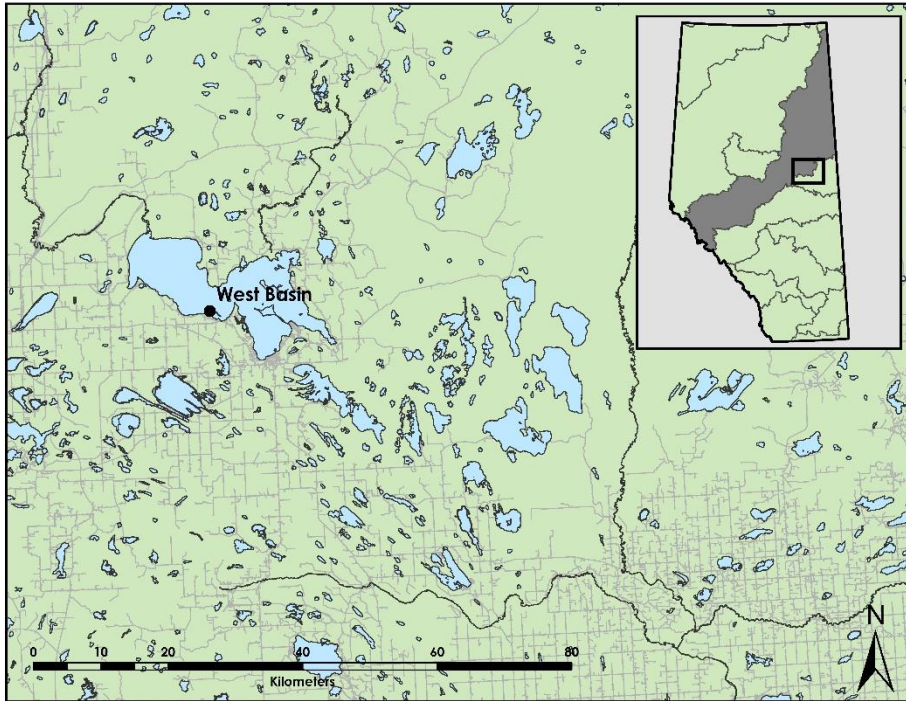


Table 1. Water chemistry (TP = total phosphorus in ug/L), environmental measurements (Air Temp. = air temperature in °C), and observations recorded at lakes in the Peace River watershed in Winter 2019-2020. TP samples taken at 0.1m depth. Note that water colour and water particle presence were not indicated at Swan Lake on February 23rd, 2020.

Site	Date	TP (ug/L)	Air Temp. (°C)	Ice Thickness (cm)	Snow Depth (cm)	Ice Colour	Water Colour	Particles?
Iosegun Lake	2020-03-19	34	-8	60	19	Clear	Colourless	No
Smoke Lake	2020-03-19	16	-14	63	19	Opaque	Colourless	No
Snipe Lake	2020-02-15	19	-9	46	41	Opaque	Colourless	No
Sturgeon Lake	2020-03-07	140	-18	62	18	Opaque	Colourless	No
Swan Lake	2020-02-23	180	-10	51	12	Clear		

Athabasca River Watershed

One lake was sampled within the Athabasca River watershed in Winter LakeKeepers 2019 – 2020 (Map 3). This lake was Lac La Biche, which is Alberta's seventh largest lake by surface area. The sample was taken close to Lac La Biche Mission, near shore on the West Basin of the lake on January 13th, 2020 (Map 3). The air temperature during sampling was -27°C, the coldest of any lake sampled in the 2019 – 2020 Winter LakeKeepers season. This location was very well oxygenated, with values of above 10 mg/L recorded for all depths including 8m, only 0.5m from the bottom (Figure 3). Total phosphorus was high at 52 ug/L (Table 2), but four times less than the 2019 summer average for the West Basin (Appendix Table 3).



Map 3. Sampling locations for Winter LakeKeepers 2019-2020, in the Athabasca River watershed. Athabasca River watershed highlighted in Alberta inset map.

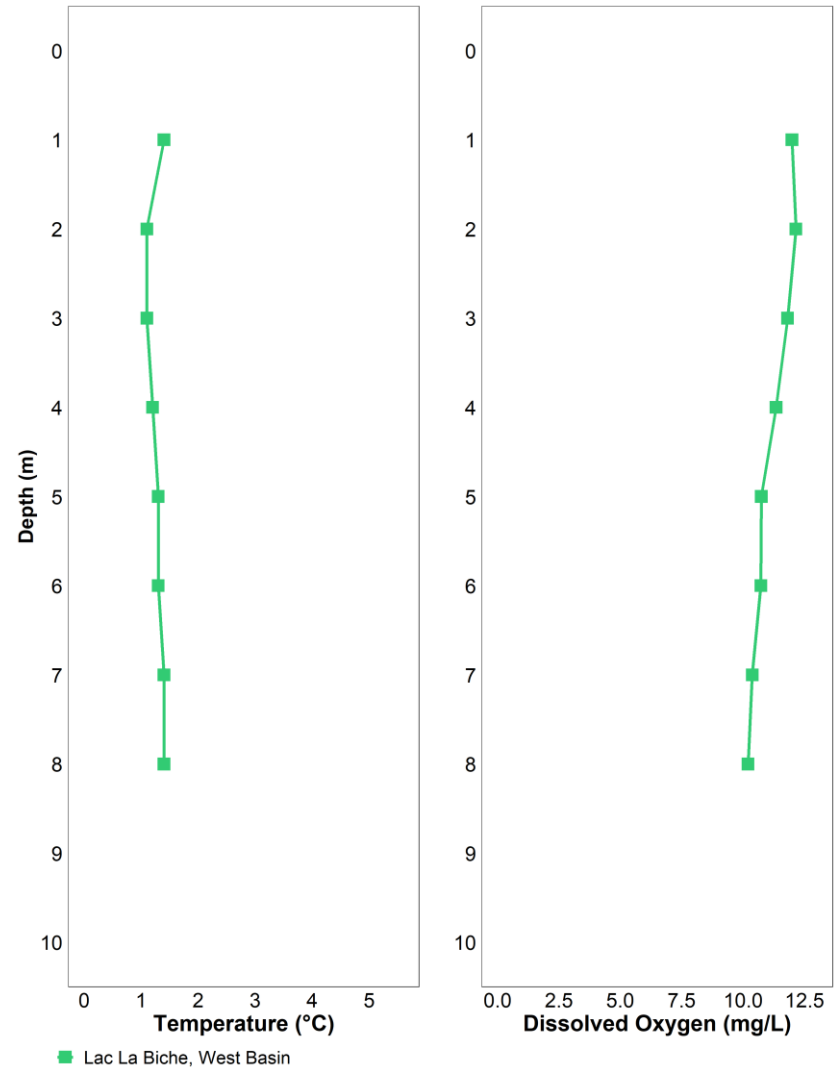


Figure 3. Temperature (°C) and dissolved oxygen (mg/L) measurements recorded at lakes in the Athabasca River watershed in Winter 2019-2020. Measurements were taken every meter starting at 1 meter from water surface, until lake bottom.

Athabasca River Watershed

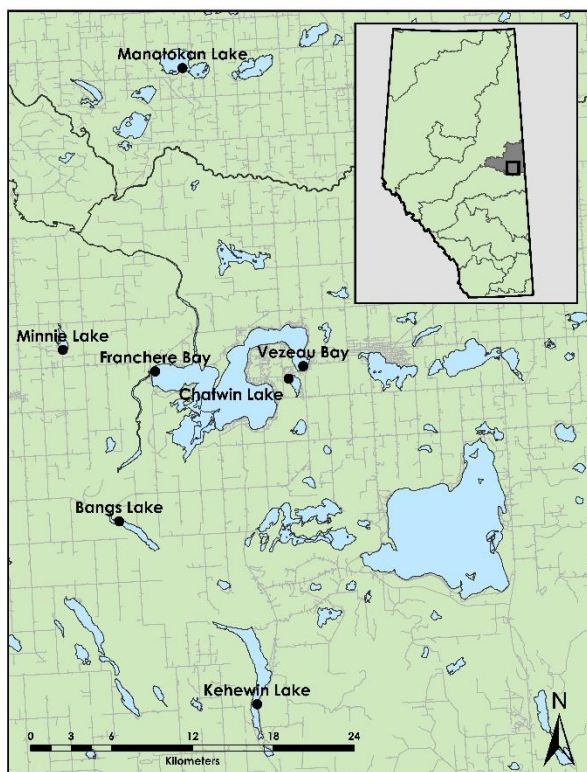


Table 2. Water chemistry (TP = total phosphorus in ug/L) and environmental measurements (Air Temp. = air temperature in °C) and observations recorded at lakes in the Athabasca River watershed in Winter 2019-2020. TP samples taken at 0.1m depth.

Site	Date	TP (ug/L)	Air Temp. (°C)	Ice Thickness (cm)	Snow Depth (cm)	Ice Colour	Water Colour	Particles?
Lac La Biche, West Basin	2020-01-13	52	-27	71	13	Clear	Colourless	No

Beaver River Watershed

Six lakes were sampled within the Beaver River watershed in Winter LakeKeepers 2019 – 2020, which was the highest number of lakes sampled in any watershed (Map 4). Most lakes were sampled on February 8th, with the exception of Manatokan Lake, which was sampled on January 25th. The lakes varied with their temperature and oxygen profiles, notably with Kehewin Lake having the most oxygen throughout its water column, and Minnie Lake having almost no oxygen column wide (Figure 4). Total phosphorus was fairly high in lakes sampled within the Beaver River watershed, with four out of six lakes being either eutrophic or hypereutrophic, or having levels of greater than 30 ug/L or 100 ug/L, respectively (Figure 1, Table 3).



Map 4. Sampling locations for Winter LakeKeepers 2019-2020, in the Beaver River watershed. Beaver River watershed highlighted in Alberta inset map.

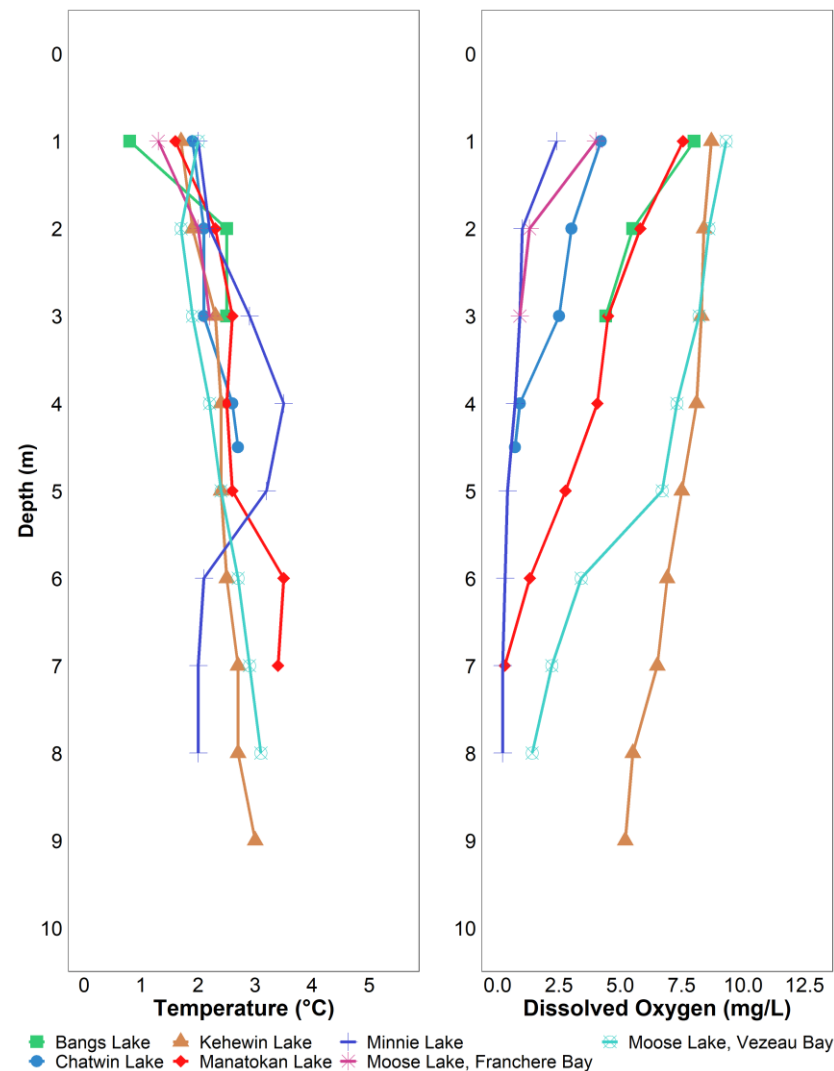


Figure 4. Temperature (°C) and dissolved oxygen (mg/L) measurements recorded at lakes in the Beaver River watershed in Winter 2019-2020. Measurements were taken every meter starting at 1 meter from water surface, until lake bottom. All lakes were sampled on February 8th, except Manatokan Lake, which was sampled on January 25th.

Beaver River Watershed

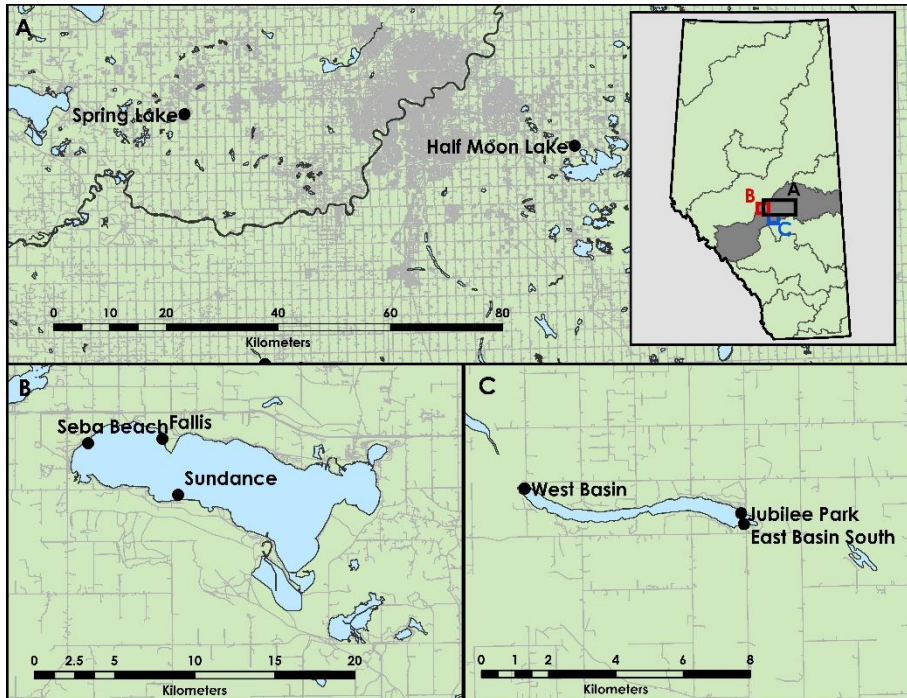


Table 3. Water chemistry (TP = total phosphorus in ug/L) and environmental measurements (Air Temp. = air temperature in °C) and observations recorded at lakes in the Beaver River watershed in Winter 2019-2020. TP samples taken at 0.1m depth.

Site	Date	TP (ug/L)	Air Temp. (°C)	Ice Thickness (cm)	Snow Depth (cm)	Ice Colour	Water Colour	Particles?
Bangs Lake	2020-02-08	110	-2	53	23	Clear	Colourless	No
Chatwin Lake	2020-02-08	170	-2	51	20	Clear	Colourless	Yes
Kehewin Lake	2020-02-08	21	-2	51	20	Clear	Colourless	No
Manatokan Lake	2020-01-25	23	-2	66	15	Clear	Colourless	No
Minnie Lake	2020-02-08	53	-2	51	20	Clear	Colourless	No
Moose Lake, Franchere Bay	2020-02-08	70	-2	48	20	Clear	Colourless	No
Moose Lake, Vezeau Bay	2020-02-08	34	-2	51	20	Clear	Colourless	No

North Saskatchewan River Watershed

Four lakes were sampled within the North Saskatchewan River watershed in Winter LakeKeepers 2019 – 2020 (Map 5). This watershed saw the highest number of locations sampled on its lakes, with Wabamun and Wizard Lakes each having three different sampling locations (Map 5). The lakes were sampled from as early as December 31st, to March 25th. The lakes varied in their oxygen levels, with Wabamun having good oxygenation throughout the season at all sites, despite reductions between December and March at Sundance and Seba Beach (Figure 5, Appendix Table 2). Half Moon had low levels in January which became even lower in March (Figure 7, Appendix Table 1), and Spring and Wizard Lakes also had very low oxygen levels at all sampling dates (Figures 6,7, Appendix Table 2). Total phosphorus levels were low or moderate, with the exception of Half Moon Lake (Table 4).



Map 5. Sampling locations for Winter LakeKeepers 2019-2020, in the North Saskatchewan River watershed. North Saskatchewan River watershed highlighted in Alberta inset map.

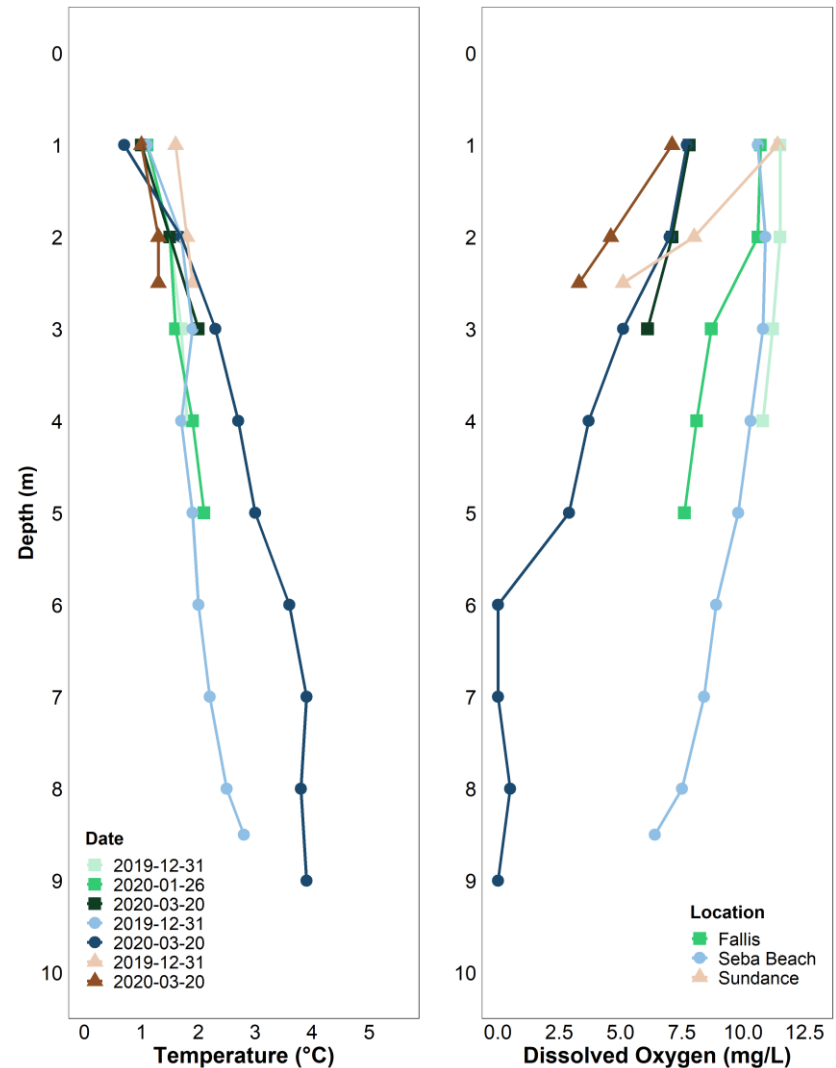


Figure 5. Temperature (°C) and dissolved oxygen (mg/L) measurements recorded at Wabamun Lake in Winter 2019-2020. Measurements were taken every meter starting at 1 meter from water surface, until lake bottom.

North Saskatchewan River Watershed

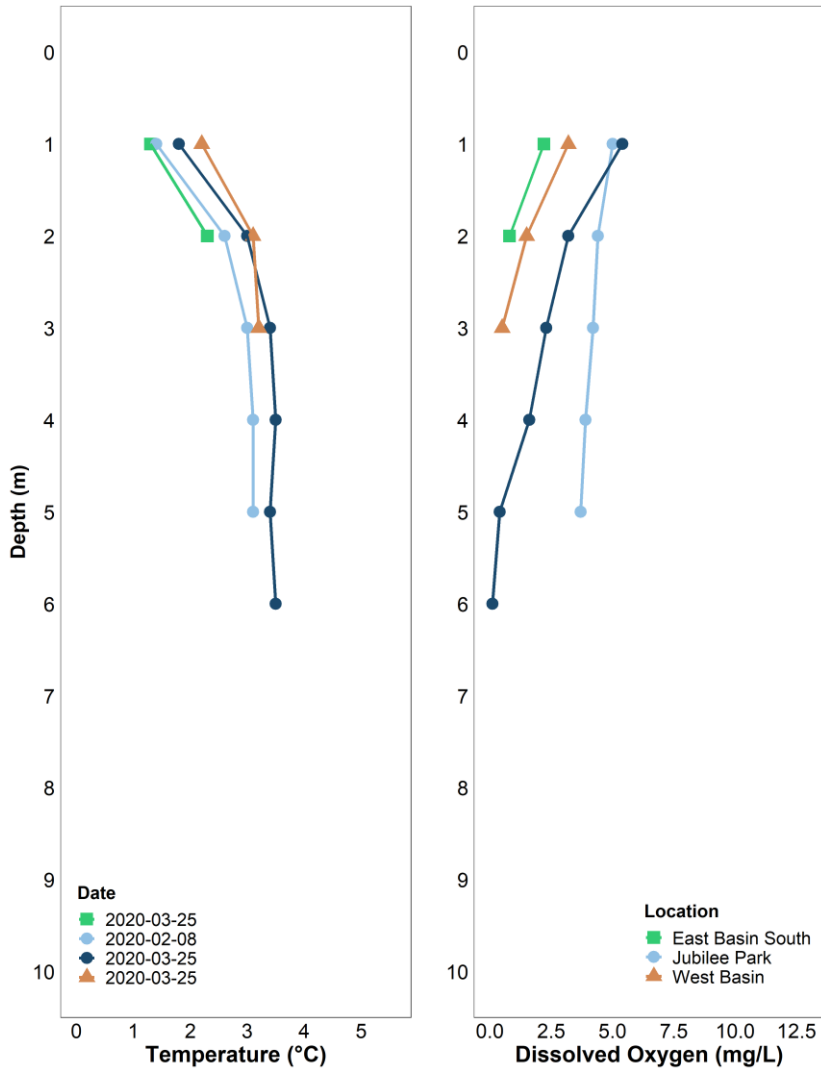


Figure 6. Temperature (°C) and dissolved oxygen (mg/L) measurements recorded at Wizard Lake in Winter 2019-2020. Measurements were taken every meter starting at 1 meter from water surface, until lake bottom.

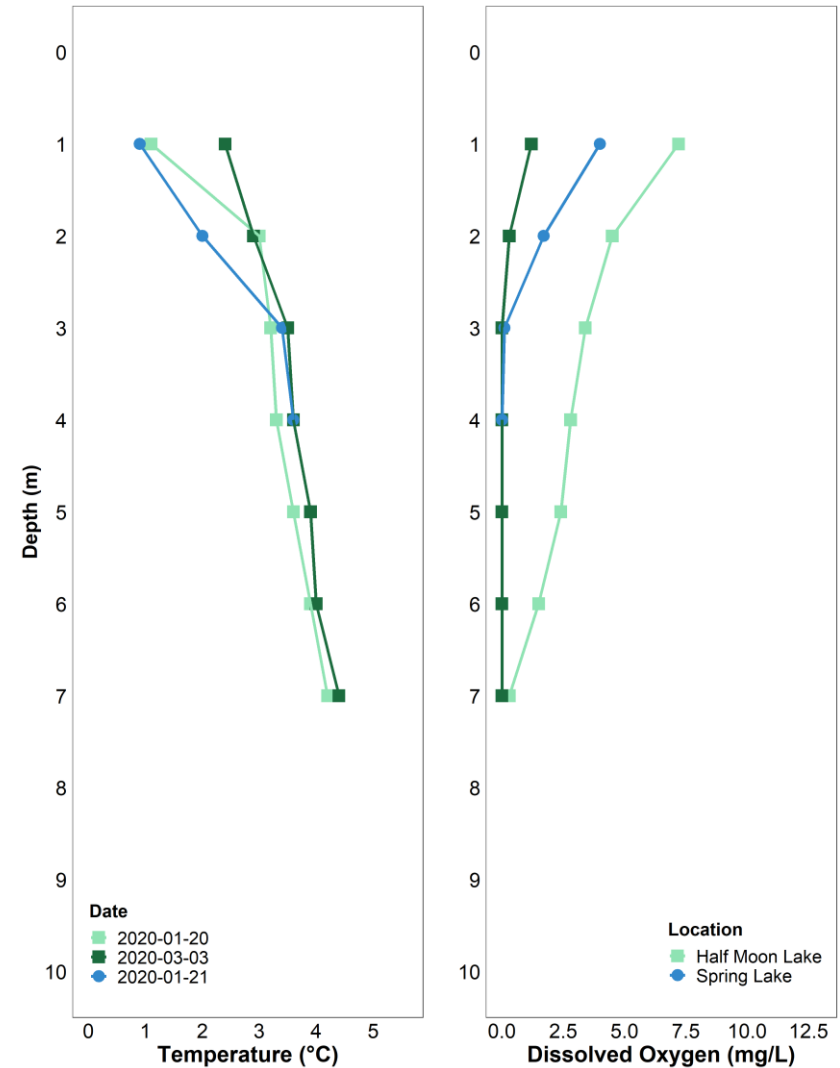


Figure 7. Temperature (°C) and dissolved oxygen (mg/L) measurements recorded at Half Moon Lake and Spring Lakes in Winter 2019-2020. Measurements were taken every meter starting at 1 meter from water surface, until lake bottom.

North Saskatchewan River Watershed

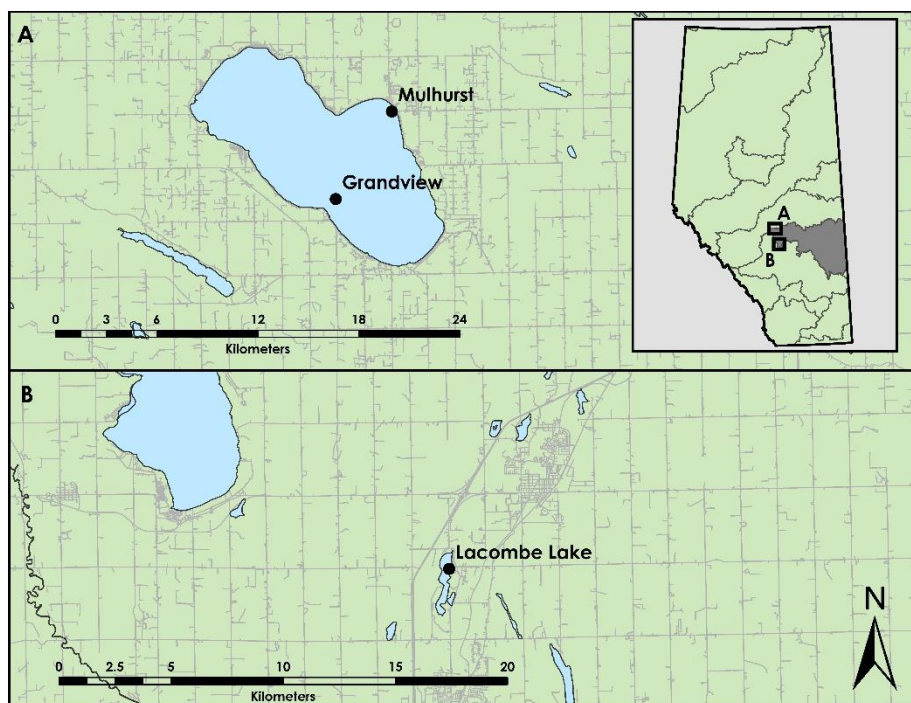


Table 4. Water chemistry (TP = total phosphorus in ug/L) and environmental measurements (Air Temp. = air temperature in °C) and observations recorded at lakes in the North Saskatchewan River watershed in Winter 2019-2020. TP samples taken at 0.1m depth. Note that water particles were not indicated at Wabamun Lake, Fallis on December 31st, 2019, and ice thickness was not recorded at Wizard Lake, East Basin South on March 25th 2020.

Site	Date	TP (ug/L)	Air Temp. (°C)	Ice Thickness (cm)	Snow Depth (cm)	Ice Colour	Water Colour	Particles?
Half Moon Lake	2020-01-20	46.0	-5	70	10	Opaque	Colourless	No
Half Moon Lake	2020-03-03	72.0	2	70	28	Opaque	Colourless	No
Spring Lake	2020-01-21	6.4	-14	36	28	Clear	Slight Yellow/Green	No
Wabamun Lake, Fallis	2019-12-31	12.0	4	30	6	Clear	Colourless	
Wabamun Lake, Fallis	2020-01-26	14.0	-2	41	15	Clear	Colourless	No
Wabamun Lake, Fallis	2020-03-20	20.0	-2	61	15	Opaque	Colourless	No
Wabamun Lake, Seba Beach	2019-12-31	12.0	4	29	1	Clear	Colourless	No
Wabamun Lake, Seba Beach	2020-03-20	22.0	-2	48	23	Opaque	Colourless	No
Wabamun Lake, Sundance	2019-12-31	9.6	2	24	15	Clear	Colourless	Yes
Wabamun Lake, Sundance	2020-03-20	18.0	-6	56	18	Opaque	Colourless	No
Wizard Lake, East Basin South	2020-03-25	33.0	4	NA	15	Opaque	Colourless	No
Wizard Lake, Jubilee Park	2020-02-08	21.0	-8	61	10	Opaque	Colourless	No
Wizard Lake, Jubilee Park	2020-03-25	29.0	1	61	30	Opaque	Colourless	No
Wizard Lake, West Basin	2020-03-25	29.0	3	61	15	Opaque	Colourless	No

Battle River Watershed

Pigeon Lake and Lacombe Lake were lakes sampled within the Battle River watershed in Winter LakeKeepers 2019 – 2020 (Map 6). The 'Grandview' sample site was the most sampled location in the 2019 – 2020 season, and displayed gradual loss of mid-column oxygen from late December to late March (Figure 8), coupled with a slight increase in water column hypoxia through the season (Appendix Tables 1, 2). Lacombe Lake's oxygen levels plummeted between the mid-January sampling and the early March sampling, for an increase in water column hypoxia from 0 to 100% (Figure 8, Appendix Table 1). This difference was also coupled with the surface total phosphorus (TP) levels increasing by 27 ug/L between the two sampling events. Pigeon Lake's TP levels were fairly consistent across all eight sampling events (Table 5).



Map 6. Sampling locations for Winter LakeKeepers 2019-2020, in the Battle River watershed. Battle River watershed highlighted in Alberta inset map.

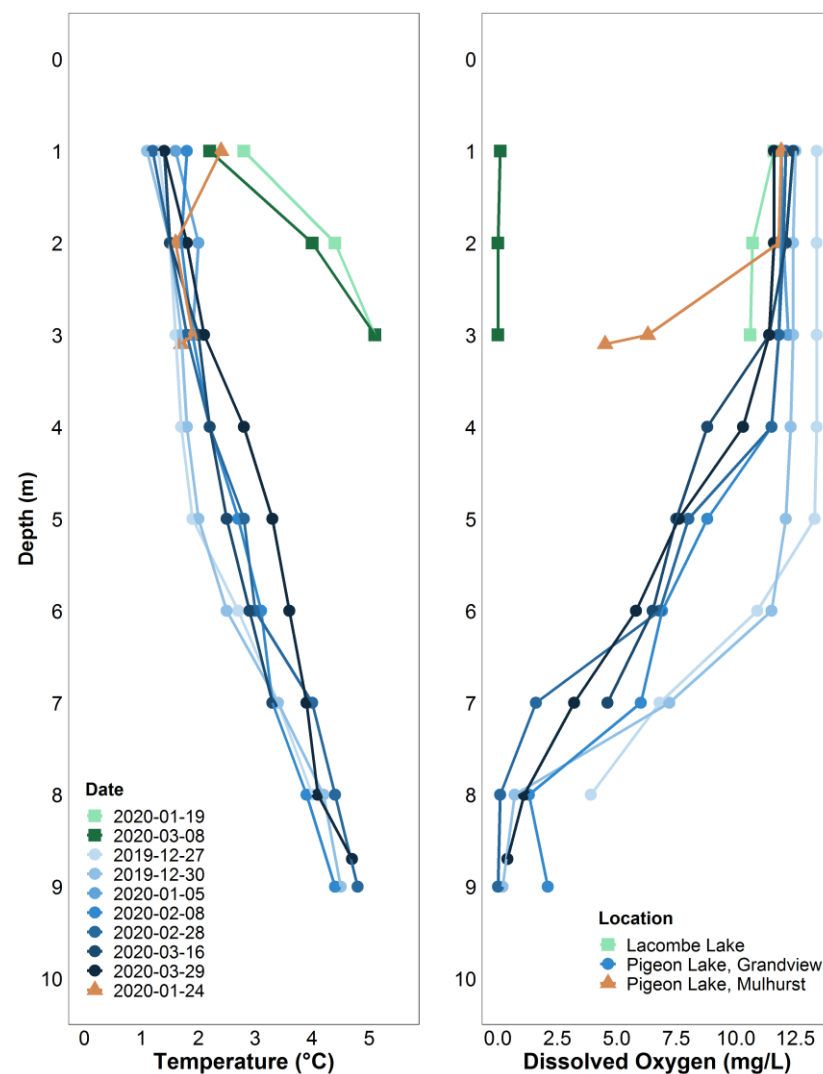


Figure 8. Temperature (°C) and dissolved oxygen (mg/L) measurements recorded at lakes in the Battle River watershed in Winter 2019-2020. Measurements were taken every meter starting at 1 meter from water surface, until lake bottom.

Battle River Watershed

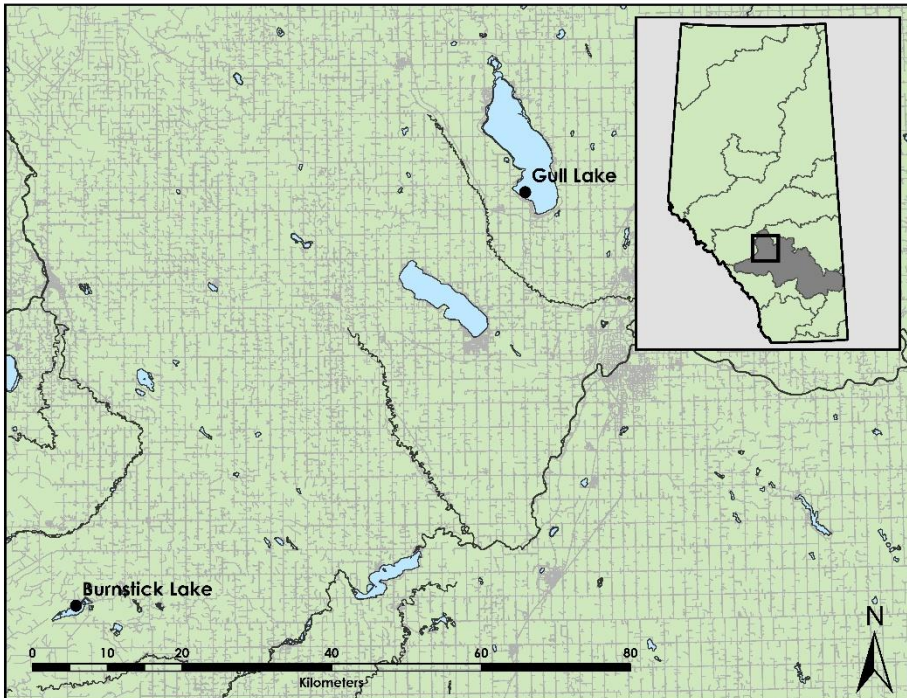


Table 5. Water chemistry (TP = total phosphorus in ug/L) and environmental measurements (Air Temp. = air temperature in °C) and observations recorded at lakes in the Battle River watershed in Winter 2019-2020. TP samples taken at 0.1m depth.

Site	Date	TP (ug/L)	Air Temp. (°C)	Ice Thickness (cm)	Snow Depth (cm)	Ice Colour	Water Colour	Particles?
Lacombe Lake	2020-01-19	11.0	-17	30	15	Opaque	Colourless	No
Lacombe Lake	2020-03-08	38.0	-16	46	23	Opaque	Colourless	No
Pigeon Lake, Grandview	2019-12-27	7.3	-1	38	15	Clear	Colourless	No
Pigeon Lake, Grandview	2019-12-30	7.4	-10	33	15	Clear	Colourless	No
Pigeon Lake, Grandview	2020-01-05	8.5	0	41	10	Clear	Colourless	No
Pigeon Lake, Grandview	2020-02-08	9.8	-4	61	13	Opaque	Colourless	No
Pigeon Lake, Grandview	2020-02-28	7.8	7	64	8	Opaque	Colourless	No
Pigeon Lake, Grandview	2020-03-16	28.0	3	76	10	Opaque	Colourless	No
Pigeon Lake, Grandview	2020-03-29	9.5	-5	61	8	Opaque	Colourless	No
Pigeon Lake, Mulhurst	2020-01-24	8.0	-7	53	13	Clear	Colourless	No

Red Deer River Watershed

Two lakes were sampled within the Red Deer River watershed in Winter LakeKeepers 2019 – 2020 (Map 7). Gull Lake was sampled three times over the course of six days in mid-February. Gull Lake's temperature profiles were unique in that they were warmer near the surface, cooled mid-column, then warmed again towards the bottom of the profile (Figure 9). Gull Lake's dissolved oxygen profiles also varied slightly, depending mainly on the profile depth. Burnstick Lake had low water column dissolved oxygen, with the whole water column being hypoxic on the March 7th sampling (Appendix Table 1). Total phosphorus (TP) values were consistent across sampling events at Gull Lake, and levels were moderate for both Gull Lake and Burnstick Lake, similar to summer levels of TP (Appendix Table 3).



Map 7. Sampling locations for Winter LakeKeepers 2019-2020, in the Red Deer River watershed. Red Deer River watershed highlighted in Alberta inset map.

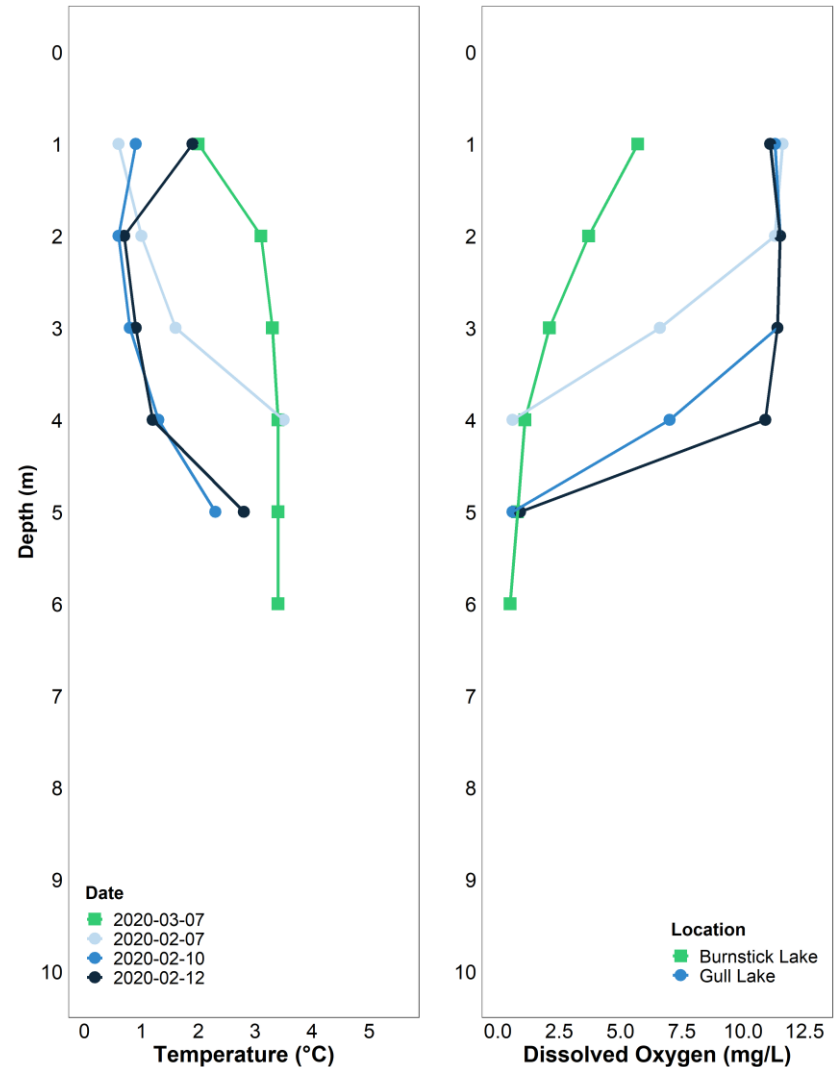


Figure 9. Temperature (°C) and dissolved oxygen (mg/L) measurements recorded at lakes in the Red Deer River watershed in Winter 2019-2020. Measurements were taken every meter starting at 1 meter from water surface, until lake bottom.

Red Deer River Watershed

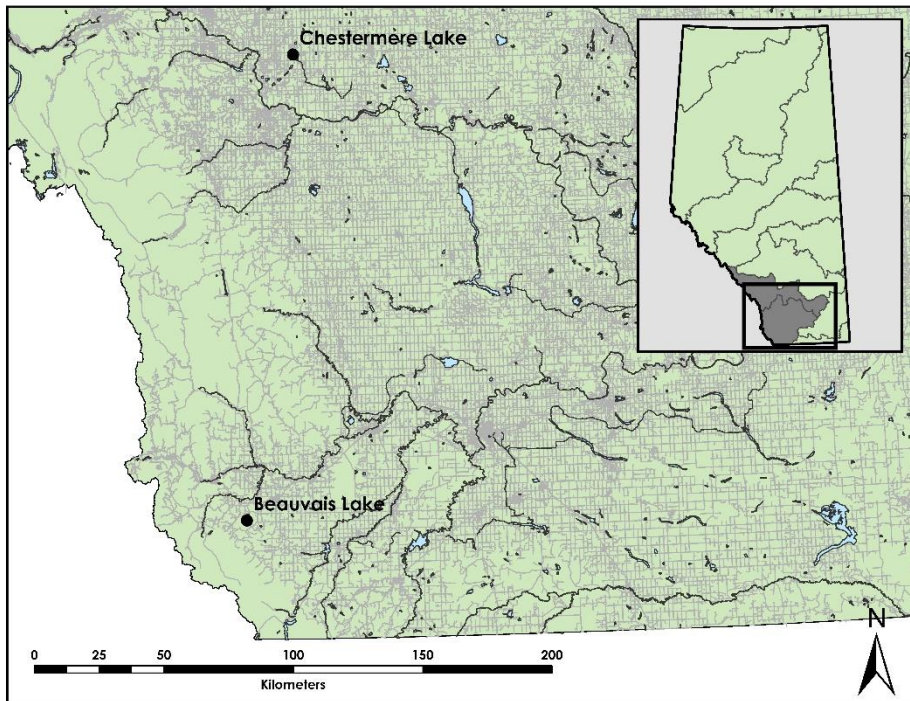


Table 6. Water chemistry (TP = total phosphorus in ug/L) and environmental measurements (Air Temp. = air temperature in °C) and observations recorded at lakes in the Red Deer River watershed in Winter 2019-2020. TP samples taken at 0.1m depth.

Site	Date	TP (ug/L)	Air Temp. (°C)	Ice Thickness (cm)	Snow Depth (cm)	Ice Colour	Water Colour	Particles?
Burnstick Lake	2020-03-07	11	-13	48	15	Clear	Colourless	No
Gull Lake	2020-02-07	13	-4	74	17	Clear	Colourless	No
Gull Lake	2020-02-10	14	-4	71	21	Clear	Colourless	No
Gull Lake	2020-02-12	15	-16	77	18	Clear	Colourless	No

Bow & Oldman River Watersheds

One lake was sampled within each of the Bow and Oldman River watersheds in Winter LakeKeepers 2019 – 2020. Chestermere Lake, in the Bow River watershed, was the only reservoir sampled in the 2019 – 2020 season. While two sampling events occurred at Beauvais Lake, profile data was not recorded from the February 25th sampling. While both lakes had high surface dissolved oxygen (Figure 10), both lakes were hypoxic for the bottom half of their water columns (Appendix Table 1). Total phosphorus (TP) was low for both sampling events at Beauvais Lake (Table 7), and moderate for the single sampling event at Chestermere, which was slightly higher compared to the 2019 summer TP average (Appendix Table 3). Both lakes had lower than average snow depths for each sampling, and the January sampling at Beauvais Lake was the second coldest of any sampling event in the 2019 – 2020 season (Table 7).



Map 8. Sampling locations for Winter LakeKeepers 2019-2020, in the Bow and Oldman River watersheds. Bow and Oldman River watersheds highlighted in Alberta inset map.

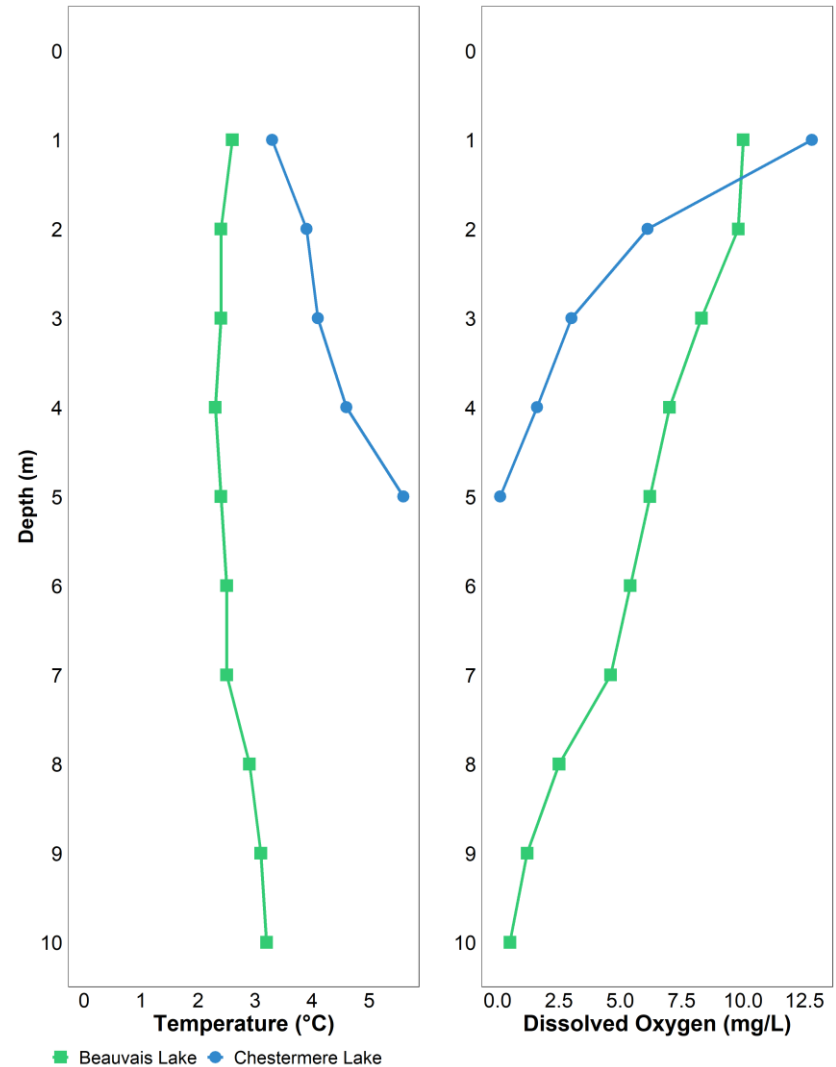


Figure 10. Temperature (°C) and dissolved oxygen (mg/L) measurements recorded at lakes in Bow and Oldman River watersheds in Winter 2019-2020. Measurements were taken every meter starting at 1 meter from water surface, until lake bottom. Beauvais Lake profile from January 13th, 2020.

Bow & Oldman Rivers Watersheds



Table 7. Water chemistry (TP = total phosphorus in ug/L) and environmental measurements (Air Temp. = air temperature in °C) and observations recorded at lakes in the Bow and Oldman River watersheds in Winter 2019-2020. TP samples taken at 0.1m depth.

Site	Date	TP (ug/L)	Air Temp. (°C)	Ice Thickness (cm)	Snow Depth (cm)	Ice Colour	Water Colour	Particles?
Beauvais Lake	2020-01-13	10.0	-24	38	10	Opaque	Colourless	No
Beauvais Lake	2020-02-25	8.8	0	51	6	Opaque	Colourless	No
Chestermere Lake	2020-03-22	20.0	2	59	5	Opaque	Colourless	No

Appendix

Appendix Table 1. Percent water column hypoxia, where hypoxia is defined as dissolved oxygen less than 6.5mg/L, according to the Alberta Government and the Canadian Council for Ministers of the Environment chronic guidelines for the protection of aquatic life, for Winter LakeKeepers lakes in the 2019-2020 season. Site bottom depth also listed for reference.

Site	Date	Water Column Hypoxia (%)	Site Bottom Depth (m)
Bangs Lake	2020-02-08	33	3.00
Beauvais Lake	2020-01-13	52	10.50
Burnstick Lake	2020-03-07	100	6.00
Chatwin Lake	2020-02-08	100	4.50
Chestermere Lake	2020-03-22	58	4.80
Gull Lake	2020-02-07	0	4.00
Gull Lake	2020-02-10	0	5.00
Gull Lake	2020-02-12	0	4.50
Half Moon Lake	2020-01-20	73	7.50
Half Moon Lake	2020-03-03	100	7.50
Iosegun Lake	2020-03-19	0	1.50
Kehewin Lake	2020-02-08	16	9.50
Lac La Biche, West Basin	2020-01-13	0	7.50
Lacombe Lake	2020-01-19	0	3.15
Lacombe Lake	2020-03-08	100	3.50
Manatokan Lake	2020-01-25	73	7.50
Minnie Lake	2020-02-08	100	8.50
Moose Lake, Franchere Bay	2020-02-08	100	3.00
Moose Lake, Vezeau Bay	2020-02-08	29	8.50
Pigeon Lake, Grandview	2019-12-27	0	7.50
Pigeon Lake, Grandview	2019-12-30	11	9.00

Appendix

Appendix Table 2. Percent water column hypoxia, where hypoxia is defined as dissolved oxygen less than 6.5mg/L, according to the Alberta Government and the Canadian Council for Ministers of the Environment chronic guidelines for the protection of aquatic life, for Winter LakeKeepers lakes in the 2019-2020 season. Site bottom depth also listed for reference.

Site	Date	Water Column Hypoxia (%)	Site Bottom Depth (m)
Pigeon Lake, Grandview	2020-01-05	0	3.5
Pigeon Lake, Grandview	2020-02-08	22	9.0
Pigeon Lake, Grandview	2020-02-28	22	9.0
Pigeon Lake, Grandview	2020-03-16	4	7.3
Pigeon Lake, Grandview	2020-03-29	32	8.8
Pigeon Lake, Mulhurst	2020-01-24	3	3.1
Smoke Lake	2020-03-19	0	4.0
Snipe Lake	2020-02-15	11	4.5
Spring Lake	2020-01-21	100	3.0
Sturgeon Lake	2020-03-07	54	6.5
Swan Lake	2020-02-23	100	3.0
Wabamun Lake, Fallis	2019-12-31	0	4.0
Wabamun Lake, Fallis	2020-01-26	0	5.2
Wabamun Lake, Fallis	2020-03-20	14	3.5
Wabamun Lake, Seba Beach	2019-12-31	0	8.5
Wabamun Lake, Seba Beach	2020-03-20	68	9.5
Wabamun Lake, Sundance	2019-12-31	0	2.5
Wabamun Lake, Sundance	2020-03-20	20	2.5
Wizard Lake, East Basin South	2020-03-25	100	2.1
Wizard Lake, Jubilee Park	2020-02-08	100	5.0
Wizard Lake, Jubilee Park	2020-03-25	100	6.0
Wizard Lake, West Basin	2020-03-25	100	3.0

Appendix

Appendix Table 3. Average total phosphorus (TP) in ug/L from lakes sampled in Winter LakeKeepers 2019-2020, compared to the latest summer average TP. 'Avg. 2020 Winter TP (ug/L)' represents the average from across sample dates, if lakes had multiple sample events, and across sample locations, if lakes had multiple sampled locations, with samples collected at 1m. 'Avg. Last Summer TP (ug/L)' is lake seasonal average from euphotic integrated, composite site sampling, or surface grab sample, depending on the sampling program.

Lake	Avg. 2020 Winter TP (ug/L)	Avg. Last Summer TP (ug/L)	Last Summer Measured
Bangs Lake	110	-	-
Beauvais Lake	9	9	2019
Burnstick Lake	11	18	2018
Chatwin Lake	170	-	-
Chestermere Lake	20	12	2019
Gull Lake	14	17	2016
Half Moon Lake	59	80	2019
Iosegun Lake	34	55	2015
Kehewin Lake	21	98	2019
Lac La Biche (West Basin)	52	199	2019
Lacombe Lake	24	21	2019
Manatokan Lake	23	80	1993
Minnie Lake	53	41	2019
Moose Lake	52	49	2019
Pigeon Lake	11	22	2019
Smoke Lake	16	37	2015
Snipe Lake	19	59	2019
Spring Lake	6	18	2016
Sturgeon Lake	140	101	2018
Swan Lake	180	197	2019
Wabamun Lake	15	27	2019
Wizard Lake	28	46	2018