LakeKeepers

Winter LakeKeepers

2022 - 2023

Updated September 5, 2023

This project supported with funding from

Johnny Morris Bass Pro Shops Cabela's OUTDOOR FUND

Alberta Conservation Association

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.

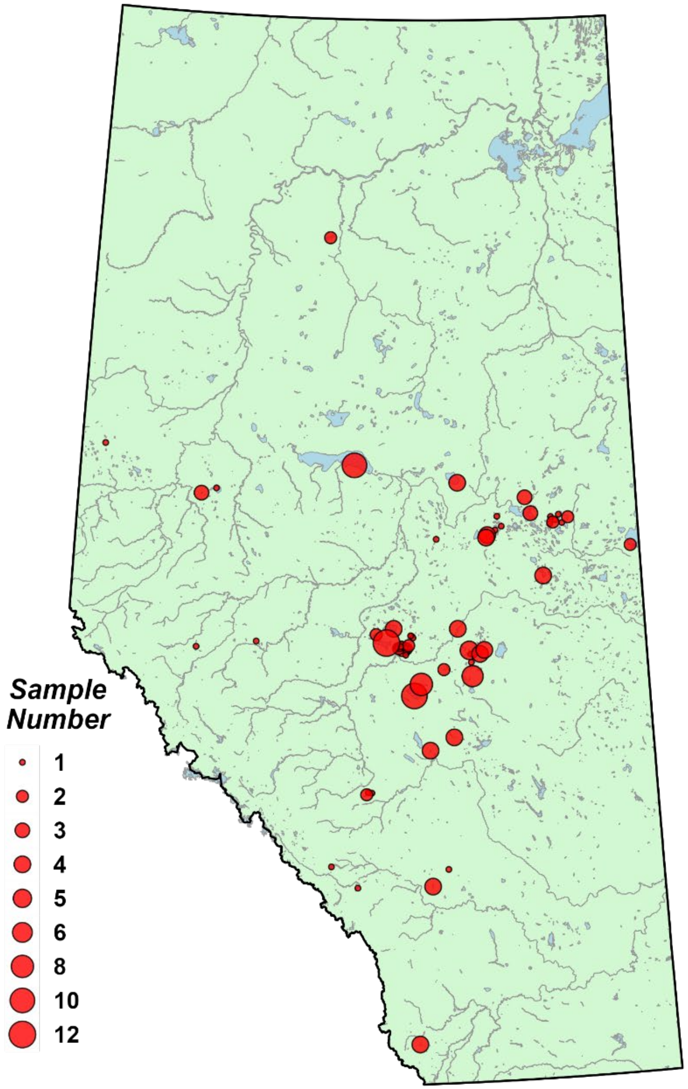
ACKNOWLEDGEMENTS

Winter LakeKeepers 2022-2023 was made possible with support from Bass Pro Shops and Cabela's Outdoor Fund, and the Alberta Conservation Association.

We would like to thank all the volunteers and partners who participated in sampling – without their commitment, this program would not exist. We would also like to thank the Mighty Peace Watershed Alliance for their assistance with coordinating volunteers and sample shipment, and to the Aquatic Ecology Laboratory at the University of Calgary for their advice on winter lake sampling methodology. ALMS staff Kirsten Letendre and Kurstyn Perrin were integral in managing program logistics, and in undertaking data management. This report was prepared by Caleb Sinn and Bradley Peter.

Report last updated: September 5th, 2023

Executive Summary



Map 1. Geographic spread of lakes sampled as part of the Winter LakeKeepers 2022-2023 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 2022-2023.

Following four successful seasons of Winter LakeKeepers beginning in the winter of 2018-2019, the Alberta Lake Management Society (ALMS) delivered a fifth Winter LakeKeepers season in 2022-2023, the results of which are presented in this report.

As in previous seasons, the participant effort consisted primarily of volunteers associated with Watershed Planning and Advisory Councils (WPACs), or Watershed Stewardship Groups (WSGs), as well as ice anglers and partner organizations. 64 volunteers and partners took part in Winter LakeKeepers 2022 – 2023, an increase of ten from the season before. 2022-2023 was the fourth season to include multiple sampling events at specific sites on lakes, as well as multiple sampling sites per lake. It was also the third season which included the collection of preserved phytoplankton samples, isotope samples, and additional water chemistry parameters. It is the second season to include three tiers of protocols to involve all participants based on their interest, comfort level, and sampling logistics. It is the first season to include white ice thickness measurements, and under-ice light measurements at some lakes.

Sampling results have been grouped by major watershed. This is the first report that represents all dissolved oxygen and temperature profiles as heatmap type visuals, and that contains figures representing seasonal dynamics of select parameters for locations that were sampled twice or more. The appendix contains information about sampling that occurred in Saskatchewan, under-ice light measurements, and data from a high-frequency sensor array deployed at Pigeon Lake which includes a comparison with Winter LakeKeepers data.

Overall, 99 locations were sampled on 70 different lakes, ranging from the Oldman watershed in the south, up to the Peace watershed in northern Alberta (Map 1). 172 sampling events took place, from as early as November 29th, 2022, to as late as April 12th, 2023. This is approximately a 30% increase in effort relative to the previous winter's sampling effort.

A wide variety of winter lake conditions were captured throughout the province, enabling greater understanding of how these lakes functioned in the winter of 2022 – 2023.

The 'Executive Summary' below describes major observations from the season, while each section following does not include interpretation. Some pages include additional information in blue boxes to support data interpretation. If further interpretation is required, please contact programs@alms.ca to arrange support.

Methods

Winter LakeKeepers participants sampling at Magee Lake, January 2023

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

Participants were provided with a training manual (available at https://alms.ca/winter-lakekeepers/). Lakes were to be sampled at least once during the ice-on period, coinciding with Alberta's ice fishing season (December 1st – March 31st), and ideally no more than once a month, per sampling location.

Participants chose their own locations for sampling, generally based on their desired location for ice fishing, or based on proximity to their residence. In some cases, ALMS provided site selection advice. Unlike other ALMS summer programs, this meant Winter LakeKeepers sampling did not necessarily occur at the deepest point in the lake.

Participants had the choice of following one of three different protocols: P1, P2, or P2 + chlorophyll-a (ChlA) filtering. This was done in order to facilitate the analysis of additional parameters and to optimize sample delivery & handling logistics, but to also provide a more straightforward program for first-time participants. Sample bottles for analysis of target parameters such as chloride (Cl), conductivity (Cond.), pH, dissolved organic carbon (DOC), nitrate (NO_3), nitrite (NO_2), ammonia (NH_3), and total dissolved phosphorus (TDP) needed to arrive at the laboratory within 3 days. ChlA samples not filtered in the field needed to arrive at the ALMS office within 24hrs, while total phosphorus (TP) and total Kjeldahl nitrogen (TKN) could arrive at the lab as late as 2 weeks after the sampling date. Sample hold times dictated which sample bottles were filled during each sampling event.

For all protocol tiers, participants were provided with field sheets, a YSI dissolved oxygen (DO) and temperature meter, a 'G2-Preserved' sample bottle with preservative (analysis of TP and TKN), sampling gloves to protect participants from cold water and preservatives, an isotope bottle, and a hot water bottle that ensured the samples and the probe did not freeze. Participants following the P2 tier were also provided with a 'G2-F' bottle (analysis of TDP, DOC), a 'Routine' bottle (analysis of Cond., pH, Cl, NO_3, NO_2, NH_3), a one 1L bottle for ChlA analysis, and a phytoplankton bottle with Lugol's preservative. Participants following P2+ChlA filtering were also provided with a ChlA filtering kit. ChlA filters were then frozen prior to shipment.

Methods

Profile measurements for DO and temperature were taken first at 0.1m and then 0.5m, then every meter starting at 1m, until lake bottom. Grab samples filling the G2-Preserved, isotope, phytoplankton, G2-F, Routine, and ChlA bottles were collected just below the surface of the ice, at around 0.5m depth. Environmental observations such as site bottom depth, ice thickness, white ice thickness, snow depth, air temperature, ice colour, water colour, and the presence of particles in the water were recorded on the field sheets. GPS coordinates of the sampling location were also recorded.

P1 samples were returned to ALMS within about one or two weeks, P2 samples were returned within 24hrs, and P2+ChlA filtering samples were returned within 3 days. ALMS coordinated delivery of samples to the analytical laboratories. In some cases, participants delivered samples directly to analytical laboratories. ALMS also coordinated the delivery of sampling kits to the volunteers throughout the season.

Winter LakeKeepers participants sampling at Lake Minnewanka, March 2023

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 was done using the program R.[1] Data was reconfigured using packages tidyr [2] and dplyr [3], figures and maps were produced using the package ggplot2[4], tables were produced using the package gt [5], and geospatial data processing was done using the package sf [6]. Trophic status for each lake is classified based on lake water characteristics using values from Nurnberg (1996)[7].

Light measurements (Photosynthetically Active Radiation – PAR) were taken at a select number of lakes using an Apogee MQ-510 Full-Spectrum Underwater Quantum Meter, oriented upwards. A surface measurement was taken to represent light above the lake, and then profile measurements were taken similarly to DO and temperature, with the exception that a separate hole was augured in an area with minimal artificial snow disruption, and the hole was back-filled with snow in order to limit light penetration through the auger hole.

[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] Iannone R, Cheng J, Schloerke B, Hughes E, Lauer A, Seo J (2023). *gt: Easily Create Presentation-Ready Display Tables*. https://gt.rstudio.com/, https://github.com/rstudio/gt.
[6] Pebesma E, Bivand R (2023). Spatial Data Science: With applications in R. Chapman and Hall/CRC. doi:10.1201/9780429459016, https://r-spatial.org/book/.
[7] 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.

Results – Executive Summary

Winter LakeKeepers participant holding a sample bottle (note the high green color), from Byers Lake, March 2023

A wide diversity of winter lake water chemistry and environmental observations were captured through the Winter LakeKeepers 2022-2023 season. The overall findings build nuance into the understanding of winter lake conditions.

Summaries of water chemistry & environmental data for each lake across the season (Figures 1 – 13) indicate high variability across lakes. Summary figures of nutrient data indicate phosphorus and nitrogen, and their fractions (dissolved phosphorus, nitrate + nitrite, ammonia), levels are similar to that observed in the summer months, with levels spread through two orders of magnitude. Chlorophyll-*a* levels (indicating growth of algae and cyanobacteria) are high or very high (eutrophic and hypereutrophic) in more than half of the lakes sampled, indicating high biological activity immediately beneath the surface of the ice in most lakes sampled. The summary of maximum observed ice thickness demonstrates the range of maximum ice thickness being 35 cm – 122 cm, with a mean maximum observed thickness of 66 cm.

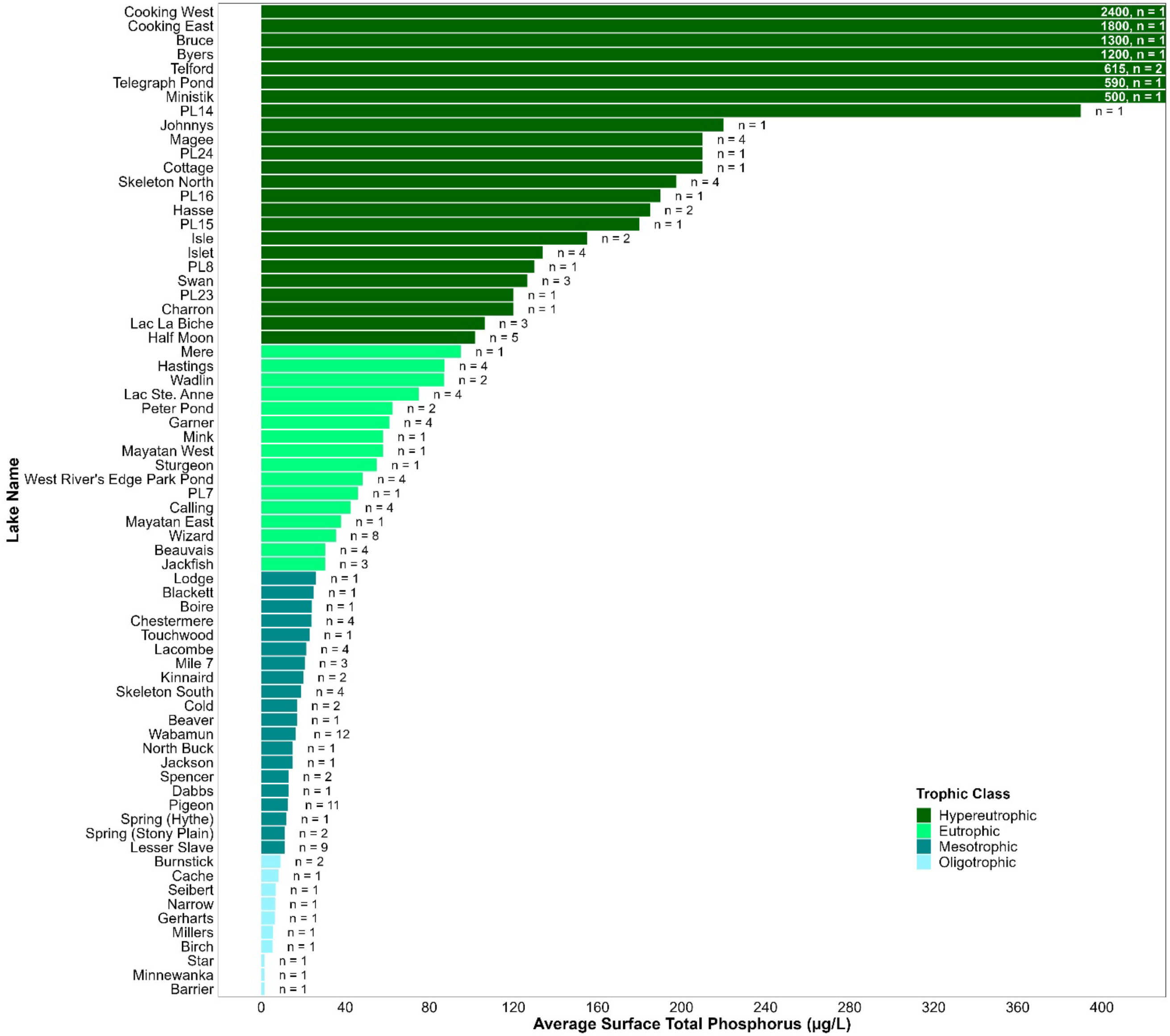
The coldest water temperatures were observed in larger lakes in the central region of Alberta (Calling, Lesser Slave, Cold, Touchwood, Wabamun, Pigeon) and Saskatchewan (Peter Pond), while warmest temperatures were observed in shallow lakes later in the winter, as well as in lakes further south, despite their depth or size (Beauvais, Chestermere, Minnewanka, Barrier, Burnstick).

Generally, larger lakes (lakes of higher surface area and depth) had higher levels of dissolved oxygen (DO) than smaller lakes. Deep lakes with small surface area generally displayed low levels of DO, indicating lake depth alone is not a good predictor of under-ice oxygen levels. In lakes with multiple sampling events, DO levels tended to decrease throughout the season, beginning with low levels towards the bottom of the lake, and leading to DO decreases further upwards in the water column later in the season. Mid-column decreases and then increases of DO at a deeper depth observed at Pigeon and Wabamun may indicate the detection of complex under-ice mixing dynamics.

Samples of total phosphorus (TP), total Kjeldahl nitrogen (TKN) and chlorophyll-*a* (ChlA) collected through the winter indicate some locations had consistent levels, while others were more dynamic. Generally, ChlA increases between the early and late winter, but some lakes displayed high levels of ChlA early in the season (Beauvais, Skeleton North, Wizard).

Measurements of ice thickness through the season indicate that ice thickness increased between early and late season, but that late season decreases in ice thickness were observed in some lakes sampled in early March or April. White ice thickness, the opaque layer in the upper region of the ice, generally increased through the season. However, there were many locations where it was observed early in the season, then not observed in mid-season, then observed again later in the season. This sort of dynamic could be due to slight variation in sample location on the lake, as the undulating surface of the ice can cause variable white ice formation at small spatial scales.

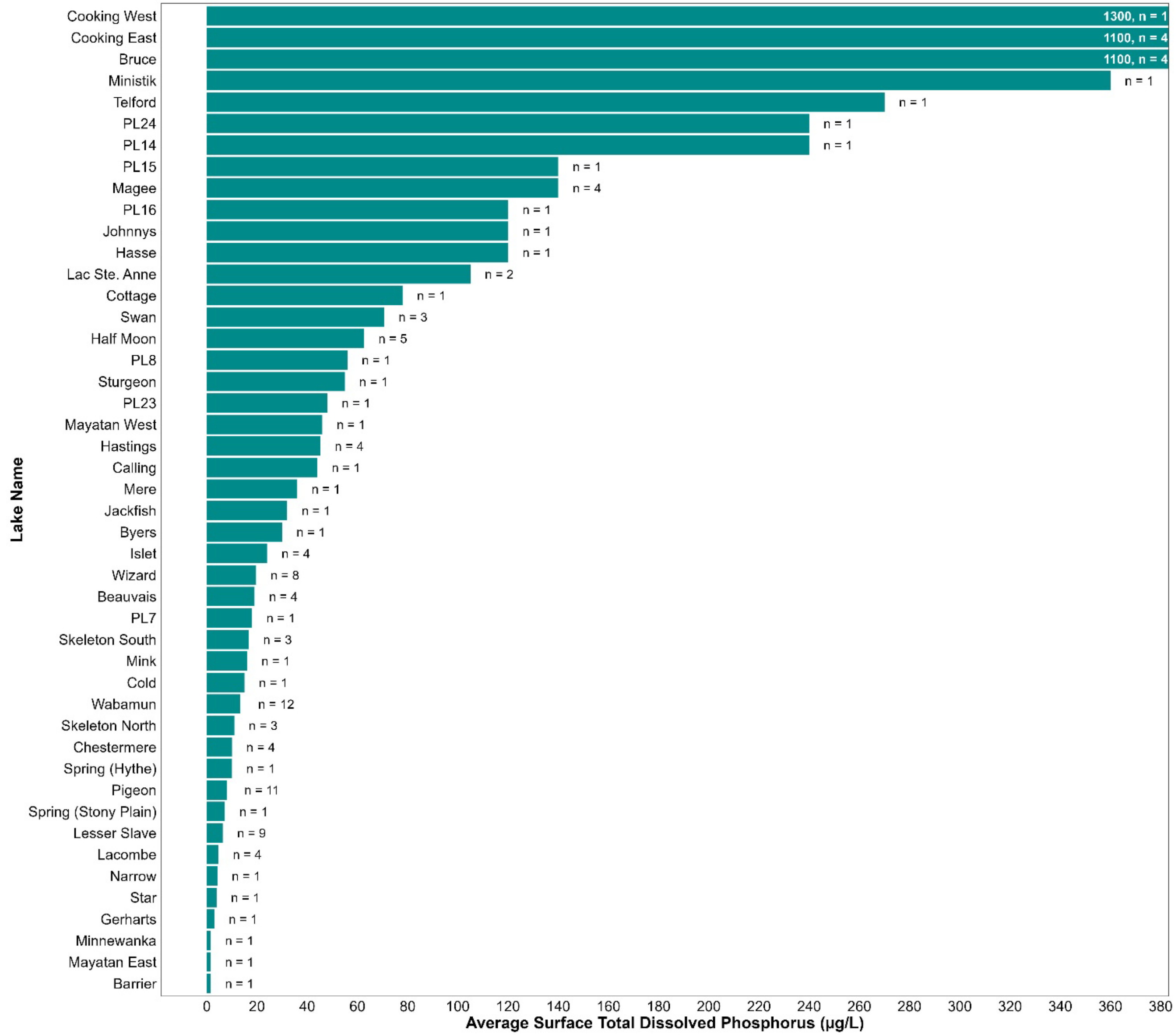
Summary



Phosphorus is an essential nutrient for the growth of algae, cyanobacteria, and aquatic plants, and is often the most limiting nutrient for growth. High levels can indicate the lake is situated in naturally high nutrient soils, but can also indicate potential nutrient pollution from the lake's watershed. Total phosphorus (TP) is used most commonly to assess levels of phosphorus, and categorize the lake based on productivity (trophic class).

Figure 1. Average surface total phosphorus (µg/L) from lakes sampled in the Winter LakeKeepers 2022-2023 season. Average surface 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 (number of samples indicated by the "n" value beside each bar). Trophic class, or lake productivity level based on total phosphorus levels, is indicated by color. Samples were taken at 0.5m at the sampling location, between November 2022 and April 2023. Extreme outliers on the upper range (>3*IQR) are not fully plotted.

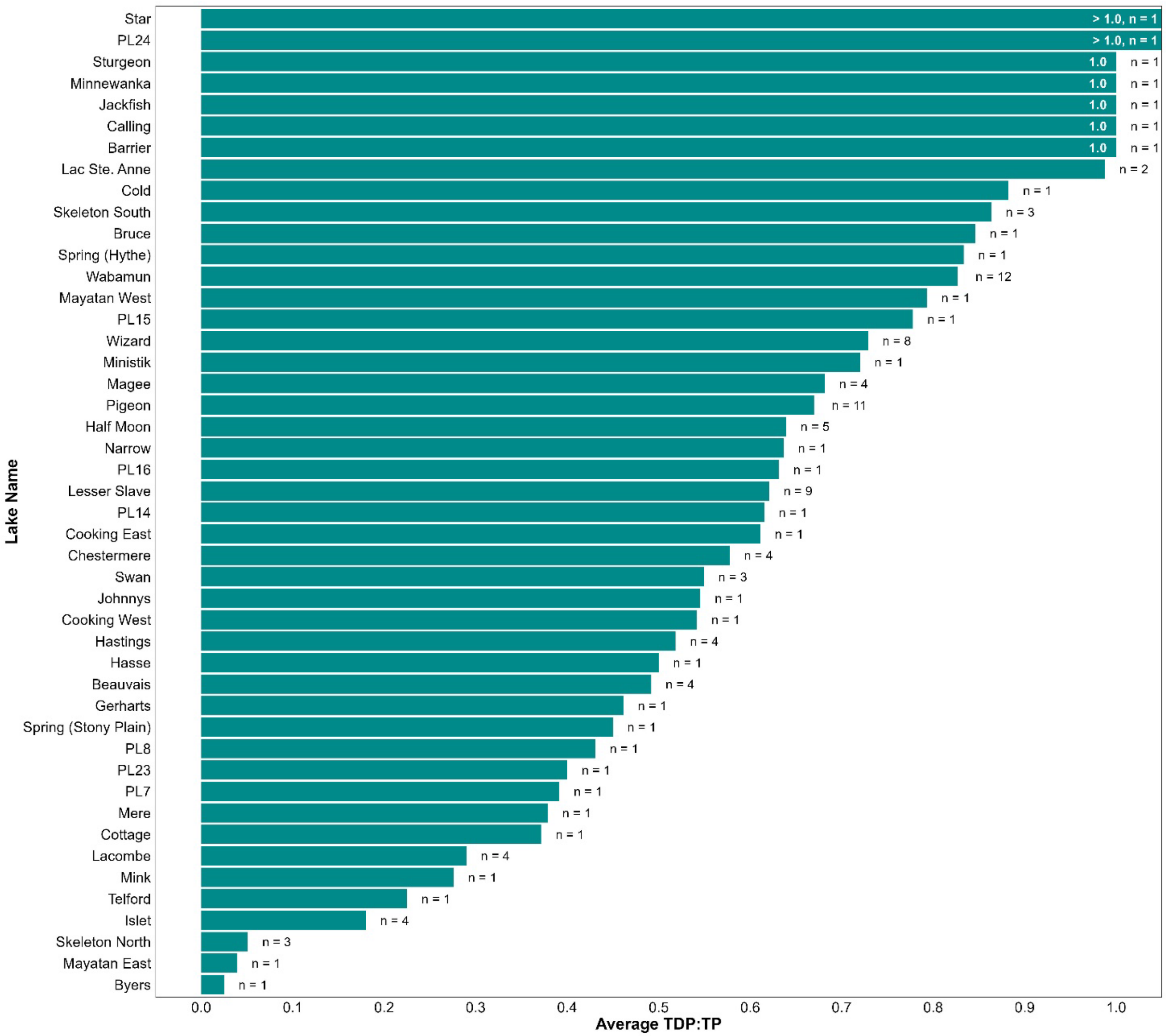
Summary



Total dissolved phosphorus (TDP) indicates the portion of the total phosphorus that is more biologically available. Generally, the distribution of TDP in lakes sampled in winter is similar to their distribution of TP values (Figure 1).

Figure 2. Average surface total dissolved phosphorus (µg/L) from lakes sampled in the Winter LakeKeepers 2022-2023 season. Average surface total dissolved phosphorus represents the average from across sample dates, if lakes had multiple sample events, and across sample locations, if lakes had multiple sampled locations (number of samples indicated by the "n" value beside each bar). Samples were taken at 0.5m at the sampling location, between November 2022 and April 2023. Extreme outliers on the upper range (>3*IQR) are not fully plotted.

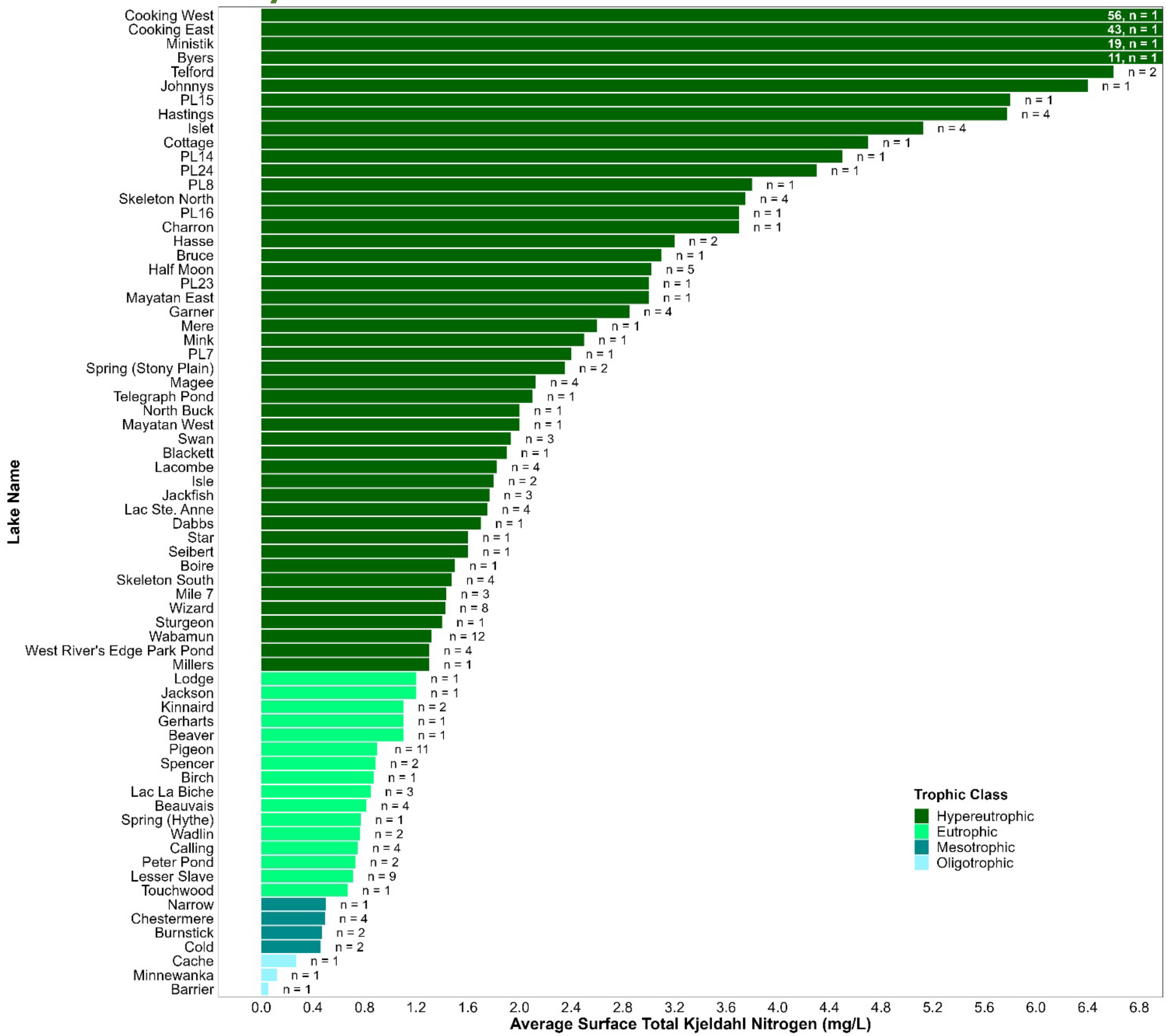
Summary



Representing nutrient levels as ratios can help describe the proportion of phosphorus which is dissolved (TDP:TP), indicating extent of biological uptake. A wide range of TDP:TP ratios existed for the lakes, with some lakes nearing or at 1:1 TDP:TP, while the three lowest lakes displayed TP values greater between 20 - 40 times larger than TDP (Figure 3). Low TDP:TP ratios in lakes with high chlorophyll-a may be a result of high biological uptake of nutrients.

Figure 3. Average total dissolved phosphorus (TDP) to average total phosphorus (TP) ratio (µg/L) from lakes sampled in the Winter LakeKeepers 2022 -2023 season. Average TDP:TP represents the average from across sample dates, if lakes had multiple sample events, and across sample locations, if lakes had multiple sampled locations (number of samples indicated by the "n" value beside each bar). Samples were taken at 0.1m, right below the ice, between November 2022 and April 2023. Extreme outliers on the upper range (>3*IQR) are not fully plotted.

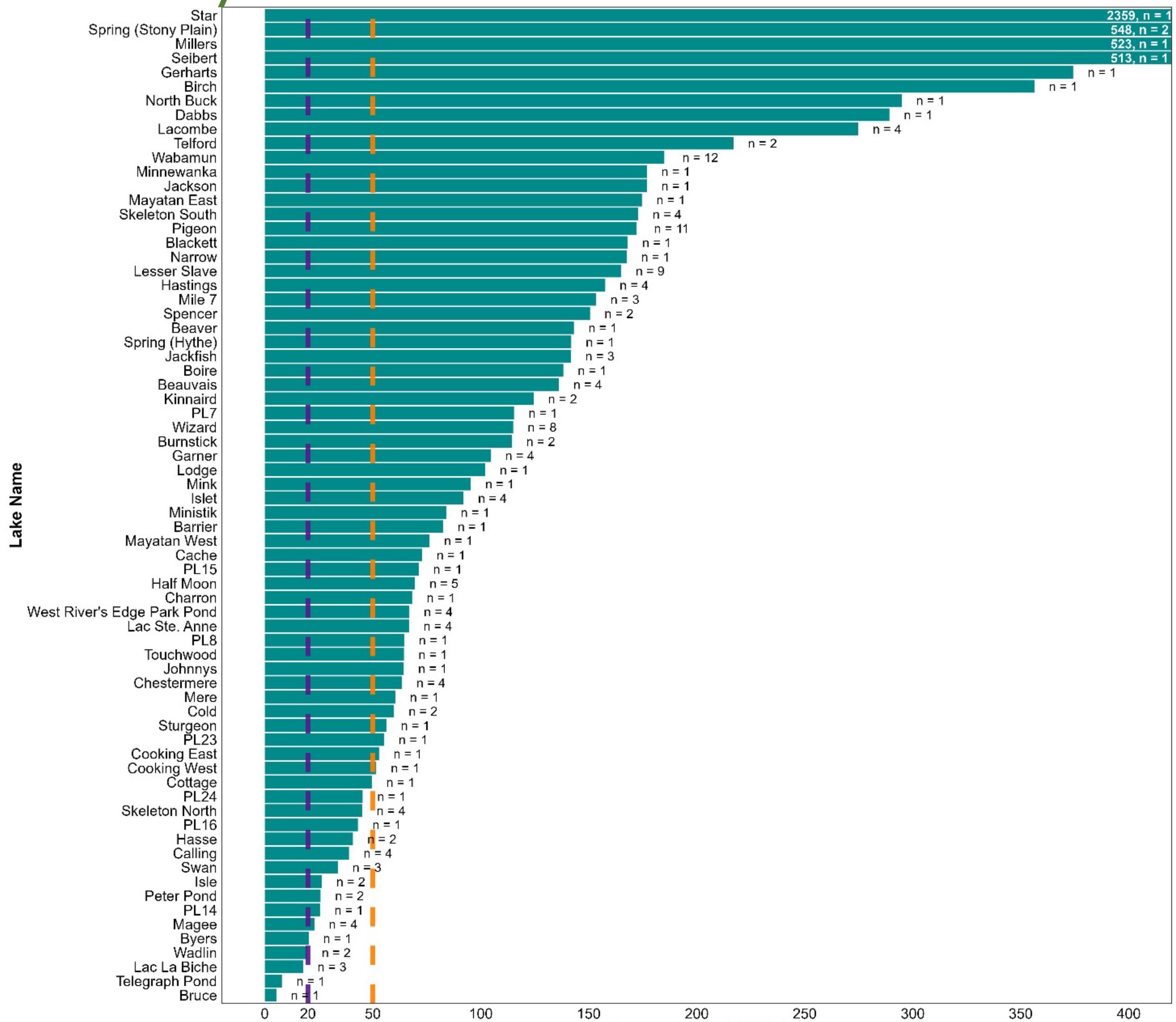
Summary



Nitrogen is an essential nutrient for the growth of algae, cyanobacteria, and aquatic plants, and are often the most limiting nutrient for growth. High levels can indicate the lake is situated in naturally high nutrient soils, but also indicate potential nutrient pollution from the lake's watershed. Total Kjeldahl nitrogen (TKN) is used commonly to assess levels of total lake nitrogen, and to categorize the lake based on productivity (trophic class).

Figure 4. Average surface total Kjeldahl nitrogen (mg/L) from lakes sampled in the Winter LakeKeepers 2022-2023 season. Average surface total Kjeldahl nitrogen represents the average from across sample dates, if lakes had multiple sample events, and across sample locations, if lakes had multiple sampled locations (number of samples indicated by the "n" value beside each bar). Trophic class, or lake productivity level based on total Kjeldahl nitrogen levels, is indicated by color. Samples were taken at 0.5m at the sampling location, between November 2022 and April 2023. Extreme outliers on the upper range (>3*IQR) are not fully plotted.

Summary

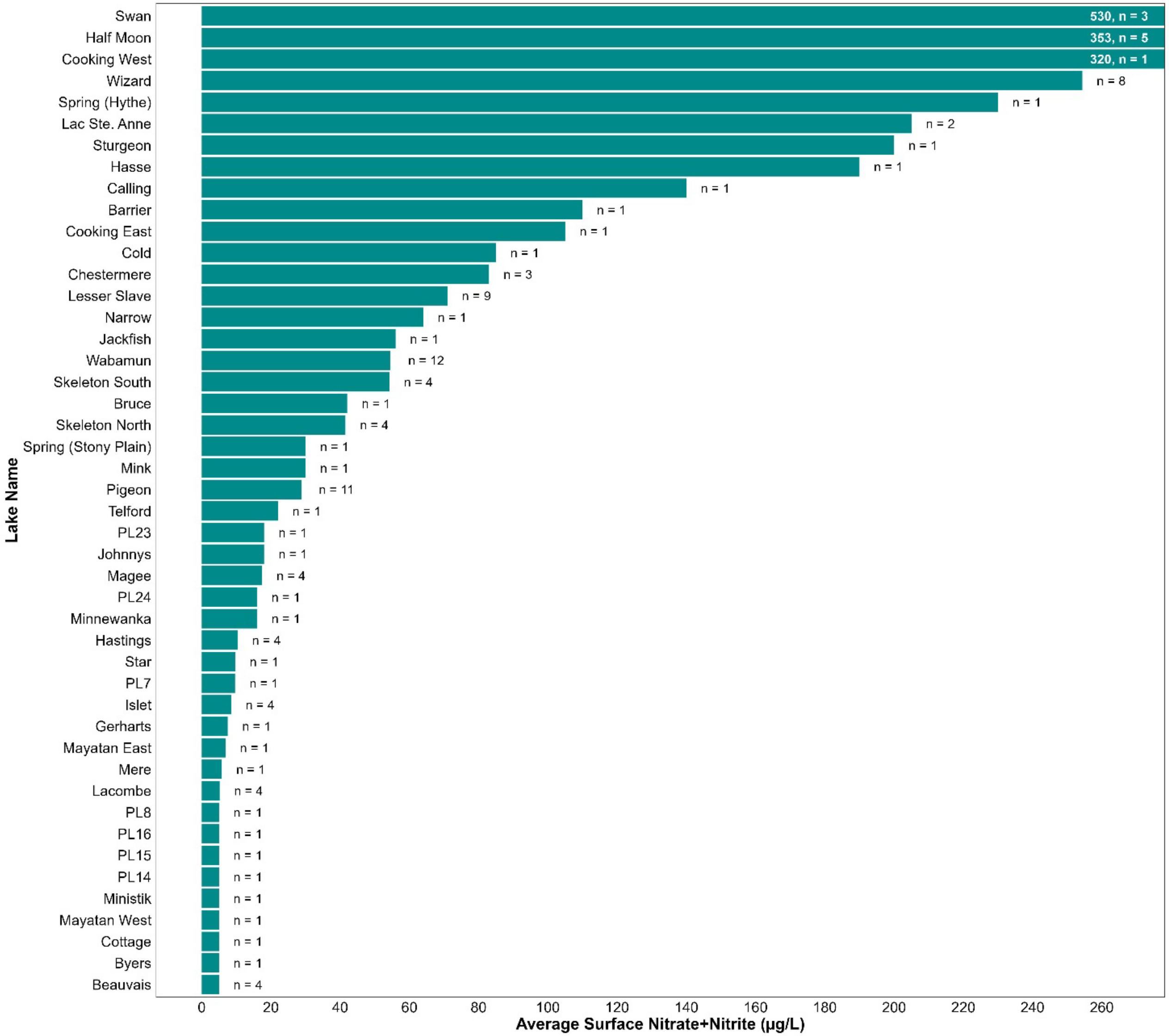


Representing nutrient levels as ratios can help describe the extent of nitrogen vs. phosphorus limitation (TKN:TP). TKN:TP ratios indicate that the majority of lakes are phosphorus limited (TKN:TP > 50, Figure 5), and a few lakes may be nitrogen limited (TKN:TP < 20), although these ratios must be interpreted in the context of TKN and TP concentrations.[9]

Figure 5. Average total Kjeldahl nitrogen (TKN) to average total phosphorus (TP) molar ratio from lakes sampled in the Winter LakeKeepers 2022-2023 season. Average TKN:TP represents the average from across sample dates, if lakes had multiple sample events, and across sample locations, if lakes had multiple sampled locations (number of samples indicated by the "n" value beside each bar). Samples were taken at 0.1m, right below the ice, between November 2022 and April 2023. Ratio of 20 is indicated by a purple dashed line, and 50 by orange dashed line, as per P and N limitation cut-offs in Guildford and Hecky, 2000. Extreme outliers on the upper range (>3*IQR) are not fully plotted.

[9] Guildford, S. J., and R. E. Hecky (2000). Total nitrogen, total phosphorus, and nutrient limitation in lakes and oceans: Is there a common relationship? Limnology and Oceanography 45(6), 1213-1223.

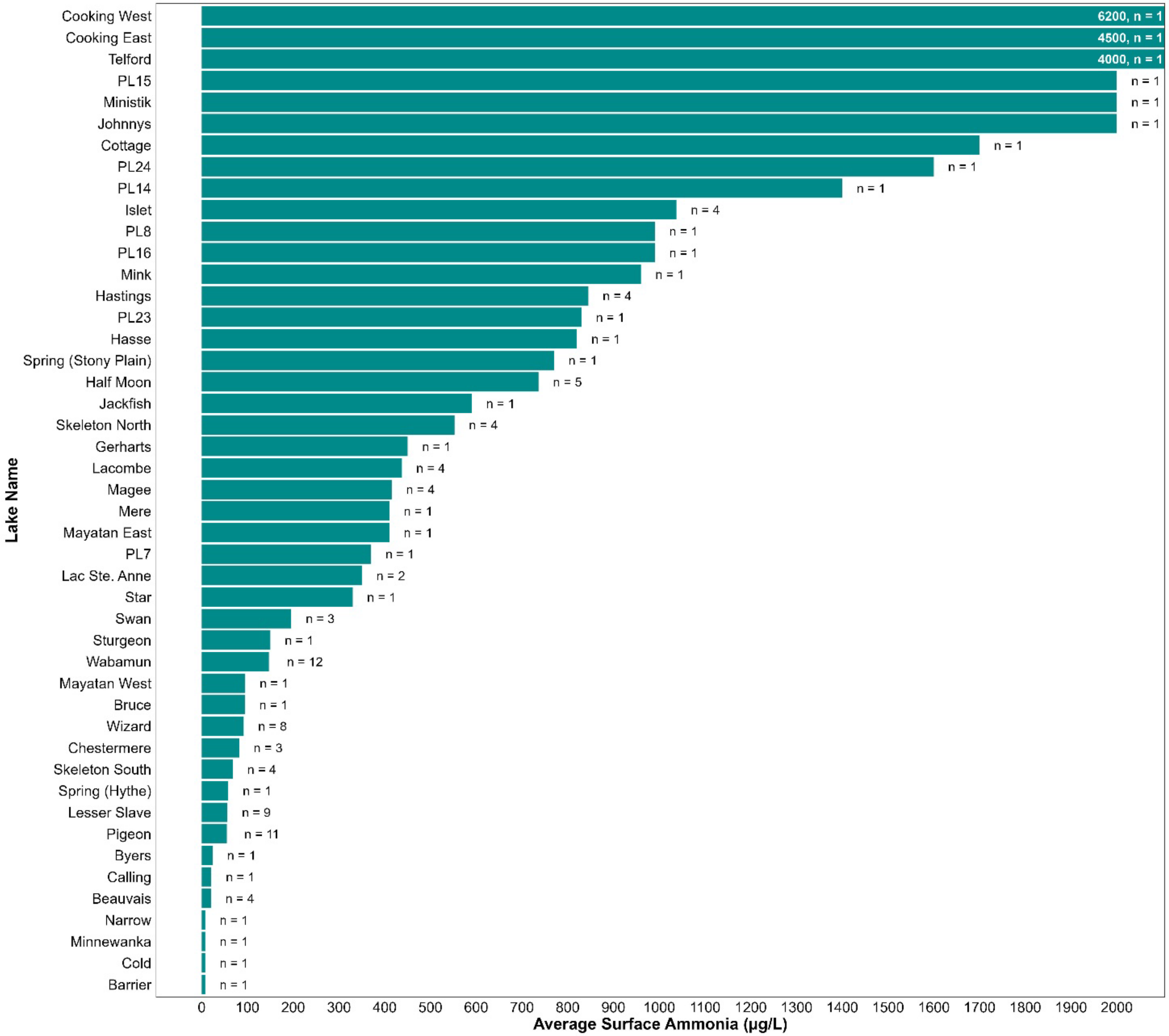
Summary



Nitrate and Nitrite are more biologically available forms of nitrogen. High levels within the winter months can be a result of degradation of algae, cyanobacteria, and aquatic plants that grew in the summer months.

Figure 6. Average sum of surface nitrate and nitrite (µg/L) from lakes sampled in the Winter LakeKeepers 2022-2023 season. Average sum of surface nitrate and nitrite represents the average from across sample dates, if lakes had multiple sample events, and across sample locations, if lakes had multiple sampled locations (number of samples indicated by the "n" value beside each bar). Samples were taken at 0.5m at the sampling location, between November 2022 and April 2023. Extreme outliers on the upper range (>3*IQR) are not fully plotted.

Summary

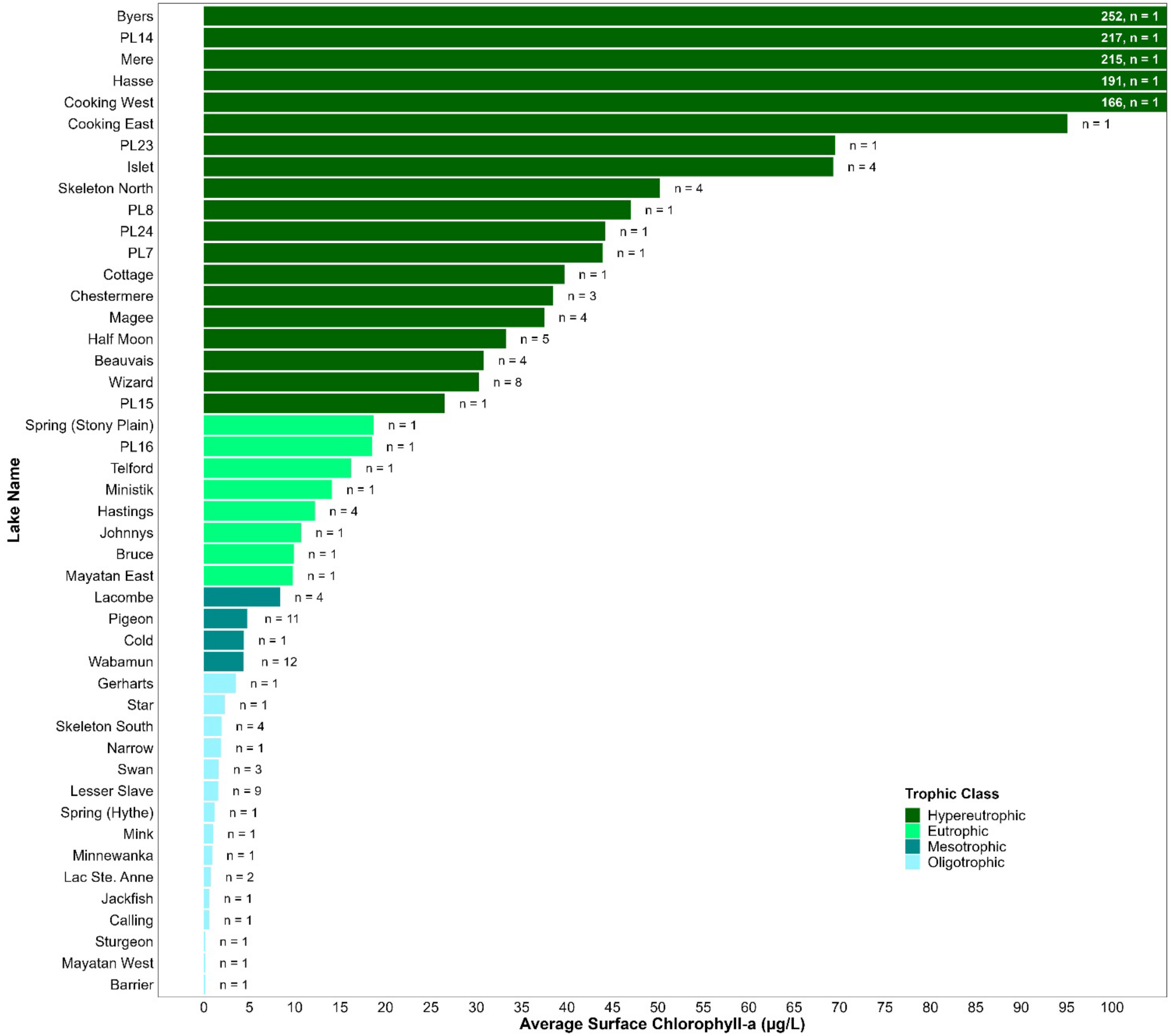


Ammonia is a more biologically available form of nitrogen. High levels within the winter months can be a result of degradation of algae, cyanobacteria, and aquatic plants that grew in the summer months. High levels of ammonia can be toxic to fish and other organisms, but the level of toxicity is dependent on temperature and pH – the lower the temperature and the lower the pH, the less toxic. [10]

Figure 7. Average surface ammonia (µg/L) from lakes sampled in the Winter LakeKeepers 2022-2023 season. Average surface ammonia represents the average from across sample dates, if lakes had multiple sample events, and across sample locations, if lakes had multiple sampled locations (number of samples indicated by the "n" value beside each bar). Samples were taken at 0.5m at the sampling location, between November 2022 and April 2023. Extreme outliers on the upper range (>3*IQR) are not fully plotted.

[10] Canadian Council of Ministers of the Environment (CCME). 2010. Canadian water quality guidelines for the protection of aquatic life: Ammonia. In: Canadian environmental quality guidelines, 1999, Canadian Council of Ministers of the Environment, Winnipeg. .

Summary



Chlorophyll-*a* is an indicator of the amount of algae and cyanobacteria within lakes. Average chlorophyll-a levels from winter 2022-2023 indicate many lakes have significant growth of algae and cyanobacteria in the winter months, however a relatively high proportion have very low (oligotrophic) levels (Figure 8).

Figure 8. Average surface Chlorophyll-a (µg/L) from lakes sampled in the Winter LakeKeepers 2022-2023 season. Average surface Chlorophyll-a represents the average from across sample dates, if lakes had multiple sample events, and across sample locations, if lakes had multiple sampled locations (number of samples indicated by the "n" value beside each bar). Trophic class, or lake productivity level based on Chlorophyll-a levels, is indicated by color. Samples were taken at 0.5m at the sampling location, between November 2022 and April 2023. Extreme outliers on the upper range (>3*IQR) are not fully plotted.

Summary

Dissolved organic carbon (DOC) is an important source of energy for microorganisms, is part of a lake's carbon cycle, and can impact light penetration.

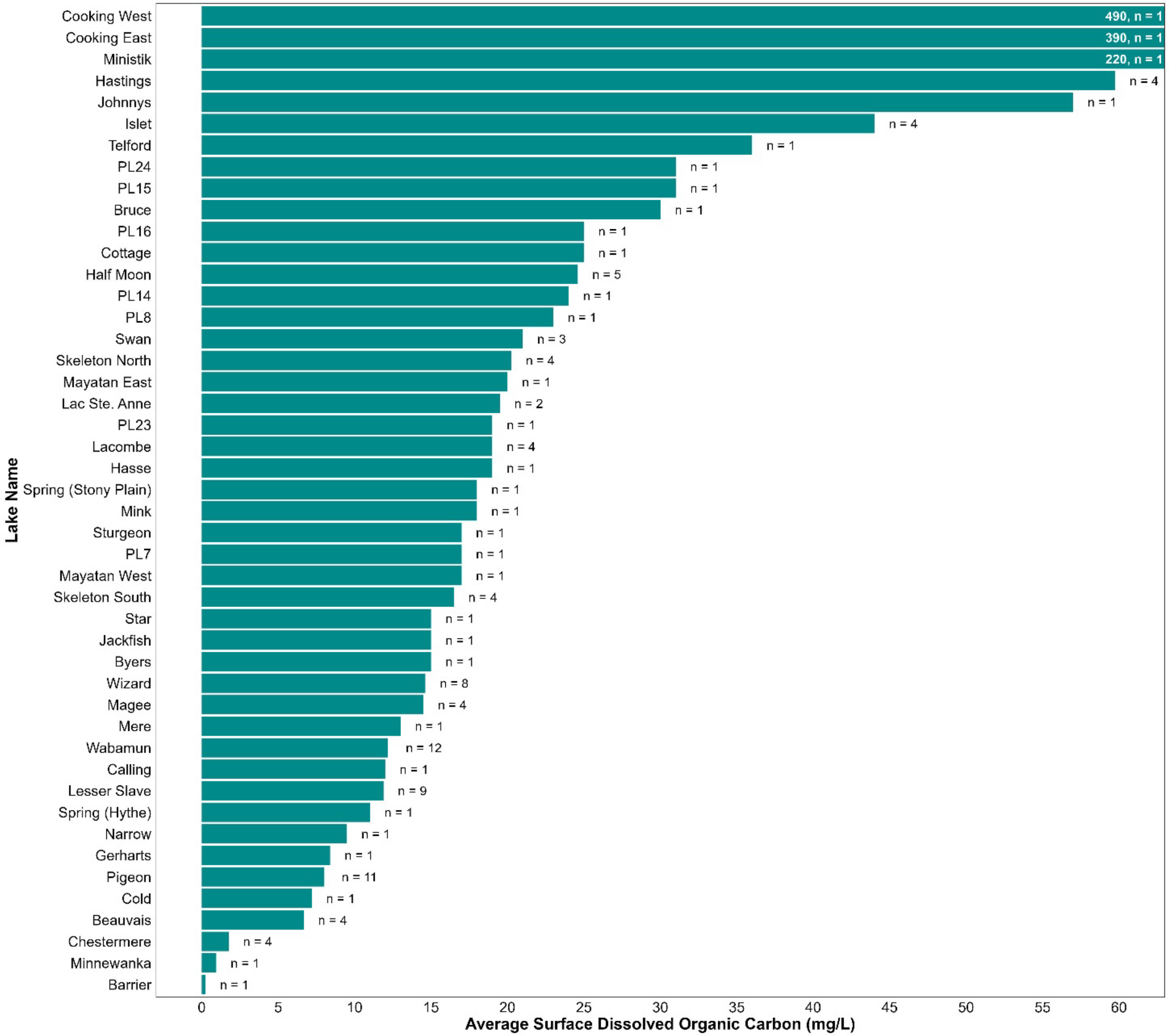
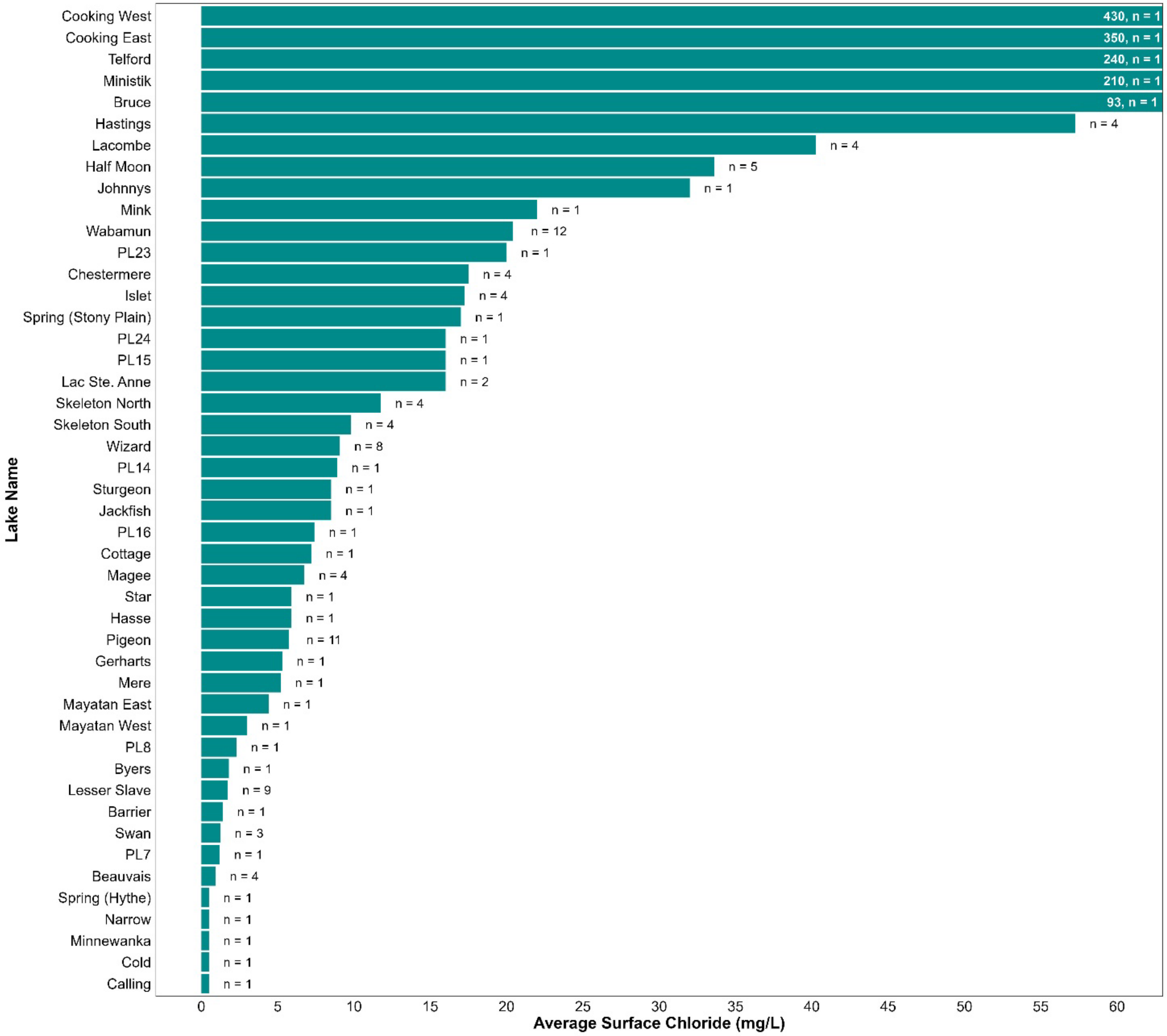


Figure 9. Average surface dissolved organic carbon (mg/L)) from lakes sampled in the Winter LakeKeepers 2022-2023 season. Average surface dissolved organic carbon represents the average from across sample dates, if lakes had multiple sample events, and across sample locations, if lakes had multiple sampled locations (number of samples indicated by the "n" value beside each bar). Samples were taken at 0.5m at the sampling location, between November 2022 and April 2023. Extreme outliers on the upper range (>3*IQR) are not fully plotted.

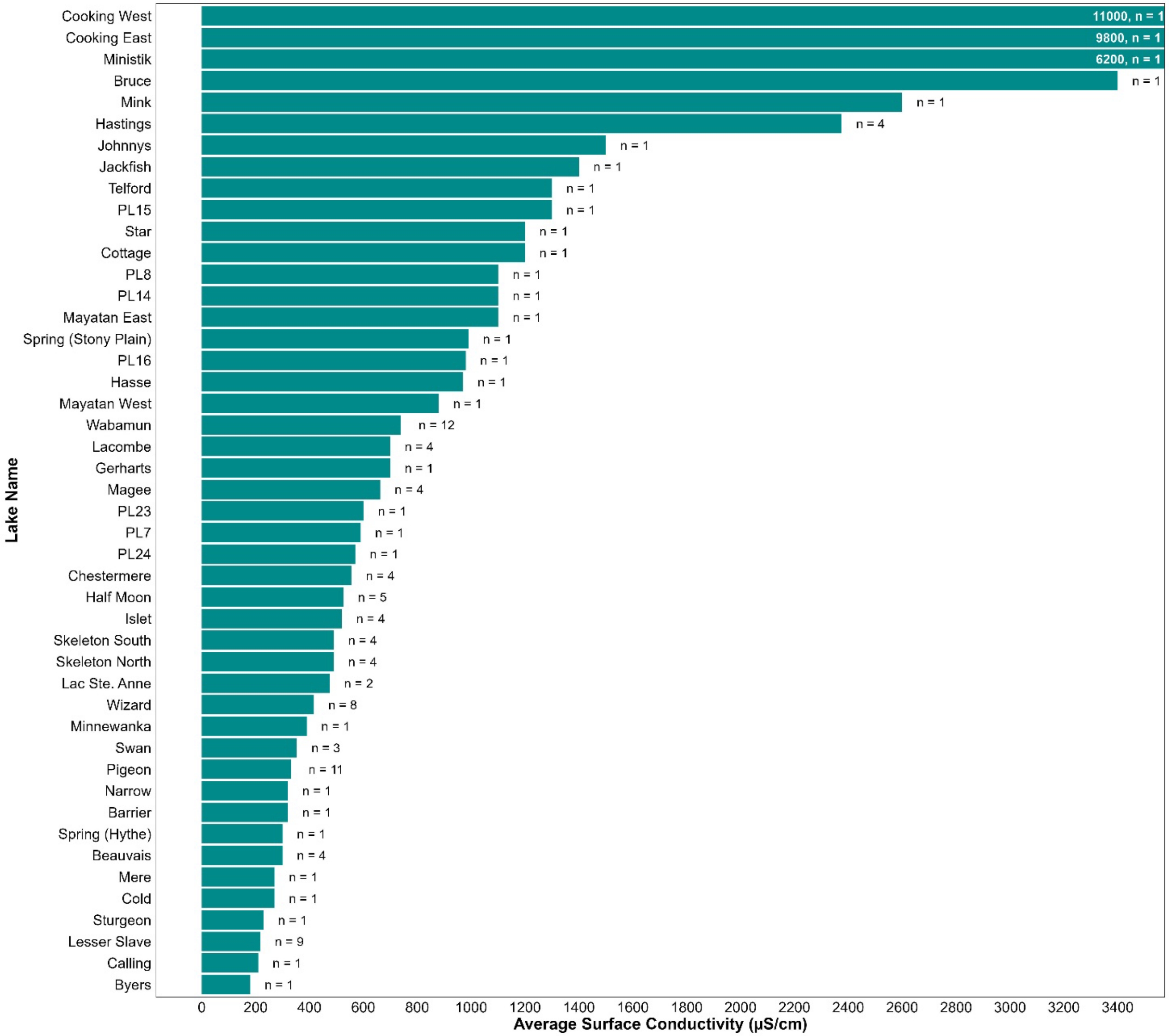
Summary



Chloride is a salt which at high levels can negatively impact lake organisms. It can vary in lakes due to groundwater connectivity, watershed geology, lake surface area, as well as pollution from road salts. It can concentrate in lakes through the winter due to ice formation.

Figure 10. Average surface chloride(mg/L) from lakes sampled in the Winter LakeKeepers 2022-2023 season. Average surface chloride represents the average from across sample dates, if lakes had multiple sample events, and across sample locations, if lakes had multiple sampled locations (number of samples indicated by the "n" value beside each bar). Samples were taken at 0.5m at the sampling location, between November 2022 and April 2023. Extreme outliers on the upper range (>3*IQR) are not fully plotted.

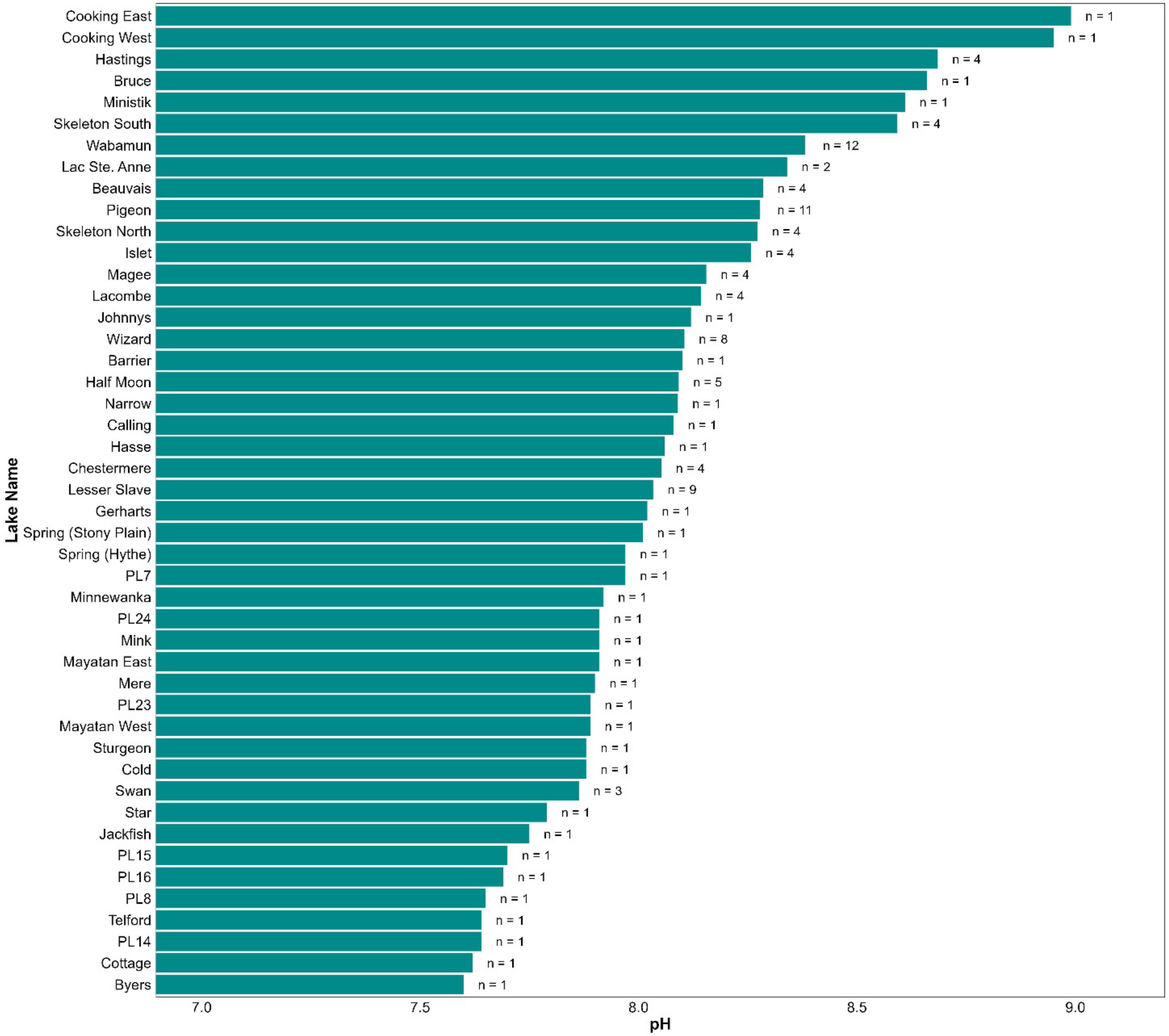
Summary



Conductivity indicates the total levels of dissolved ions or salt within water, which can impact aquatic habitat for lake organisms, and can vary in lakes due to groundwater connectivity, watershed geology, lake surface area, as well as pollution from watershed runoff. It can concentrate in lakes through the winter due to ice formation.

Figure 11. Average surface conductivity (µS/cm) from lakes sampled in the Winter LakeKeepers 2022-2023 season. Average surface conductivity represents the average from across sample dates, if lakes had multiple sample events, and across sample locations, if lakes had multiple sampled locations (number of samples indicated by the "n" value beside each bar). Samples were taken at 0.5m at the sampling location, between November 2022 and April 2023. Extreme outliers on the upper range (>3*IQR) are not fully plotted.

Summary



pH is used to understand the acidity of water and is important for evaluating fish habitat and general lake chemistry.

Figure 12. Average surface pH from lakes sampled in the Winter LakeKeepers 2022-2023 season. Average surface pH represents the average from across sample dates, if lakes had multiple sample events, and across sample locations, if lakes had multiple sampled locations (number of samples indicated by the "n" value beside each bar). Samples were taken at 0.5m at the sampling location, between November 2022 and April 2023.

Summary

LakeKeepers

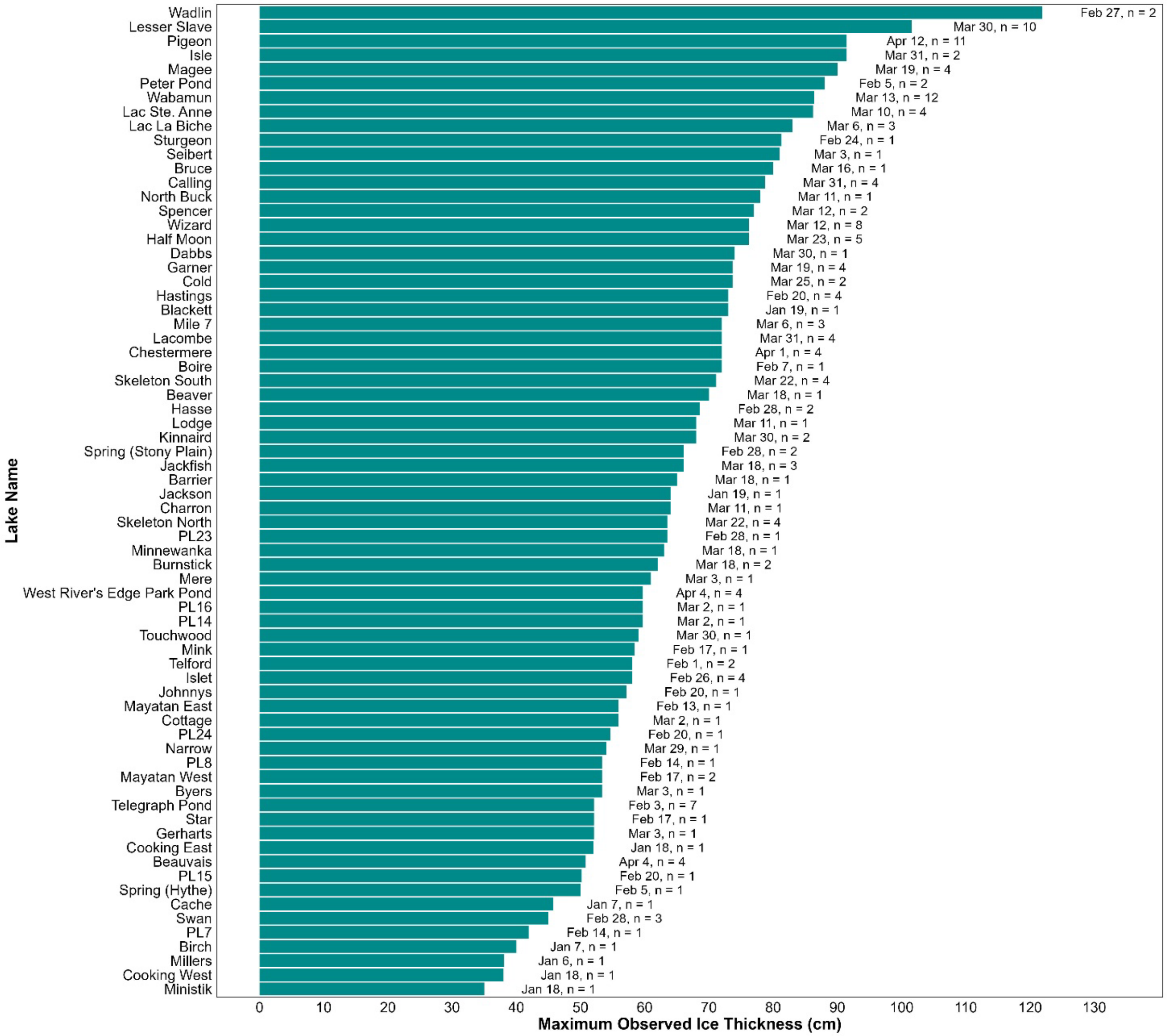
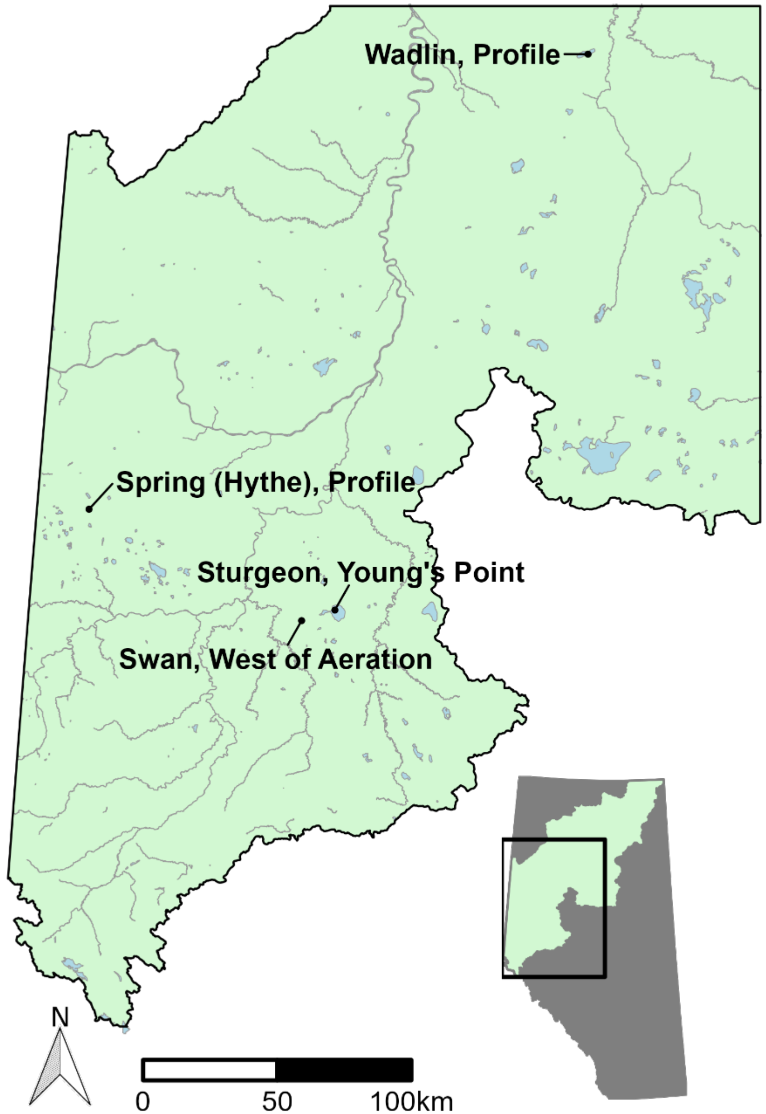


Figure 13. Maximum observed ice thickness from lakes sampled in the Winter LakeKeepers 2022-2023 season. Maximum observed ice thickness represents the greatest thickness of ice from each lake, with the sample date where this measurement took place is referenced beside the bar, as well as number of measurements from that lake the entire season indicated by the "n =". Measurements were taken between November 2022 and April 2023.

Peace River Watershed

LakeKeepers



Map 2. Lakes sampled in the Peace River watershed during the Winter LakeKeepers 2022-2023 season. The Peace River watershed is highlighted in the Alberta inset map.

Peace River Watershed

Table 1. Surface water chemistry (TP = total phosphorus, TDP = total dissolved phosphorus, TKN = total Kjeldahl nitrogen, NO3+NO2 = nitrate plus nitrite, NH3 = ammonia, DOC = dissolved organic carbon, Cl- = chloride, Cond. = conductivity, ChlA = chlorophyll-*a*, MCYST = microcystin) and environmental measurements (Air Temp. = air temperature) recorded at lakes in the Peace River watershed in the Winter LakeKeepers 2022-2023 season. Microcystin values above the recreational guideline of 10 µg/L are colored red.

	TP (µg/L)	TDP (µg/L)	TKN (mg/L)	NO3 + NO2 (µg/L)	NH3 (µg/L)	DOC (mg/L)	Cl- (mg/L)	Cond. (µS/cm)	pH	ChlA (µg/L)	MCYST (µg/L)	Air Temp. (°C)	Snow Depth (cm)	Ice Thickness (cm)	White Ice Thickness (cm)
Spring (Hythe), Profile															
Feb 5	12.0	10.0	0.8	230.0	58.0	11.0	<1.0	300	7.97	1.2	-	4	15	50	15
Sturgeon, Young's Point															
Feb 24	55.0	55.0	1.4	200.0	150.0	17.0	8.5	230	7.88	<0.3	-	−34	15	81	8
Swan, West of Aeration															
Jan 25	120.0	27.0	2.1	340.0	370.0	21.0	1.3	350	7.81	0.8	-	2	16	39	10
Feb 28	130.0	120.0	1.8	590.0	170.0	23.0	1.3	360	7.93	1.0	-	−14	14	45	17
Mar 28	130.0	65.0	1.9	660.0	47.0	19.0	1.1	350	7.85	3.1	-	−4	5	28	13
Wadlin, Profile															
Feb 27	79.0	-	0.8	-	-	-	-	-	-	-	-	−15	30	122	0
Mar 24	95.0	-	0.8	-	-	-	-	-	-	-	-	−6	46	107	0

Peace River Watershed

LakeKeepers

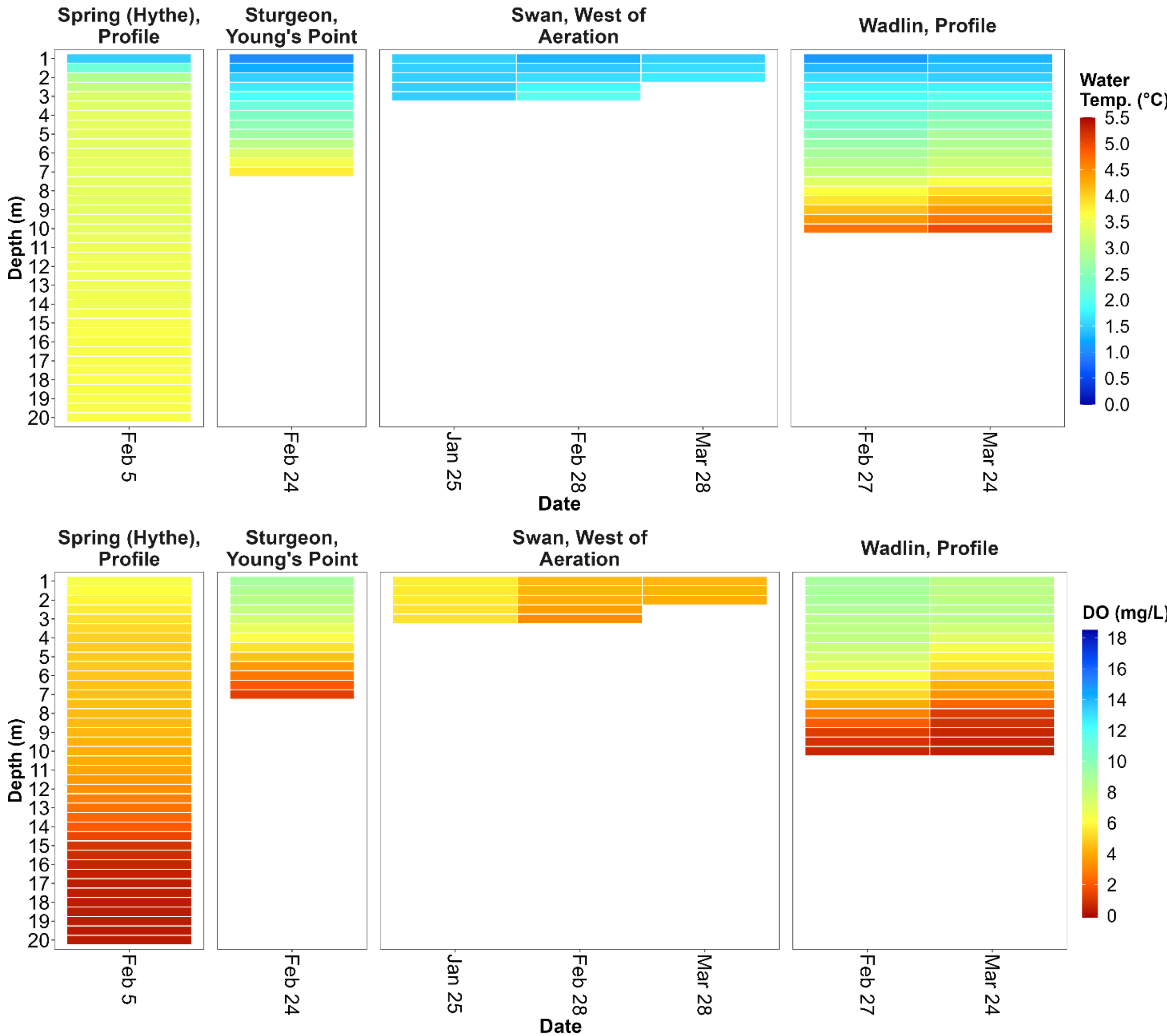


Figure 14. Water temperature (Water Temp.; °C) and dissolved oxygen (DO; mg/L) measurements recorded at lakes sampled in the Peace River watershed in the Winter LakeKeepers 2022-2023 season. Measurements were taken at 0.1m and 0.5m, then every meter starting at 1 meter from ice surface, until lake bottom, however only measurements at 1m and below are plotted. Note that the measurements are linearly interpolated to 0.5m increments to improve data visualization.

Peace River Watershed

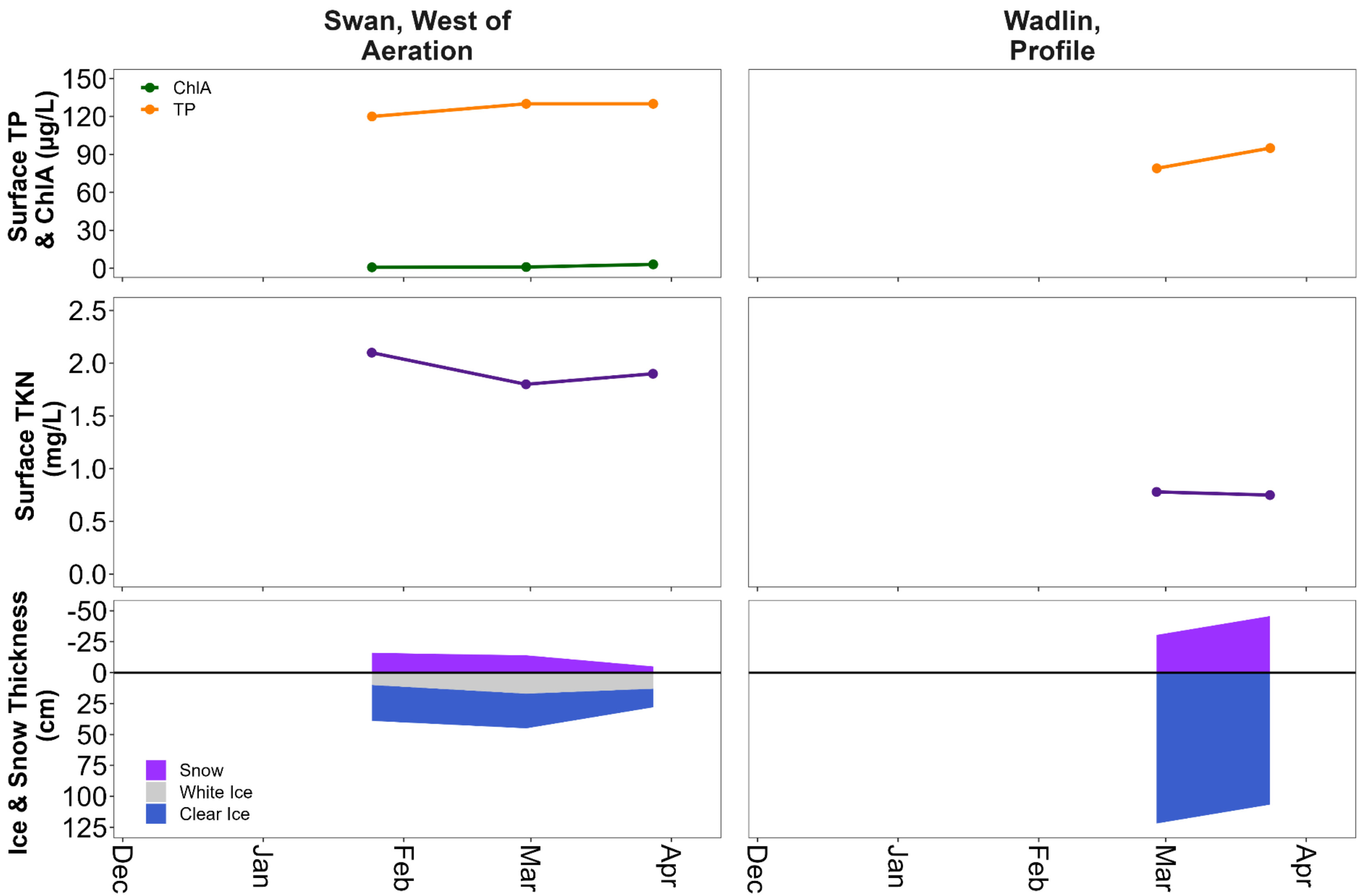
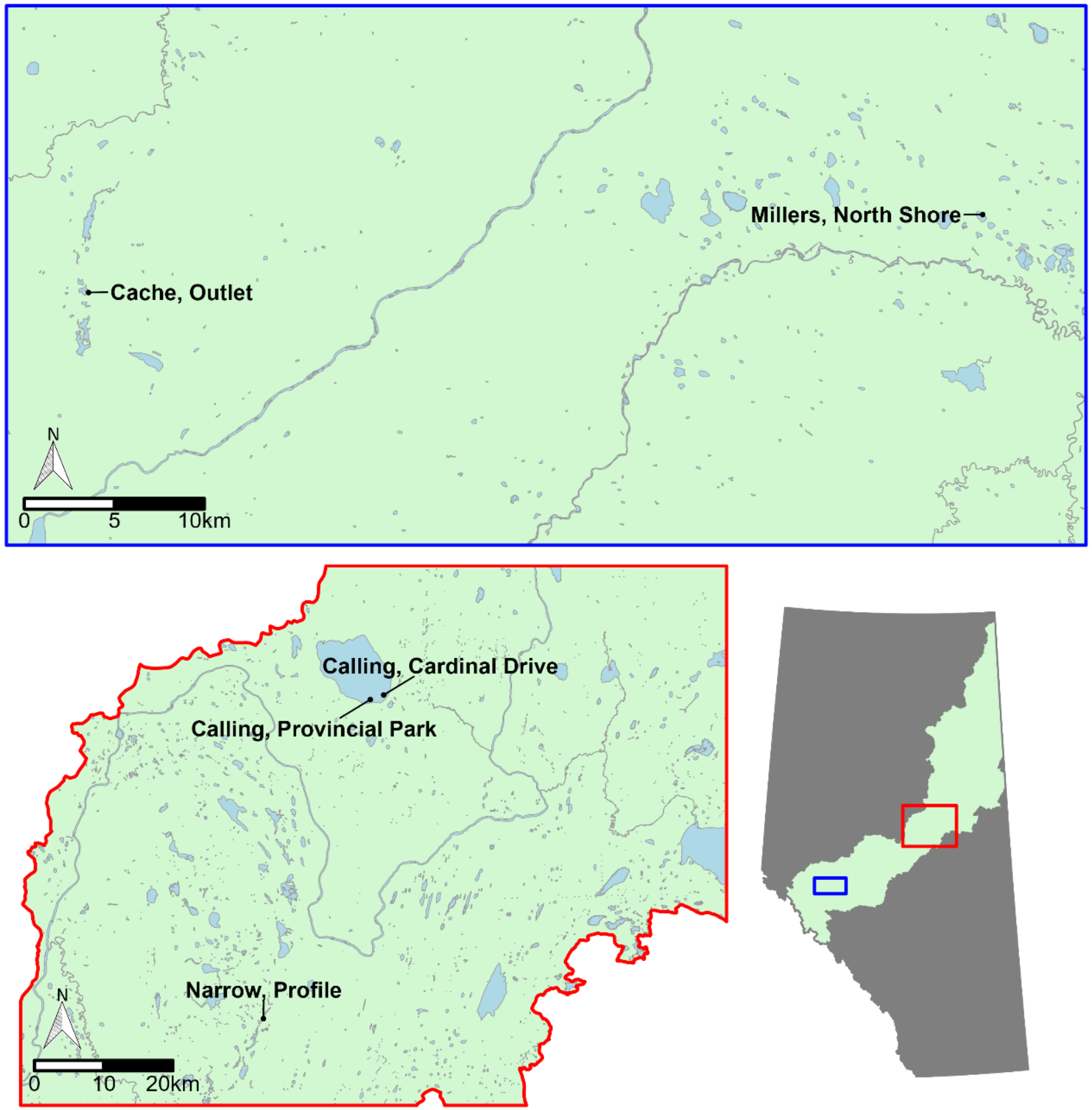


Figure 15. Seasonal surface water chemistry (TP = total phosphorus and ChlA = chlorophyll-a, Top; TKN = total Kjeldahl nitrogen, middle) and ice (clear and white) and snow thickness(bottom) from lakes sampled in the Peace River watershed in the Winter LakeKeepers 2022 season. In the top panel, TP is orange and ChlA is green, TKN in the middle section is purple, and in the bottom section snow is pick, white ice is gray, and clear ice is blue. Note that ice and snow thickness is plotted in reference to the ice surface (horizontal black line).

Athabasca River Watershed

Map 3a. Lakes sampled in the Lac La Biche region of the Athabasca River watershed during the Winter LakeKeepers 2022-2023 season. The Athabasca River watershed is highlighted in the Alberta inset map.

Athabasca River Watershed



Map 3b. Lakes sampled in a western region (blue outline) and a central region (red outline) of the Athabasca River watershed during the Winter LakeKeepers 2022-2023 season. The Athabasca River watershed is highlighted in the Alberta inset map

Athabasca River Watershed

Table 2. Surface water chemistry (TP = total phosphorus, TDP = total dissolved phosphorus, TKN = total Kjeldahl nitrogen, NO3+NO2 = nitrate plus nitrite, NH3 = ammonia, DOC = dissolved organic carbon, Cl- = chloride, Cond. = conductivity, ChlA = chlorophyll-*a*, MCYST = microcystin) and environmental measurements (Air Temp. = air temperature) recorded at lakes in the Athabasca River watershed in the Winter LakeKeepers 2022-2023 season. Microcystin values above the recreational guideline of 10 µg/L are colored red.

	TP (µg/L)	TDP (µg/L)	TKN (mg/L)	NO3 + NO2 (µg/L)	NH3 (µg/L)	DOC (mg/L)	Cl- (mg/L)	Cond. (µS/cm)	pH	ChlA (µg/L)	MCYST (µg/L)	Air Temp. (°C)	Snow Depth (cm)	Ice Thickness (cm)	White Ice Thickness (cm)
Blackett, West Shore															
Jan 19	25.0	-	1.9	-	-	-	-	-	-	-	-	−4	35	73	11
Cache, Outlet															
Jan 7	8.2	-	0.3	-	-	-	-	-	-	-	-	−5	30	46	5
Calling, Cardinal Drive															
Jan 7	43.0	-	0.8	-	-	-	-	-	-	-	-	−17	20	61	0
Feb 12	41.0	-	0.7	-	-	-	-	-	-	-	-	−5	23	66	0
Mar 31	42.0	-	0.8	-	-	-	-	-	-	-	-	−4	15	79	0
Calling, Provincial Park															
Feb 22	44.0	44.0	0.7	140.0	21.0	12.0	<1.0	210	8.08	0.6	-	−37	30	66	0
Charron, South Side															
Mar 11	120.0	-	3.7	-	-	-	-	-	-	-	-	−4	25	64	10
Dabbs, North Island															
Mar 30	13.0	-	1.7	-	-	-	-	-	-	-	-	−6	19	74	14
Jackson, West Basin															
Jan 19	15.0	-	1.2	-	-	-	-	-	-	-	-	−4	35	64	9
Kinnaird, South End															
Dec 30	17.0	-	1.1	-	-	-	-	-	-	-	-	−9	39	48	3
Kinnaird, North Island															
Mar 30	23.0	-	1.1	-	-	-	-	-	-	-	-	−8	35	68	8
Lac La Biche, Golden Sands S															
Dec 16	99.0	-	0.9	-	-	-	-	-	-	-	-	−10	6	53	3
Lac La Biche, Currant Island East															
Jan 9	110.0	-	0.8	-	-	-	-	-	-	-	-	−10	29	66	2
Lac La Biche, Golden Sands															
Mar 6	110.0	-	0.8	-	-	-	-	-	-	-	-	−6	41	83	0
Lodge, Boat Launch															
Mar 11	26.0	-	1.2	-	-	-	-	-	-	-	-	−5	18	68	20
Mile 7, East Side															
Dec 17	19.0	-	1.3	-	-	-	-	-	-	-	-	−15	27	40	0
Jan 10	20.0	-	1.4	-	-	-	-	-	-	-	-	−10	40	62	29
Mar 6	23.0	-	1.6	-	-	-	-	-	-	-	-	−16	43	72	14
Millers, North Shore															
Jan 6	5.5	-	1.3	-	-	-	-	-	-	-	-	−7	30	38	1
Narrow, Profile															
Mar 29	6.6	4.2	0.5	64.0	<15.0	9.5	<1.0	320	8.09	1.9	-	2	6	54	0

Athabasca River Watershed

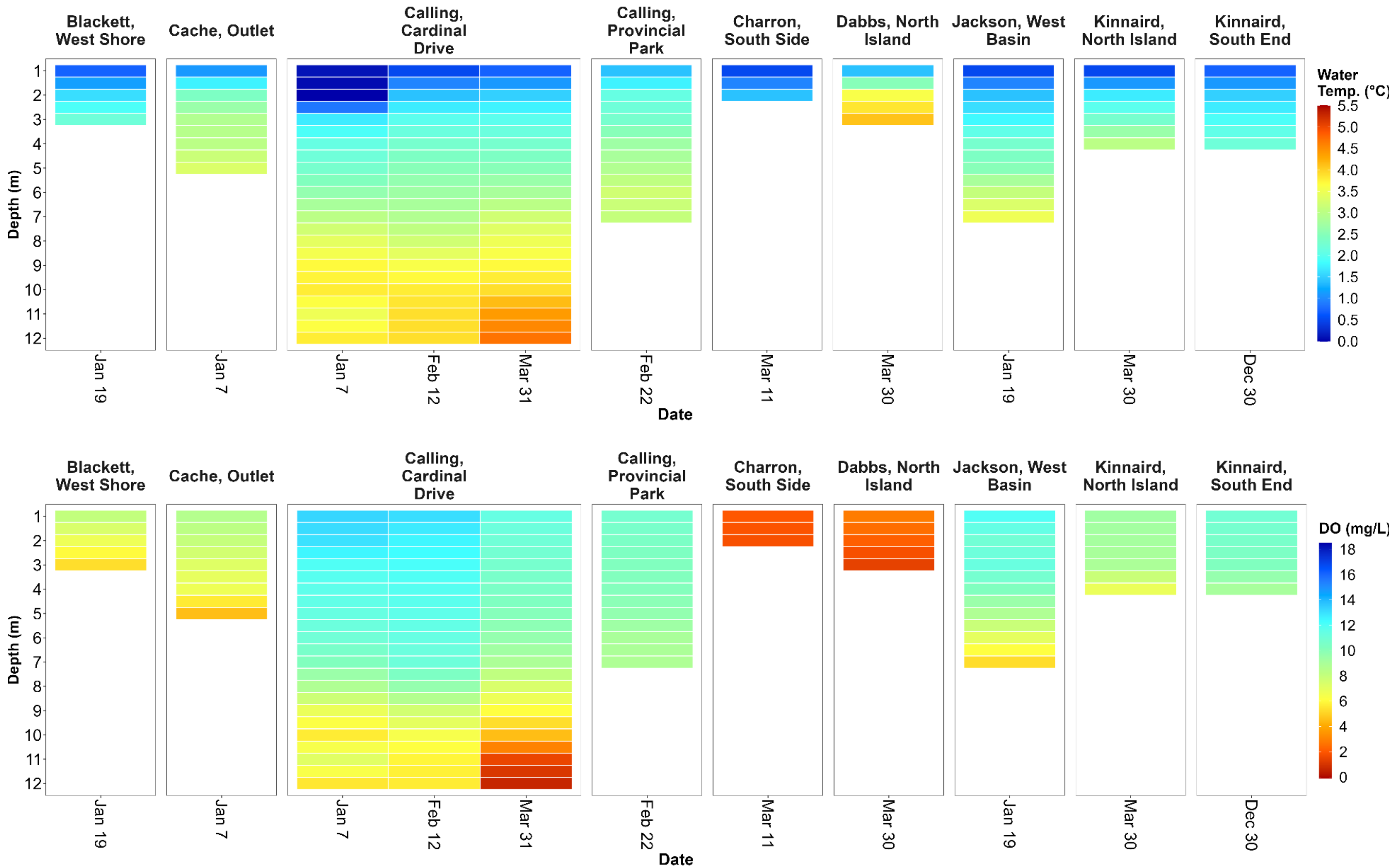


Figure 16a. Water temperature (Water Temp.; °C) and dissolved oxygen (DO; mg/L) measurements recorded at lakes sampled in the Athabasca River watershed in the Winter LakeKeepers 2022-2023 season. Measurements were taken at 0.1m and 0.5m, then every meter starting at 1 meter from ice surface, until lake bottom, however only measurements at 1m and below are plotted. Note that the measurements are linearly interpolated to 0.5m increments to improve data visualization.

Athabasca River Watershed

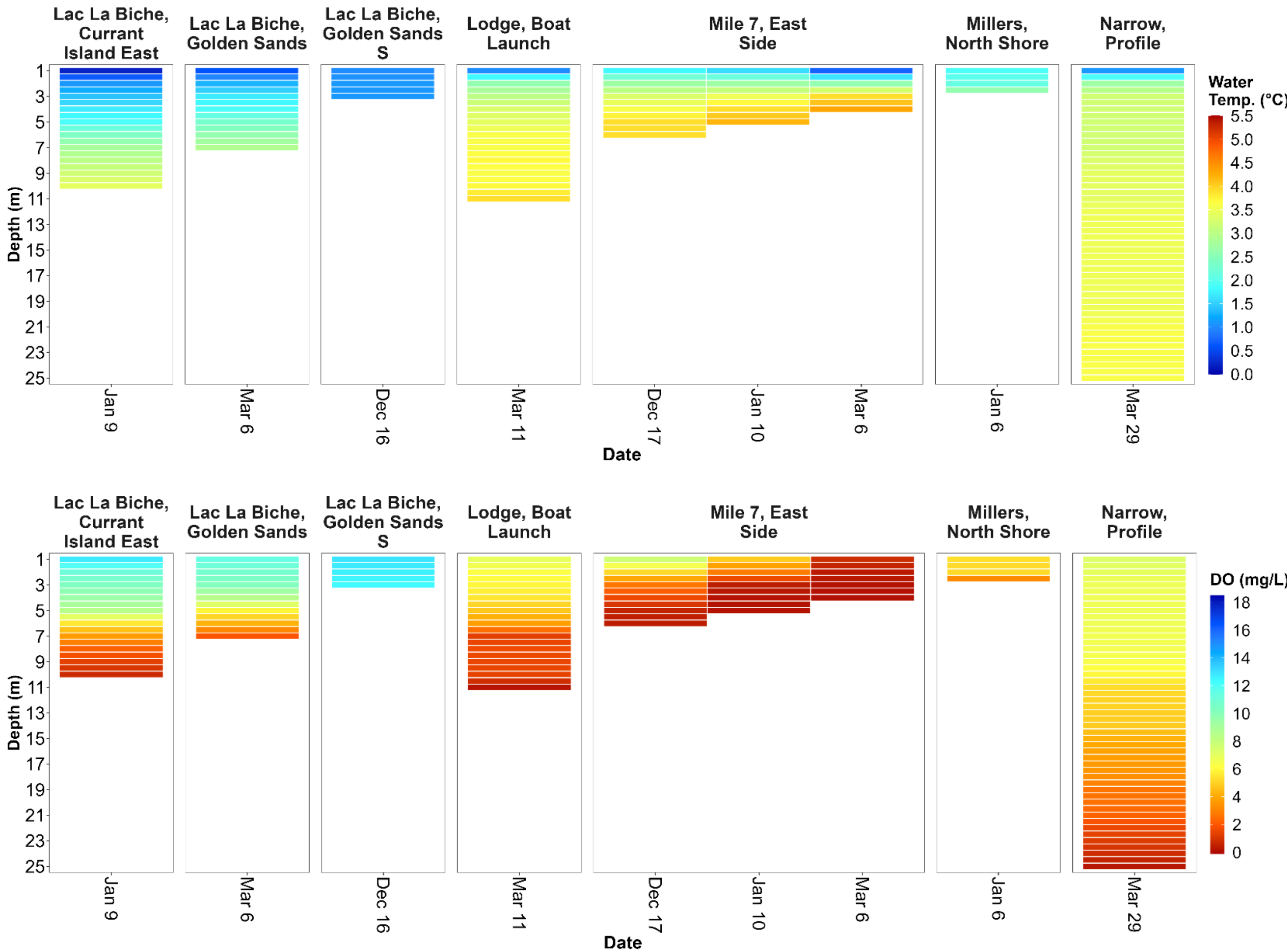


Figure 16b. Water temperature (Water Temp.; °C) and dissolved oxygen (DO; mg/L) measurements recorded at lakes sampled in the Athabasca River watershed in the Winter LakeKeepers 2022-2023 season. Measurements were taken at 0.1m and 0.5m, then every meter starting at 1 meter from ice surface, until lake bottom, however only measurements at 1m and below are plotted. Note that the measurements are linearly interpolated to 0.5m increments to improve data visualization.

Athabasca River Watershed

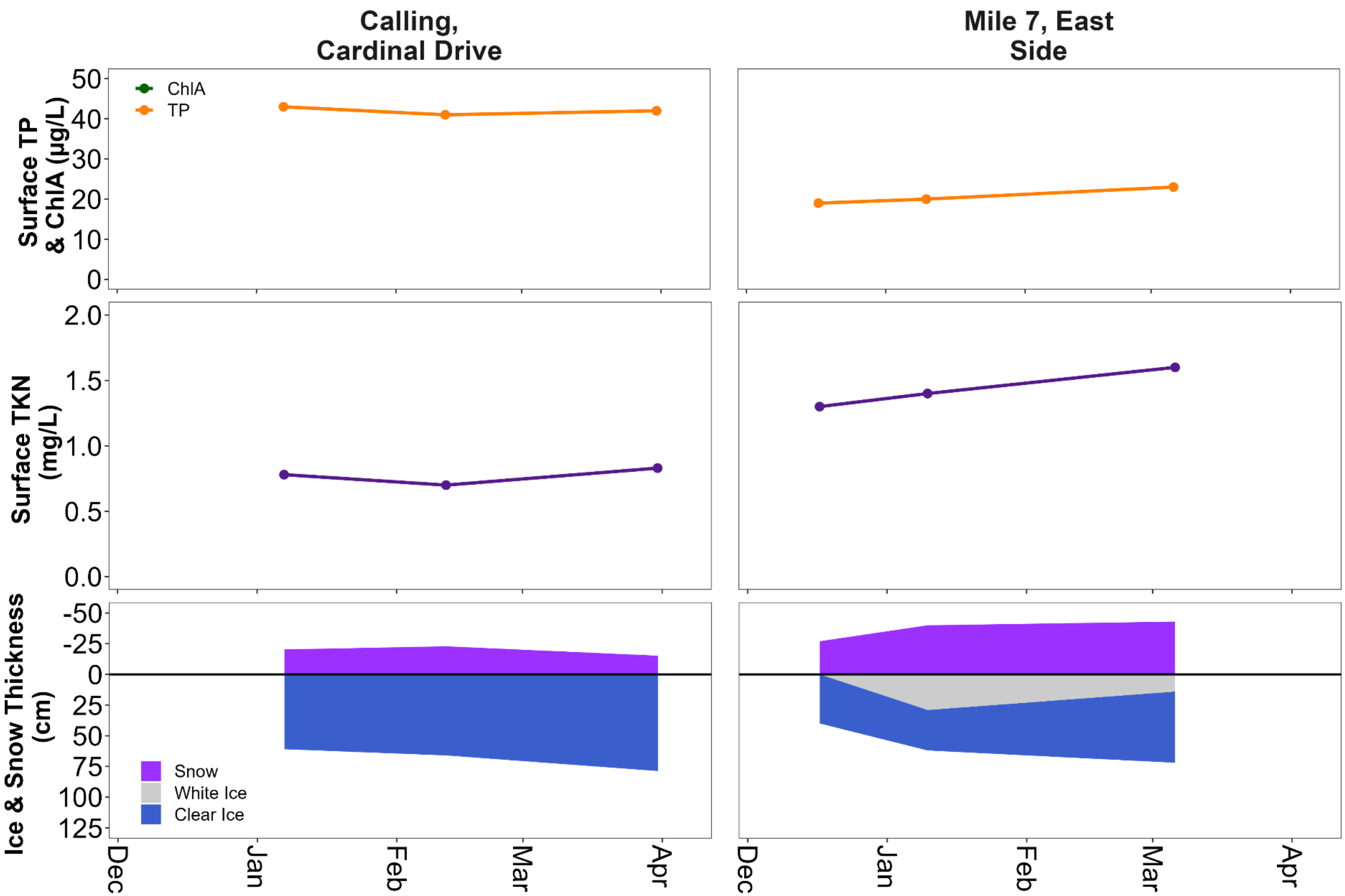
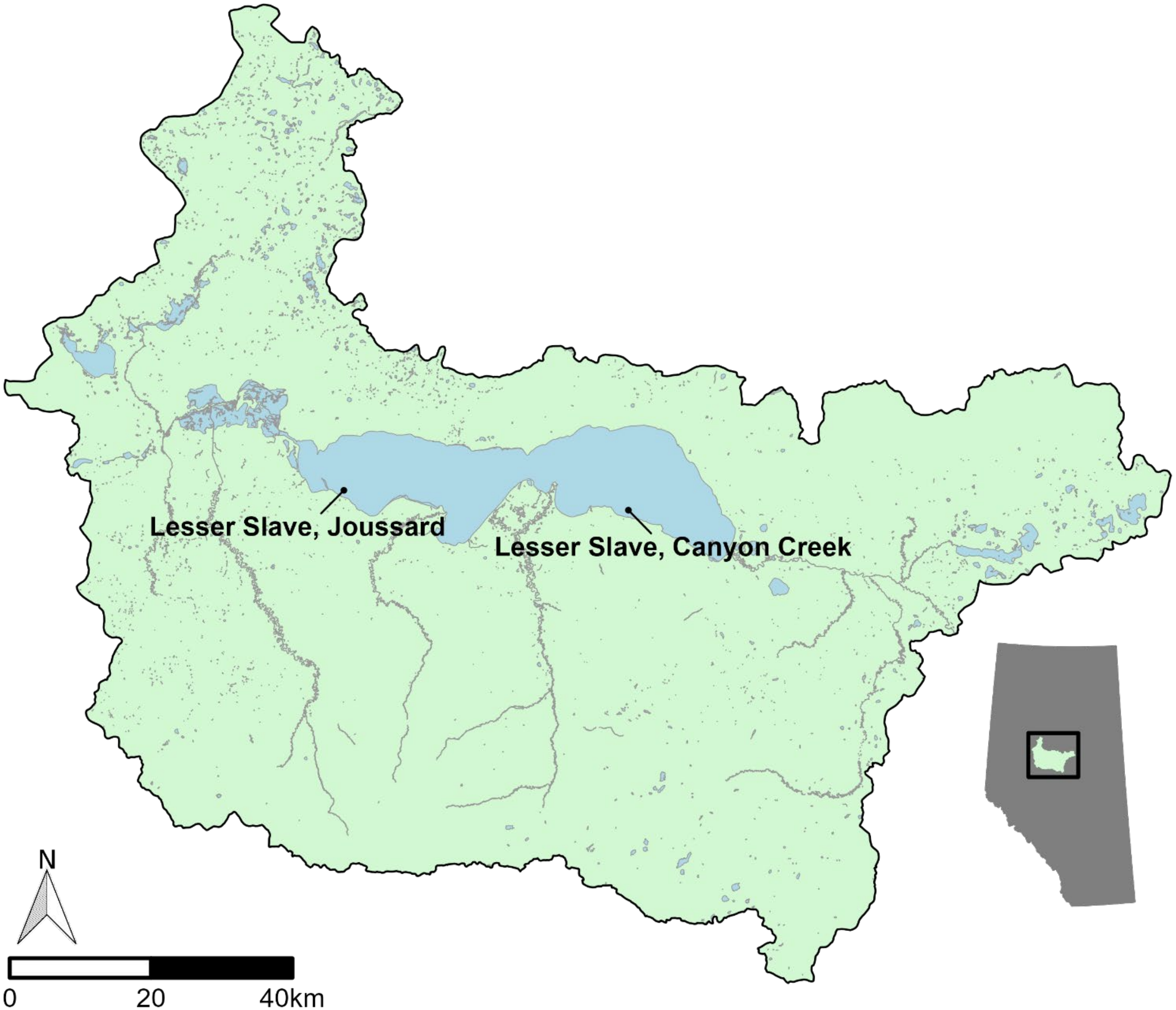


Figure 17. Seasonal surface water chemistry (TP = total phosphorus and ChlA = chlorophyll-a, Top; TKN = total Kjeldahl nitrogen, middle) and ice (clear and white) and snow thickness(bottom) from lakes sampled in the Athabasca River watershed in the Winter LakeKeepers 2022 season. In the top panel, TP is orange and ChlA is green, TKN in the middle section is purple, and in the bottom section snow is pick, white ice is gray, and clear ice is blue. Note that ice and snow thickness is plotted in reference to the ice surface (horizontal black line).

Lesser Slave Lake Watershed



Map 4. Lakes sampled in the Lesser Slave Lake watershed during the Winter LakeKeepers 2022-2023 season. The Lesser Slave Lake watershed is highlighted in the Alberta inset map.

Lesser Slave Lake Watershed

Table 3. Surface water chemistry (TP = total phosphorus, TDP = total dissolved phosphorus, TKN = total Kjeldahl nitrogen, NO3+NO2 = nitrate plus nitrite, NH3 = ammonia, DOC = dissolved organic carbon, Cl- = chloride, Cond. = conductivity, ChlA = chlorophyll-*a*, MCYST = microcystin) and environmental measurements (Air Temp. = air temperature) recorded at lakes in the Lesser Slave Lake watershed in the Winter LakeKeepers 2022-2023 season. Microcystin values above the recreational guideline of 10 µg/L are colored red.

	TP (µg/L)	TDP (µg/L)	TKN (mg/L)	NO3 + NO2 (µg/L)	NH3 (µg/L)	DOC (mg/L)	Cl- (mg/L)	Cond. (µS/cm)	pH	ChlA (µg/L)	MCYST (µg/L)	Air Temp. (°C)	Snow Depth (cm)	Ice Thickness (cm)	White Ice Thickness (cm)
Lesser Slave, Canyon Creek															
Jan 5	5.7	4.0	0.6	16.0	43.0	12.0	2.2	200	8.10	1.0	-	−12	25	66	0
Feb 6	12.0	9.1	0.6	21.0	29.0	11.0	2.1	210	8.07	2.4	-	−2	5	81	0
Feb 22	5.2	3.3	0.5	30.0	<15.0	10.0	1.0	200	8.07	2.7	-	−21	8	84	15
Feb 23	-	-	-	-	-	-	-	-	-	-	-	−25	8	84	15
Mar 2	7.2	3.2	0.6	23.0	21.0	10.0	2.1	200	8.03	1.4	-	3	15	94	8
Mar 30	7.0	3.5	0.6	32.0	29.0	10.0	<1.0	200	8.03	2.2	-	1	5	102	15
Lesser Slave, Joussard															
Jan 5	10.0	7.9	1.0	69.0	150.0	14.0	2.2	240	7.99	0.6	-	−13	30	61	20
Feb 6	12.0	11.0	0.9	88.0	140.0	15.0	1.9	240	8.09	0.6	-	−2	5	81	0
Mar 2	14.0	8.4	0.9	160.0	57.0	13.0	2.4	230	7.93	1.1	-	3	15	94	8
Mar 30	27.0	6.5	0.9	200.0	29.0	12.0	1.2	240	7.99	2.2	-	0	25	91	20

Lesser Slave Lake Watershed

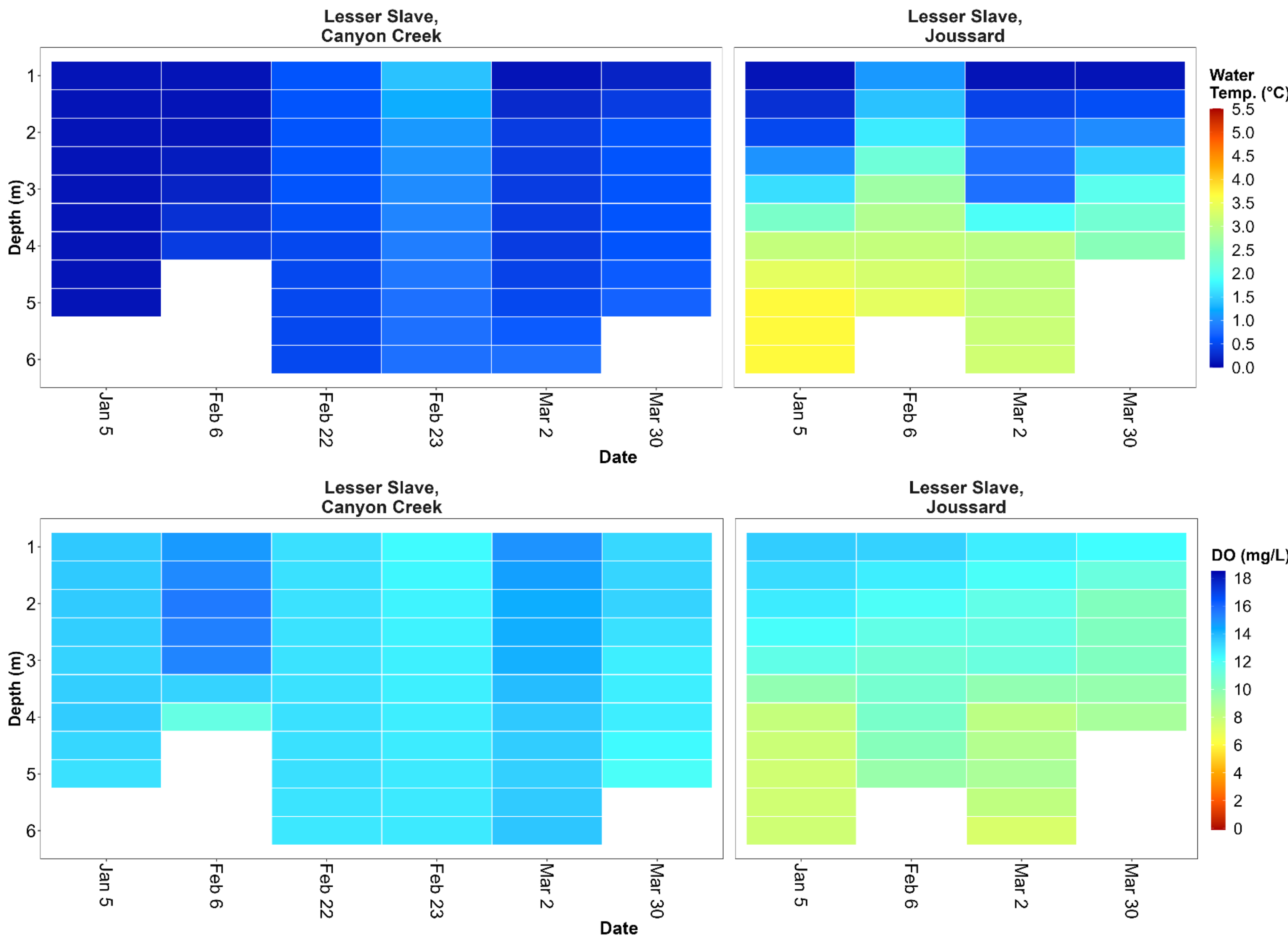


Figure 18. Water temperature (Water Temp.; °C) and dissolved oxygen (DO; mg/L) measurements recorded at lakes sampled in the Lesser Slave Lake watershed in the Winter LakeKeepers 2022-2023 season. Measurements were taken at 0.1m and 0.5m, then every meter starting at 1 meter from ice surface, until lake bottom, however only measurements at 1m and below are plotted. Note that the measurements are linearly interpolated to 0.5m increments to improve data visualization.

Lesser Slave Lake Watershed

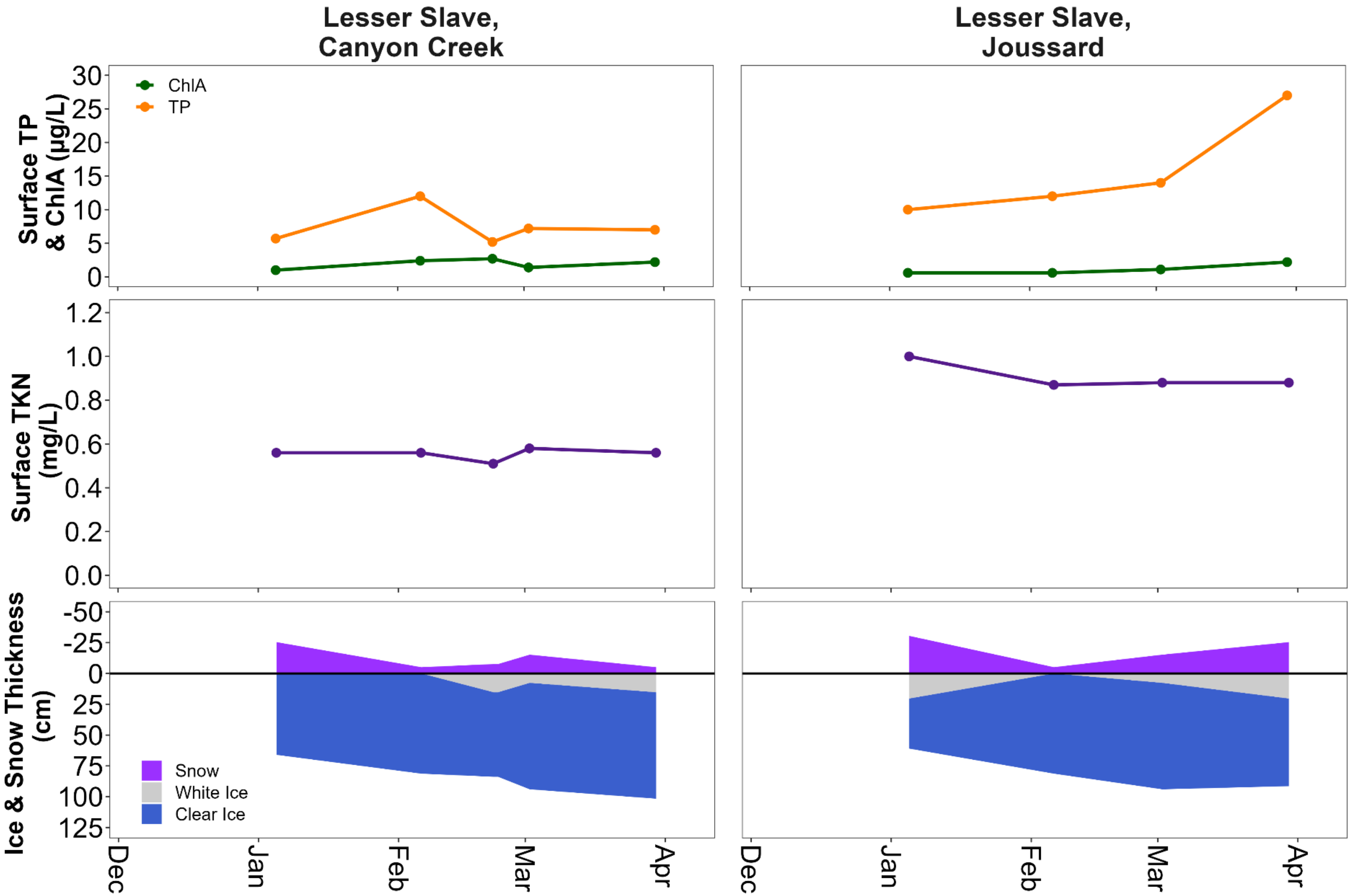
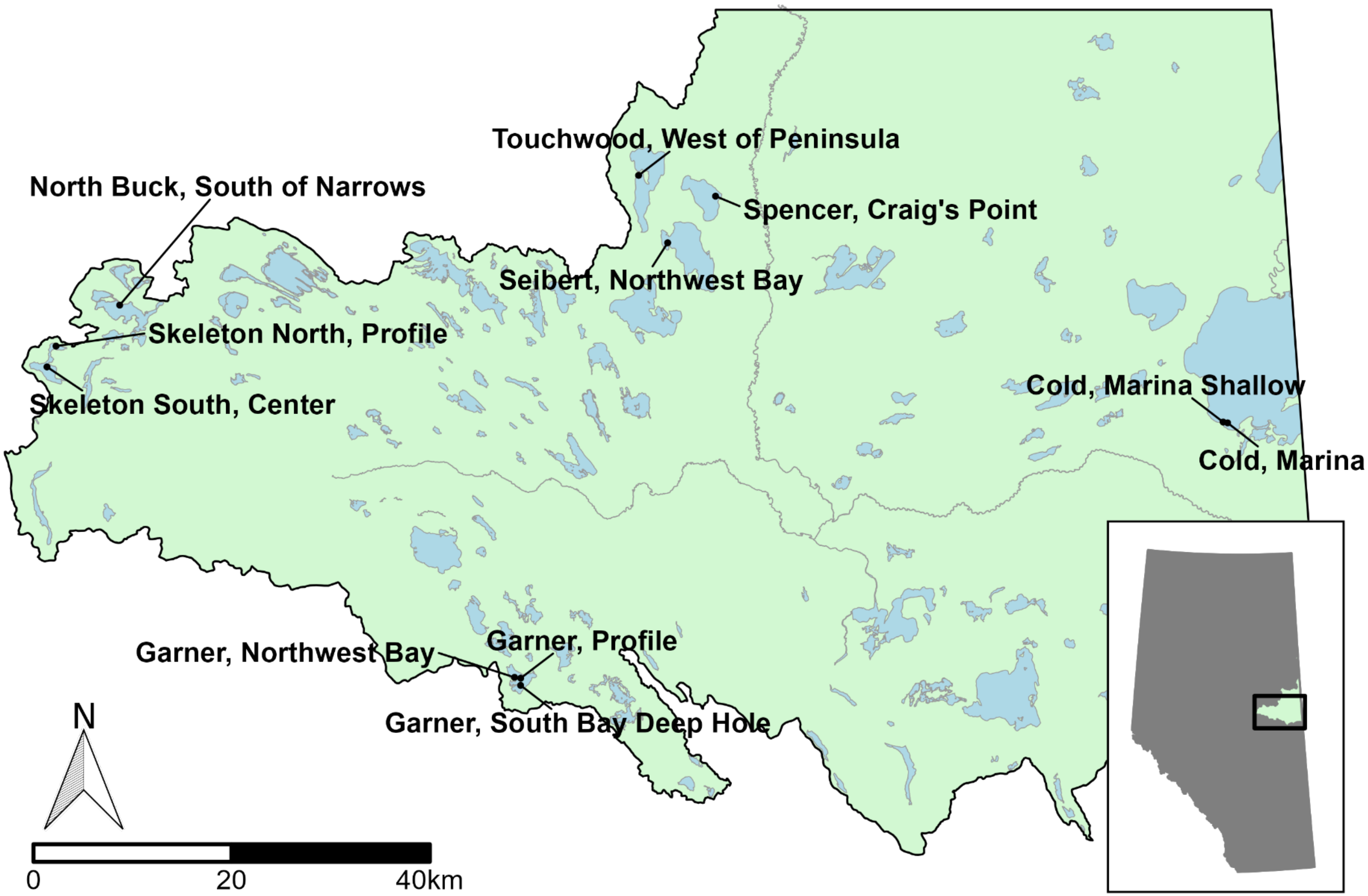


Figure 19. Seasonal surface water chemistry (TP = total phosphorus and ChlA = chlorophyll-a, Top; TKN = total Kjeldahl nitrogen, middle) and ice (clear and white) and snow thickness(bottom) from lakes sampled in the Lesser Slave Lake watershed in the Winter LakeKeepers 2022 season. In the top panel, TP is orange and ChlA is green, TKN in the middle section is purple, and in the bottom section snow is pick, white ice is gray, and clear ice is blue. Note that ice and snow thickness is plotted in reference to the ice surface (horizontal black line).

Beaver River Watershed



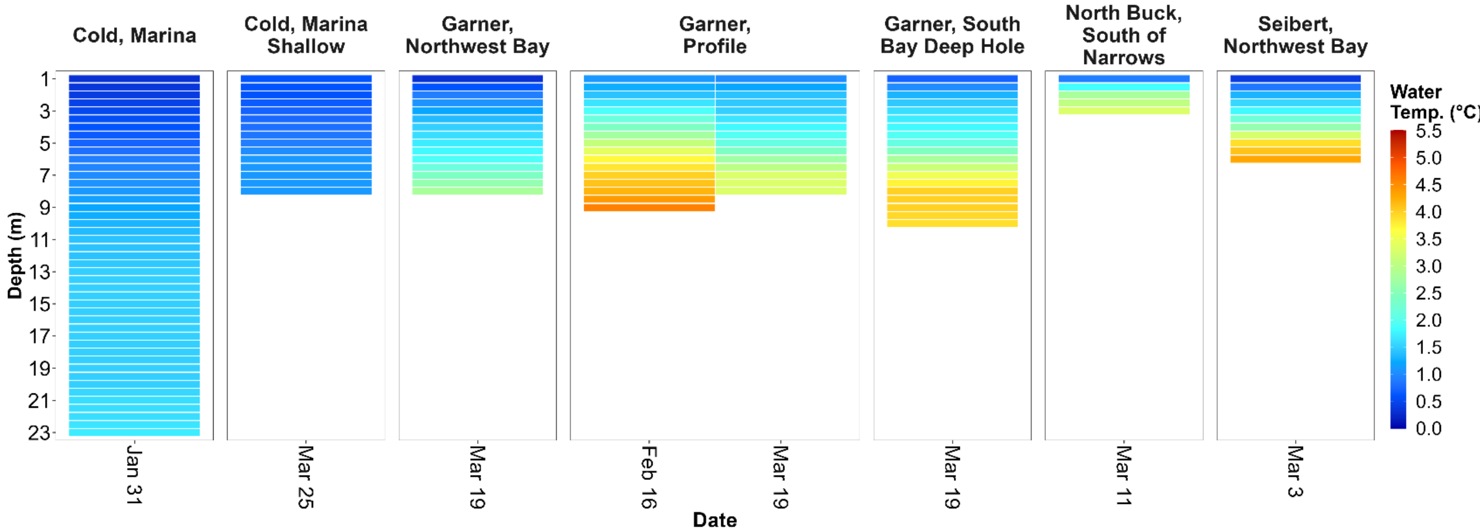
Map 5. Lakes sampled in the Beaver River watershed during the Winter LakeKeepers 2022-2023 season. The Beaver River watershed is highlighted in the Alberta inset map.

Beaver River Watershed

Table 4. Surface water chemistry (TP = total phosphorus, TDP = total dissolved phosphorus, TKN = total Kjeldahl nitrogen, NO3+NO2 = nitrate plus nitrite, NH3 = ammonia, DOC = dissolved organic carbon, Cl- = chloride, Cond. = conductivity, ChlA = chlorophyll-*a*, MCYST = microcystin) and environmental measurements (Air Temp. = air temperature) recorded at lakes in the Beaver River watershed in the Winter LakeKeepers 2022-2023 season. Microcystin values above the recreational guideline of 10 µg/L are colored red.

	TP (µg/L)	TDP (µg/L)	TKN (mg/L)	NO3 + NO2 (µg/L)	NH3 (µg/L)	DOC (mg/L)	Cl- (mg/L)	Cond. (µS/cm)	pH	ChlA (µg/L)	MCYST (µg/L)	Air Temp. (°C)	Snow Depth (cm)	Ice Thickness (cm)	White Ice Thickness (cm)
Cold, Marina															
Jan 31	17.0	-	0.5	-	-	-	-	-	-	-	-	−15	4	65	5
Cold, Marina Shallow															
Mar 25	17.0	15.0	0.4	85.0	<15.0	7.2	<1.0	270	7.88	4.4	-	−1	15	74	15
Garner, Profile															
Feb 16	56.0	-	3.0	-	-	-	-	-	-	-	-	−3	9	66	0
Mar 19	61.0	-	2.8	-	-	-	-	-	-	-	-	2	13	74	0
Garner, Northwest Bay															
Mar 19	72.0	-	2.8	-	-	-	-	-	-	-	-	2	8	74	0
Garner, South Bay Deep Hole															
Mar 19	55.0	-	2.8	-	-	-	-	-	-	-	-	2	15	61	0
North Buck, South of Narrows															
Mar 11	15.0	-	2.0	-	-	-	-	-	-	-	-	−7	12	78	16
Seibert, Northwest Bay															
Mar 3	6.9	-	1.6	-	-	-	-	-	-	-	-	−3	42	81	9
Skeleton North, Profile															
Dec 15	160.0	8.9	3.6	21.0	560.0	19.0	12.0	490	8.23	46.2	21.84	−17	5	30	0
Jan 6	310.0	13.0	4.9	18.0	470.0	21.0	11.0	470	8.27	81.8	32.65	−10	8	41	5
Feb 10	120.0	-	3.2	27.0	570.0	19.0	12.0	500	8.42	25.2	13.81	−1	5	51	9
Mar 22	200.0	11.0	3.3	100.0	610.0	22.0	12.0	500	8.17	47.6	10.01	−7	13	64	8
Skeleton South, Center															
Dec 15	17.0	13.0	1.3	7.7	77.0	17.0	9.9	480	8.71	2.5	<0.10	−17	5	41	0
Jan 6	18.0	18.0	1.5	7.3	62.0	18.0	9.7	480	8.67	1.3	0.10	−8	15	46	1
Feb 10	18.0	-	1.5	42.0	80.0	16.0	10.0	500	8.54	1.9	<0.10	1	3	61	8
Mar 22	23.0	19.0	1.6	160.0	54.0	15.0	9.6	500	8.45	2.0	<0.10	−5	13	71	8
Spencer, Craig's Point															
Dec 30	12.0	-	0.8	-	-	-	-	-	-	-	-	−10	38	50	0
Mar 12	14.0	-	0.9	-	-	-	-	-	-	-	-	−8	43	77	28
Touchwood, West of Peninsula															
Mar 30	23.0	-	0.7	-	-	-	-	-	-	-	-	−5	28	59	16

Beaver River Watershed



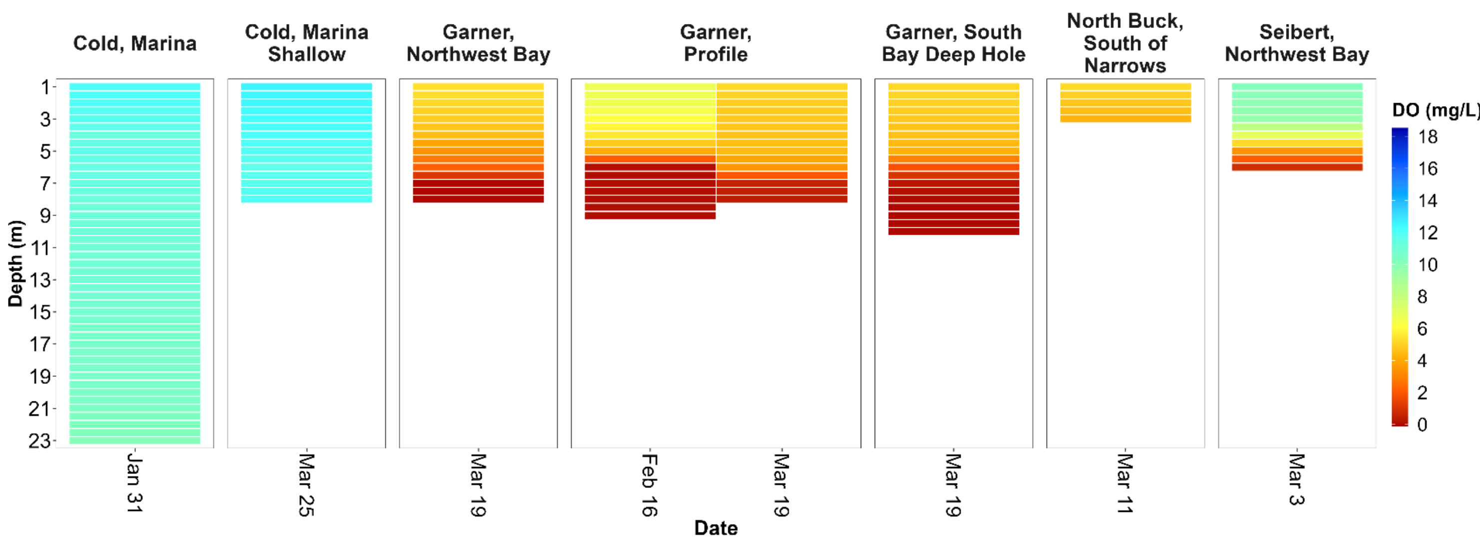


Figure 20a. Water temperature (Water Temp.; °C) and dissolved oxygen (DO; mg/L) measurements recorded at lakes sampled in the Beaver River watershed in the Winter LakeKeepers 2022-2023 season. Measurements were taken at 0.1m and 0.5m, then every meter starting at 1 meter from ice surface, until lake bottom, however only measurements at 1m and below are plotted. Note that the measurements are linearly interpolated to 0.5m increments to improve data visualization.

Beaver River Watershed

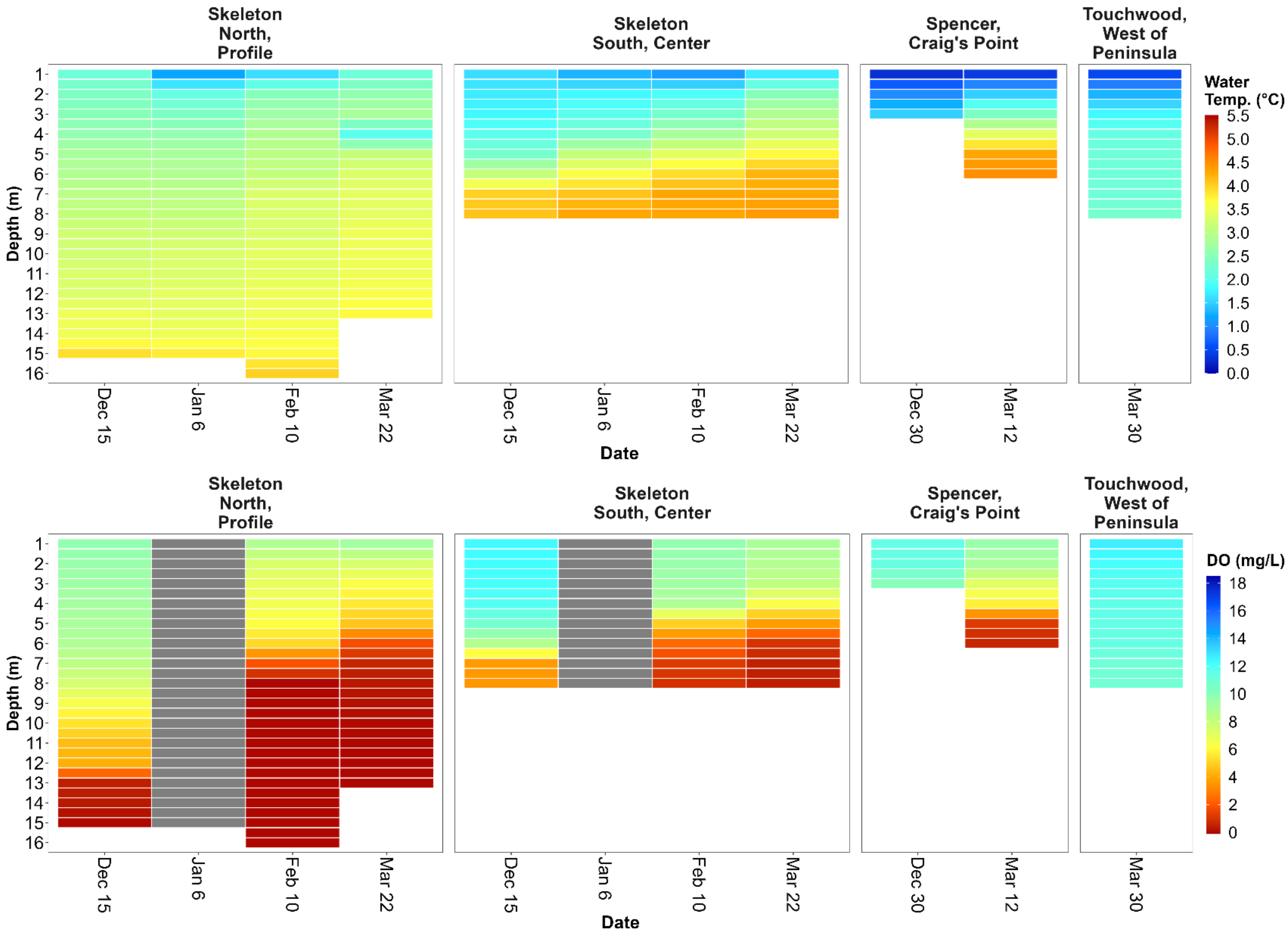


Figure 20b. Water temperature (Water Temp.; °C) and dissolved oxygen (DO; mg/L) measurements recorded at lakes sampled in the Beaver River watershed in the Winter LakeKeepers 2022-2023 season. Measurements were taken at 0.1m and 0.5m, then every meter starting at 1 meter from ice surface, until lake bottom, however only measurements at 1m and below are plotted. Note that the measurements are linearly interpolated to 0.5m increments to improve data visualization. Note that DO measurements from 'Skeleton North, Profile' and 'Skeleton South, Center' taken on January 6th, 2023 are unavailable.

Beaver River Watershed

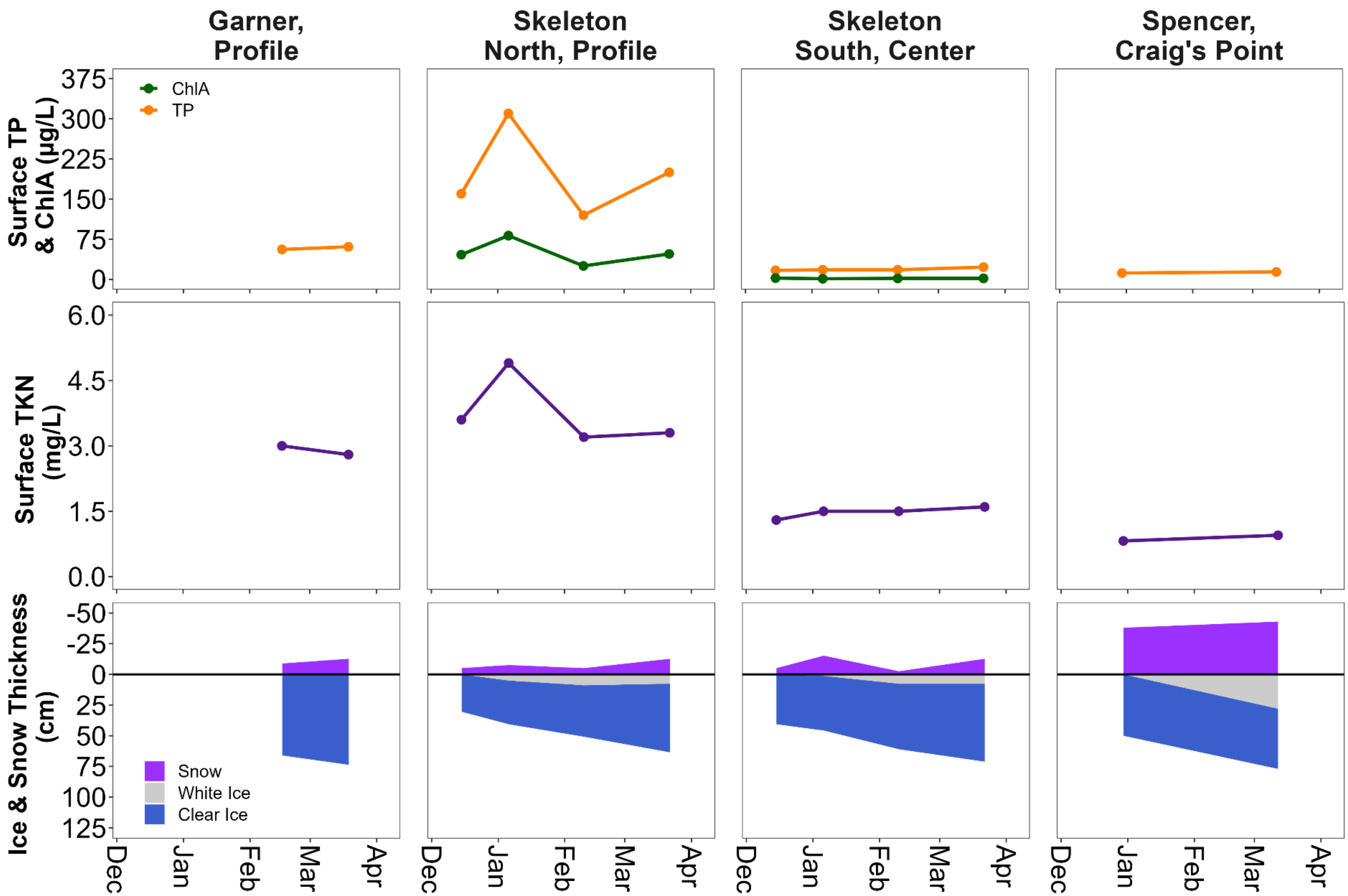
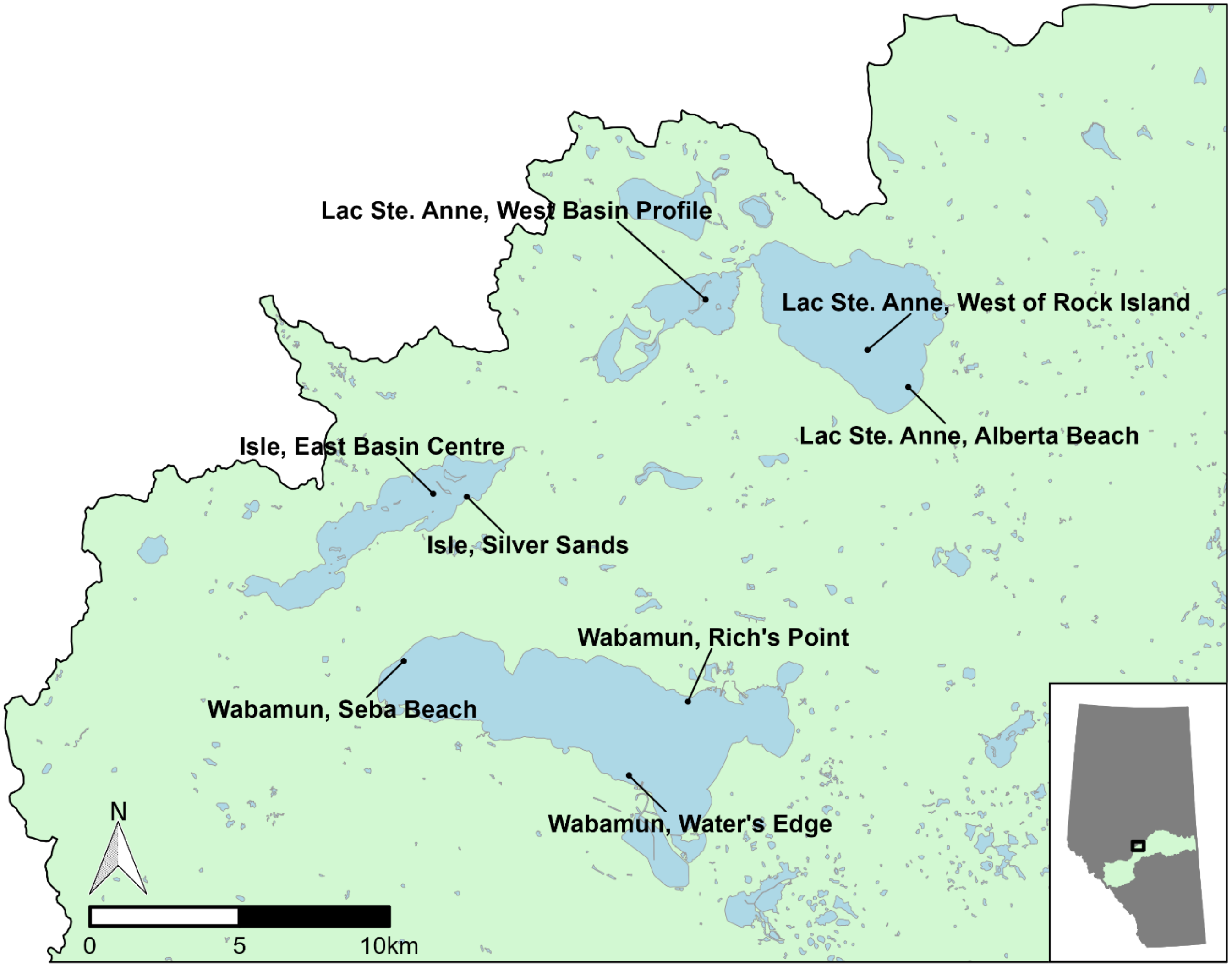


Figure 21. Seasonal surface water chemistry (TP = total phosphorus and ChlA = chlorophyll-a, Top; TKN = total Kjeldahl nitrogen, middle) and ice (clear and white) and snow thickness(bottom) from lakes sampled in the Beaver River watershed in the Winter LakeKeepers 2022 season. In the top panel, TP is orange and ChlA is green, TKN in the middle section is purple, and in the bottom section snow is pick, white ice is gray, and clear ice is blue. Note that ice and snow thickness is plotted in reference to the ice surface (horizontal black line).

North Saskatchewan River Watershed

LakeKeepers

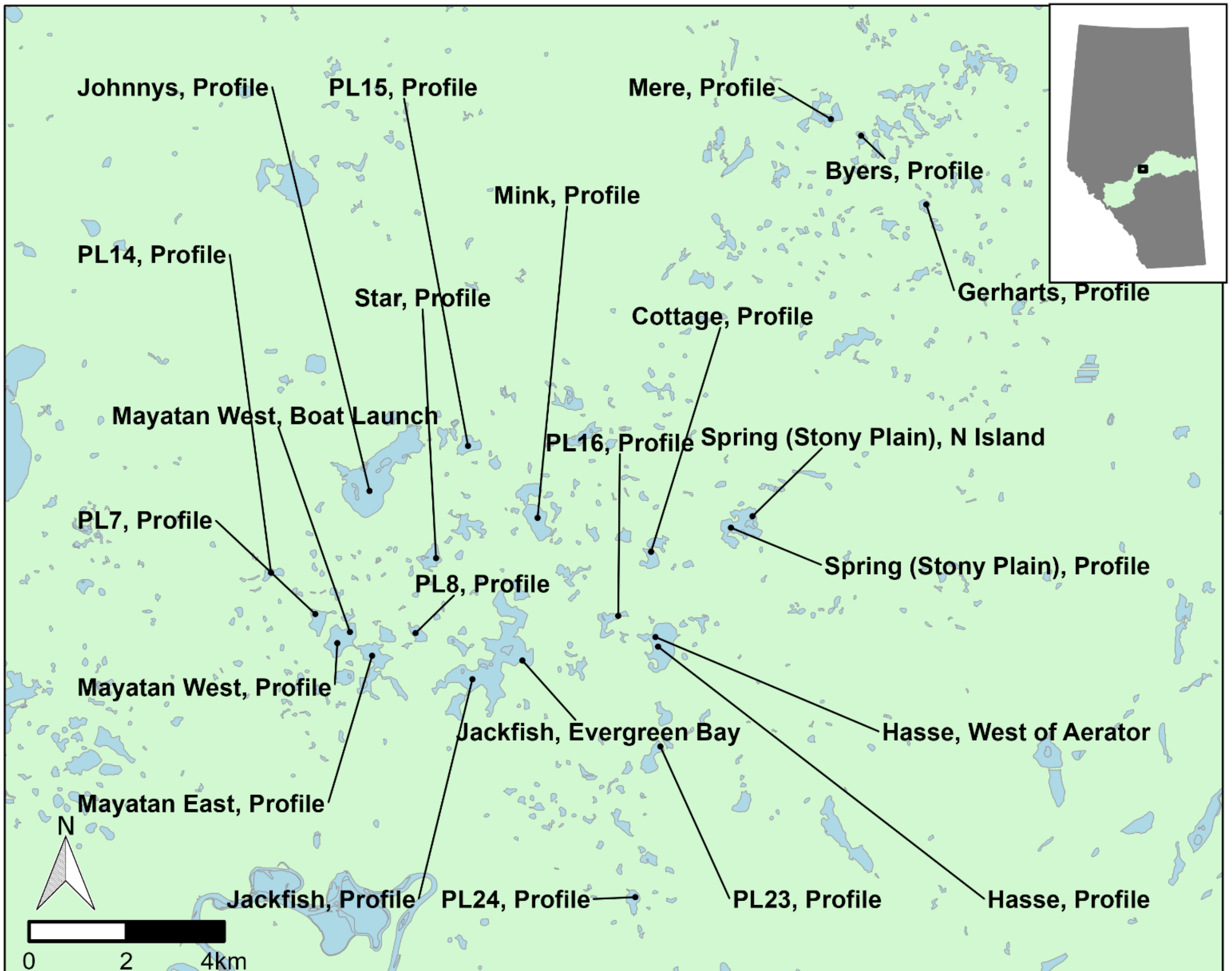


Map 6a. Lakes sampled in the Modeste and Sturgeon subwatersheds of the North Saskatchewan River watershed during the Winter LakeKeepers 2022-2023 season. The North Saskatchewan River watershed is highlighted in the Alberta inset map.

North Saskatchewan River Watershed

Map 6b. Lakes sampled in the Strawberry and Beaverhill subwatersheds (blue outline) of the North Saskatchewan River watershed during the Winter LakeKeepers 2022-2023 season. West River's Edge Park Pond (red) is also represented separately to highlight multiple sampling locations across the lake. The North Saskatchewan River watershed is highlighted in the Alberta inset map.

North Saskatchewan River Watershed



Map 6c. Lakes sampled in the Carvel Pitted Delta region of the North Saskatchewan River watershed during the Winter LakeKeepers 2022-2023 season. The North Saskatchewan River watershed is highlighted in the Alberta inset map.

North Saskatchewan River Watershed

Table 5a. Surface water chemistry (TP = total phosphorus, TDP = total dissolved phosphorus, TKN = total Kjeldahl nitrogen, NO3+NO2 = nitrate plus nitrite, NH3 = ammonia, DOC = dissolved organic carbon, Cl- = chloride, Cond. = conductivity, ChlA = chlorophyll-a, MCYST = microcystin) and environmental measurements (Air Temp. = air temperature) recorded at lakes in the North Saskatchewan River watershed in the Winter LakeKeepers 2022-2023 season. Microcystin values above the recreational guideline of 10 μg/L are colored red.

	TP (μg/L)	TDP (μg/L)	TKN (mg/L)	NO3 + NO2 (μg/L)	NH3 (μg/L)	DOC (mg/L)	Cl- (mg/L)	Cond. (μS/cm)	pH	ChlA (μg/L)	MCYST (μg/L)	Air Temp. (°C)	Snow Depth (cm)	Ice Thickness (cm)	White Ice Thickness (cm)
Byers, Profile															
Mar 3	1200.0	30.0	11.0	<4.2	24.0	15.0	1.8	180	7.60	252.0	<0.10	−2	18	53	4
Cooking, East Basin South															
Jan 18	1800.0	1100.0	43.0	<210.0	4500.0	390.0	350.0	9,800	8.99	95.1	-	−11	15	52	0
Cooking, West Basin Central															
Jan 18	2400.0	1300.0	56.0	320.0	6200.0	490.0	430.0	11,000	8.95	166.0	-	−11	30	38	0
Cottage, Profile															
Mar 2	210.0	78.0	4.7	<4.2	1700.0	25.0	7.2	1,200	7.62	39.7	-	2	13	56	6
Gerharts, Profile															
Mar 3	6.5	3.0	1.1	7.5	450.0	8.4	5.3	700	8.02	3.5	-	−9	13	52	5
Half Moon, East Central															
Nov 29	74.0	48.0	2.8	200.0	940.0	24.0	32.0	520	8.29	16.5	-	−13	0	23	3
Dec 15	76.0	56.0	3.0	490.0	830.0	23.0	33.0	520	8.04	9.0	-	−14	8	30	1
Jan 3	99.0	73.0	2.8	620.0	620.0	26.0	34.0	520	7.96	21.4	-	−7	18	34	0
Feb 9	110.0	69.0	3.4	370.0	770.0	24.0	35.0	530	8.03	12.4	-	−6	5	60	4
Mar 23	150.0	67.0	3.1	83.0	520.0	26.0	34.0	540	8.14	107.0	-	4	13	76	4
Hasse, West of Aerator															
Jan 2	130.0	-	2.9	-	-	-	-	-	-	-	-	−7	25	46	0
Hasse, Profile															
Feb 28	240.0	120.0	3.5	190.0	820.0	19.0	5.9	970	8.06	191.0	-	−14	6	69	4
Hastings, Profile															
Dec 15	59.0	31.0	5.0	17.0	450.0	55.0	53.0	2,200	8.79	16.3	-	−7	15	30	0
Jan 18	62.0	33.0	5.4	15.0	640.0	58.0	54.0	2,400	8.85	7.7	-	−7	10	55	10
Feb 20	98.0	46.0	6.2	4.4	990.0	59.0	60.0	2,400	8.59	5.1	-	−10	0	73	16
Mar 26	130.0	71.0	6.5	<4.2	1300.0	67.0	62.0	2,500	8.51	19.8	-	−5	10	70	2
Isle, Silver Sands															
Dec 30	190.0	-	2.0	-	-	-	-	-	-	-	-	−12	25	51	0
Isle, East Basin Centre															
Mar 31	120.0	-	1.6	-	-	-	-	-	-	-	-	6	5	91	10
Islet, Profile															
Dec 13	76.0	15.0	4.2	<4.2	450.0	38.0	18.0	470	8.49	80.4	<0.10	−16	6	36	3
Jan 17	110.0	15.0	4.9	<4.2	1100.0	40.0	16.0	510	8.61	41.0	<0.10	−7	9	53	8
Feb 26	210.0	36.0	6.2	12.0	1300.0	43.0	18.0	560	7.94	88.5	-	−8	10	58	0
Mar 25	140.0	30.0	5.2	12.0	1300.0	55.0	17.0	540	7.99	67.3	-	−3	5	40	0
Jackfish, Evergreen Bay															
Jan 8	20.0	-	1.9	-	-	-	-	-	-	-	-	−4	14	48	0
Mar 18	39.0	-	1.6	-	-	-	-	-	-	-	-	5	10	66	0
Jackfish, Profile															
Feb 28	32.0	32.0	1.8	56.0	590.0	15.0	8.5	1,400	7.75	0.6	-	−11	5	64	3
Johnnys, Profile															
Feb 20	220.0	120.0	6.4	18.0	2000.0	57.0	32.0	1,500	8.12	10.7	-	−10	8	57	3

North Saskatchewan River Watershed

Table 5b. Surface water chemistry (TP = total phosphorus, TDP = total dissolved phosphorus, TKN = total Kjeldahl nitrogen, NO3+NO2 = nitrate plus nitrite, NH3 = ammonia, DOC = dissolved organic carbon, Cl- = chloride, Cond. = conductivity, ChlA = chlorophyll-a, MCYST = microcystin) and environmental measurements (Air Temp. = air temperature) recorded at lakes in the North Saskatchewan River watershed in the Winter LakeKeepers 2022-2023 season. Microcystin values above the recreational guideline of 10 µg/L are colored red.

	TP (µg/L)	TDP (µg/L)	TKN (mg/L)	NO3 + NO2 (µg/L)	NH3 (µg/L)	DOC (mg/L)	Cl- (mg/L)	Cond. (µS/cm)	pH	ChlA (µg/L)	MCYST (µg/L)	Air Temp. (°C)	Snow Depth (cm)	Ice Thickness (cm)	White Ice Thickness (cm)
Lac Ste. Anne, Alberta Beach															
Feb 5	41.0	40.0	1.6	300.0	140.0	17.0	16.0	480	8.15	1.0	-	3	5	77	3
Mar 10	43.0	-	1.5	-	-	-	-	-	-	-	-	−11	2	86	3
Lac Ste. Anne, West Basin Profile															
Feb 5	170.0	170.0	2.4	110.0	560.0	22.0	16.0	470	8.53	0.5	-	3	5	62	0
Lac Ste. Anne, West of Rock Island															
Feb 20	46.0	-	1.5	-	-	-	-	-	-	-	-	−10	6	71	0
Mayatan East, Profile															
Feb 13	38.0	<3.0	3.0	6.9	410.0	20.0	4.4	1,100	7.91	9.8	-	3	5	56	5
Mayatan West, Profile															
Feb 13	58.0	46.0	2.0	<4.2	95.0	17.0	3.0	880	7.89	<0.3	-	1	8	51	0
Mayatan West, Boat Launch															
Feb 17	-	-	-	-	-	-	-	-	-	-	-	−3	8	53	0
Mere, Profile															
Mar 3	95.0	36.0	2.6	5.8	410.0	13.0	5.2	270	7.90	215.0	<0.10	0	13	61	5
Ministik, Profile															
Jan 18	500.0	360.0	19.0	<4.2	2000.0	220.0	210.0	6,200	8.61	14.1	-	−6	30	35	0
Mink, Profile															
Feb 17	58.0	16.0	2.5	30.0	960.0	18.0	22.0	2,600	7.91	1.0	-	−1	8	58	4
PL14, Profile															
Mar 2	390.0	240.0	4.5	<4.2	1400.0	24.0	8.9	1,100	7.64	217.0	-	0	10	60	6
PL15, Profile															
Feb 20	180.0	140.0	5.8	<4.2	2000.0	31.0	16.0	1,300	7.70	26.5	-	−8	8	50	3
PL16, Profile															
Mar 2	190.0	120.0	3.7	<4.2	990.0	25.0	7.4	980	7.69	18.5	-	4	9	60	6
PL23, Profile															
Feb 28	120.0	48.0	3.0	18.0	830.0	19.0	20.0	600	7.89	69.5	-	−10	8	64	6
PL24, Profile															
Feb 20	210.0	240.0	4.3	16.0	1600.0	31.0	16.0	570	7.91	44.2	-	−8	8	55	4
PL7, Profile															
Feb 14	46.0	18.0	2.4	9.6	370.0	17.0	1.2	590	7.97	43.9	-	−9	10	42	3
PL8, Profile															
Feb 14	130.0	56.0	3.8	<4.2	990.0	23.0	2.3	1,100	7.65	47.0	-	−5	8	53	10
Spring (Stony Plain), N Island															
Jan 2	6.3	-	2.1	-	-	-	-	-	-	-	-	−9	23	51	0
Spring (Stony Plain), Profile															
Feb 28	16.0	7.2	2.6	30.0	770.0	18.0	17.0	990	8.01	18.7	-	−12	9	66	5

North Saskatchewan River Watershed

Table 5c. Surface water chemistry (TP = total phosphorus, TDP = total dissolved phosphorus, TKN = total Kjeldahl nitrogen, NO3+NO2 = nitrate plus nitrite, NH3 = ammonia, DOC = dissolved organic carbon, Cl- = chloride, Cond. = conductivity, ChlA = chlorophyll-a, MCYST = microcystin) and environmental measurements (Air Temp. = air temperature) recorded at lakes in the North Saskatchewan River watershed in the Winter LakeKeepers 2022-2023 season. Microcystin values above the recreational guideline of 10 μg/L are colored red.

	TP (μg/L)	TDP (μg/L)	TKN (mg/L)	NO3 + NO2 (μg/L)	NH3 (μg/L)	DOC (mg/L)	Cl- (mg/L)	Cond. (μS/cm)	pH	ChlA (μg/L)	MCYST (μg/L)	Air Temp. (°C)	Snow Depth (cm)	Ice Thickness (cm)	White Ice Thickness (cm)
Star, Profile															
Feb 17	<3.0	3.9	1.6	9.7	330.0	15.0	5.9	1,200	7.79	2.3	-	−5	8	52	5
Telford, Leduc Boat Club															
Dec 15	<60.0	-	5.7	-	-	-	-	-	-	-	-	−8	3	30	4
Feb 1	1200.0	270.0	7.5	22.0	4000.0	36.0	240.0	1,300	7.64	16.2	-	−16	25	58	5
Wabamun, Rich's Point															
Dec 14	11.0	9.1	1.1	28.0	74.0	11.0	19.0	720	8.57	1.8	-	−6	10	36	0
Jan 16	14.0	18.0	1.2	9.6	160.0	13.0	21.0	740	8.36	1.2	-	−7	10	53	0
Feb 14	14.0	14.0	1.3	42.0	190.0	12.0	21.0	750	8.35	1.5	-	−5	15	66	0
Mar 13	17.0	9.7	1.2	63.0	110.0	12.0	21.0	770	8.28	6.0	-	−11	10	80	4
Wabamun, Seba Beach															
Dec 14	14.0	12.0	1.0	25.0	190.0	12.0	19.0	690	8.50	2.2	-	−6	9	33	0
Jan 16	19.0	17.0	1.3	6.6	240.0	12.0	20.0	720	8.36	1.4	-	−7	13	42	0
Feb 14	19.0	9.9	1.5	35.0	310.0	12.0	20.0	710	8.32	2.5	-	−7	8	58	0
Mar 13	22.0	15.0	1.2	240.0	64.0	11.0	20.0	730	8.22	2.8	-	−12	15	66	0
Wabamun, Water's Edge															
Dec 14	15.0	11.0	1.2	35.0	120.0	13.0	21.0	740	8.58	2.6	-	−6	5	48	13
Jan 16	14.0	13.0	2.2	18.0	130.0	13.0	21.0	750	8.38	2.0	-	−8	5	63	8
Feb 14	14.0	11.0	1.2	51.0	140.0	13.0	21.0	750	8.35	2.4	-	−9	3	76	15
Mar 13	24.0	20.0	1.4	100.0	33.0	12.0	21.0	790	8.30	25.6	-	−12	10	86	15
West River's Edge Park Pond, 1															
Feb 19	36.0	-	1.3	-	-	-	-	-	-	-	-	−4	13	58	2
Apr 4	35.0	-	1.1	-	-	-	-	-	-	-	-	−1	3	60	0
West River's Edge Park Pond, 2															
Feb 19	36.0	-	1.3	-	-	-	-	-	-	-	-	−4	13	58	2
West River's Edge Park Pond, 3															
Apr 4	86.0	-	1.5	-	-	-	-	-	-	-	-	−1	3	60	0
Wizard, Jubilee															
Dec 11	62.0	22.0	1.8	88.0	180.0	15.0	11.0	410	8.12	81.5	0.19	−14	5	34	0
Jan 8	53.0	19.0	1.5	240.0	140.0	15.0	9.1	420	8.13	21.9	<0.10	−3	10	51	0
Feb 12	16.0	16.0	1.2	420.0	20.0	14.0	8.5	410	8.06	8.2	<0.10	5	3	69	3
Mar 12	52.0	19.0	1.5	370.0	18.0	14.0	8.5	420	7.95	28.7	<0.10	−6	10	76	3
Wizard, West Basin															
Dec 11	36.0	25.0	1.6	57.0	120.0	16.0	9.1	410	8.19	67.6	<0.10	−15	5	33	3
Jan 8	21.0	19.0	1.3	110.0	200.0	15.0	8.9	410	8.29	15.2	<0.10	−4	9	53	8
Feb 12	11.0	17.0	1.2	370.0	39.0	14.0	8.7	410	8.14	8.3	<0.10	5	4	61	5
Mar 12	33.0	20.0	1.3	380.0	17.0	14.0	8.8	440	7.96	10.8	<0.10	−6	11	74	9

North Saskatchewan River Watershed

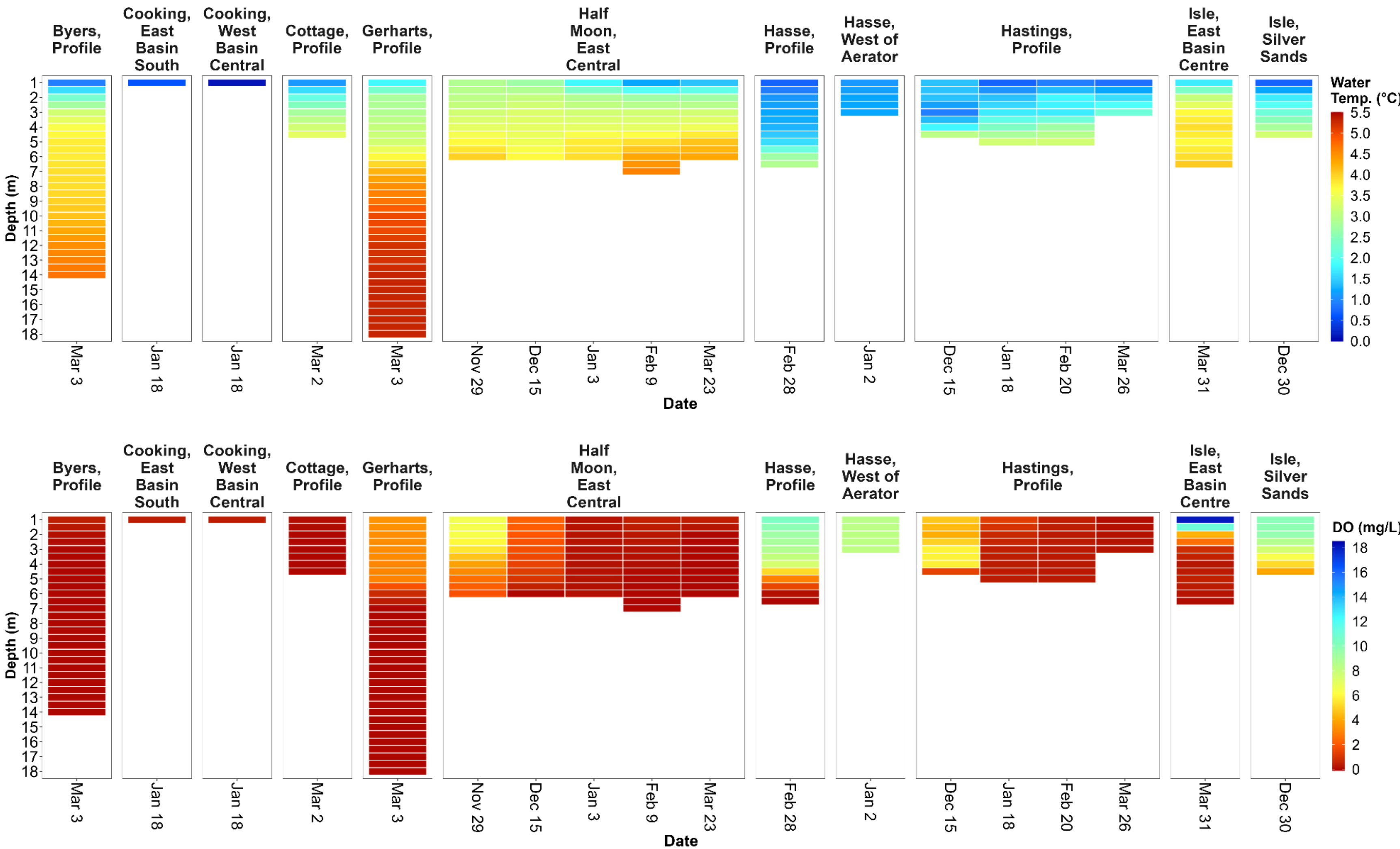
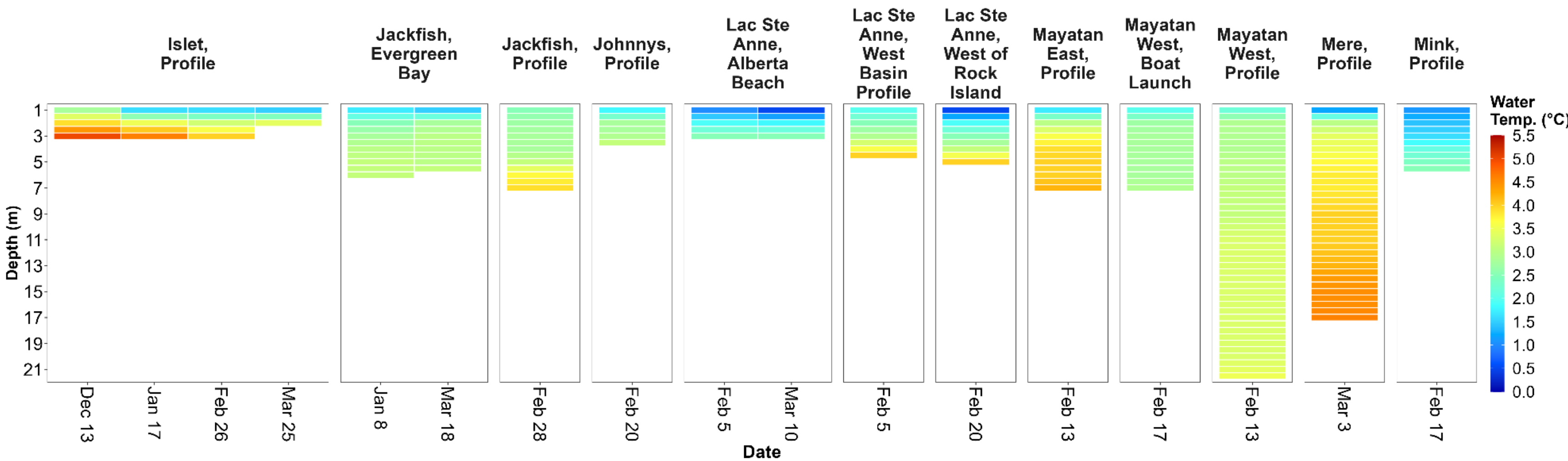


Figure 22a. Water temperature (Water Temp.; °C) and dissolved oxygen (DO; mg/L) measurements recorded at lakes sampled in the North Saskatchewan River watershed in the Winter LakeKeepers 2022-2023 season. Measurements were taken at 0.1m and 0.5m, then every meter starting at 1 meter from ice surface, until lake bottom, however only measurements at 1m and below are plotted. Note that the measurements are linearly interpolated to 0.5m increments to improve data visualization.

North Saskatchewan River Watershed



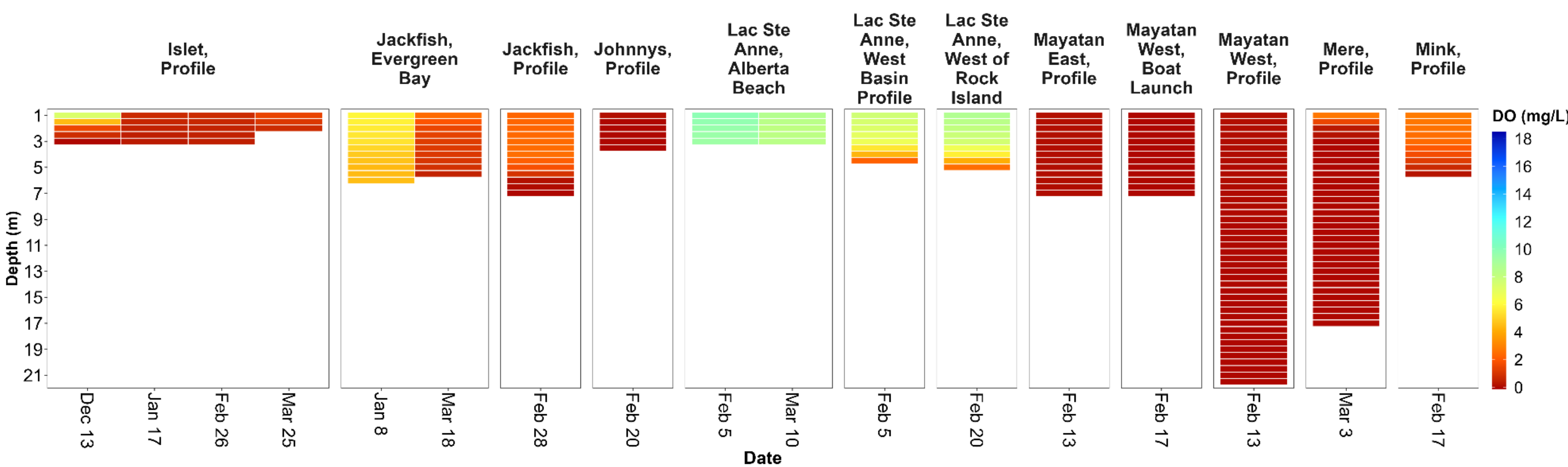


Figure 22b. Water temperature (Water Temp.; °C) and dissolved oxygen (DO; mg/L) measurements recorded at lakes sampled in the North Saskatchewan River watershed in the Winter LakeKeepers 2022-2023 season. Measurements were taken at 0.1m and 0.5m, then every meter starting at 1 meter from ice surface, until lake bottom, however only measurements at 1m and below are plotted. Note that the measurements are linearly interpolated to 0.5m increments to improve data visualization, and that profile data from Ministik Lake is unavailable due to the lake being <1m depth.

North Saskatchewan River Watershed

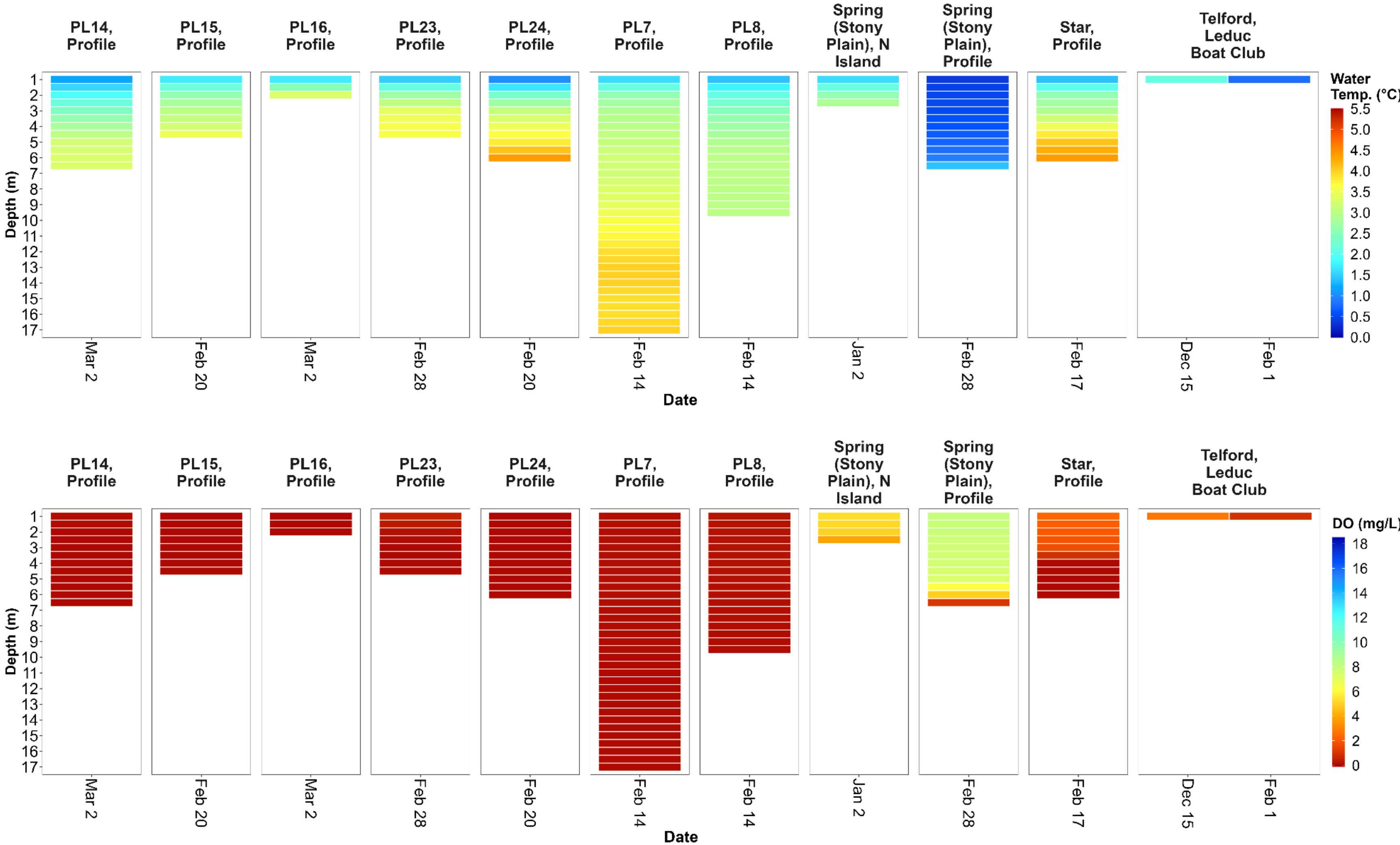


Figure 22c. Water temperature (Water Temp.; °C) and dissolved oxygen (DO; mg/L) measurements recorded at lakes sampled in the North Saskatchewan River watershed in the Winter LakeKeepers 2022-2023 season. Measurements were taken at 0.1m and 0.5m, then every meter starting at 1 meter from ice surface, until lake bottom, however only measurements at 1m and below are plotted. Note that the measurements are linearly interpolated to 0.5m increments to improve data visualization.

North Saskatchewan River Watershed

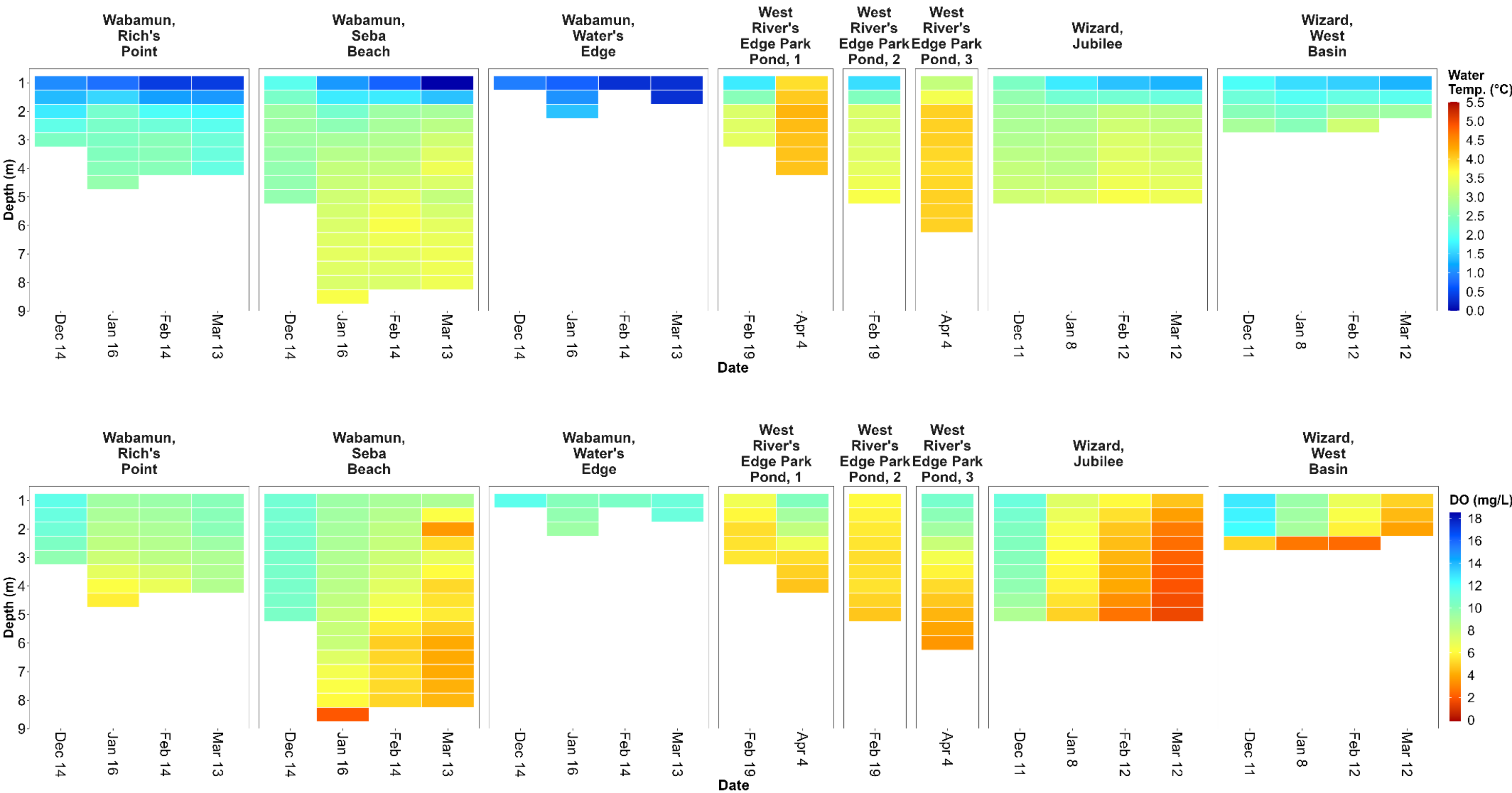


Figure 22d. Water temperature (Water Temp.; °C) and dissolved oxygen (DO; mg/L) measurements recorded at lakes sampled in the North Saskatchewan River watershed in the Winter LakeKeepers 2022-2023 season. Measurements were taken at 0.1m and 0.5m, then every meter starting at 1 meter from ice surface, until lake bottom, however only measurements at 1m and below are plotted. Note that the measurements are linearly interpolated to 0.5m increments to improve data visualization.

North Saskatchewan River Watershed

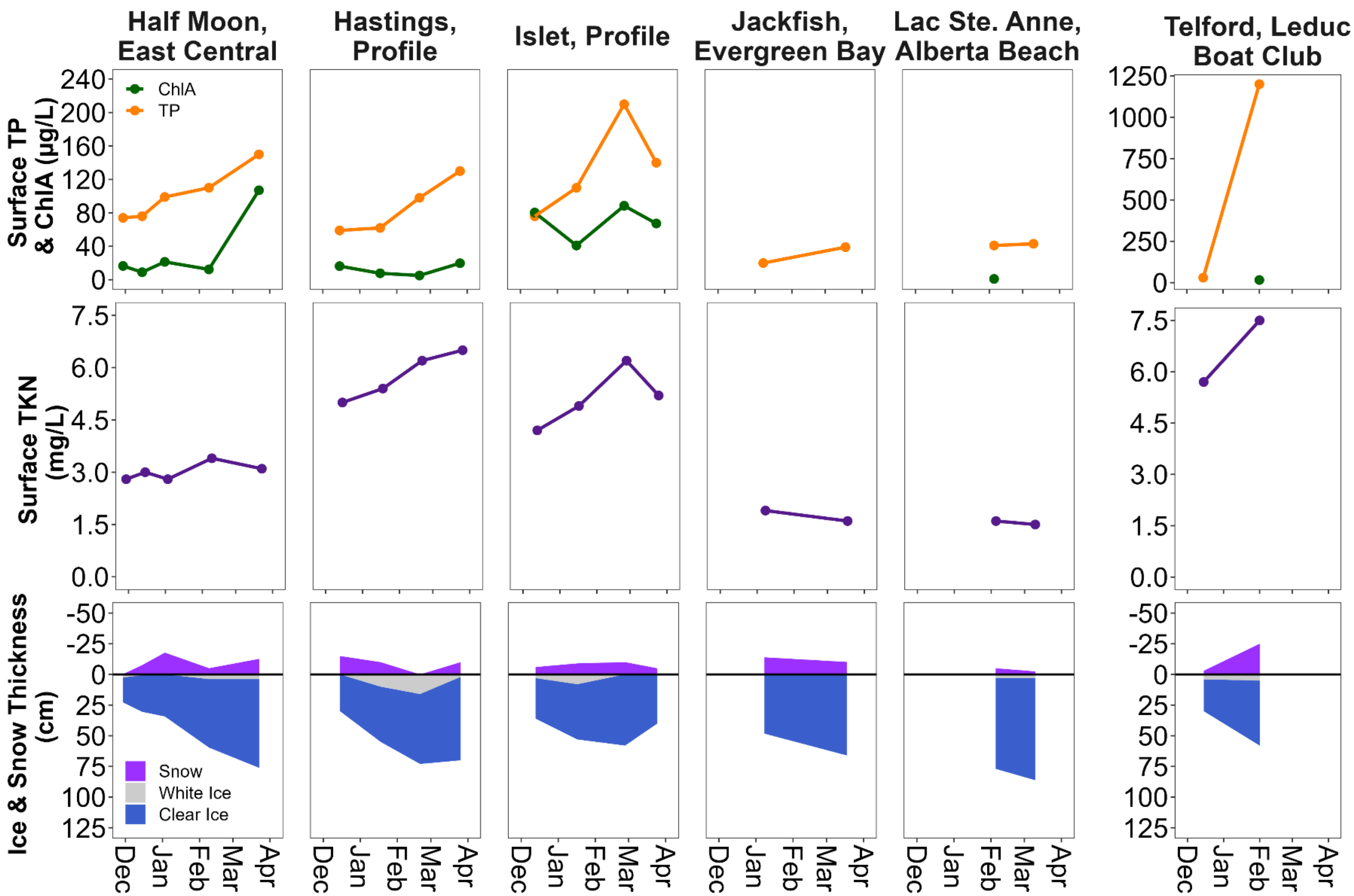


Figure 23a. Seasonal surface water chemistry (TP = total phosphorus and ChlA = chlorophyll-a, Top; TKN = total Kjeldahl nitrogen, middle) and ice (clear and white) and snow thickness(bottom) from lakes sampled in the North Saskatchewan River watershed in the Winter LakeKeepers 2022 season. In the top panel, TP is orange and ChlA is green, TKN in the middle section is purple, and in the bottom section snow is pick, white ice is gray, and clear ice is blue. Note that ice and snow thickness is plotted in reference to the ice surface (horizontal black line), and that 'Telford, Leduc Boat Club' is plotted with a difference Surface TP and ChlA scale due to the magnitude of TP during the February 1st, 2023 sampling event.

North Saskatchewan River Watershed

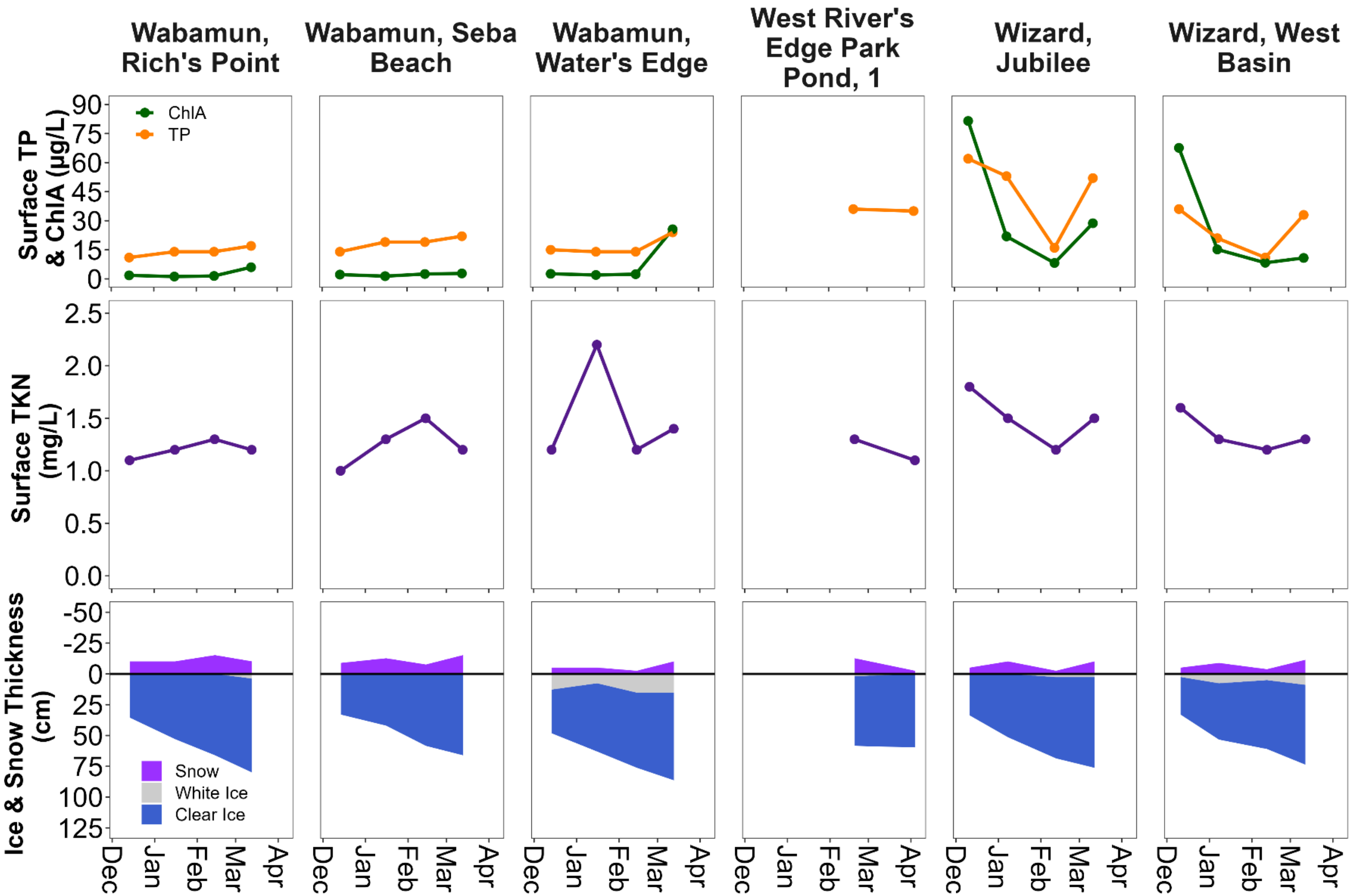
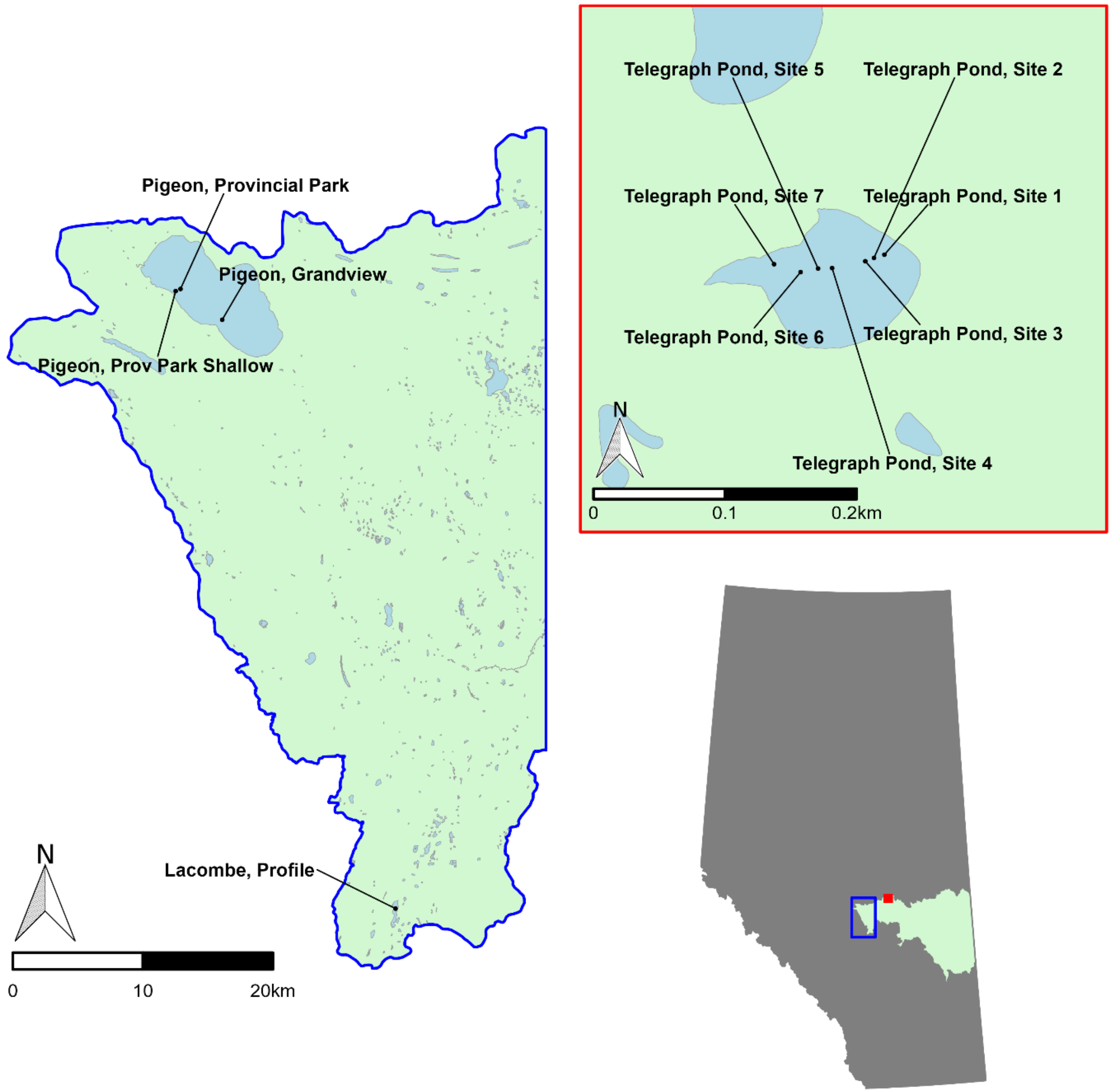


Figure 23b. Seasonal surface water chemistry (TP = total phosphorus and ChlA = chlorophyll-a, Top; TKN = total Kjeldahl nitrogen, middle) and ice (clear and white) and snow thickness(bottom) from lakes sampled in the North Saskatchewan River watershed in the Winter LakeKeepers 2022 season. In the top panel, TP is orange and ChlA is green, TKN in the middle section is purple, and in the bottom section snow is pick, white ice is gray, and clear ice is blue. Note that ice and snow thickness is plotted in reference to the ice surface (horizontal black line).

Battle River Watershed

LakeKeepers



Map 7. Lakes sampled in western region (blue outline) the Battle River watershed during the Winter LakeKeepers 2022-2023 season. Telegraph Pond (red) is also represented separately to highlight multiple sampling locations across the lake. The Battle River watershed is highlighted in the Alberta inset map.

Battle River Watershed

Table 6. Surface water chemistry (TP = total phosphorus, TDP = total dissolved phosphorus, TKN = total Kjeldahl nitrogen, NO3+NO2 = nitrate plus nitrite, NH3 = ammonia, DOC = dissolved organic carbon, Cl- = chloride, Cond. = conductivity, ChlA = chlorophyll-*a*, MCYST = microcystin) and environmental measurements (Air Temp. = air temperature) recorded at lakes in the Battle River watershed in the Winter LakeKeepers 2022-2023 season. Microcystin values above the recreational guideline of 10 µg/L are colored red.

	TP (µg/L)	TDP (µg/L)	TKN (mg/L)	NO3 + NO2 (µg/L)	NH3 (µg/L)	DOC (mg/L)	Cl- (mg/L)	Cond. (µS/cm)	pH	ChlA (µg/L)	MCYST (µg/L)	Air Temp. (°C)	Snow Depth (cm)	Ice Thickness (cm)	White Ice Thickness (cm)
Lacombe, Profile															
Dec 17	10.0	3.7	1.1	5.5	260.0	17.0	36.0	620	8.17	7.2	-	−19	5	41	8
Jan 22	9.5	3.6	2.0	4.9	430.0	19.0	41.0	700	8.08	4.7	-	−1	13	56	8
Feb 26	15.0	4.1	2.0	5.3	510.0	19.0	41.0	730	8.22	7.8	-	−8	13	69	8
Mar 31	51.0	7.0	2.2	<4.2	550.0	21.0	43.0	750	8.10	13.9	-	−4	10	72	5
Pigeon, Grandview															
Dec 1	13.0	6.7	0.9	<4.2	36.0	8.7	5.9	350	8.29	5.1	-	−20	4	32	0
Jan 8	18.0	8.9	0.9	13.0	68.0	8.2	6.3	370	8.44	4.1	-	−7	8	61	0
Feb 3	11.0	8.1	1.1	4.7	62.0	10.0	6.7	370	8.48	2.2	-	1	3	81	0
Mar 2	13.0	6.0	1.0	10.0	38.0	8.3	6.1	370	8.37	9.4	-	0	4	81	0
Apr 12	13.0	7.9	0.7	110.0	92.0	5.3	3.5	210	8.11	6.0	-	−1	10	91	10
Pigeon, Provincial Park															
Dec 11	8.2	7.7	0.8	<4.2	61.0	8.1	7.1	370	8.36	5.9	-	−22	8	38	0
Jan 8	15.0	10.0	1.0	8.6	82.0	8.9	6.8	350	8.40	1.7	-	−7	8	76	0
Feb 2	8.6	7.1	1.0	<4.2	66.0	10.0	6.6	380	8.45	0.9	-	−10	5	71	0
Mar 9	8.2	7.6	1.0	19.0	17.0	8.3	6.2	390	8.29	5.6	-	−5	5	86	0
Apr 12	17.0	8.4	0.5	110.0	60.0	4.1	1.5	82	7.56	4.1	-	3	5	86	5
Pigeon, Prov Park Shallow															
Mar 11	13.0	9.1	1.0	26.0	22.0	8.3	6.4	400	8.30	7.3	-	−10	4	82	0
Telegraph Pond, Site 1															
Feb 3	-	-	-	-	-	-	-	-	-	-	-	−7	10	46	8
Telegraph Pond, Site 2															
Feb 3	-	-	-	-	-	-	-	-	-	-	-	-	-	46	-
Telegraph Pond, Site 3															
Feb 3	590.0	-	2.1	-	-	-	-	-	-	-	-	-	-	23	-
Telegraph Pond, Site 4															
Feb 3	-	-	-	-	-	-	-	-	-	-	-	-	-	25	-
Telegraph Pond, Site 5															
Feb 3	-	-	-	-	-	-	-	-	-	-	-	-	-	46	-
Telegraph Pond, Site 6															
Feb 3	-	-	-	-	-	-	-	-	-	-	-	-	-	51	-
Telegraph Pond, Site 7															
Feb 3	-	-	-	-	-	-	-	-	-	-	-	-	-	52	-

Battle River Watershed

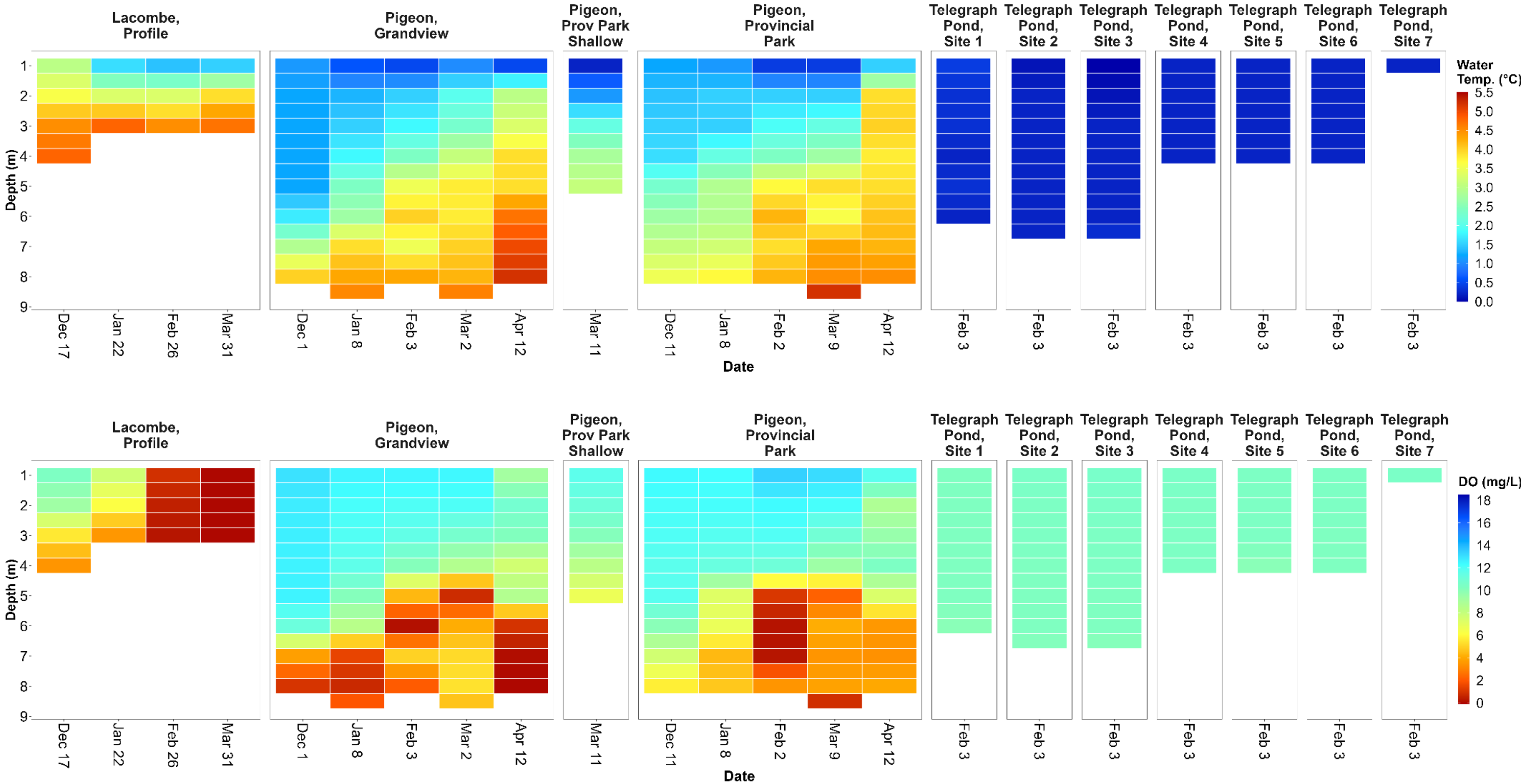


Figure 24. Water temperature (Water Temp.; °C) and dissolved oxygen (DO; mg/L) measurements recorded at lakes sampled in the Battle River watershed in the Winter LakeKeepers 2022-2023 season. Measurements were taken at 0.1m and 0.5m, then every meter starting at 1 meter from ice surface, until lake bottom, however only measurements at 1m and below are plotted. Note that the measurements are linearly interpolated to 0.5m increments to improve data visualization.

Battle River Watershed

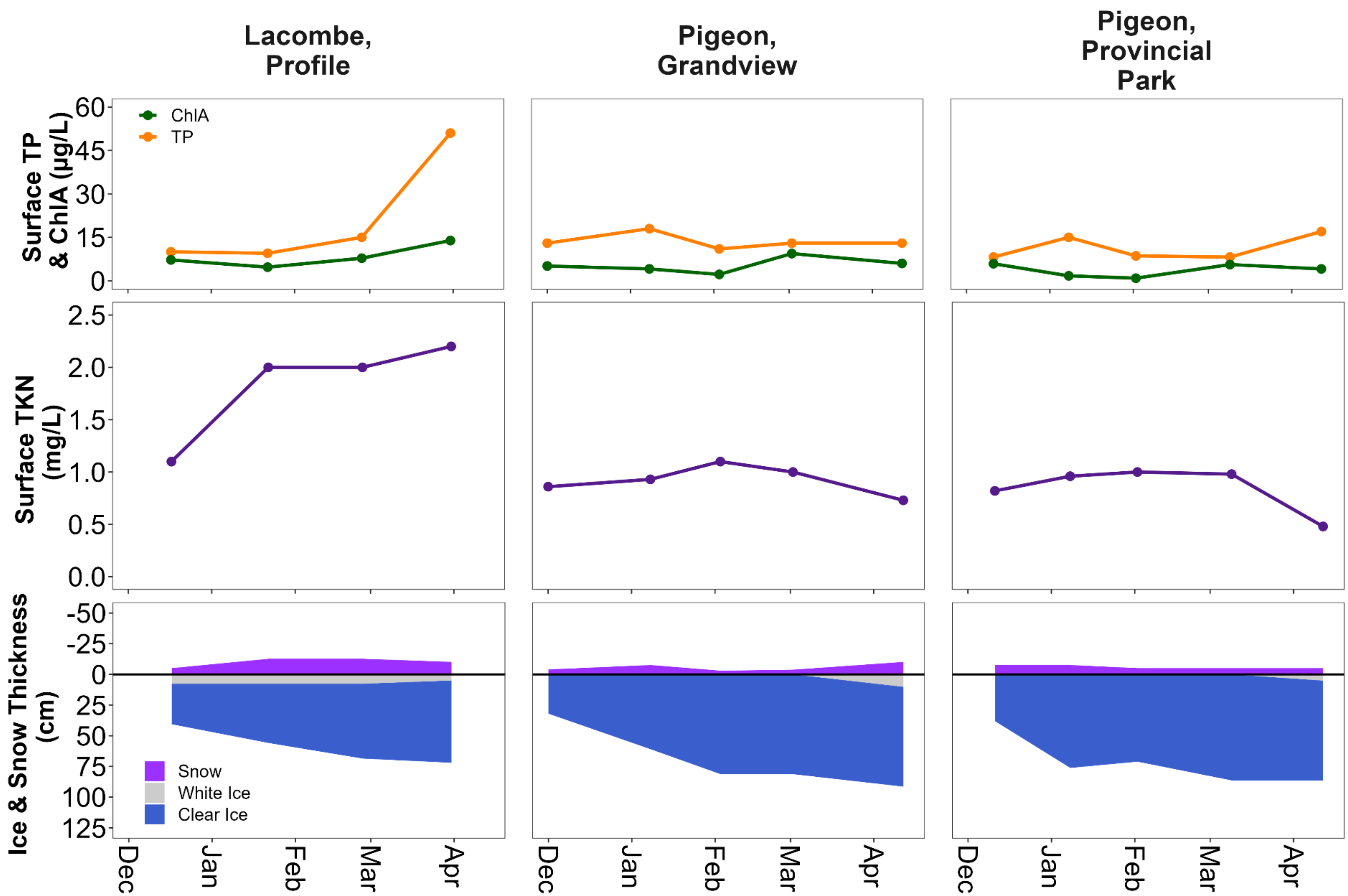
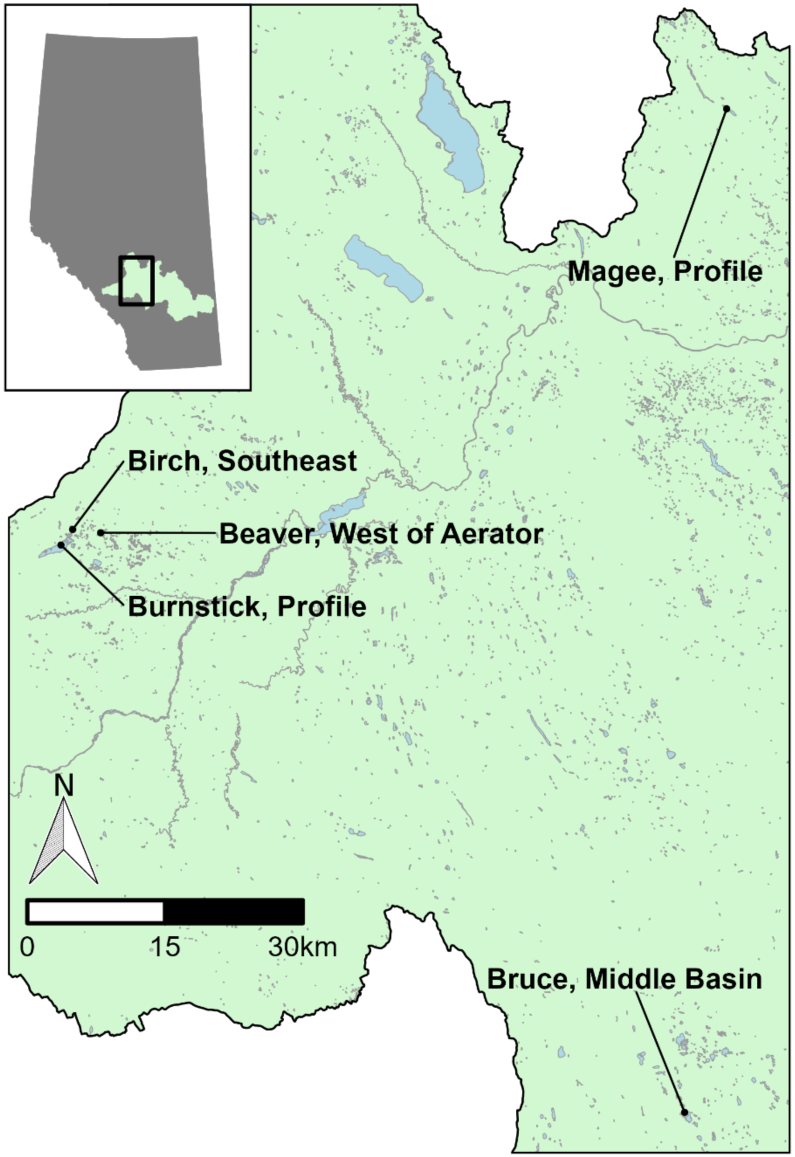


Figure 25. Seasonal surface water chemistry (TP = total phosphorus and ChlA = chlorophyll-a, Top; TKN = total Kjeldahl nitrogen, middle) and ice (clear and white) and snow thickness(bottom) from lakes sampled in the Battle River watershed in the Winter LakeKeepers 2022 season. In the top panel, TP is orange and ChlA is green, TKN in the middle section is purple, and in the bottom section snow is pick, white ice is gray, and clear ice is blue. Note that ice and snow thickness is plotted in reference to the ice surface (horizontal black line).

Red Deer River Watershed



Map 8. Lakes sampled in the Red Deer River watershed during the Winter LakeKeepers 2022-2023 season. The Red Deer River watershed is highlighted in the Alberta inset map.

Red Deer River Watershed

Table 7. Surface water chemistry (TP = total phosphorus, TDP = total dissolved phosphorus, TKN = total Kjeldahl nitrogen, NO3+NO2 = nitrate plus nitrite, NH3 = ammonia, DOC = dissolved organic carbon, Cl- = chloride, Cond. = conductivity, ChlA = chlorophyll-*a*, MCYST = microcystin) and environmental measurements (Air Temp. = air temperature) recorded at lakes in the Red Deer River watershed in the Winter LakeKeepers 2022-2023 season. Microcystin values above the recreational guideline of 10 µg/L are colored red.

	TP (µg/L)	TDP (µg/L)	TKN (mg/L)	NO3 + NO2 (µg/L)	NH3 (µg/L)	DOC (mg/L)	Cl- (mg/L)	Cond. (µS/cm)	pH	ChlA (µg/L)	MCYST (µg/L)	Air Temp. (°C)	Snow Depth (cm)	Ice Thickness (cm)	White Ice Thickness (cm)
Beaver, West of Aerator															
Mar 18	17.0	-	1.1	-	-	-	-	-	-	-	-	2	20	70	20
Birch, Southeast															
Jan 7	5.4	-	0.9	-	-	-	-	-	-	-	-	−1	18	40	0
Bruce, Middle Basin															
Mar 16	1300.0	1100.0	3.1	42.0	94.0	30.0	93.0	3,400	8.66	9.9	0.12	−6	15	80	5
Burnstick, Profile															
Jan 7	9.6	-	0.4	-	-	-	-	-	-	-	-	−1	15	44	0
Mar 18	8.7	-	0.5	-	-	-	-	-	-	-	-	2	32	62	4
Magee, Profile															
Jan 3	210.0	120.0	2.1	50.0	520.0	16.0	6.7	630	8.15	10.2	-	−8	10	45	10
Jan 22	160.0	130.0	2.0	9.3	110.0	16.0	6.7	660	8.09	7.9	-	−2	15	60	12
Feb 23	200.0	150.0	2.0	4.6	470.0	13.0	6.9	660	8.18	14.8	-	−23	10	70	10
Mar 19	270.0	160.0	2.4	5.9	560.0	13.0	6.7	700	8.20	117.0	-	3	15	90	10

Red Deer River Watershed

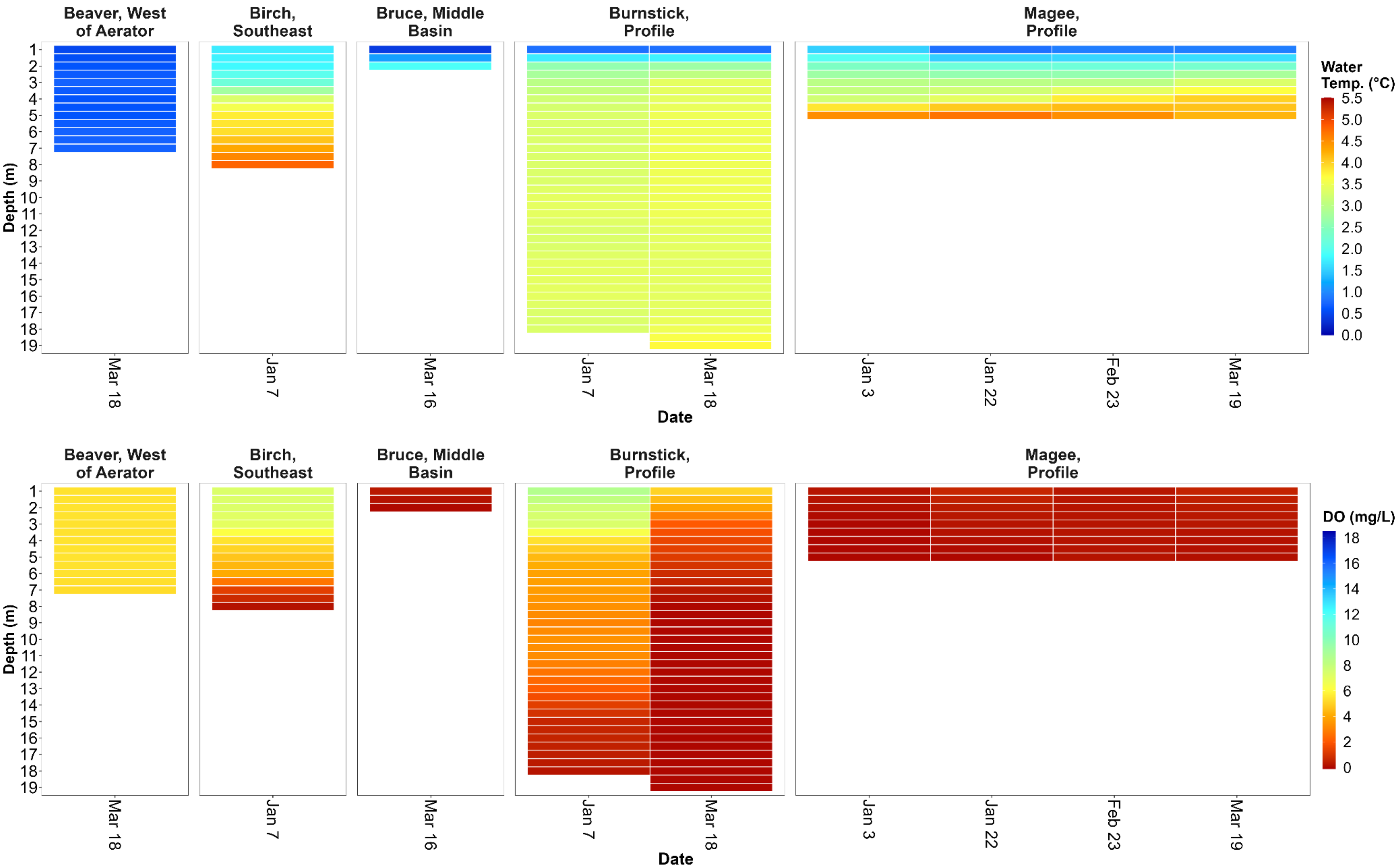


Figure 26. Water temperature (Water Temp.; °C) and dissolved oxygen (DO; mg/L) measurements recorded at lakes sampled in the Red Deer River watershed in the Winter LakeKeepers 2022-2023 season. Measurements were taken at 0.1m and 0.5m, then every meter starting at 1 meter from ice surface, until lake bottom, however only measurements at 1m and below are plotted. Note that the measurements are linearly interpolated to 0.5m increments to improve data visualization.

Red Deer River Watershed

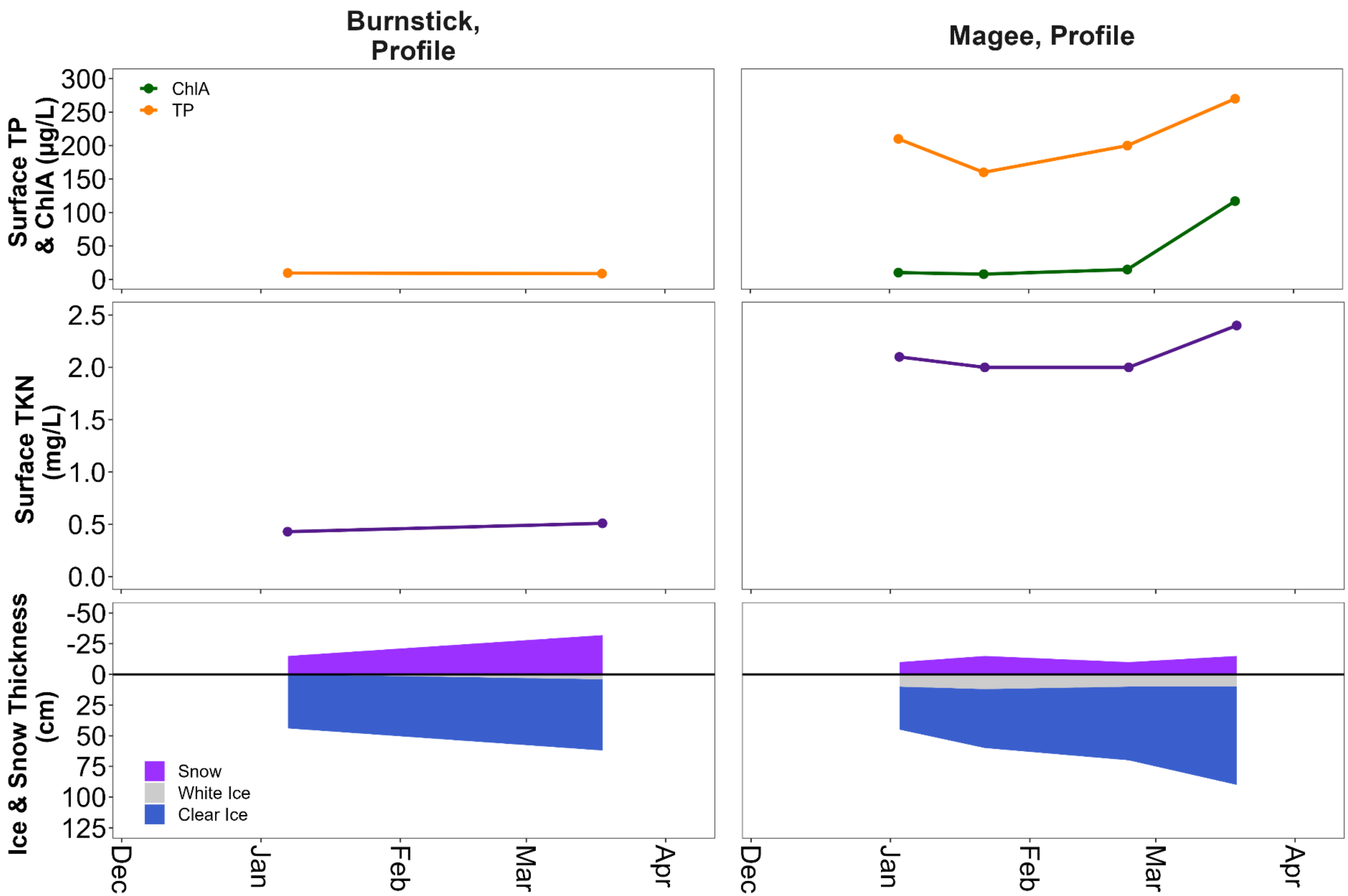
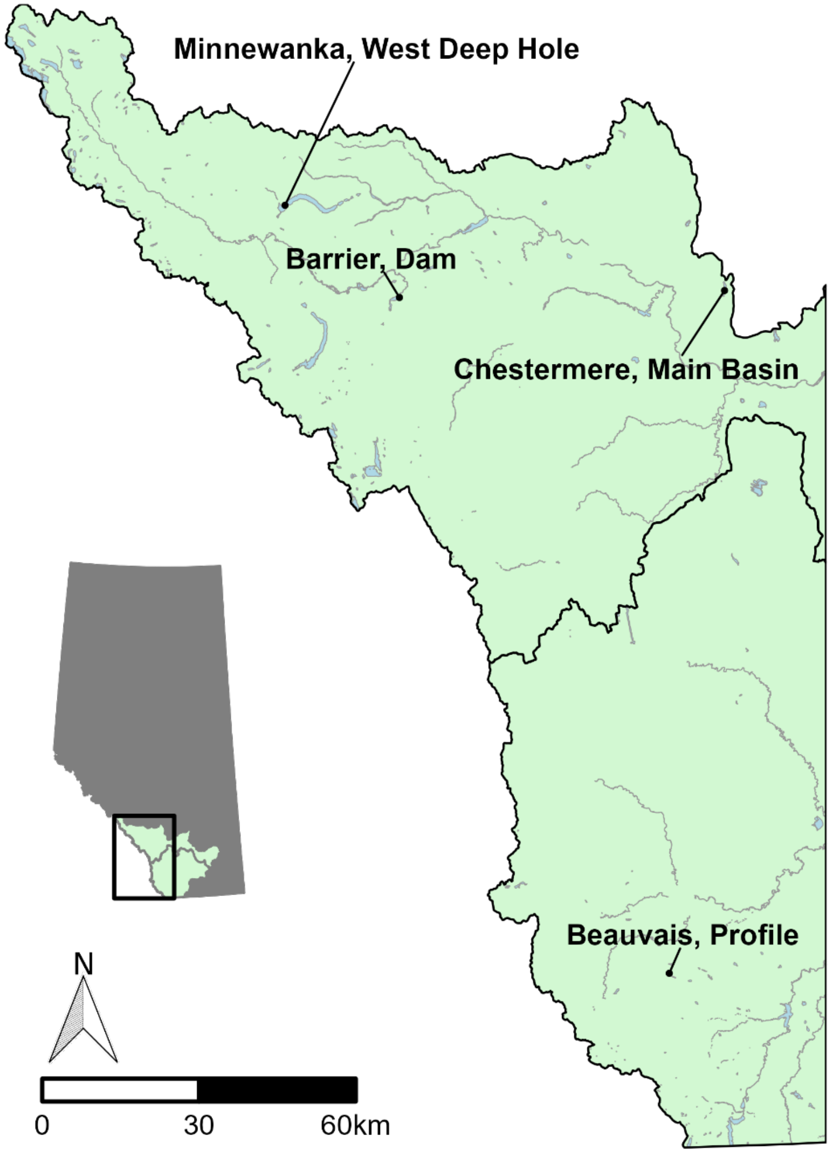


Figure 27. Seasonal surface water chemistry (TP = total phosphorus and ChlA = chlorophyll-a, Top; TKN = total Kjeldahl nitrogen, middle) and ice (clear and white) and snow thickness(bottom) from lakes sampled in the Red Deer River watershed in the Winter LakeKeepers 2022 season. In the top panel, TP is orange and ChlA is green, TKN in the middle section is purple, and in the bottom section snow is pick, white ice is gray, and clear ice is blue. Note that ice and snow thickness is plotted in reference to the ice surface (horizontal black line).

Bow & Oldman River Watershed

LakeKeepers



Map 8. Lakes sampled in the Bow River and Oldman watersheds during the Winter LakeKeepers 2022-2023 season. The Bow River and Oldman watersheds are highlighted in the Alberta inset map.

Bow & Oldman River Watershed

Table 8. Surface water chemistry (TP = total phosphorus, TDP = total dissolved phosphorus, TKN = total Kjeldahl nitrogen, NO3+NO2 = nitrate plus nitrite, NH3 = ammonia, DOC = dissolved organic carbon, Cl- = chloride, Cond. = conductivity, ChlA = chlorophyll-*a*, MCYST = microcystin) and environmental measurements (Air Temp. = air temperature) recorded at lakes in the Bow River and Oldman watersheds in the Winter LakeKeepers 2022-2023 season. Microcystin values above the recreational guideline of 10 µg/L are colored red.

	TP (µg/L)	TDP (µg/L)	TKN (mg/L)	NO3 + NO2 (µg/L)	NH3 (µg/L)	DOC (mg/L)	Cl- (mg/L)	Cond. (µS/cm)	pH	ChlA (µg/L)	MCYST (µg/L)	Air Temp. (°C)	Snow Depth (cm)	Ice Thickness (cm)	White Ice Thickness (cm)
Barrier, Dam															
Mar 18	<3.0	<3.0	0.1	110.0	<15.0	<0.5	1.4	320	8.10	<0.3	-	−3	4	65	2
Beauvais, Profile															
Dec 14	100.0	67.0	1.6	<4.2	21.0	7.2	1.1	300	8.29	113.0	-	−3	15	20	0
Jan 16	6.9	3.5	0.6	<4.2	36.0	6.5	<1.0	300	8.27	1.4	-	−1	3	41	4
Feb 11	6.5	4.0	0.6	<4.2	<15.0	6.1	1.0	300	8.38	5.2	-	3	8	43	5
Apr 4	8.6	<3.0	0.5	<4.2	16.0	6.9	1.1	300	8.20	3.6	-	3	10	51	5
Chestermere, Main Basin															
Dec 27	6.7	8.5	0.4	29.0	110.0	1.9	17.0	530	8.09	-	-	1	12	43	0
Jan 30	22.0	6.1	0.5	100.0	120.0	2.1	18.0	560	8.01	29.0	-	−10	10	61	0
Feb 25	45.0	17.0	0.6	120.0	16.0	1.8	18.0	560	8.10	65.0	-	10	13	69	9
Apr 1	22.0	8.5	0.4	-	-	1.3	17.0	570	8.01	21.4	-	5	13	72	6
Minnewanka, West Deep Hole															
Mar 18	<3.0	<3.0	0.1	16.0	<15.0	0.9	<1.0	390	7.92	0.9	-	−7	2	63	0

Bow & Oldman River Watershed

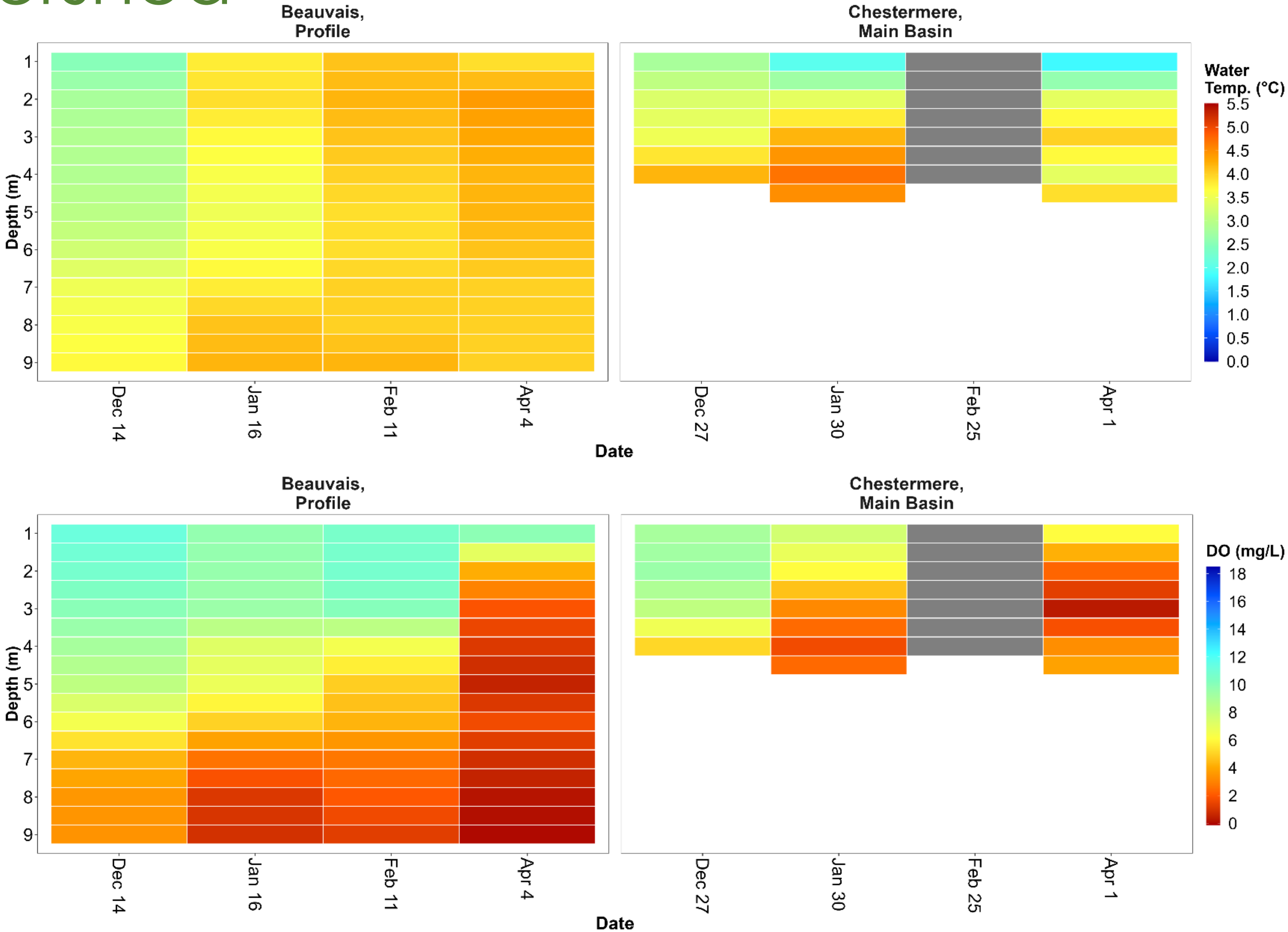


Figure 28a. Water temperature (Water Temp.; °C) and dissolved oxygen (DO; mg/L) measurements recorded at lakes sampled in the Bow River and Oldman watersheds in the Winter LakeKeepers 2022-2023 season. Measurements were taken at 0.1m and 0.5m, then every meter starting at 1 meter from ice surface, until lake bottom, however only measurements at 1m and below are plotted. Note that the measurements are linearly interpolated to 0.5m increments to improve data visualization, and Water Temp. and DO measurements are unavailable from 'Chestermere, Main Basin' sampled on February 25th, 2023.

Bow & Oldman River Watershed

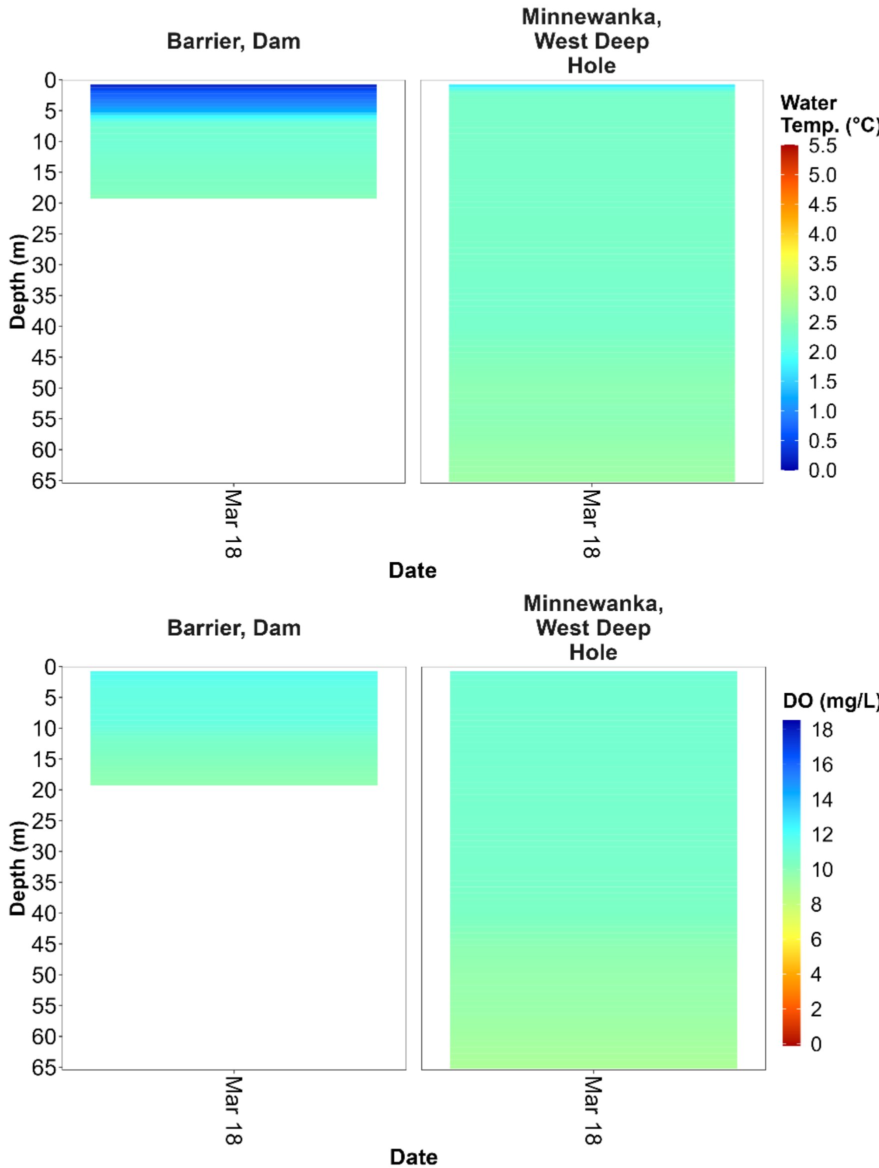


Figure 28b. Water temperature (Water Temp.; °C) and dissolved oxygen (DO; mg/L) measurements recorded at lakes sampled in the Bow River and Oldman watersheds in the Winter LakeKeepers 2022-2023 season. Measurements were taken at 0.1m and 0.5m, then every meter starting at 1 meter from ice surface, until lake bottom, however only measurements at 1m and below are plotted. Note that the measurements are linearly interpolated to 0.5m increments to improve data visualization, and that the bottom of the lake at the 'Minnewanka, West Deep Hole' sampling location was not reached due to the cord length of the water quality meter.

Bow & Oldman River Watershed

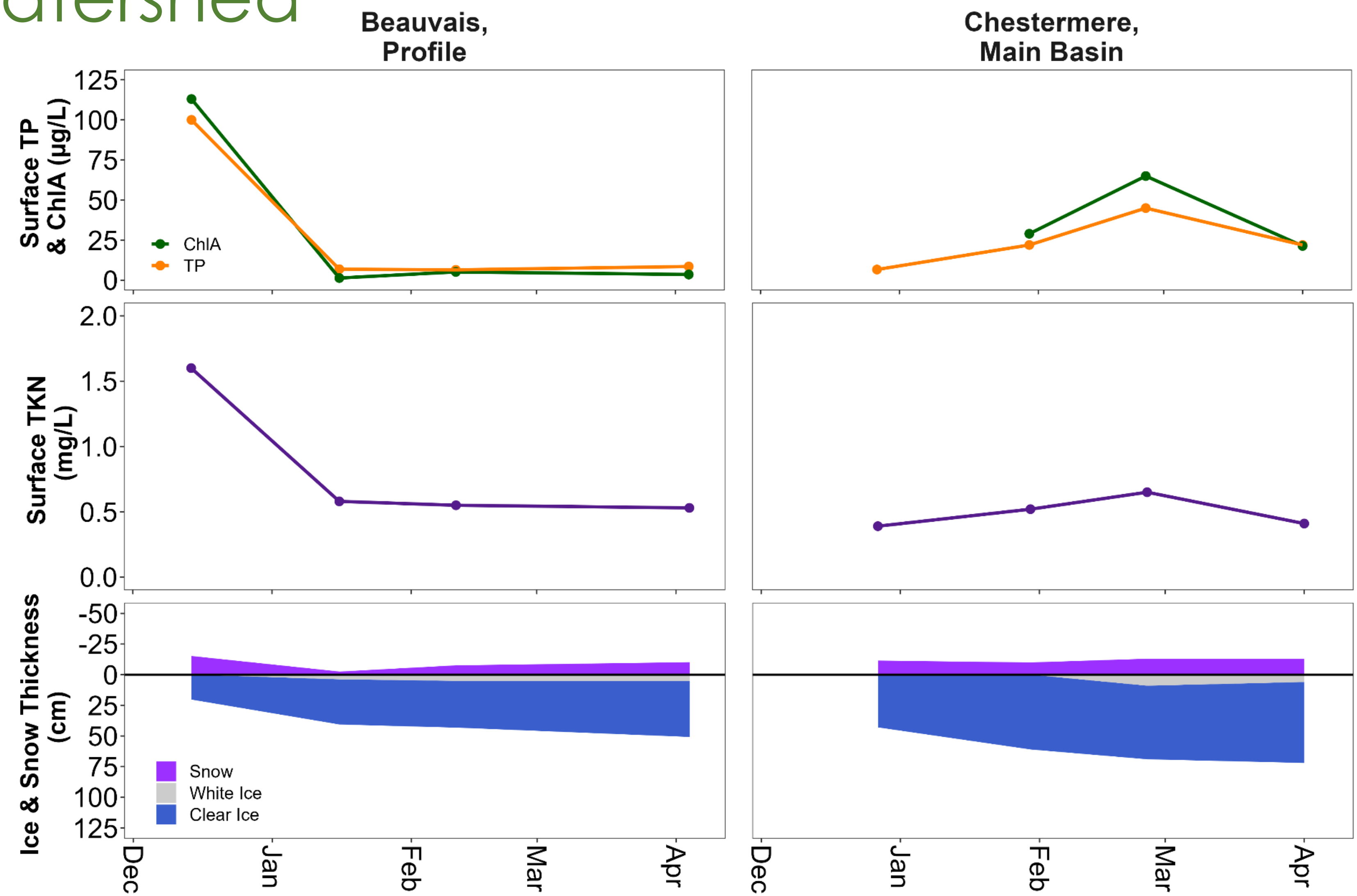
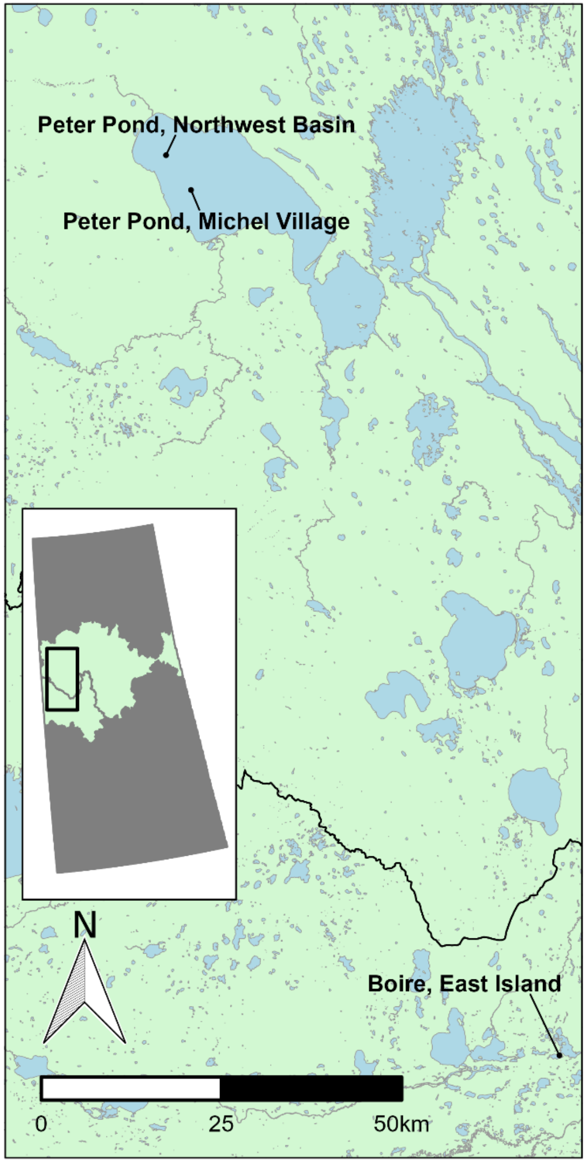


Figure 29. Seasonal surface water chemistry (TP = total phosphorus and ChlA = chlorophyll-a, Top; TKN = total Kjeldahl nitrogen, middle) and ice (clear and white) and snow thickness(bottom) from lakes sampled in the Bow River and Oldman watersheds in the Winter LakeKeepers 2022 season. In the top panel, TP is orange and ChlA is green, TKN in the middle section is purple, and in the bottom section snow is pick, white ice is gray, and clear ice is blue. Note that ice and snow thickness is plotted in reference to the ice surface (horizontal black line).

Appendix - Saskatchewan

LakeKeepers



Appendix Map 1. Lakes sampled in the Churchill River and Beaver River watersheds of Saskatchewan during the Winter LakeKeepers 2022-2023 season. The Churchill River and Beaver River watersheds are highlighted in the Saskatchewan inset map.

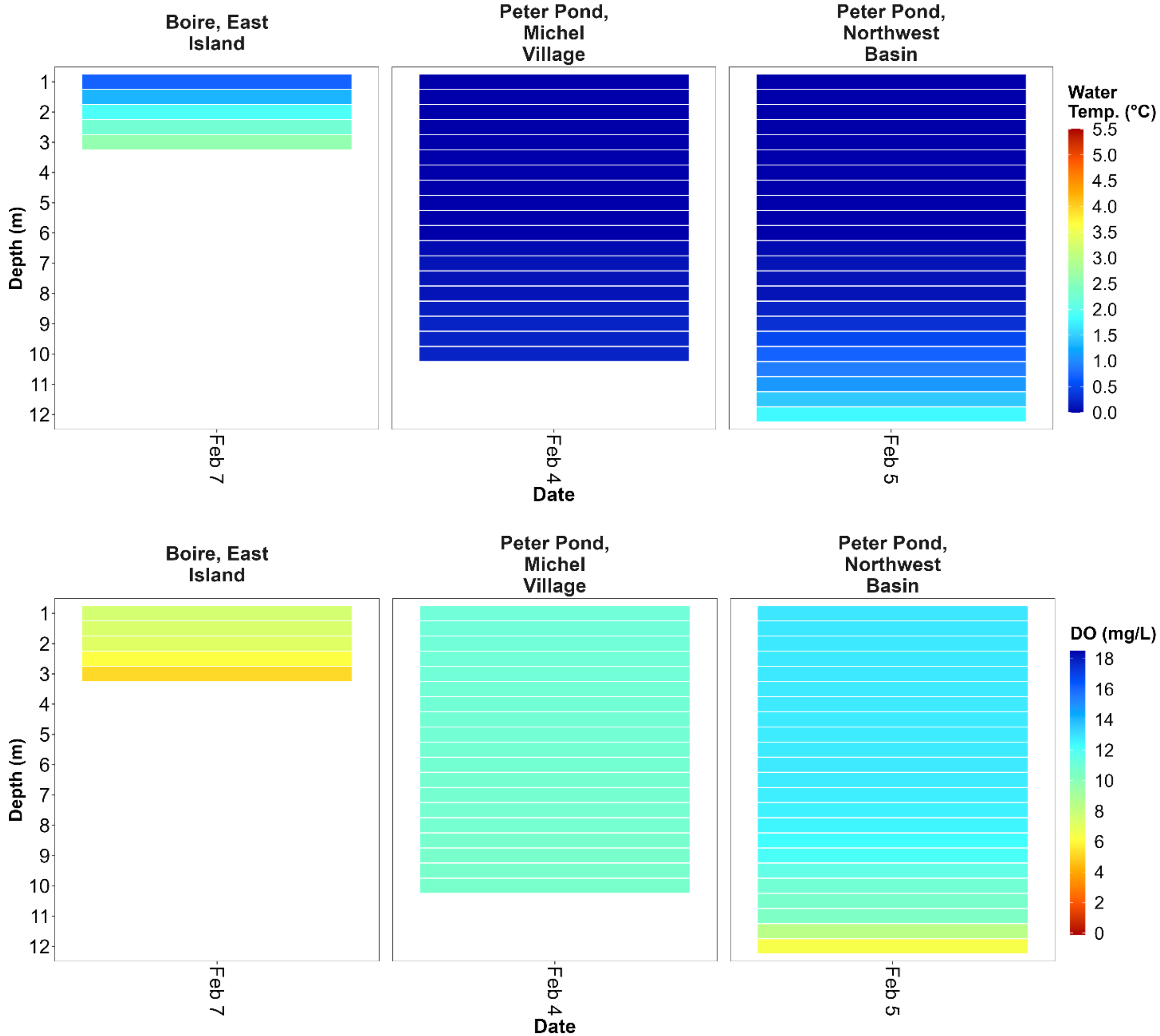
Appendix - Saskatchewan

LakeKeepers

Appendix Table 1. Surface water chemistry (TP = total phosphorus, TDP = total dissolved phosphorus, TKN = total Kjeldahl nitrogen, NO3+NO2 = nitrate plus nitrite, NH3 = ammonia, DOC = dissolved organic carbon, Cl- = chloride, Cond. = conductivity, ChlA = chlorophyll-*a*, MCYST = microcystin) and environmental measurements (Air Temp. = air temperature) recorded at lakes in the Churchill River and Beaver River watersheds of Saskatchewan in the Winter LakeKeepers 2022-2023 season. Microcystin values above the recreational guideline of 10 µg/L are colored red.

	TP (µg/L)	TDP (µg/L)	TKN (mg/L)	NO3 + NO2 (µg/L)	NH3 (µg/L)	DOC (mg/L)	Cl- (mg/L)	Cond. (µS/cm)	pH	ChlA (µg/L)	MCYST (µg/L)	Air Temp. (°C)	Snow Depth (cm)	Ice Thickness (cm)	White Ice Thickness (cm)
Boire, East Island															
Feb 7	24.0	-	1.5	-	-	-	-	-	-	-	-	−2	-	72	8
Peter Pond, Michel Village															
Feb 4	62.0	-	0.6	-	-	-	-	-	-	-	-	-	40	74	8
Peter Pond, Northwest Basin															
Feb 5	63.0	-	0.8	-	-	-	-	-	-	-	-	−3	36	88	14

Appendix - Saskatchewan



Appendix Figure 1. Water temperature (Water Temp.; °C) and dissolved oxygen (DO; mg/L) measurements recorded at lakes sampled in the Churchill River and Beaver River watersheds of Saskatchewan in the Winter LakeKeepers 2022-2023 season. Measurements were taken at 0.1m and 0.5m, then every meter starting at 1 meter from ice surface, until lake bottom, however only measurements at 1m and below are plotted. Note that the measurements are linearly interpolated to 0.5m increments to improve data visualization.

Appendix – Light Measurements

LakeKeepers

Appendix Table 2. Depth of 1% Light Penetration derived from photosynthetically active radiation (PAR) measurements from select lakes in the Athabasca, Beaver, North Saskatchewan, and Battle river watersheds in the Winter LakeKeepers 2022-2023 season. Measurements were taken at the surface above the snow and ice, then at 0.5m relative to the surface of the ice, and then every 1m till lake bottom. Note that 0.5m readings are excluded where ice thickness >0.5m. Parameters relevant to light penetration also represented (DOC = dissolved organic carbon, ChlA = chlorophyll-*a*). Table ordered by greatest Depth of 1% Light Penetration to least, where '< 1% Light' means at no depth below the ice was there light at or above 1% of surface levels. Each column is filled according to relative magnitude of that parameter from each sampling event; darker blue is greater magnitude, lighter blue is less magnitude.

	Date	Depth of 1% Light Penetration (m)	Total Ice Thickness (m)	Clear Ice Thickness (m)	White Ice Thickness (m)	Snow Depth (m)	DOC (mg/L)	ChlA (µg/L)
Mayatan West, Profile	Feb 13	7.36	0.51	0.51	0.00	0.08	17.0	<0.3
Pigeon, Grandview	Feb 3	5.47	0.81	0.81	0.00	0.03	10.0	2.2
Mink, Profile	Feb 17	3.83	0.58	0.55	0.04	0.08	18.0	1.0
Star, Profile	Feb 17	3.45	0.52	0.47	0.05	0.08	15.0	2.3
Jackfish, Profile	Feb 28	2.96	0.64	0.61	0.03	0.05	15.0	0.6
Narrow, Profile	Mar 29	2.78	0.54	0.54	0.00	0.06	9.5	1.9
Pigeon, Provincial Park	Apr 12	2.72	0.86	0.81	0.05	0.05	4.1	4.1
Pigeon, Grandview	Apr 12	2.48	0.91	0.81	0.10	0.10	5.3	6.0
Skeleton South, Center	Feb 10	2.29	0.61	0.53	0.08	0.03	16.0	1.9
Mayatan East, Profile	Feb 13	1.92	0.56	0.51	0.05	0.05	20.0	9.8
PL8, Profile	Feb 14	1.74	0.53	0.43	0.10	0.08	23.0	47.0
Spring (Stony Plain), Profile	Feb 28	1.70	0.66	0.61	0.05	0.09	18.0	18.7
Gerharts, Profile	Mar 3	1.09	0.52	0.47	0.05	0.13	8.4	3.5
PL7, Profile	Feb 14	0.95	0.42	0.39	0.03	0.10	17.0	43.9
Byers, Profile	Mar 3	< 1% Light	0.53	0.50	0.04	0.18	15.0	252.0
Cottage, Profile	Mar 2	< 1% Light	0.56	0.50	0.06	0.13	25.0	39.7
Hasse, Profile	Feb 28	< 1% Light	0.69	0.65	0.04	0.06	19.0	191.0
Johnnys, Profile	Feb 20	< 1% Light	0.57	0.55	0.03	0.08	57.0	10.7
Lacombe, Profile	Mar 31	< 1% Light	0.72	0.67	0.05	0.10	21.0	13.9
Mere, Profile	Mar 3	< 1% Light	0.61	0.56	0.05	0.13	13.0	215.0
PL14, Profile	Mar 2	< 1% Light	0.60	0.53	0.06	0.10	24.0	217.0
PL15, Profile	Feb 20	< 1% Light	0.50	0.47	0.03	0.08	31.0	26.5
PL16, Profile	Mar 2	< 1% Light	0.60	0.53	0.06	0.09	25.0	18.5
PL23, Profile	Feb 28	< 1% Light	0.64	0.57	0.06	0.08	19.0	69.5
PL24, Profile	Feb 20	< 1% Light	0.55	0.51	0.04	0.08	31.0	44.2
Skeleton North, Profile	Feb 10	< 1% Light	0.51	0.42	0.09	0.05	19.0	25.2

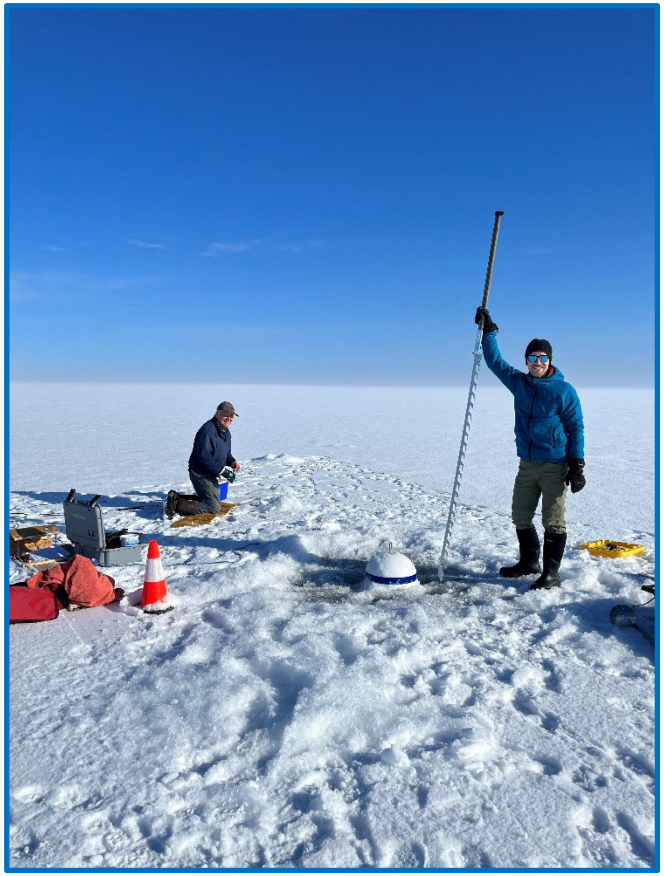
Monitoring light levels under the snow & ice surface of lakes can develop further understanding of water clarity conditions in the lake during winter. Light levels paired with other parameters may further contextualize whether low light levels below the ice and snow surface is due to:

- Snow & ice (e.g. low light at 'Gerharts, Profile' on Mar. 3rd is likely due to greater levels of white ice thickness and snow depth, while DOC and ChlA are low)
- High surface DOC (e.g. very low light at 'Johnnys, Profile' from Feb. 20th is likely due to high surface DOC)
- High surface ChlA (e.g. very low light at 'Mere, Profile' from Mar. 3rd is likely due to high surface ChlA, which means enough light for high photosynthesis is penetrating the snow and ice surface, but that the density of algae & cyanobacteria is preventing light from penetrating below the ice – water interface, where the algae & cyanobacteria are most dense.

Appendix – Pigeon Lake Sensor Array

A sensor array was deployed in Pigeon Lake at the Grandview sample location during the winter 2022-2023 season to learn more about water temperature, dissolved oxygen, and light dynamics under the ice. The sensor array consisted of dissolved oxygen (DO) and temperature (temp) loggers attached to a chain at 1m, 3.5m, 6m and 8.5m depth relative to the level of water within an ice auger hole. These loggers were programmed to record DO and temp readings every 30min. The array also consisted of light loggers measuring light intensity (lux) deployed at the same four depths. While the 1m logger was programmed to record lux every 30min, the other three light loggers were programmed to record every hour. The sensor array was deployed on December 1st, 2022 and removed April 12th, 2023 by ALMS staff and Pigeon Lake Watershed Association (PLWA) volunteer Don Davidson. Video footage from mid-winter confirmed that each logger remained deployed correctly. The bottom depth of the Grandview site is 8.9m. ALMS would like to thank Don Davidson for his assistance in deploying and removing the sensor, as well as monitoring the sensor array through the season. ALMS would also like to thank Alberta Environment and Protected Areas for providing the loggers for the sensor array.

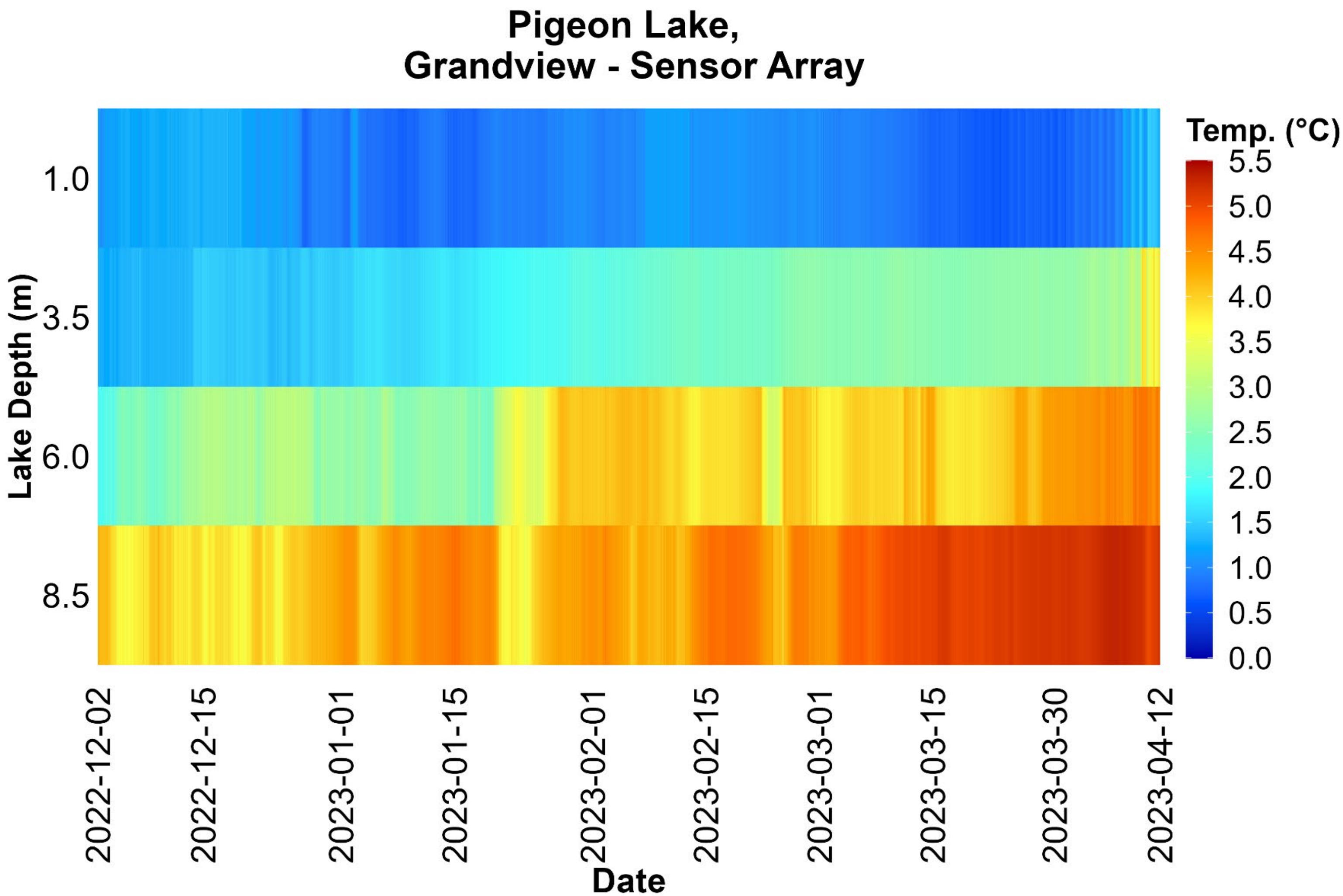
PLWA volunteer Don Davidson and ALMS staff Kirsten Letendre preparing to install the sensor array at Pigeon Lake, December 1st, 2022.



PLWA volunteer Don Davidson and ALMS staff Caleb Sinn removing the sensor array from the ice, April 12th, 2023.

Appendix – Pigeon Lake Sensor Array

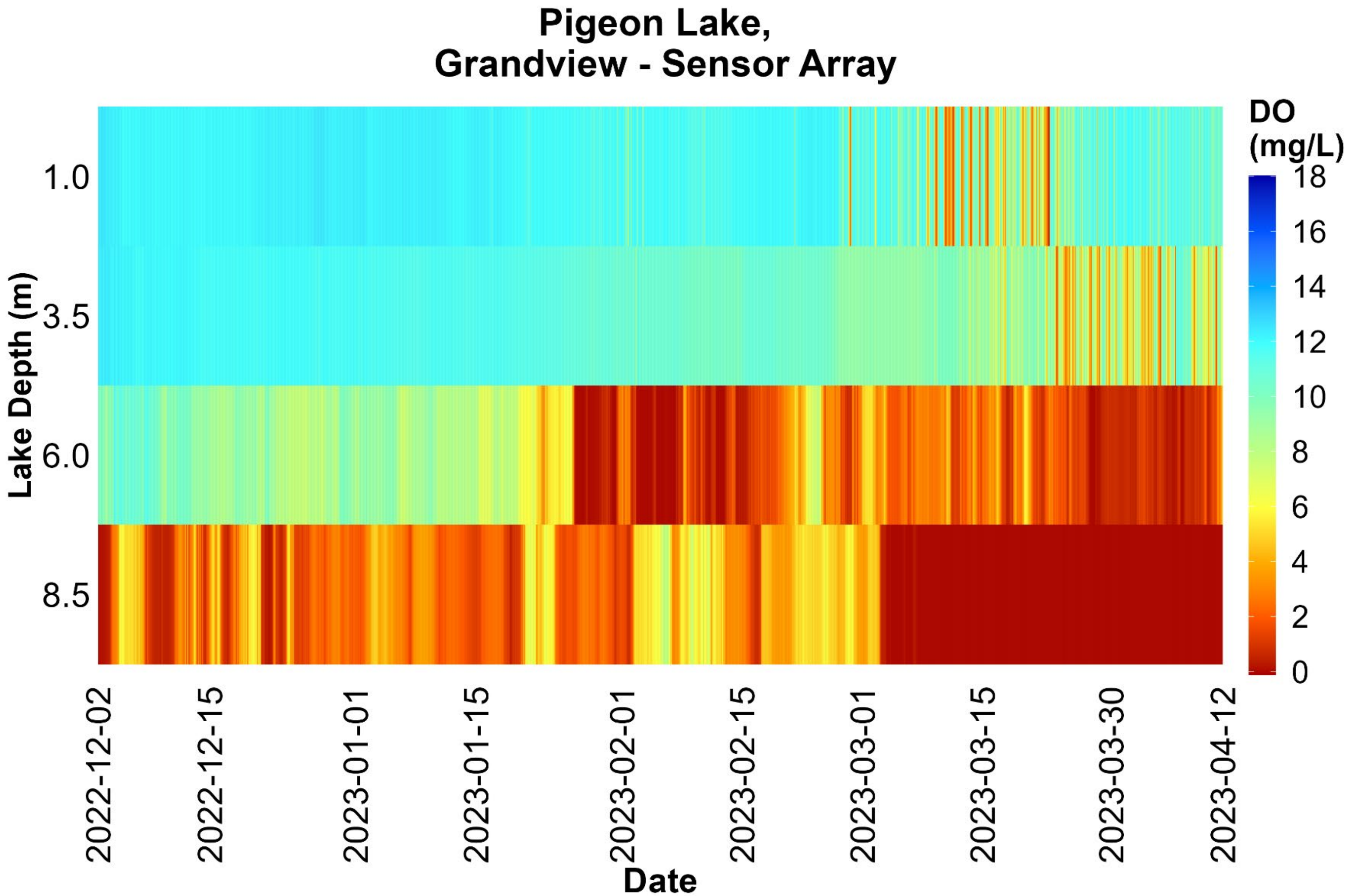
Water temperature data indicates a gradual warming of water at all depths below 1m from the beginning of the season to the end, and an increase of stratification between each depth through the season. It also demonstrates the high variability of under-ice lake temperatures through the season at every depth.



Appendix Figure 2. Water temperature (Temp.; °C) recorded with temperature loggers (HOBO Dissolved Oxygen Logger – U26-001) deployed at 1m, 3.5m, 6m and 8.5m on a sensor array at the 'Pigeon Lake, Grandview' sample location. Measurements logged every 30 minutes. The sensor array was deployed on December 1st 2022, and removed on April 12th 2023.

Appendix – Pigeon Lake Sensor Array

Dissolved oxygen (DO) data indicates a gradual but variable decrease in oxygen through the season at 6m and 8.5m. It also demonstrates an increase in daily variability of DO later in the winter at 1m and 3.5m, and to some extent down to 6m and 8.5m as well. Interestingly, there are some periods of time where there is higher DO at 8.5m than at 6m (also observed in 'Pigeon, Grandview' DO profiles, Figure 24), possibly indicating the interaction of complex mixing regimes and DO production at the bottom of the lake due to algal photosynthesis.

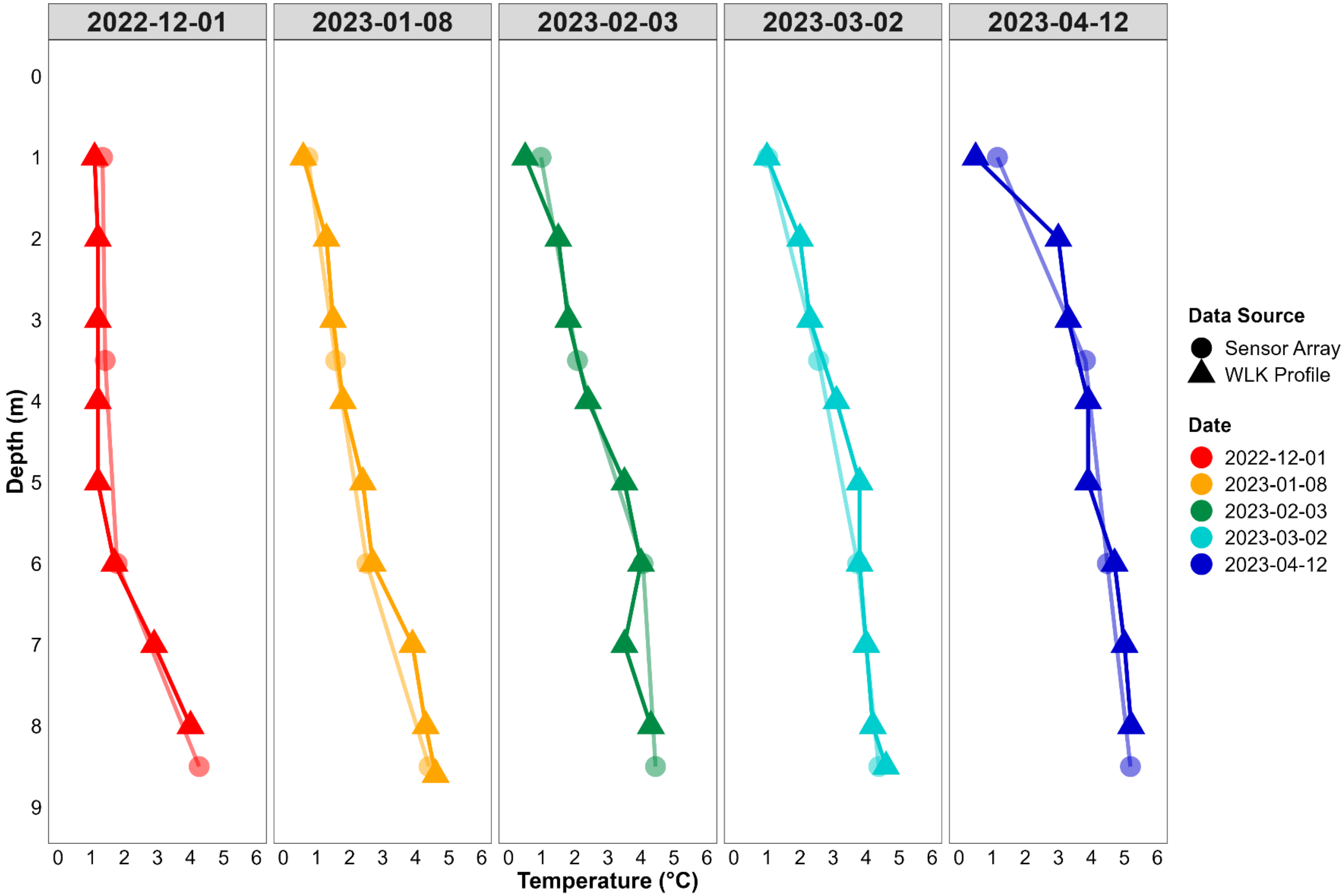


Appendix Figure 3. Dissolved oxygen (DO; °C) recorded with DO loggers (HOBO Dissolved Oxygen Logger – U26-001) deployed at 1m, 3.5m, 6m and 8.5m on a sensor array at the 'Pigeon Lake, Grandview' sample location. Measurements logged every 30 minutes. The sensor array was deployed on December 1st 2022, and removed on April 12th 2023.

Appendix – Pigeon Lake Sensor Array

LakeKeepers

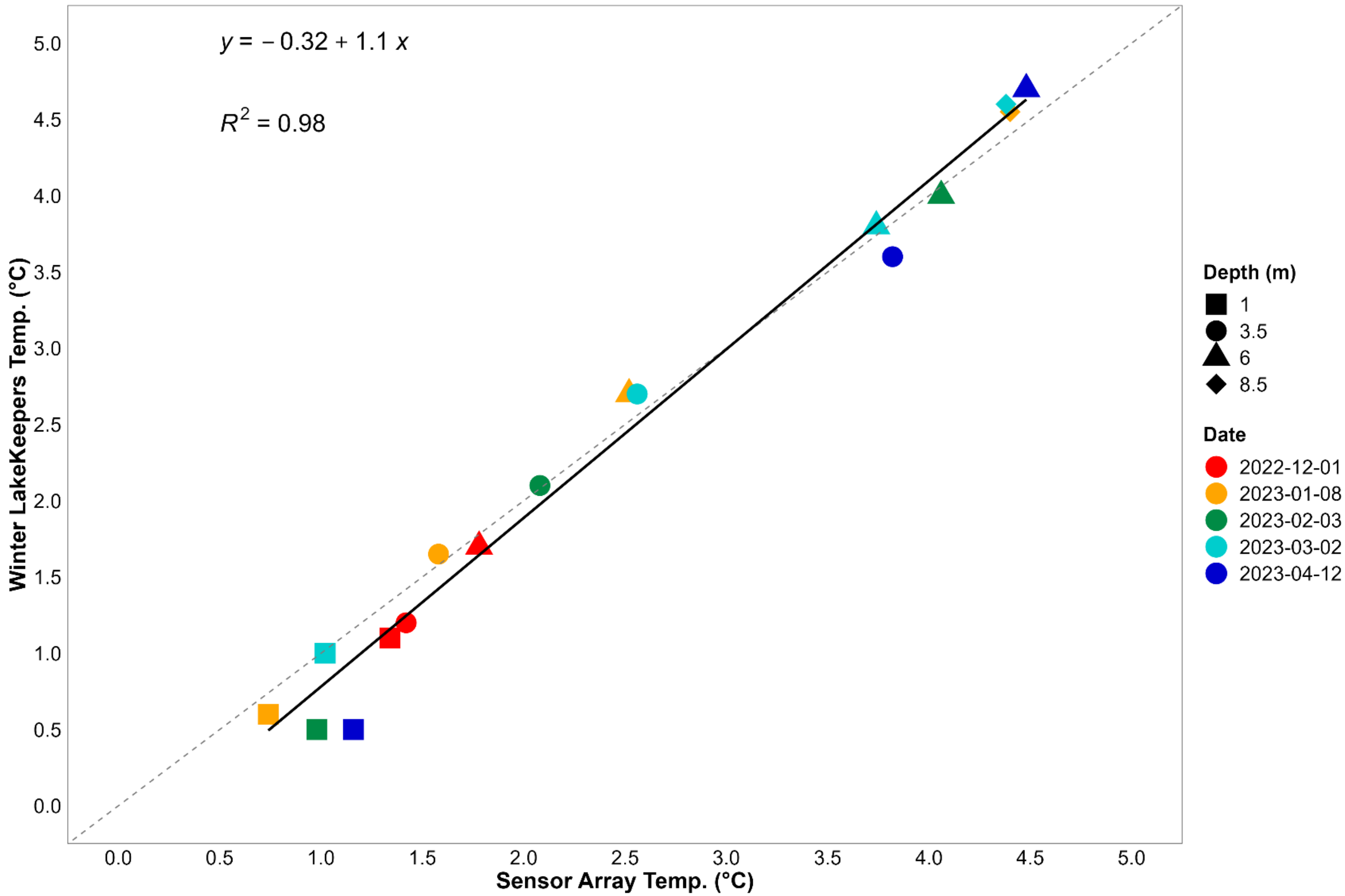
Comparing the sensor array water temperature data with the water temperature profiles taken through the Winter LakeKeepers program at the 'Pigeon, Grandview' location can help to understand data quality from both methods. Generally, water temperature readings agree well between each method. Most disagreement occurred at 1m, and in a few areas of the water column where the Winter LakeKeepers profile detected higher variability between each 1m reading that the sensor array couldn't represent having readings spaced every 2.5m.



Appendix Figure 4. Water temperature (Temperature; °C) recorded with temperature loggers (HOBO Dissolved Oxygen Logger – U26-001) deployed at 1m, 3.5m, 6m and 8.5m on a sensor array at the 'Pigeon Lake, Grandview' sample location ('Sensor Array'; circles) paired with water temperature readings taken through the Winter LakeKeepers 2022-2023 season at the 'Pigeon, Grandview' sample location ('WLK Profile'; triangles). Profile measurements taken every meter. Note that timestamps selected from the sensor array are as close as possible to the recorded sampling times from the Winter LakeKeepers profile, but the 2022-12-01 sensor array timestamp is ~2hrs after and the 2023-04-12 timestamp is ~1hr before the profile sampling times due to the timing of the sensor array deployment and removal on those dates.

Appendix – Pigeon Lake Sensor Array

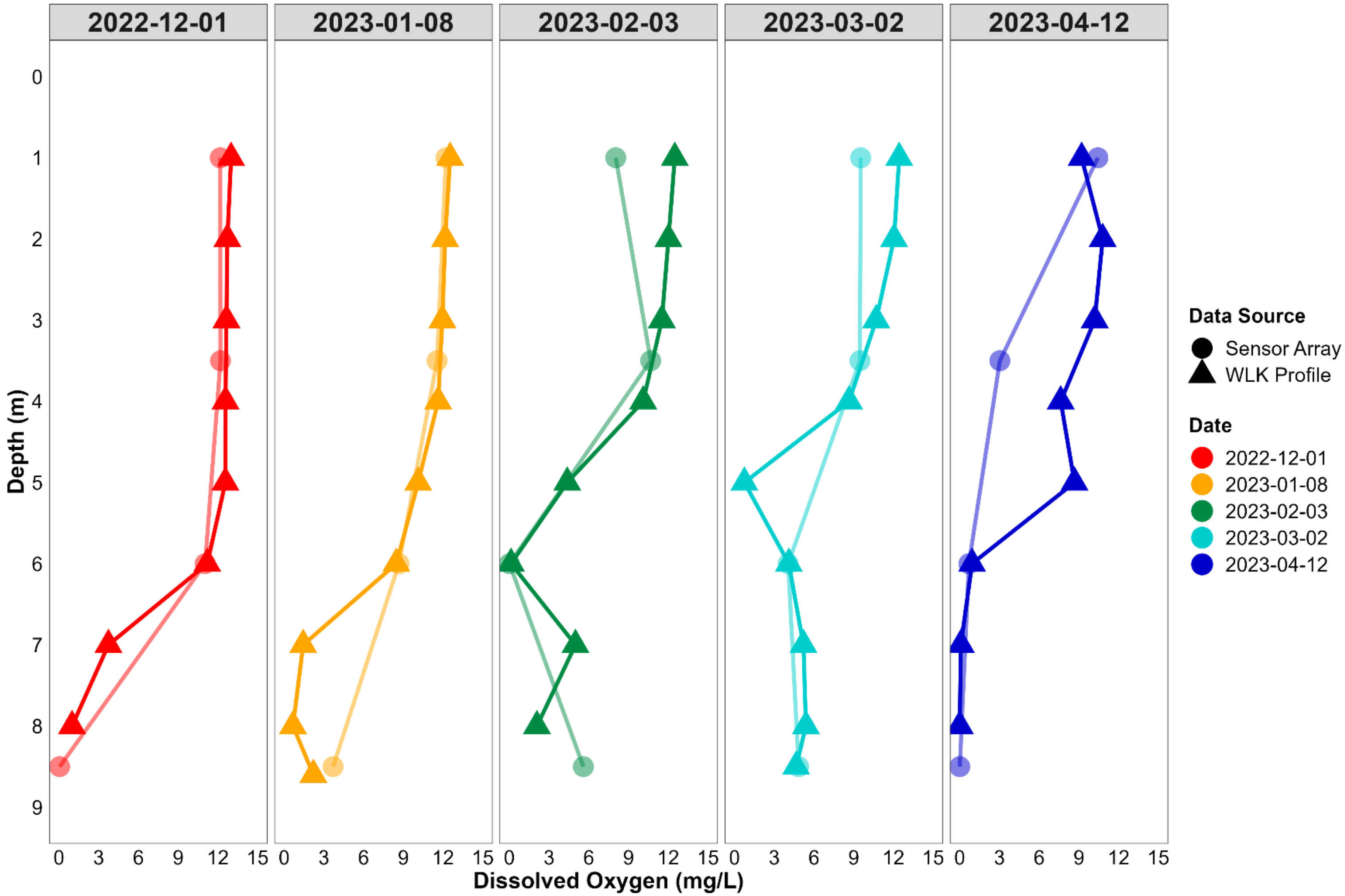
Further comparison of the two datasets indicates a strong linear relationship ($R^2 = 0.98$), mainly skewed by the sensor array temperature readings at 1m being slightly warmer than the 1m Winter LakeKeepers profiles. This may be due to the Winter LakeKeepers probes being slightly colder from measurements through the ice auger hole, and not being equilibrated long enough to represent ambient temperature.



Appendix Figure 5. Water temperature recorded with temperature loggers (HOBO Dissolved Oxygen Logger – U26-001) deployed at 1m, 3.5m, 6m and 8.5m on a sensor array at the 'Pigeon Lake, Grandview' sample location (Sensor Array Temp.; °C) paired with water temperature readings taken through the Winter LakeKeepers 2022-2023 season at the 'Pigeon, Grandview' sample location (Winter LakeKeepers Temp.; °C). Note that timestamps selected from the sensor array are as close as possible to the recorded sampling times from the Winter LakeKeepers profile, but the 2022-12-01 sensor array timestamp is ~2hrs after and the 2023-04-12 timestamp is ~1hr before the profile sampling times due to the timing of the sensor array deployment and removal on those dates. 'Winter LakeKeepers Temp.' at 3.5m and 8.5m are interpolated, and no 8.5m readings are available from Dec. 1, Feb. 2, and Apr. 12 as Winter LakeKeepers profiles only went as deep as 8m on those dates. Black line represents linear correlation line, with corresponding line equation and R^2 are noted in the top left. Gray dashed line represent 1:1 relationship between measurements

Appendix – Pigeon Lake Sensor Array

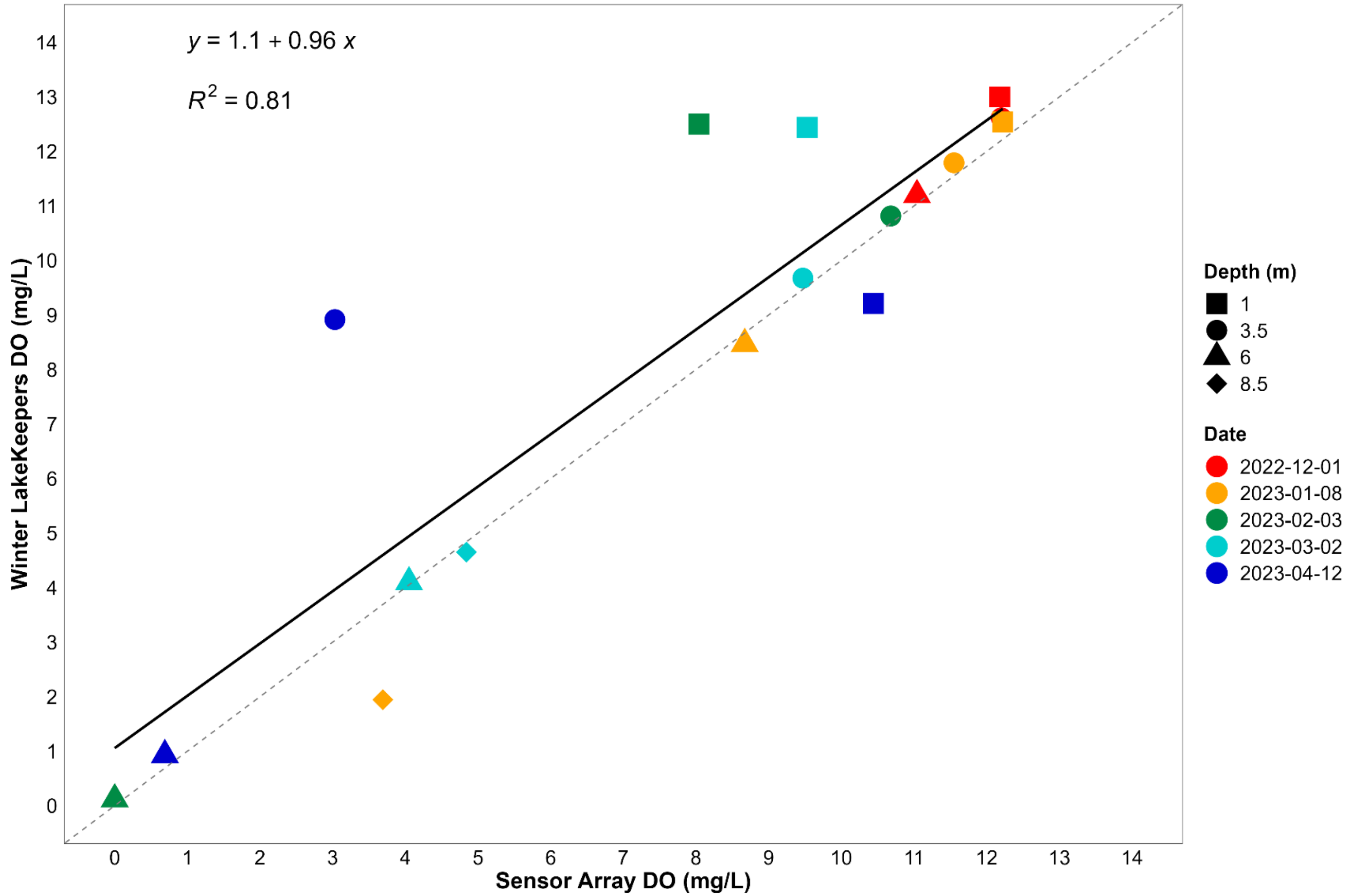
Comparing the sensor array dissolved oxygen (DO) data with the DO profiles taken through the Winter LakeKeepers program at the 'Pigeon, Grandview' location can help to understand data quality from both methods. Generally, DO readings agree well between each method. Most disagreement occurred at 1m, at 3.5m on Apr. 12th, and in a few areas of the water column where the Winter LakeKeepers profile detected higher variability between each 1m reading that the sensor array couldn't represent having readings spaced every 2.5m.



Appendix Figure 6. Dissolved oxygen (mg/L) recorded with dissolved oxygen loggers (HOBO Dissolved Oxygen Logger – U26-001) deployed at 1m, 3.5m, 6m and 8.5m on a sensor array at the 'Pigeon Lake, Grandview' sample location ('Sensor Array'; circles) paired with dissolved oxygen readings taken through the Winter LakeKeepers 2022-2023 season at the 'Pigeon, Grandview' sample location ('WLK Profile'; triangles). Profile measurements taken every meter. Note that timestamps selected from the sensor array are as close as possible to the recorded sampling times from the Winter LakeKeepers profile, but the 2022-12-01 sensor array timestamp is ~2hrs after and the 2023-04-12 timestamp is ~1hr before the profile sampling times due to the timing of the sensor array deployment and removal on those dates.

Appendix – Pigeon Lake Sensor Array

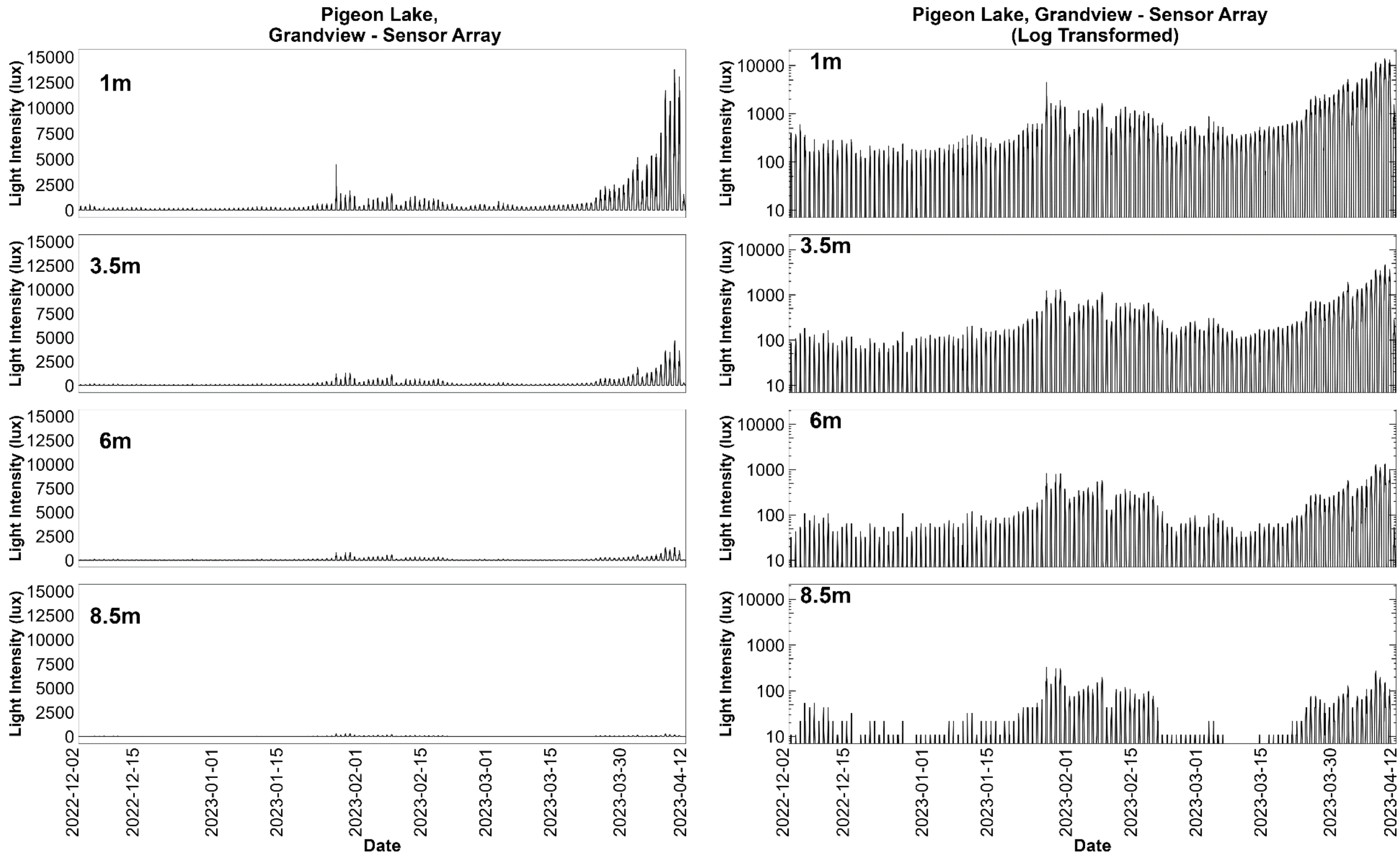
Further comparison of the two datasets indicates a moderately strong linear relationship ($R^2 = 0.81$), primarily skewed by the sensor array DO readings at 1m being lower on Feb. 3rd and Mar. 2nd, as well as at 3.5m on Apr. 12th. This may be due to the sensor array loggers being slightly fouled (algae & bacteria biofilm growth on the logger), which may bias the readings of the sensors lower due to respiration of the biofilm.



Appendix Figure 7. Dissolved oxygen recorded with dissolved oxygen loggers (HOBO Dissolved Oxygen Logger – U26-001) deployed at 1m, 3.5m, 6m and 8.5m on a sensor array at the 'Pigeon Lake, Grandview' sample location (Sensor Array DO; mg/L) paired with dissolved oxygen readings taken through the Winter LakeKeepers 2022-2023 season at the 'Pigeon, Grandview' sample location (Winter LakeKeepers DO.; mg/L). Note that timestamps selected from the sensor array are as close as possible to the recorded sampling times from the Winter LakeKeepers profile, but the 2022-12-01 sensor array timestamp is ~2hrs after and the 2023-04-12 timestamp is ~1hr before the profile sampling times due to the timing of the sensor array deployment and removal on those dates. 'Winter LakeKeepers DO' at 3.5m and 8.5m are interpolated, and no 8.5m readings are available from Dec. 1, Feb. 2, and Apr. 12 as Winter LakeKeepers profiles only went as deep as 8m on those dates. Black line represents linear correlation line, with corresponding line equation and R^2 are noted in the top left. Gray dashed line represent 1:1 relationship between measurements

Appendix – Pigeon Lake Sensor Array

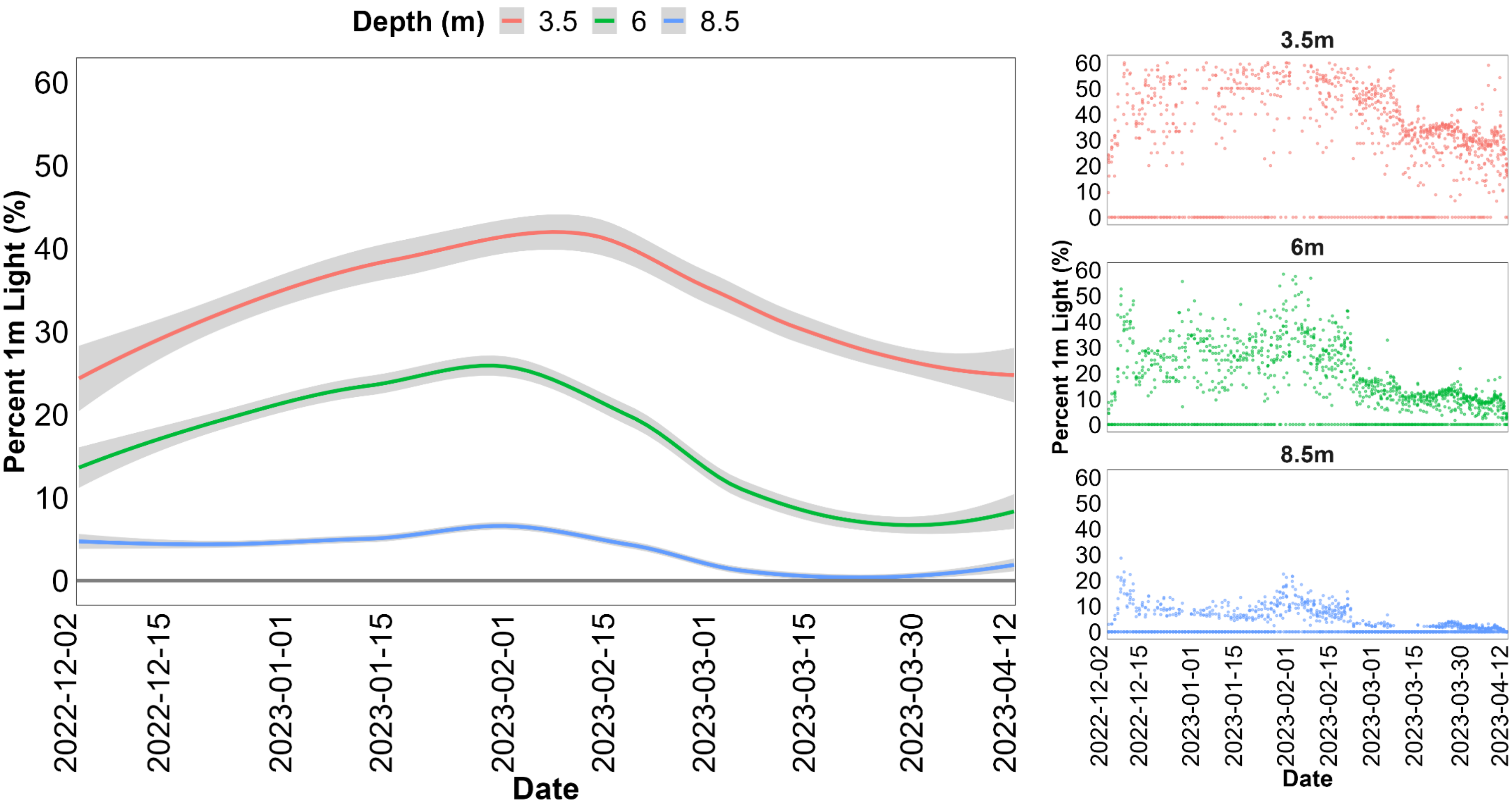
Light data indicates relatively low light penetration between December and mid-January, followed by increases in light penetration at each depth between mid-January and mid-February, corresponding with decreased levels of surface snow (Figure 25). Light penetration decreased through the water column between mid-February and mid-March, before ramping up to the highest levels at each depth until the removal of the logger in mid-April. Interestingly, light was detected at the bottom of the lake throughout the entire winter.



Appendix Figure 8. Light Intensity (lux) measurements recorded with the light loggers (HOBO Pendant Temperature/Light Data Logger – UA-002-08) at 1m, 3.5m, 6m and 8.5m on a sensor array at the 'Pigeon Lake, Grandview' sample location. Measurements logged every 30 minutes at 1m, and every 1 hour at 3.5m, 6m and 8.5m . The sensor array was deployed on December 1st 2022, and removed on April 12th 2023. Raw data is on the left, and log-transformed data is on the right (in order to improve comparability of seasonal patterns at each depth.

Appendix – Pigeon Lake Sensor Array

While surface light levels are not available to investigate the depth of 1% light penetration like the 'Light Measurement' section of the appendix above, investigating the changes of light at each depth below 1m relative to the light detected at 1m can indicate changes in water clarity through the water column. This analysis indicates that clarity increased from early December and peaked in mid-February, before decreasing again until the end of the season, in line with increases in surface chlorophyll-*a* (Figure 25), indicating that surface algae growth likely limited light penetration to depths below 1m.



Appendix Figure 9. Smoothed (left) and raw (right) percent light relative to light intensity from the 1m light logger (Percent 1m Light; %) at 3.5m, 6m, and 8.5m. Light Intensity (lux) measurements recorded with the light loggers (HOBO Pendant Temperature/Light Data Logger – UA-002-08) at 1m, 3.5m, 6m and 8.5m on a sensor array at the 'Pigeon Lake, Grandview' sample location. Measurements logged every 30 minutes at 1m, and every 1 hour at 3.5m, 6m and 8.5m . The sensor array was deployed on December 1st 2022, and removed on April 12th 2023. Note that timestamps where lux = 0 at 1m are removed, and that raw percentage have been smoothed with a LOESS trend line. On the left figure, the gray area around each line represents standard error of the LOESS trend, and the 0% level is highlighted with a gray horizontal line.