Lakes Environmental Association

2022 Winter Monitoring Report

LEA's Winter Lake Monitoring

Introduction

For decades, Lakes Environmental Association (LEA) has watched over the water quality of lakes in the greater Bridgton area by making measurements and collecting water samples during late spring through early fall. Winter-time was mostly ignored due to challenging work conditions and the long-held perception that lakes are dormant during the cold, ice-covered period. More recently, the scientific community has challenged that perception through a growing number of studies that highlight the importance of evaluating winter-time lake conditions and linking those to overall lake health.

Climate change plays a large role in the increased interest in winter lake conditions. Long-term records of lake freeze and break-up dates show that ice cover periods have decreased significantly for many places. Less time with ice cover has and will lead to a reduction or loss of cultural and recreational activities. The impact on water quality throughout the year from a reduction or loss of ice cover is not as well known. So to fill that void, researchers have increased efforts to study lakes during winter and improve basic understanding of winter conditions and how those might link to open water periods.

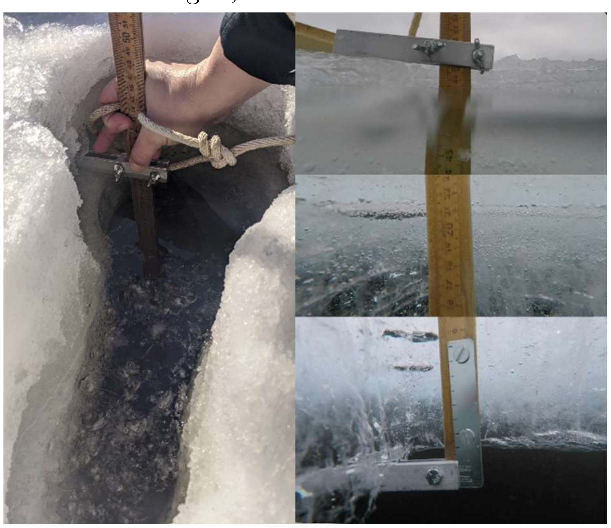
LEA has joined in that effort to make wintertime field work a more regular part of lake monitoring. Our staff began detailed winter field work in 2018 with nine trips to a total of four of our service-area lakes. The total trip number doubled in the next year with six lakes visited. We made 13 trips to 7 different lakes and 29 trips to 11 different lakes in 2020 and 2021, respectively.

In 2022, our plans were even more ambitious and we were able to make trips to 13 different lakes two to three times each for a total of 32 visits. This report is a summary of the information gathered during these visits. Partial support for this work was provided by the Five Kezars Watershed Association, Hancock & Sand Ponds Association, the Keoka Lake Association, the Keyes Pond Environmental Protection Association, the McWain Pond Association, the Moose Pond Association, the Peabody Pond Association, the Trickey Pond Environmental Protection Association, and the Woods Pond Association. Thanks also go to Rebecca Gould and Bill Buckley, Ann and Dan Lasman, Bob Mercier, Ken Sharples, and Camp Tapawingo for providing lake access.

Methods

We made three visits to Keoka Lake, McWain Pond, Moose Pond (main basin), Peabody Pond, Trickey Pond, and Woods Pond. Back Pond, Hancock Pond, Highland Lake, Long Lake (north basin), Middle Pond, Keyes Pond, and Sand Pond were each visited twice. For each lake visit, we traveled by foot over the ice to the deep site and used an ice auger to drill a hole. Holes were widened using an ice saw or by drilling an extra hole in order to accommodate larger gear. We used a homemade gauge to measure ice thickness, snow depth, and water level in the hole. We also captured video footage of the ice and under-ice conditions for each lake using a GoPro camera in a waterproof housing. Staff involved in these trips included Maggie Welch, Shannon Nelligan, and Ben Peierls.

Maggie with ice auger (left) and fitting Secchi disk through expanded ice hole (right).



Ice gauge in use (left) and as seen under water (right).

On two visits for each lake, we measured light levels above and at several depths below the ice using a LI-COR LI-192 underwater quantum sensor. During these measurements, we covered the hole with three layers of window screening to prevent light passing through from affecting the readings. The attenuation of light due to ice was calculated as the percent of surface light that reaches the water just under the ice layer. Water clarity below ice was measured during each visit using a Secchi disk lowered through the hole and viewed with our standard slanted-glass viewing scope.

We used a calibrated YSI EXO2 multiparameter sonde connected to a handheld data logger to measure depth-based profiles of temperature, dissolved oxygen, conductivity (normalized to 25 °C), pH, turbidity, chlorophyll fluorescence, and phycocyanin fluorescence. Sonde depth was converted to and reported as depth below ice. Measurements were recorded every 0.5 or 1 meter to the bottom (determined by feel or when turbidity levels rose an order of magnitude). Phycocyanin, which relates to cyanobacteria biomass, was mostly low and omitted from this report.

Maggie calibrating the sonde.

Water samples were collected using flexible tubing (known as a core tube). This sampler integrates water from the ice to 10 m depth (or to 1 m above the bottom in shallow lakes). These samples were analyzed for total phosphorus using a SEAL segmented flow analyzer and for algae using a Yokogawa Fluid Imaging Technologies FlowCam, a flow imaging microscope that captures images of algae for counting and identification. The samples were also analyzed for water color and processed for chlorophyll, but the results were not available for this report.

Maggie using the sonde and handheld data logger on Moose Pond (left) and measuring Secchi depth on Keyes Pond (right).

Shannon measuring light above the ice Keoka Lake (left) and using a core tube with Ben to collect water samples on Woods Pond (right).

Overall Results

Ice cover is the dominant feature of LEA service area lakes during winter. Variation in ice cover timing, duration, and characteristics (known as ice phenology) is driven by local weather conditions. Ice-in happened in late December 2021 and we were able to begin our field trips in mid-January 2022. **Ice thickness** ranged from 22 to 53.7 cm (8.7–21.1 in, Fig. 1), with the maximum occurring on Middle Pond. Our past maximum ice thickness records were 55, 75, 41, and 57.4 cm for 2018, 2019, 2020, and 2021, respectively. Ice on Highland Lake and Long Lake (and maybe Moose Pond) was thicker than expected due to frozen slush and snow. Snow covered the ice through early February and then again in early March. Ice thickness generally increased from January through early March. By the time of the last visits in mid-March, the ice had started to thin at some locations; most lakes were ice free by early April.

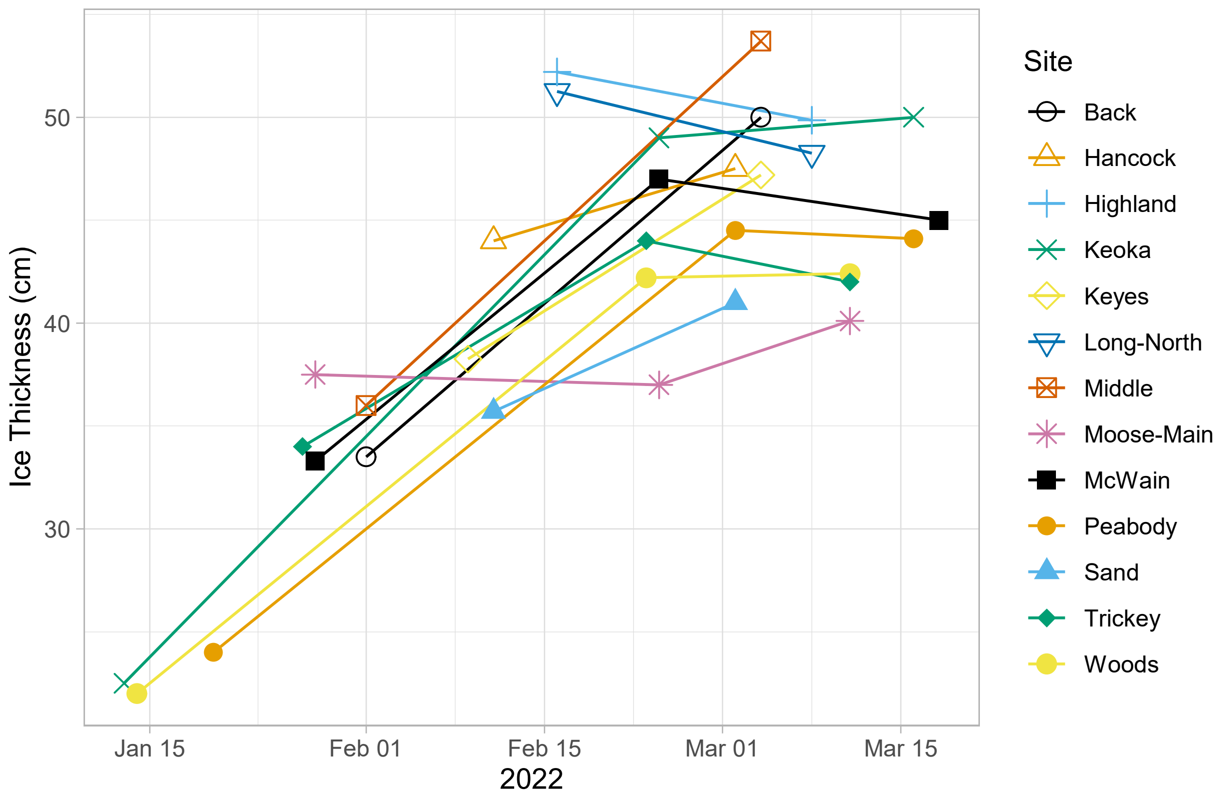


Figure 1. Ice thickness in cm versus date for lakes visited in winter 2022; lines to aid visualization only.

Aside from cold temperatures and ice, one of the key features of winter-time conditions in lake water is low **light**. Sunlight controls water temperature and provides energy for photosynthesis by algae. When lakes are covered by ice or ice and snow, light is blocked from reaching the water below. Our measurements with the light meter demonstrated that light just under ice alone varied from about 3 to 37% of surface irradiance, but ice thickness did not affect that light attenuation consistently (if it did, one would see thinnest ice with the greatest light penetration; Fig 2). Ice clarity had a strong impact on light penetration: lakes with layers transitioning from snow and slush to ice (white ice) had proportionally less light underneath the ice (see box in Fig. 2). Snow cover reduced light even more. With up to 10 cm (3.9 in) of snow, light was reduced to about 10% or less of surface light; that dropped to 5% or less of surface light when snow was greater than 10 cm deep. Considering that lake photic zones (where algae have enough light to grow) are usually defined as the layer extending down to where light is 1% of surface irradiance, one can see how algal growth could be limited to very shallow layers in winter.

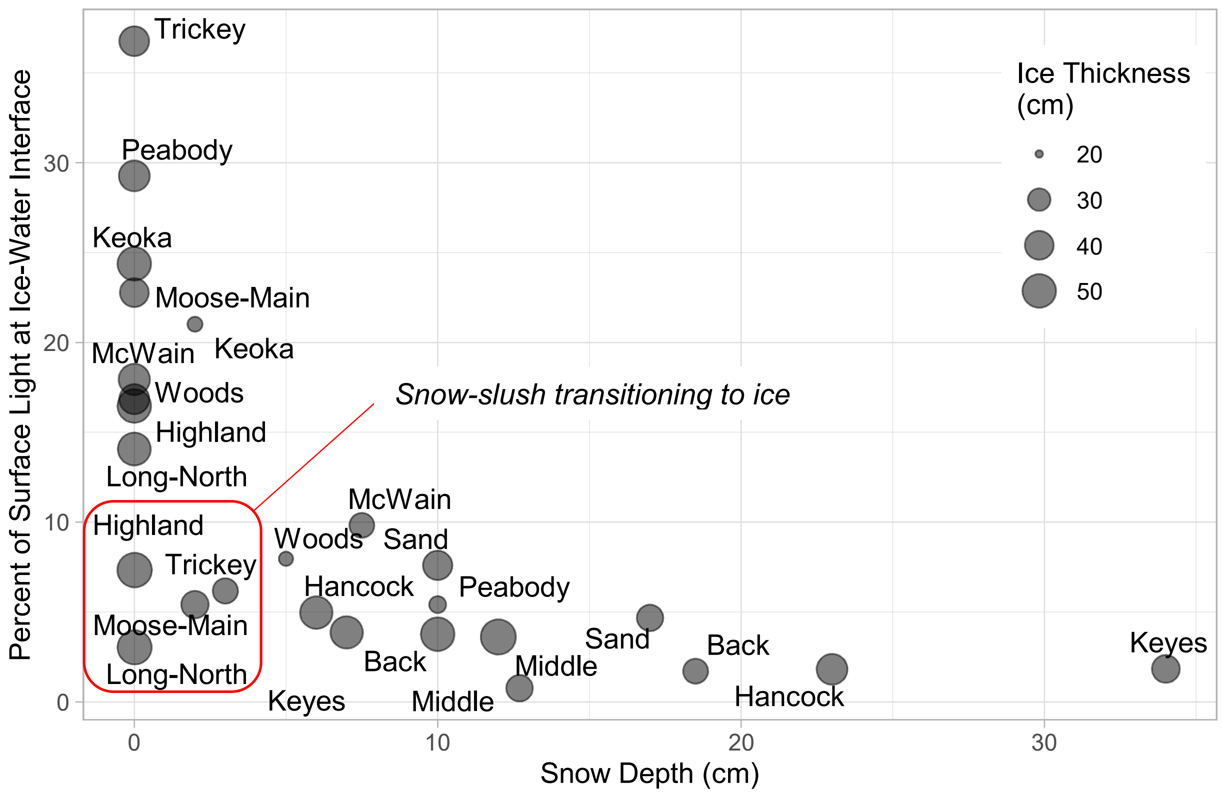


Figure 2. Light just underneath the ice (expressed as percent of surface values) decreases with increasing snow depth, as expected. Symbol size indicates ice thickness.

This was our first year measuring **water clarity** by Secchi disk through lake ice. Just as in summer, water clarity plays a role in controlling light availability in winter, though we knew little about typical values. We had concerns that light under the ice might be insufficient to get valid readings, but that was not the case. A comparison with the long-term Secchi depth data distribution showed that the winter 2022 readings were mostly within the typical range for the studied lakes and at least half of the values were above the long-term averages (Fig. 3). Secchi depth values for Keoka Lake, McWain Pond, and Trickey Pond were particularly high (meaning clearer water) at least some of the time. Some measurements from Hancock and Middle Ponds were on the extreme low end of the range (less clear water). These values coincided with relatively higher chlorophyll and turbidity, which can reduce water clarity. It is also possible that the true values were biased due to the potential difficulty distinguishing the Secchi disk at depth under the low light conditions beneath ice and snow.

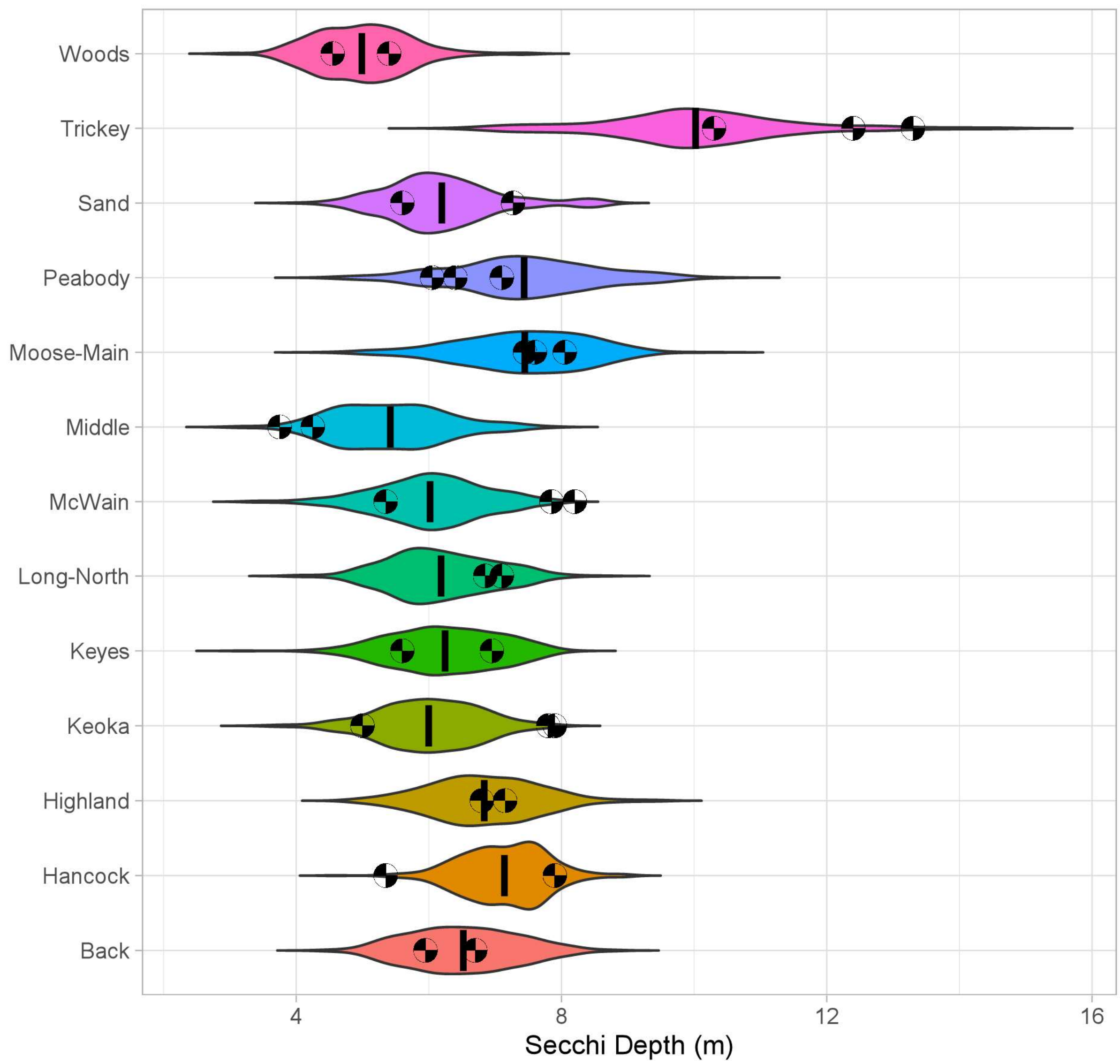


Figure 3. 2022 under-ice Secchi depths compared to long-term open-water measurements by lake. Secchi disk symbols represent the two to three winter 2022 readings and colored areas represent the distribution of long-term (1996-2021) data, where area thickness represents the number of measurements by value. Vertical bar is long-term average.

A common method for assessing lake condition is to collect depth-specific physical, chemical, and biological measurements. The sonde-based measurements (or profiles) gave us a snapshot of lake stability and mixing, oxygenation, algae biomass, turbidity, and inorganic chemistry throughout the whole water column at specific points in time. Across all 13 lakes, the sonde profiles were remarkably consistent for each variable albeit with some minor variations. A general discussion is presented here and the individual lake profiles follow starting on page 10.

The most significant feature captured in these profiles is the inverse temperature stratification typical of ice-covered lakes. Water is most dense at 4 °C (39.2 °F), so in winter the warmest water is at the bottom and the coldest water is at the surface (ice-water interface), opposite of the pattern in summer. Temperatures increased rapidly with depth within the first few meters and then more slowly to the bottom. As winter progressed, heat from sunlight and from sediment storage gradually increased the water column temperatures even as the ice-water interface stayed near 0 °C (32 °F).

Microbial respiration and other oxygen-consuming processes do occur despite the cold temperatures. As a result, dissolved oxygen (DO) decreased with increasing depth and time, much like in summer. Near-ice DO concentrations were mostly near saturation and a few lakes went anoxic (complete absence of DO) near the sediments.

pH, a measure of acidity, generally paralleled the oxygen response since water tends to become more acidic (pH < 7) as respiring organisms use up oxygen and generate dissolved carbon dioxide. The pH sensor was switched after the first two trips and this sensor turned out to be slow to respond and was biased high, even though it passed calibration. All pH values starting on January 20, therefore, were considered suspect. We present the pH profile data to show relative changes with depth, even though the values are probably higher than actual conditions.

Conductivity, a measure of dissolved ions in the water, spanned mostly low values as is typical in softwater lakes. Values did increase with depth depending on the lake, mostly likely in response to the dissolved matter being released from the sediments and the changing chemistry as oxygen declined. Near-ice readings were often quite variable and we assume that elevated readings were caused by the concentrating effect of water freezing slowly and leaving impurities behind. Similarly, ice and snow melt water can cause localized decreases in conductivity.

Turbidity, which is a measure of particle content in water, also tended to increase with depth from generally low surface values. Some of the turbidity increase could be due to changing chemical conditions in the deeper water that allows dissolved material to come out of solution as aggregates. Also, cells and detritus (non-living material) will gradually settle downwards into deeper, denser water driving turbidity higher. Deep turbidity can be even higher as convective currents disturb fine, light sediments upward.

Finally, chlorophyll fluorescence profiles represent the vertical distribution of algae, an important part of lake food webs and an indicator of lake trophic status (i.e., how green a lake is). Chlorophyll fluorescence is a relative measure of chlorophyll pigment, which is itself a proxy for algae biomass. The sonde chlorophyll profiles displayed much more variability, but in general when there was a peak in fluorescence it tended occur within a few meters of the ice-water interface and sometimes directly under the ice. Peaks at the bottom were probably sediment-associated dead or dying cells. The variation with depth can be explained by light and nutrient availability and possibly by differences algae species present. Zooplankton (tiny grazers of algae) can also control algae abundance by eating them; we often observed abundant zooplankton populations in the under-ice videos and in the surface water. Fluorescence magnitude ranged as high if not higher than summer values suggesting the presence of an active and productive algal community.

We used our FlowCam analyzer to characterize the taxa that make up the lake algae community in winter. Quantitative data is not presented here, since we have yet to finish fine tuning the classification process. We did capture images of several abundant and charismatic species or groups (Fig. 4), including diatoms, *Mallomonas* and *Synura* (Synurophyceae), *Dinobryon* (Chrysophyceae or "Golden Brown"), cyanobacteria, dinoflagellates, cryptophytes, and chorophytes ("Greens"). Several of these taxa are capable of deriving nutrition from organic matter and microbial prey in addition to photosynthesis, which makes sense in the light limited conditions of winter. The FlowCam also captured some images of rotifers, part of the non-photosynthetic grazing community (zooplankton).

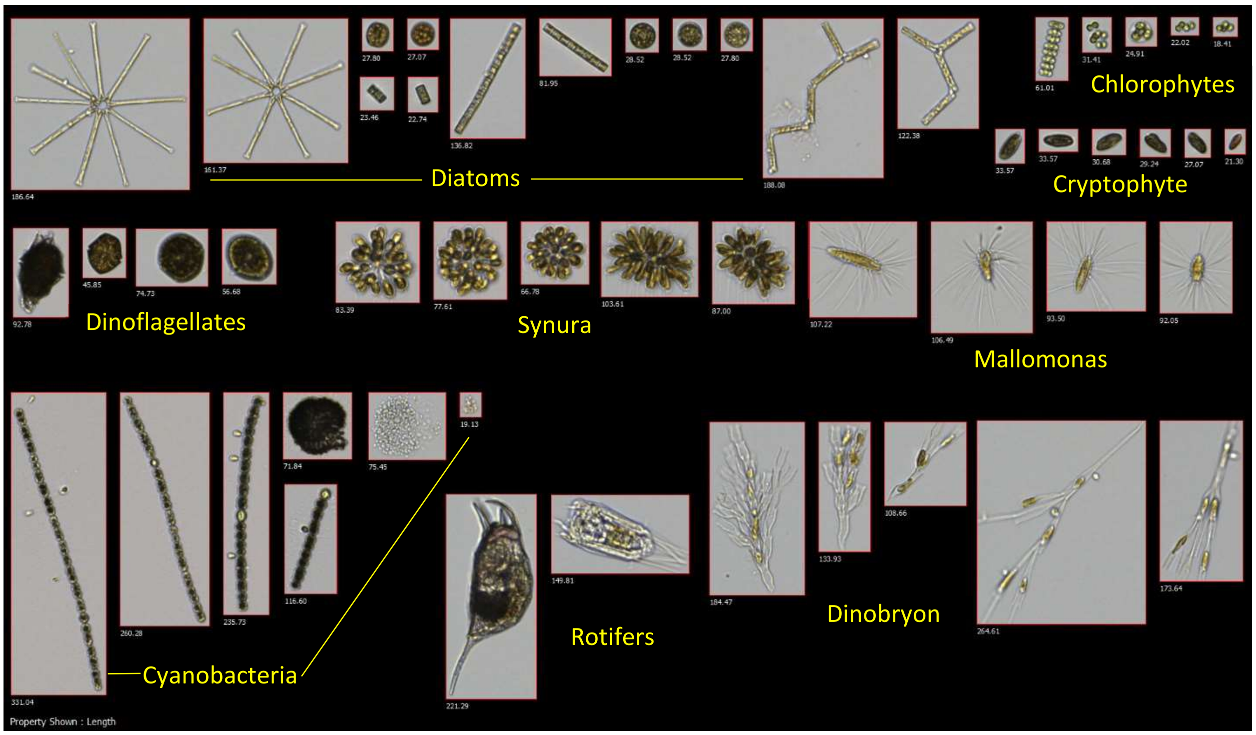


Figure 4. Composite of selected images collected by the FlowCam from various winter-time lake samples in the LEA service area. Specific taxa identified to genus or class.

Total phosphorus (TP) is a key indicator of water quality, where values much greater than about 12 parts per billion (ppb) indicate an excess of nutrients that can fuel algae growth. We measured TP on eight separate under-ice lake samples from the last set of visits. Most of the winter samples were near or below the long-term average and well within the "normal range" of TP measurements for each lake (Fig. 5). These samples came from water in the upper 10 m of the lake, but nutrients can build up in bottom waters if conditions permit. We did not collect samples to evaluate this, but in winter 2021 we did measure TP concentrations >20 ppb in the deep, anoxic lake samples.

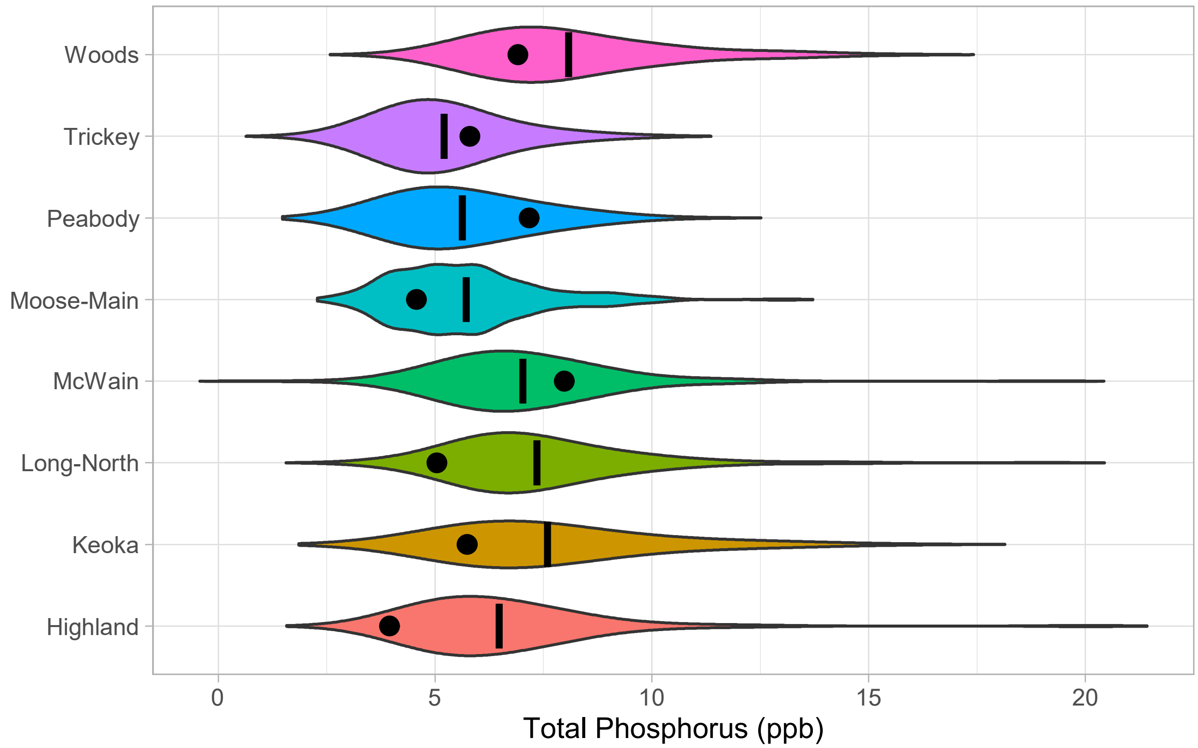
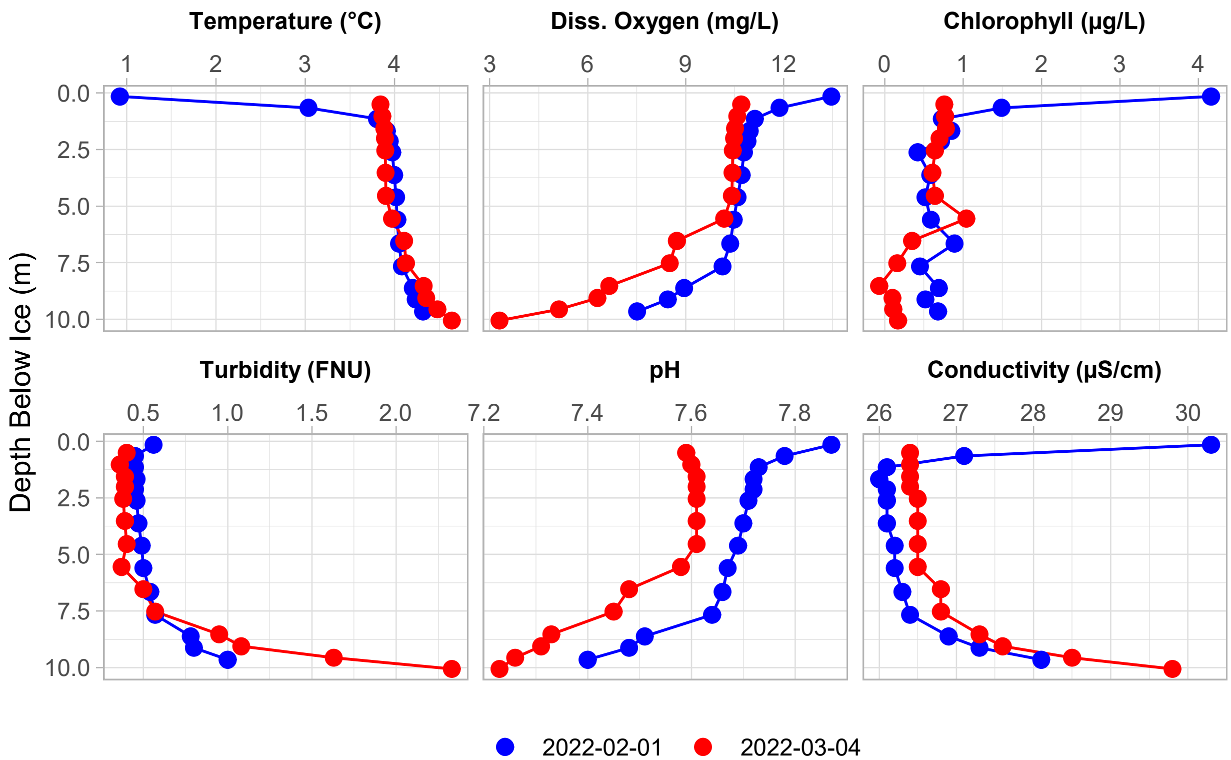


Figure 5. 2022 under-ice total phosphorus (TP) concentrations compared to long-term open-water measurements by lake. Black circles represent the winter 2022 readings and colored areas represent the distribution of long-term (1996-2021) data, where area thickness represents the number of measurements by value. Vertical bar is long-term average.

As in previous years, the two to three winter-time sampling trips allowed us to capture typical conditions and also some of the changes that happened throughout the season. With multiple years of winter data, we now can start examining the data for changes over time and connections between ice-covered and open-water lake conditions. Eventually, we hope to be able to forecast lake water quality changes, if any, as ice cover continues to decrease or disappear altogether due to climate change.

Back Pond

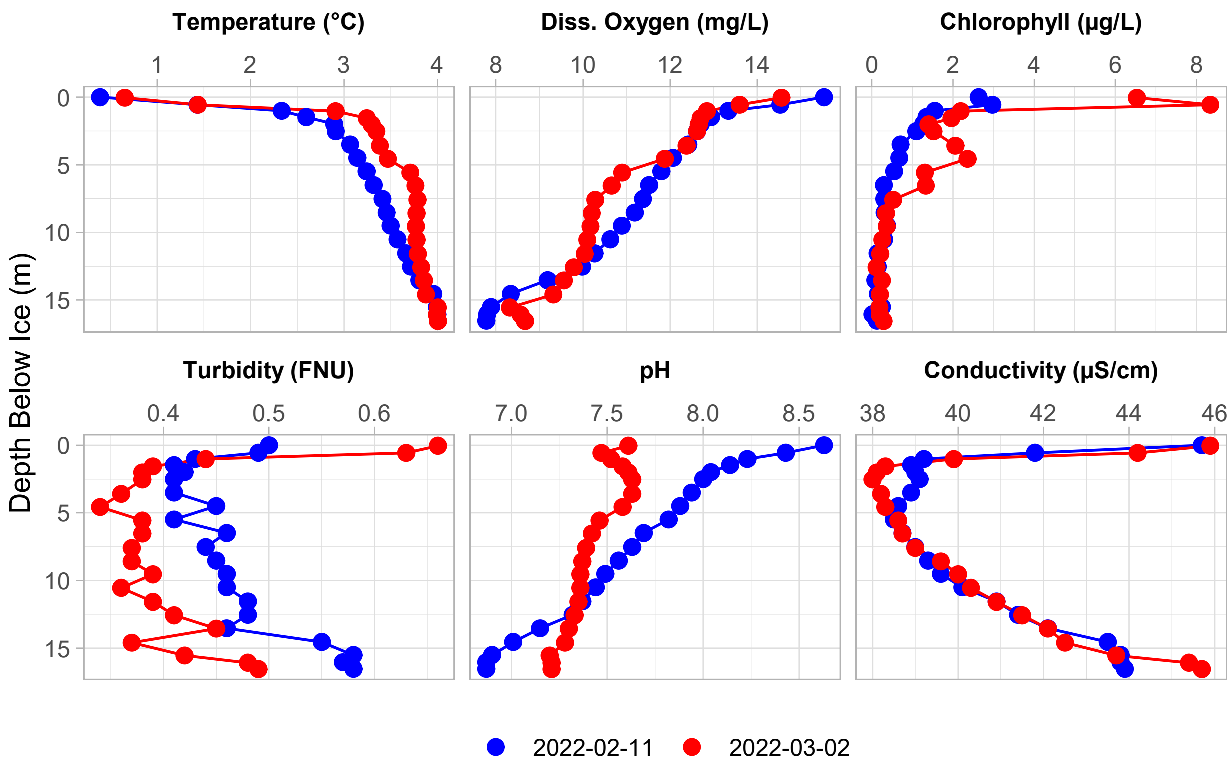
2022 was the second year we visited Back Pond in winter. Even with a month between the two trips, the profiles showed only minor differences. Temperature reached 4 °C (39.2 °F) by about 4 m depth below ice, but changed little over the month between visits. Dissolved oxygen decreased with depth and time (mirrored by the pH pattern), reaching hypoxic conditions in the near-bottom water by March. Chlorophyll was low except for a peak just under the ice in February. Turbidity was typically low and constant over time, but increased noticeably over the bottom 2 to 3 m. Conductivity was slightly elevated just under the ice in February, probably due to impurities leftover as water froze. Otherwise, conductivity was stable with depth until it increased slightly in the bottom layer.



View above and below ice at Back Pond, February 1, 2022.

Hancock Pond

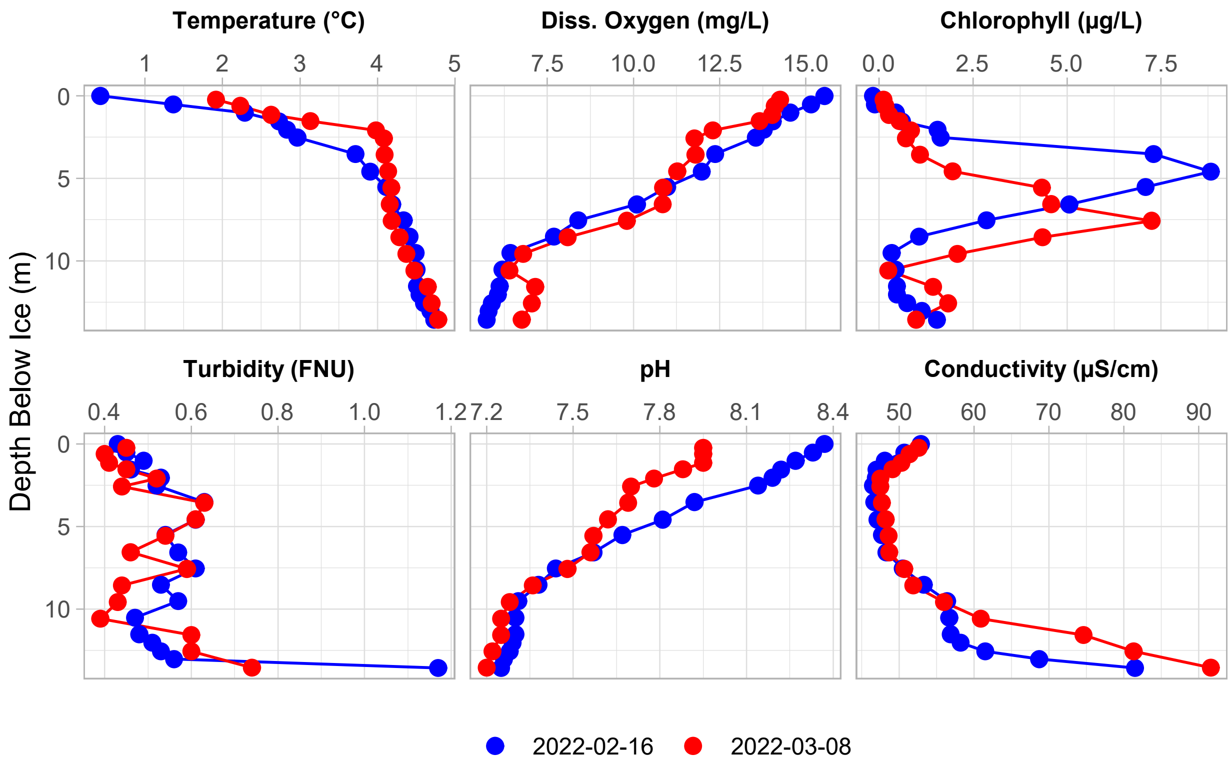
2022 was the second year we visited Hancock Pond in winter. The basic patterns in the sonde profiles were the same as the previous year. Temperature only reached 4 °C (39.2 °F) near the bottom and increased slightly over the three weeks between trips. Dissolved oxygen decreased with depth and only slightly with time (mirrored in the pH pattern), but the water remained oxic to the bottom. Chlorophyll was elevated near the ice and decreased with depth except for a small peak near 5 m depth below ice in March. The large peak in chlorophyll near 1 m depth coincided with a lower-than-average Secchi depth. Turbidity was mostly low (note the narrow range of values) and slightly increased over time The slight near-ice peak in March is probably associated with the high chlorophyll at the same depth. Elevated conductivity near the ice reflected the impurities left after ice formation. Conductivity increased somewhat with depth, but stayed generally low.



View above and below ice at Hancock Pond, February 11, 2022.

Highland Lake

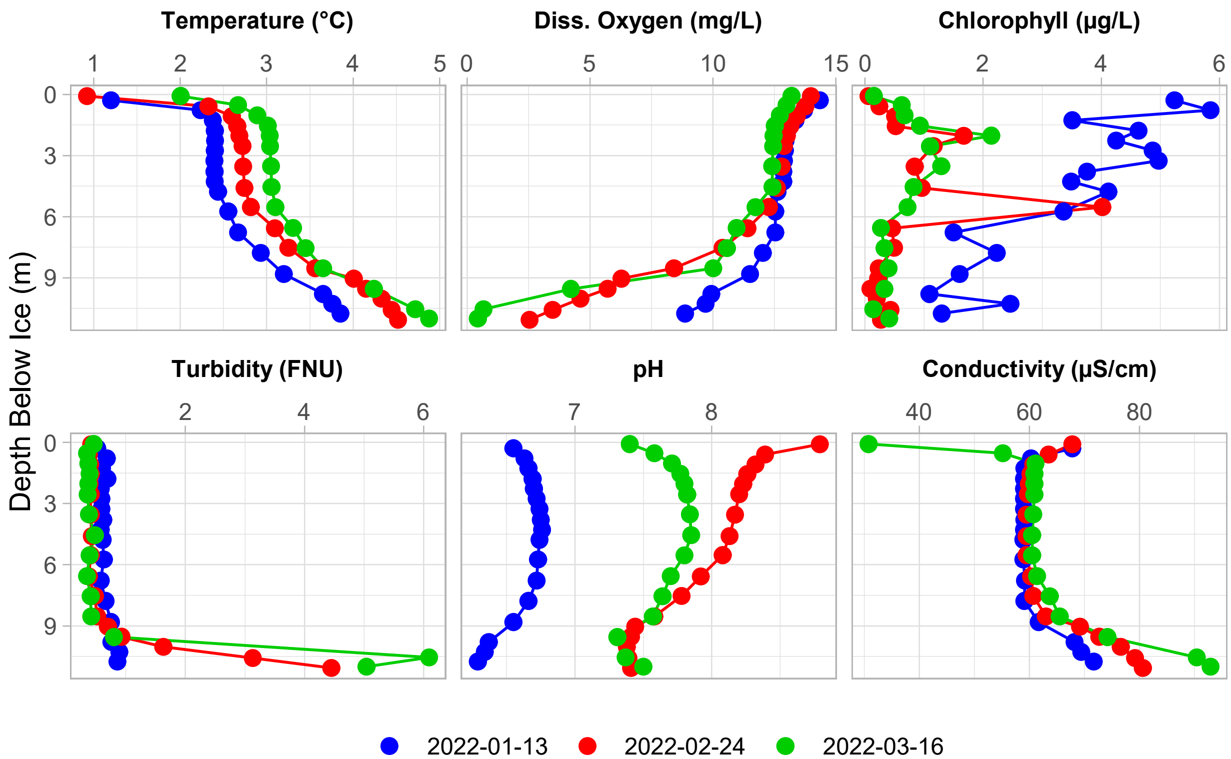
Highland Lake was the first site visited when LEA began regular winter lake monitoring in 2018. Winter visits continued through 2020, but not in 2021. Some of the same patterns seen in previous years' sonde profiles were evident in 2022. Water temperature reached 4 °C (39.2 °F) at about 5 m depth below the ice and continued warming with depth. The water between about 2 and 5 m warmed as much as a degree between visits. Dissolved oxygen decreased with depth (mirrored by the pH profile), but the water column remained oxic throughout. The chlorophyll profiles were quite distinctive with large peaks from 5 to almost 8 m below ice, with the deeper peak happening in March when the water was clearer and more illuminated. Turbidity was low and changed little except near the bottom. Conductivity showed a more dramatic increase with depth, which was assumed to be from dissolved material mixing up from the sediments.

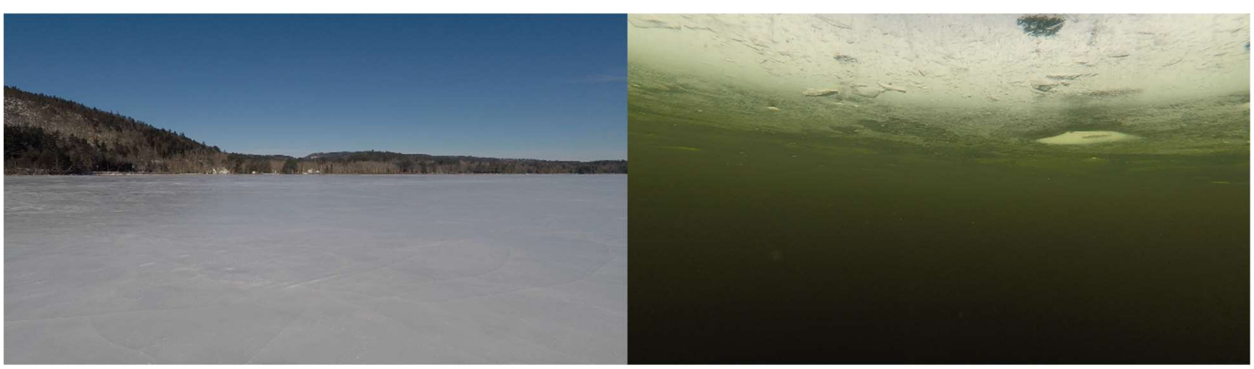


View above and below ice at Highland Lake, March 8, 2022.

Keoka Lake

We visited Keoka Lake in the winter for the fourth consecutive year in 2022. Many of the sonde profile patterns stayed the same. Temperature stayed less than 4 °C (39.2 °F) except in deep waters, though the water warmed with time. Dissolved oxygen decreased with depth (partially mirrored in the pH profiles) and the bottom waters became anoxic by March; Keoka was one of only two lakes to exhibit anoxia. Chlorophyll was elevated and variable throughout the water column in January, and it decreased with time. Peaks in chlorophyll were observed at about 2 and 6 m below ice during the later visits. Turbidity was typically low and constant over time, but increased significantly in the deep waters, corresponding to particulates forming under low oxygen conditions. Conductivity was fairly constant at mid-depths, but increased with depth over the bottom 2 m. Near-ice conductivity diverged from deeper readings due to freezing and melting ice; during the March visit, rain and melt water was running into the ice hole.

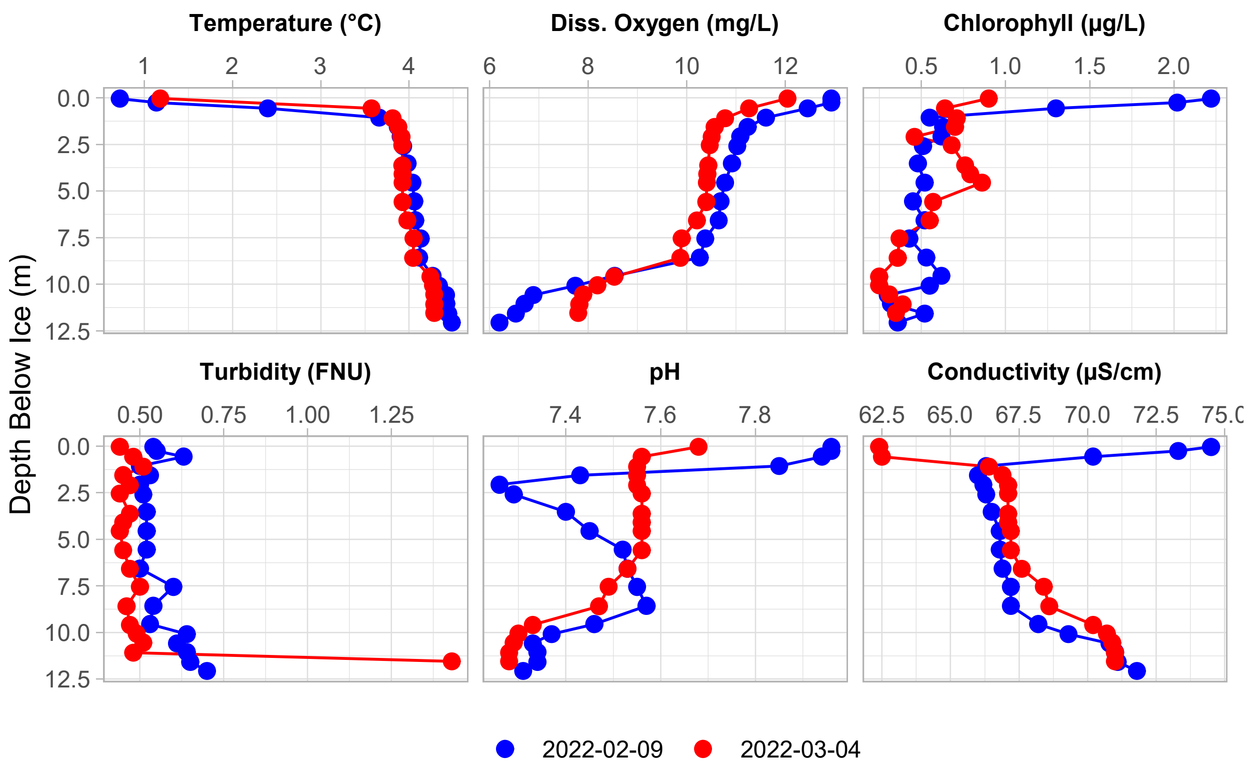




View above and below ice at Keoka Lake, February 24, 2022.

Keyes Pond

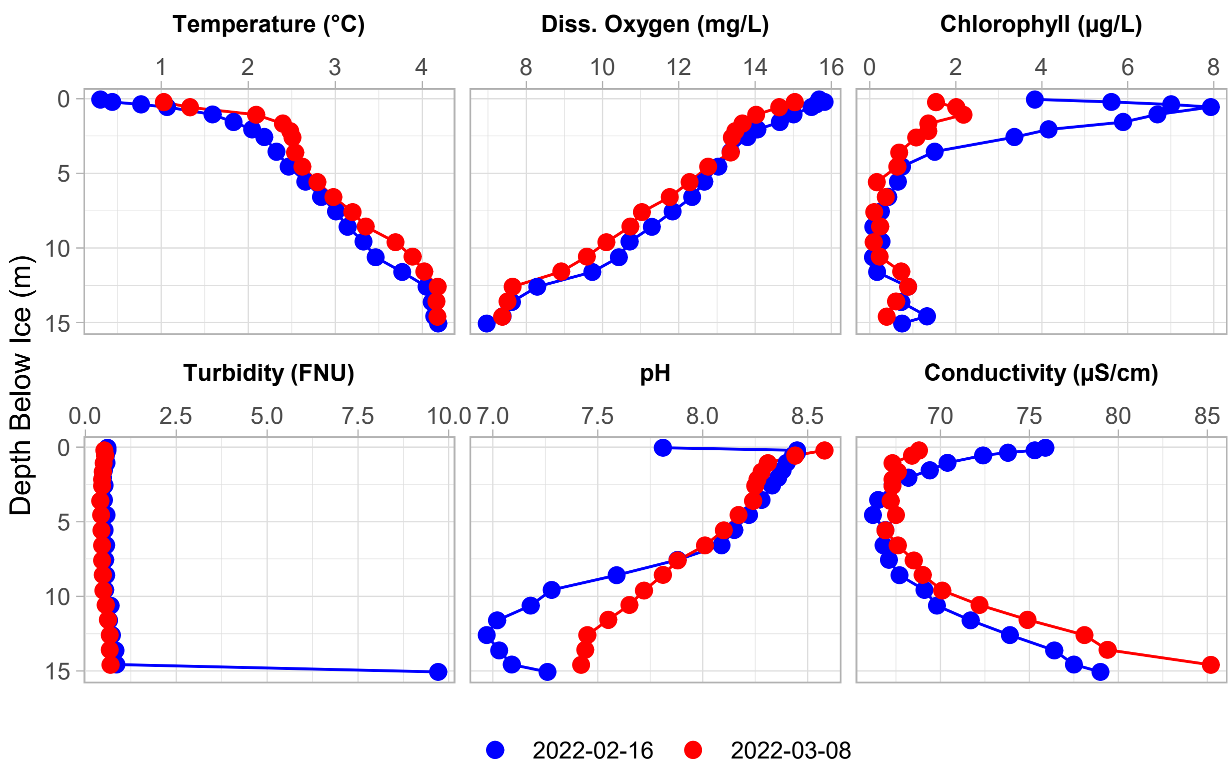
2022 was the second year we visited Keyes Pond in winter and the sonde profile patterns differed in some ways. Temperature reached 4 ˚C (39.2 ˚F) at about 4 m depth below ice, which was shallower than in 2021. Dissolved oxygen decreased with depth and slightly with time (partially mirrored in the pH pattern), but the bottom waters did not go anoxic as was the case in the previous year. Chlorophyll was at low to moderate levels with the peak concentration just under ice. Turbidity was typically low and constant over time and depth, except for a minor increase at the bottom. Conductivity varied only slightly with depth and time. The near-ice pattern diverged between dates, which might have been caused by minor melting in March.



View above and below ice at Keyes Pond, February 9, 2022.

Long Lake-North Basin

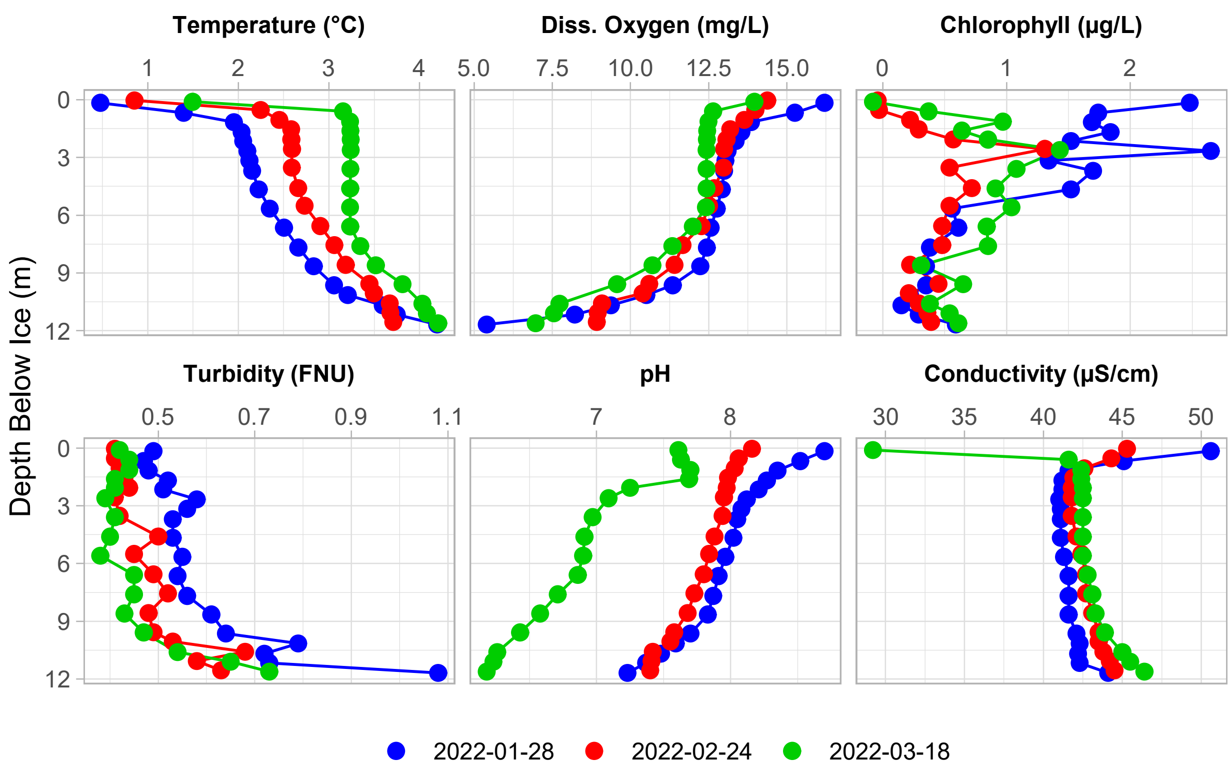
2022 was the first year we visited Long Lake in winter. Temperature increased gradually with depth reaching 4 °C (39.2 °F) in the bottom three meters, but increased only slightly with time. Dissolved oxygen decreased steadily with depth and slightly with time (perhaps mirrored in the pH pattern), but the water remained oxic to the bottom. Chlorophyll was low to moderate throughout most of the water column except for the top 2 m, where peaks were measured on both trips. Turbidity remained typically low and constant over time and depth except for a small, near-bottom spike that was probably stirred-up sediments. Conductivity decreased with depth down to a mid-depth minimum and then increased with depth to the bottom. Between visits, the conductivity changed only a small amount.



View above and below ice at Long Lake—North Basin, March 8, 2022.

McWain Pond

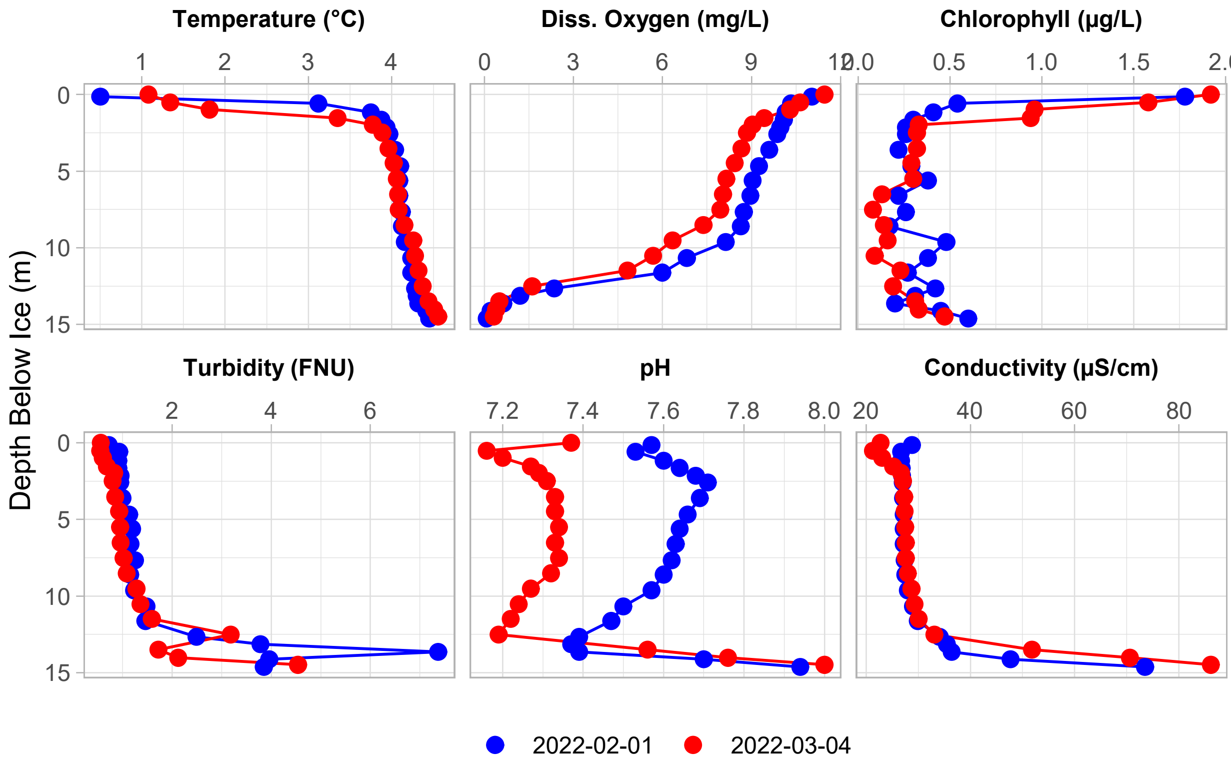
2022 was the second year we visited McWain Pond in winter. Temperature remained less than 4 °C (39.2 °F) everywhere except deep water, and the water warmed significantly with time. Interestingly, February bottom-water temperature was slightly lower than in January or March. Dissolved oxygen decreased with depth and slightly with time (partially mirrored in the pH pattern), but the water remained oxic to the bottom. Chlorophyll was generally low and variable except for slight peaks in the upper 4 to 5 m in January and at 3 m in February and March. Turbidity remained typically low, showing a slight increase with depth and a slight decrease with time. Conductivity increased slightly with depth and time, except for a minor peak just under the ice. In March, however, near-ice conductivity was much lower, which was probably caused by melting ice.



View above and below ice at McWain Pond, January 28, 2022.

Middle Pond

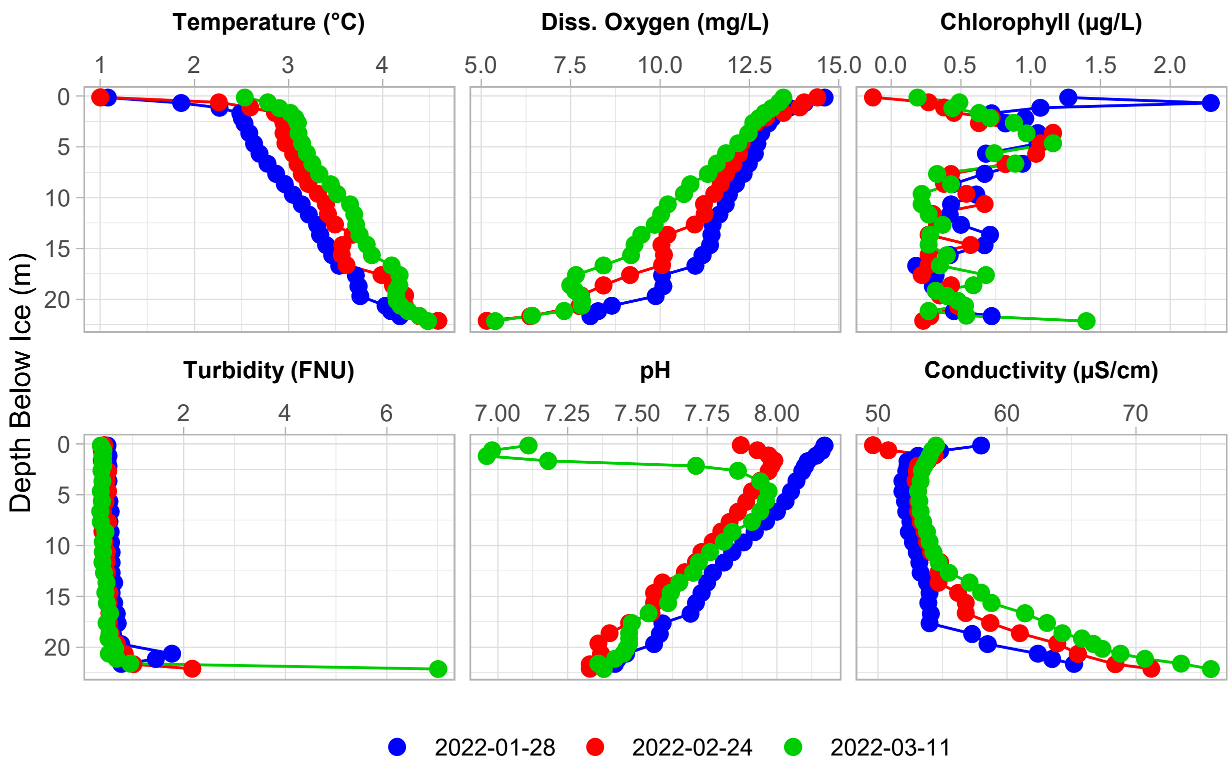
2022 was the second year we visited Middle Pond in winter. The sonde profiles seemed to have changed little between years and visits, except that temperature increased to 4 °C (39.2 °F) by about 3 m as opposed to near bottom in 2021. Dissolved oxygen decreased slightly with time and rapidly with depth, reaching anoxic conditions (0 mg/L) at the bottom (one of only two lakes to do this). Chlorophyll was low except for moderate peaks near the ice-water interface. Turbidity was moderate and constant over time, but increased significantly with depth starting at 12 m. This coincided with increases in pH and conductivity with depth (the only lake to show this). Conductivity exhibited a minor decrease near the ice, but the increase at depth was the largest seen among all lakes visited.



View above and below ice at Middle Pond, March 4, 2022.

Moose Pond-Main Basin

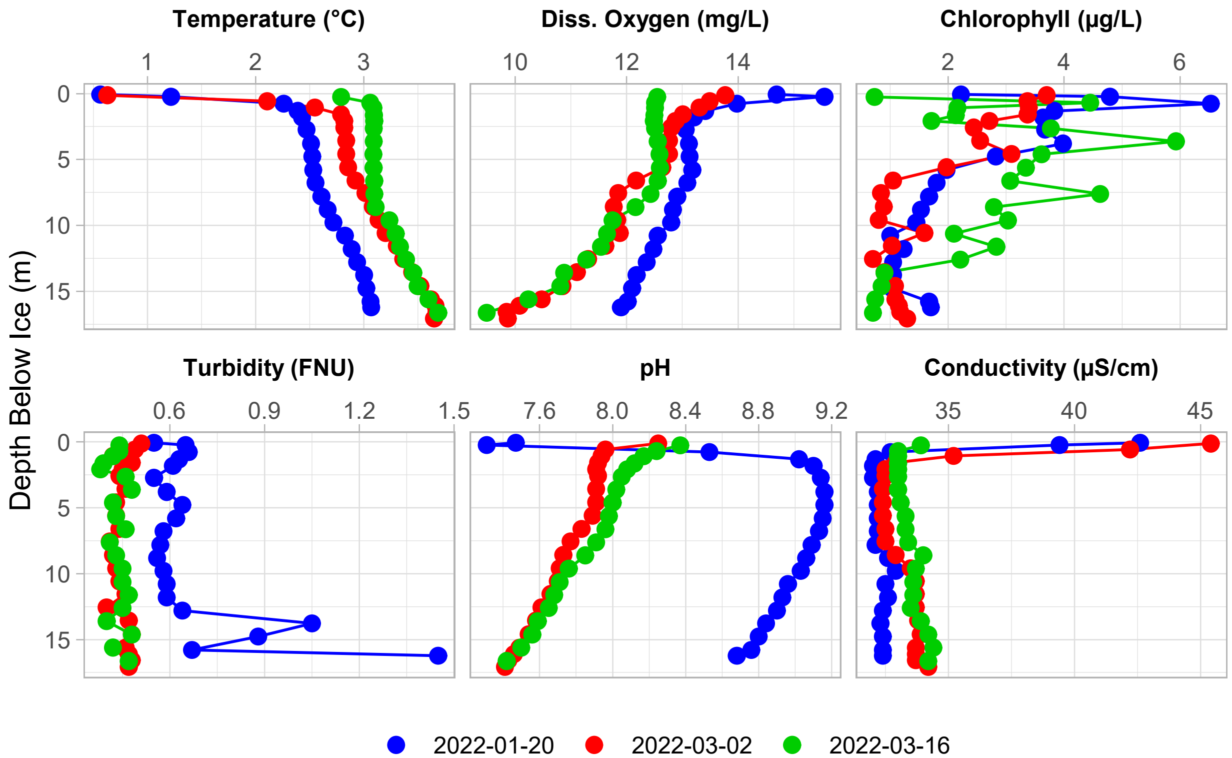
2022 was the second year we visited Moose Pond in winter. Temperature increased with depth and time, but remained below 4 °C (39.2 °F) until about 16 to 20 m depth below ice. Dissolved oxygen (DO) decreased with depth and also with time; although concentrations reached as low as 5 mg/L, the deep water never went anoxic. Chlorophyll was low and variable throughout the water column, except for minor peaks just under the ice in January and closer to 5 m below ice later in the season. Turbidity was typically low and constant over time, but increased in the deepest waters. The pH pattern mirrored the DO pattern of a decrease with depth. There is no clear explanation for the low near-ice pH in March other than perhaps a sensor malfunction. Conductivity increased with depth and time, but mostly in deep waters. Conductivity was elevated near the ice for the first and last visits, but was slightly lower on the February visit (possibly from melt water).



View above and below ice at Moose Pond Main Basin, February 24, 2022.

Peabody Pond

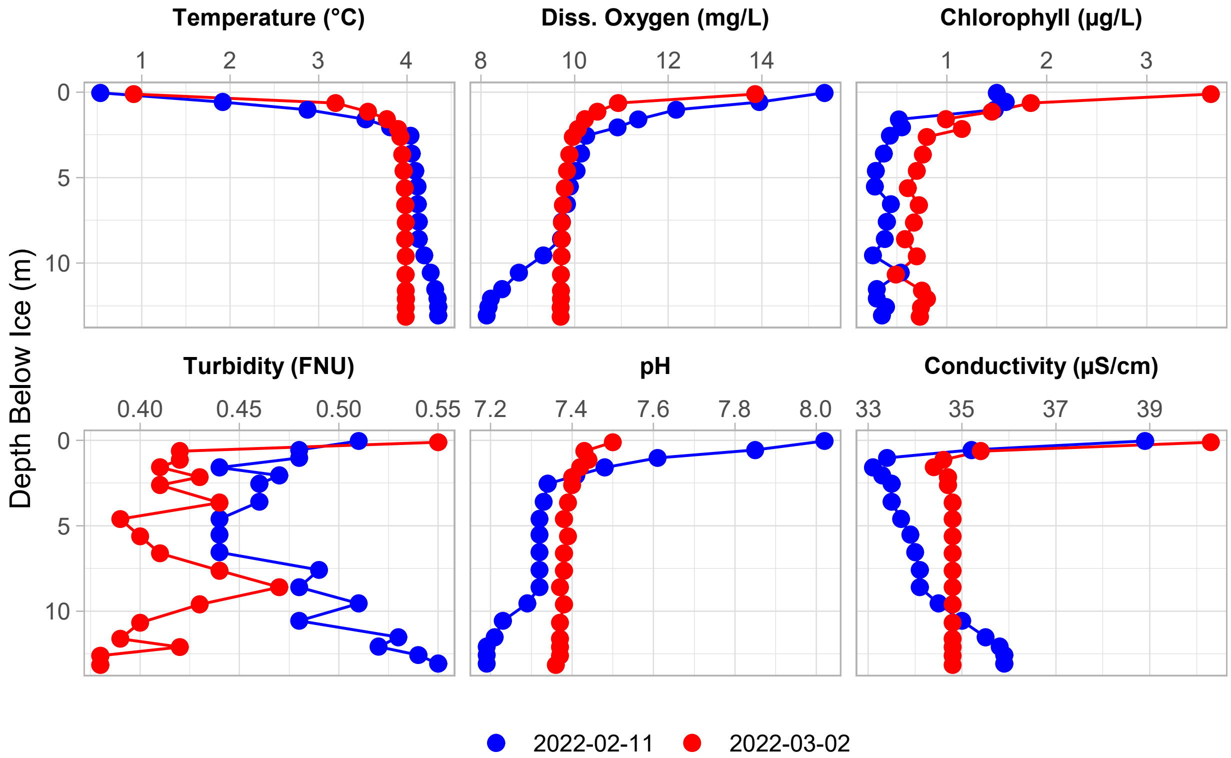
We visited Peabody Pond in winter for the second time in 2022. The sonde profiles were remarkably similar to the 2021 data. Temperature never reached 4 °C (39.2 °F) during our visits, though the water warmed about 0.5 °C by the last trip. Dissolved oxygen decreased with depth and somewhat with time (mirrored in the pH pattern despite differences due to a sensor issue), but the water remained oxic to the bottom. Chlorophyll was moderate and quite variable, especially on the last trip. The January and early March profiles showed highest values within the top 2 m. Turbidity remained typically low and constant over depth except for a small, near-bottom spike in January. Conductivity was slightly elevated near the ice for all visits, but otherwise it remained generally low and constant with depth and time.



View above and below ice at Peabody Pond, March 2, 2022.

Sand Pond

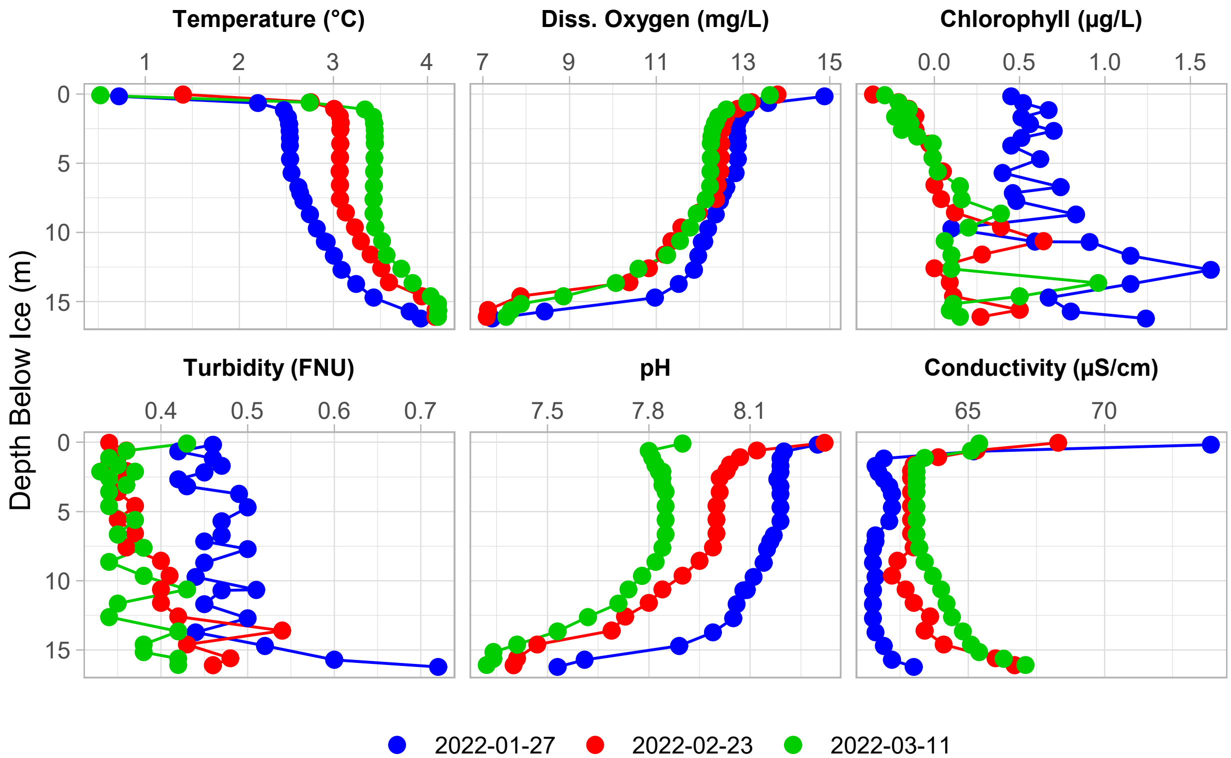
In 2022, we visited Sand Pond in winter for the fifth consecutive year and many of the patterns stayed the same. Temperature increased quickly with depth to 4 °C (39.2 °F) at about 2 to 3 m below the ice. By March, the water column cooled slightly, which could be due to mixing of the warmer and less dense bottom waters recorded in February. Dissolved oxygen decreased with depth and appeared to increase with time in water deeper than 10 m (mirrored in the pH profiles), but the water column remained oxic on both visits. Chlorophyll was mostly low except for elevated readings in the upper 2 m. Turbidity was typically low and constant over depth and time; note the exaggeration caused by the extremely small plot scale range, which is similar to typical sensor noise. Apart from elevated values near the ice, conductivity was low and either increased slightly or remained relatively constant with depth.



View above and below ice at Sand Pond, March 2, 2022.

Trickey Pond

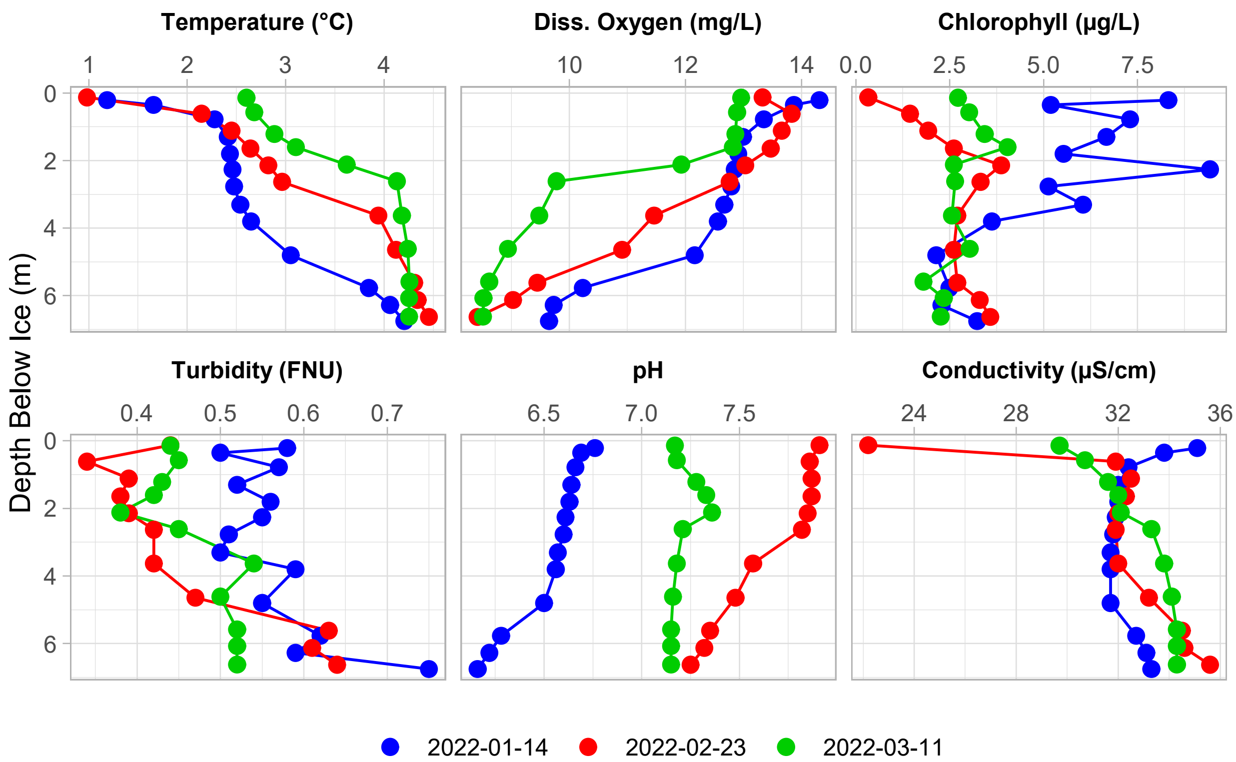
2022 was the third consecutive year of winter trips for Trickey Pond and many of the patterns stayed the same. Temperature increased with depth and time, but remained below 4 °C (39.2 °F) until about 15 m depth below ice in February and March. Dissolved oxygen decreased with depth and slightly with time (mirrored somewhat in the pH profiles), but the water column remained completely oxic on all visits. Chlorophyll was mostly low except for a slight peak at about 12 m in January (note that sensor noise at low levels can cause readings < 0). Turbidity was typically low and constant over time and depth (note the small plot scale range), though there were small increases near the bottom. Conductivity was elevated near the ice, but otherwise it increased slightly with time and slightly with depth in the bottom 5 m of the water column.



View above and below ice at Trickey Pond, January 27, 2022.

Woods Pond

In 2022, we visited Woods Pond in winter for the third consecutive year and many of the patterns remained the same. Temperature increased with depth and time, and reached 4 °C (39.2 °F) and above at depths ranging from 6 m in January to 2.5 m in March. Dissolved oxygen decreased with depth and time (partially mirrored in the pH profiles despite differences due to a sensor issue), but the water column remained completely oxic on all visits. Chlorophyll was mostly moderate and constant with depth except for elevated levels throughout the upper 4 m in January. Turbidity was typically low, though levels increased slightly with depth (note the small plot scale range). Conductivity was mostly constant or slightly increased with depth and time, except for a minor peak just under the ice. In February, however, near-ice conductivity was much lower, which was probably caused by melting ice.



View above and below ice at Woods Pond, February 23, 2022.