Lakes Environmental Association
2021 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. And in 2020, we made 13 trips to seven different lakes.

In 2021, our plans were even more ambitious and we were able to make trips to 11 different lakes two or three times each for a total of 28 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 Association, and the Woods Pond Association. Thanks go also 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, Middle Pond, Keyes Pond, and Sand Pond were visited twice each. On each lake visit, we traveled by foot over the ice to the deep site and used an ice auger to drill a hole. On visits where we used an instrument wider than the auger's diameter, we dug two adjacent holes and removed any ice between with a saw. Ice thickness, snow depth, and water level were measured using a homemade gauge. We captured video footage of the ice and under-ice conditions once for each lake using a GoPro camera in a waterproof housing. Staff involved in these trips included Maggie Welch, Mary Jewett, and Ben Peierls.

Ben with ice auger (left) and expanded ice hole (right)

We used our calibrated YSI EXO2 multiparameter sonde connected to a handheld data logger to measured depth-based profiles of temperature, dissolved oxygen, conductivity (normalized to 25 °C), pH, turbidity, chlorophyll fluorescence, and phycocyanin fluorescence. The water depth in the hole was subtracted from the sonde's depth reading and depths were reported as depth below ice. Measurements were recorded every 0.5 or 1 meter to the bottom. Phycocyanin, which relates to cyanobacteria biomass, was mostly low and not included for clarity.

Maggie with ice gauge (left) and gauge in use (right)

On the first visit to each lake, we measured light levels using a LI-COR LI-192 underwater quantum sensor above and at several depths below the ice. During these measurements, we covered the hole with two layers of window screening to prevent light passing through the hole from affecting the readings. The attenuation of light due to ice was calculated as the percent of surface light that reaches to just under the ice layer.

We used a peristaltic pump on several trips to collect water at the approximate depth of greatest chlorophyll fluorescence. These samples were analyzed with a Yokogawa Fluid Imaging Technologies FlowCam, a flow imaging microscope that captures images of single cells or colonies of algae for counting and identification. Additional lake water samples were also collected from Keoka, McWain, Peabody, and Trickey and saved for nutrient comparison between upper and lower water layers; the chemical analysis for that will happen later this year.

Maggie using the sonde and handheld data logger on Keoka Lake

Ben using the light sensor above ice on Peabody Pond (left) and Mary using the peristaltic pump to collect Sand Pond water (right)

Overall Results

Ice cover is the dominant feature of LEA service area lakes during winter. Variation in ice cover timing, duration, and characteristics is driven by local weather conditions and this past season certainly provided an interesting set of conditions. The unusually warm late December 2020 broke up existing lake ice and delayed final ice-in until early January 2021. This meant conditions were not safe for field work until mid to late January. When we did get out for the first time, ice thickness ranged from 14.5 to 26.7 cm (5.7–10.5 in, Fig. 1). Snow cover was evident only in the first half of February. Mid-winter thaw and rain caused a unique ice crust-slush "sandwich" layer to form. Ice thickness increased through March, but the ice was thinning by the last visits; most lakes were ice free by early April. Maximum ice thickness measured was 57.4 cm (21.5 in) on both Middle and McWain Ponds. Our past maximum ice thickness records were 55, 75, and 41 cm for 2018, 2019, and 2020, respectively.

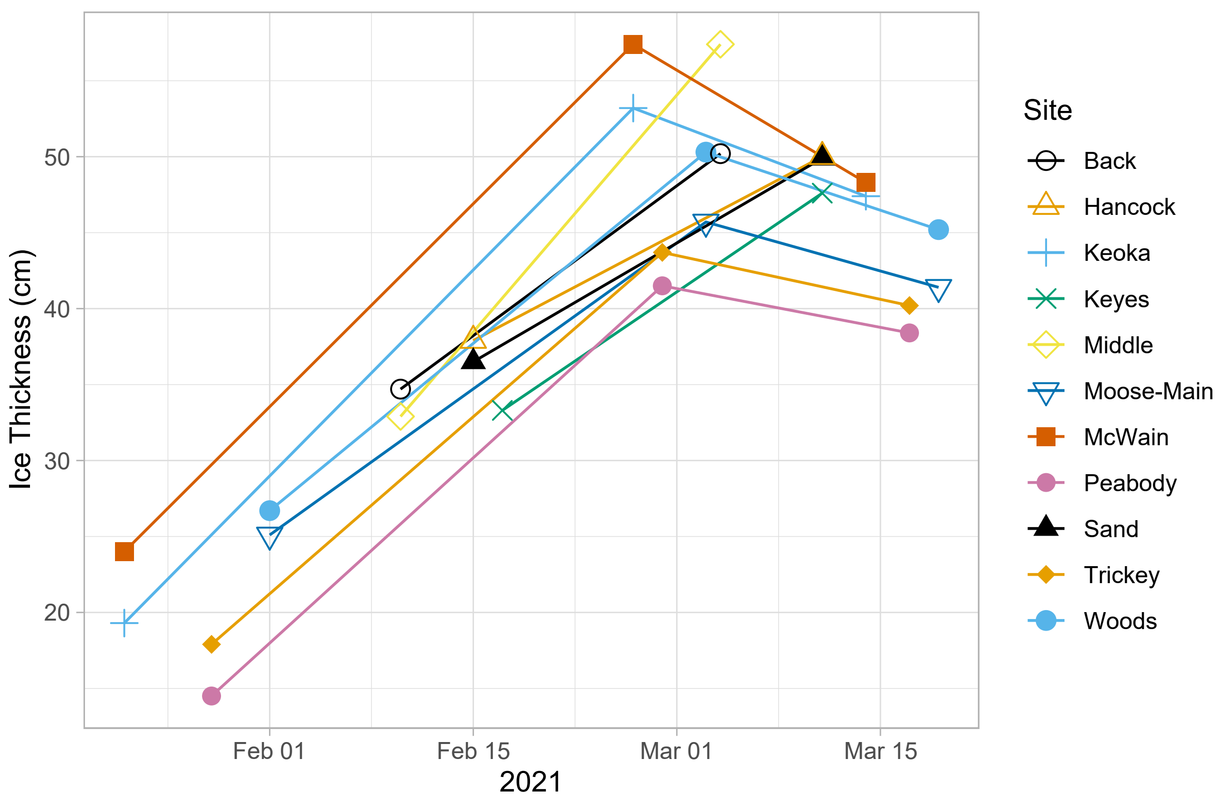


Figure 1. Ice thickness in cm versus date for lakes visited in winter 2021; lines to aid visualization only.

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 30 to 40% of surface irradiance, but ice thickness did not affect that light attenuation consistently (Fig 2). Snow cover reduced light even more. With a 5–7 cm (2–2.8 in) layer of snow, light was reduced to about 10% of surface light; that dropped to 5% or less of surface light when snow depths reached 17.5 cm (6.9 in). 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.

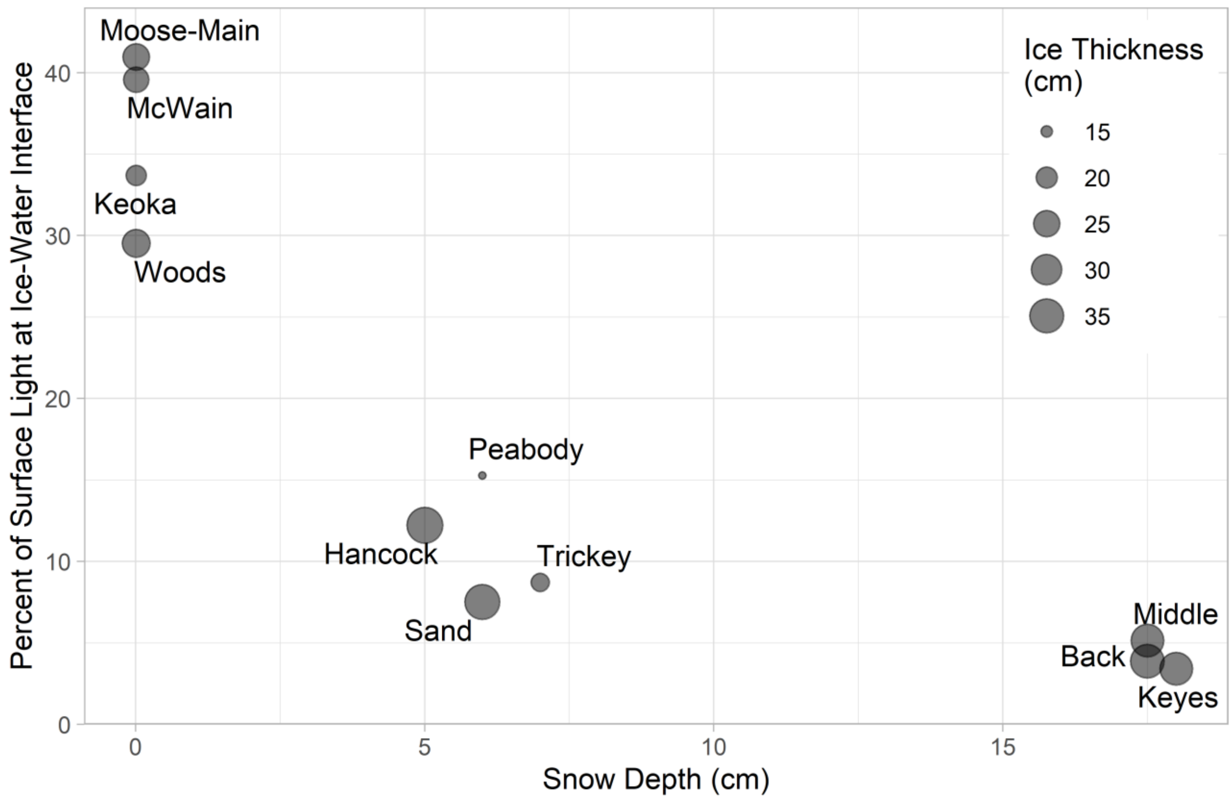
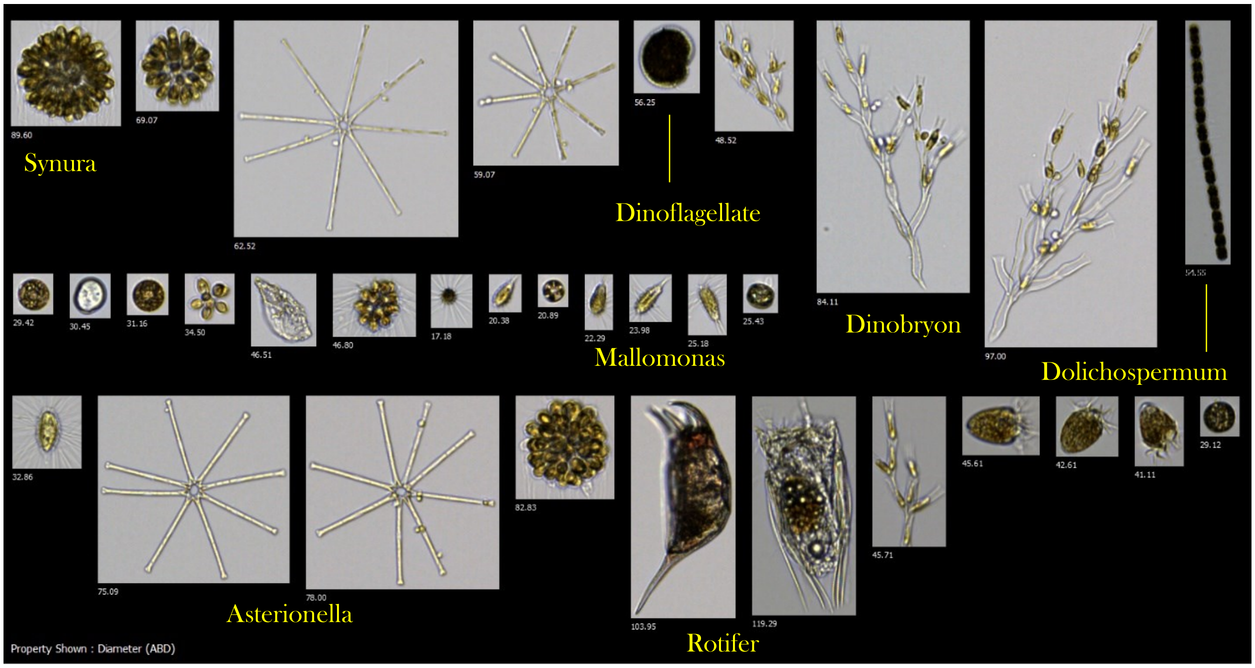


Figure 2. Light just underneath the ice (expressed as percent of surface values) decreases with increasing snow depth, as expected. Symbol size indicates ice thickness, which had minimal additional impact on light penetration.

We used our FlowCam analyzer to get a sense of what species make up the lake algae community in winter. Since we had not yet completed necessary training and fine tuning, we do not present any quantitative data on species present or differences by lake. We did capture images of several abundant and charismatic species, including *Asterionella* (Diatom), *Mallomonas* and *Synura* (Synurophyceae), *Dinobryon* (Chrysophyceae or "Golden Brown"), *Dolichospermum* (Cyanobacteria), and unidentified dinoflagellates. 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).



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.

A common method for assessing lake condition is to collect depth-specific physical, chemical, and biological measurements. The sonde-based measurements (or profiles) give 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 11 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.

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. Temperature increased rapidly with depth within the first one to two 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.

Surface **acidity (pH)** generally paralleled the oxygen response since water tends to become more acidic (lower pH) as respiring organisms generate dissolved carbon dioxide; pH values tended towards slightly acidic overall (a pH of seven is considered neutral 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 dissolved ions behind. Similarly, ice and snow melt water can cause localized decreases in conductivity.

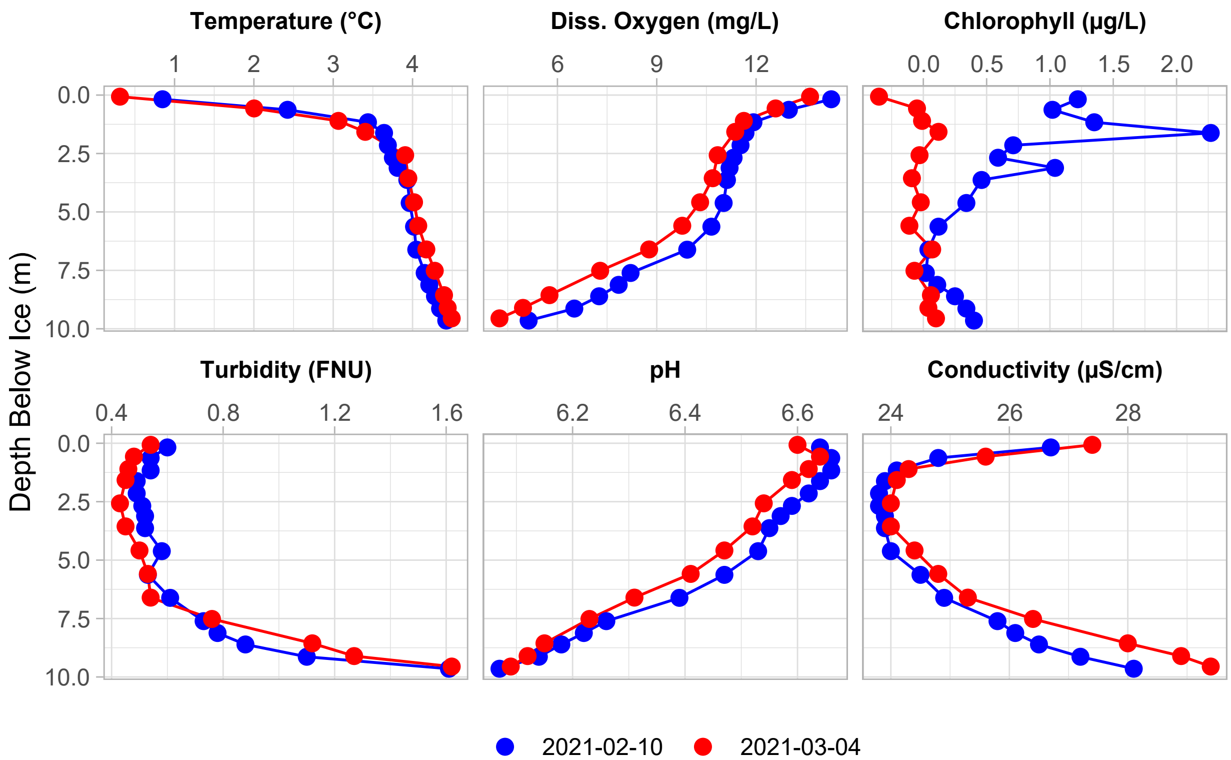
Turbidity, which is a measure of particle content in water, also tended to increase with depth from generally low surface values. Some of the turbidity increase could be due to changing chemical conditions in the deeper water that allows dissolved material to come out of solution as aggregates. Also, 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.

With these two to three winter-time sampling trips, we were able to capture typical conditions and also some of the changes that happened throughout the season. With multiple years of winter data, we will be able to start making 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

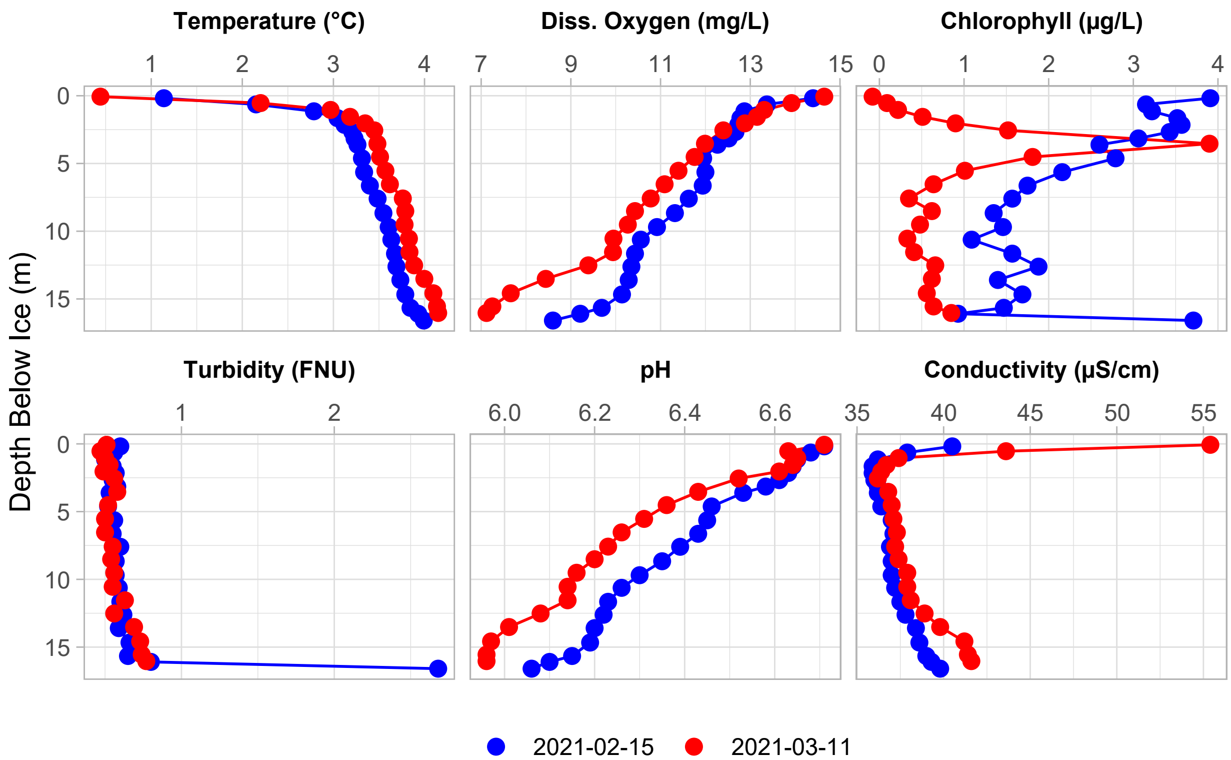
2021 was the first year we visited Back Pond in winter. Despite three weeks between the two trips, the profiles showed only minor differences over time. Temperature reached 4 °C (39.2 °F) by four meters depth below ice, but changed little over time. DO decreased with depth and time slightly (closely mirrored in the pH pattern), but the water remained oxic to the bottom. Chlorophyll was low (sensor noise at low levels can cause readings < 0) except for a peak at about a meter in February. Turbidity was typically low and constant over time, but increased noticeably over the bottom three meters. After a rapid decrease from elevated values near the ice, conductivity increased slightly with depth and time, but was generally very low and spanned a narrow range.

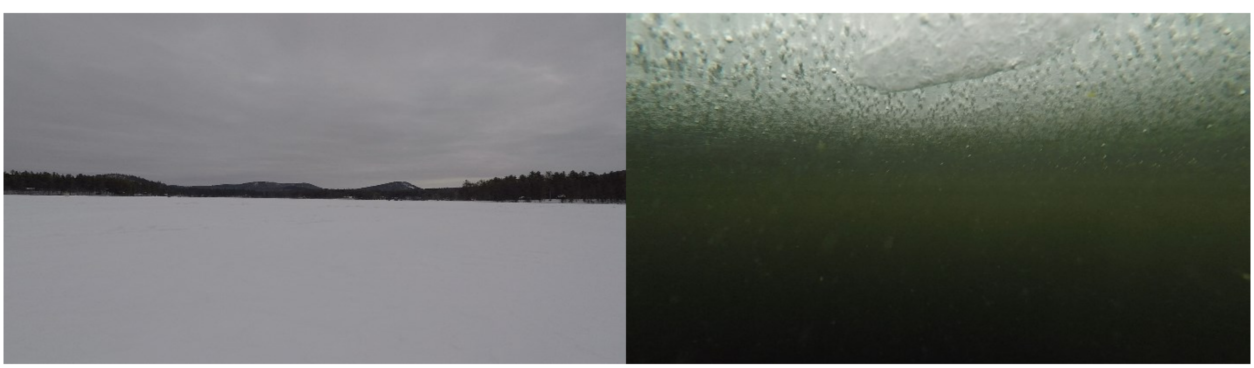


View above and below ice at Back Pond, February 10, 2021

Hancock Pond

2021 was the first year we visited Hancock Pond in winter. Temperature reached 4 °C (39.2 °F) only near the bottom and increased slightly over the three weeks between trips. DO decreased with depth and time (mirrored in the pH pattern), but the water remained oxic to the bottom. Chlorophyll was moderate with peaks near the ice in February and at four meters in March. Turbidity was typically low and constant over time with a slight increase at depth and a significant peak at the bottom in February; this was seen in the chlorophyll and could be algal cells that settled out from the surface. After a rapid decrease from elevated values near the ice, conductivity increased slightly with depth and time, but was generally low.

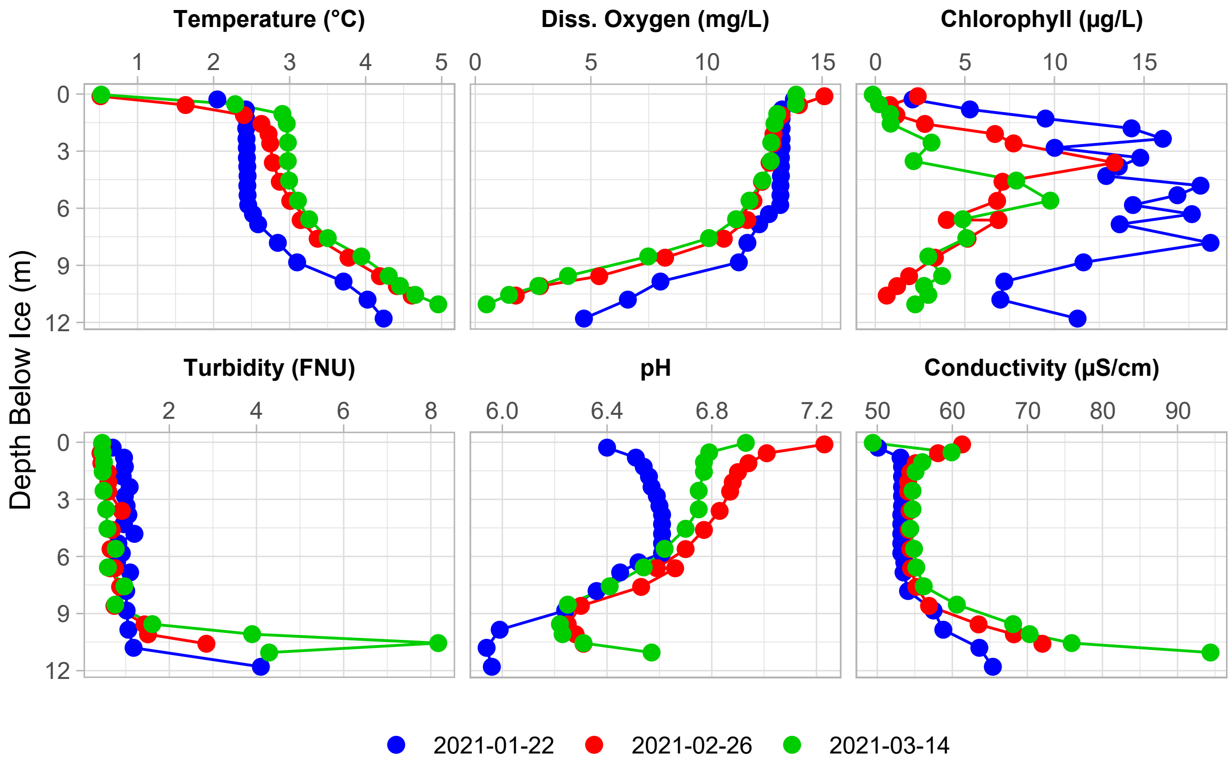




View above and below ice at Hancock Pond, February 15, 2021

Keoka Lake

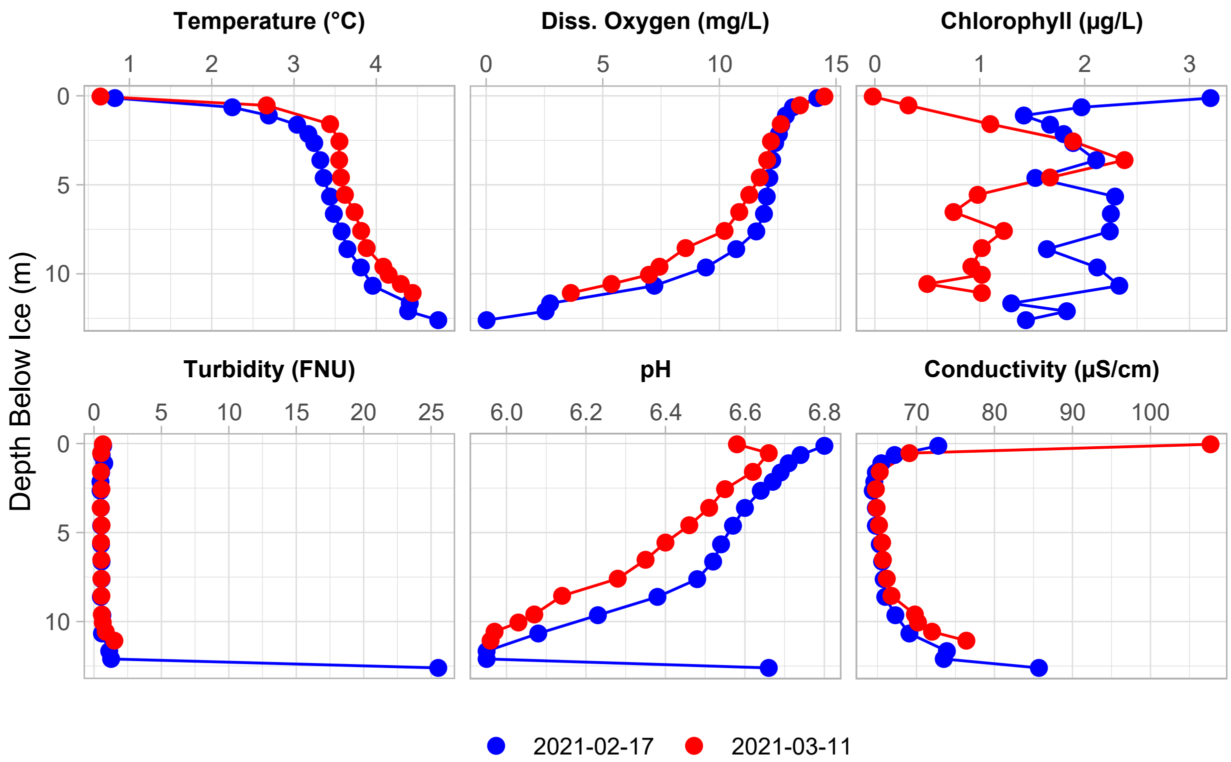
2021 was the third consecutive year of winter trips for Keoka Lake and many of the patterns stayed the same. Temperature stayed less than 4 °C (39.2 °F) except in deep waters, though the water warmed with time. DO decreased with depth and the bottom waters became anoxic late February. Chlorophyll was unusually high and variable throughout the water column, though it decreased with time and exhibited peaks in the three to six meter range. Turbidity was typically low and constant over time, but increased significantly in the deep waters. Conductivity and pH profiles were almost mirror images of each other, and the values increased and decreased with depth, respectively. Near-ice conductivity diverged from deeper readings due to freezing and melting ice, and increases at depth were significant.



View above and below ice at Keoka Lake, January 22, 2021

Keyes Pond

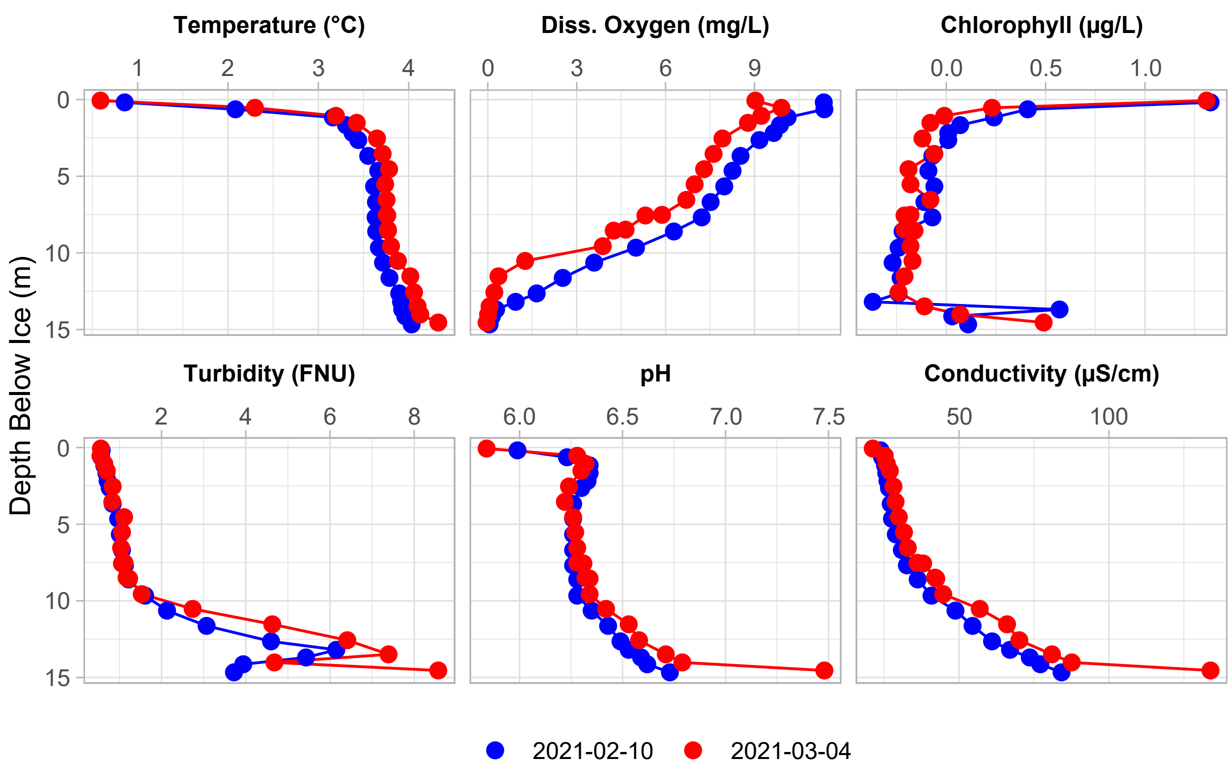
2021 was the first year we visited Keyes Pond in winter. Water column depth was more shallow on the second trip due to an alternate site selection. Temperature reached 4 °C (39.2 °F) at about 10 meters depth below ice, with the water warming slightly over time. DO decreased with depth and time slightly (mirrored in the pH pattern), and the deep water was anoxic in February. Chlorophyll was at moderate levels with the peak concentration moving from just under ice to four meters in March. Turbidity was typically low and constant over time, except for a bottom peak that was probably disturbed sediments. After a rapid decrease from elevated values near the ice, conductivity increased slightly with depth and time, while pH exhibited the opposite pattern.



View above and below ice at Keyes Pond, February 17, 2021

Middle Pond

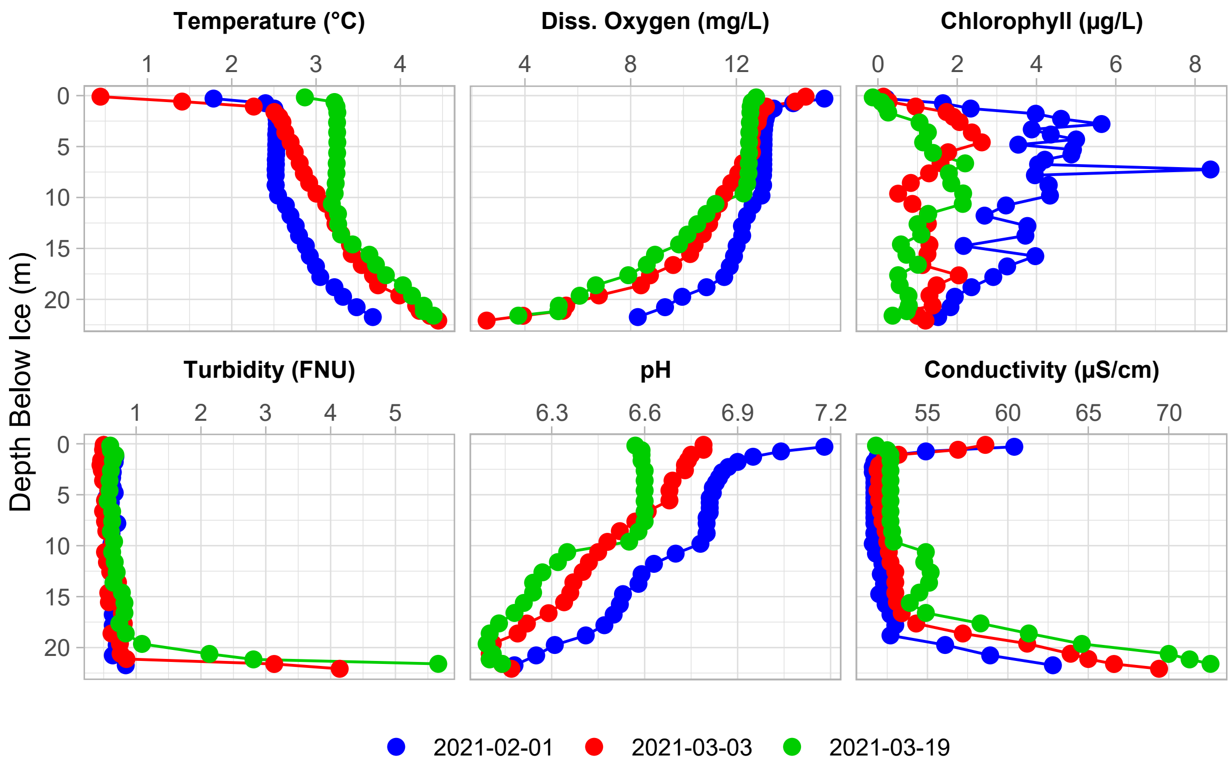
2021 was the first year we visited Middle Pond in winter. Despite three weeks between the two trips, the profiles showed remarkable similarity over time. Temperature reached 4 °C (39.2 °F) at the bottom, and increased slightly with time. DO decreased rapidly with depth and slightly with time; concentrations were below saturation at the surface and 0 at the bottom. The anoxic layer thickened to about three meters by March. Chlorophyll was low (sensor noise at low levels can cause readings < 0) except for small peaks near the ice-water interface. Turbidity was moderate and constant over time, but increased significantly with depth starting at 10 m. This coincided with increases in pH (the only lake to show this) and conductivity with depth. The pH pattern diverged from that in connected Back Pond and the reason for this divergence is unclear. Conductivity exhibited a minor decrease near the ice, but the increase at depth was the largest seen among all lakes visited.

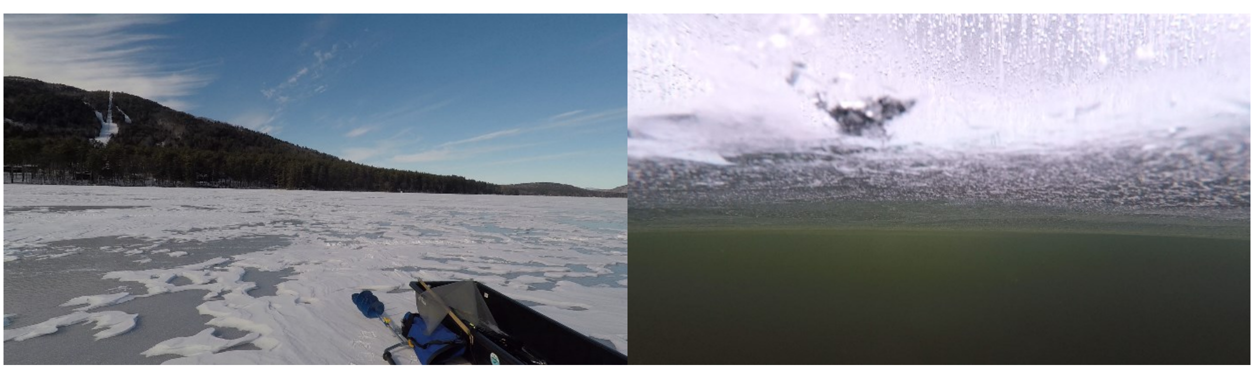


View above and below ice at Middle Pond, February 10, 2021

Moose Pond-Main Basin

2021 was the first year we visited Moose Pond in winter. Temperatures increased with depth and time, but remained below 4 °C (39.2 °F) until 20 meters depth in March. DO decreased with depth and also with time. Although DO reached < 4 mg/L, the deep water never went anoxic. Chlorophyll was moderate and variable throughout the water column, though it decreased with time. Turbidity was typically low and constant over time, but increased in the deepest waters. The pH pattern resembled the DO pattern of decrease with depth and time, while conductivity increased with depth and time, but mostly in deep waters. Conductivity was elevated near the ice for the first two visits, but decreased slightly on the last visit (possibly from melt water).

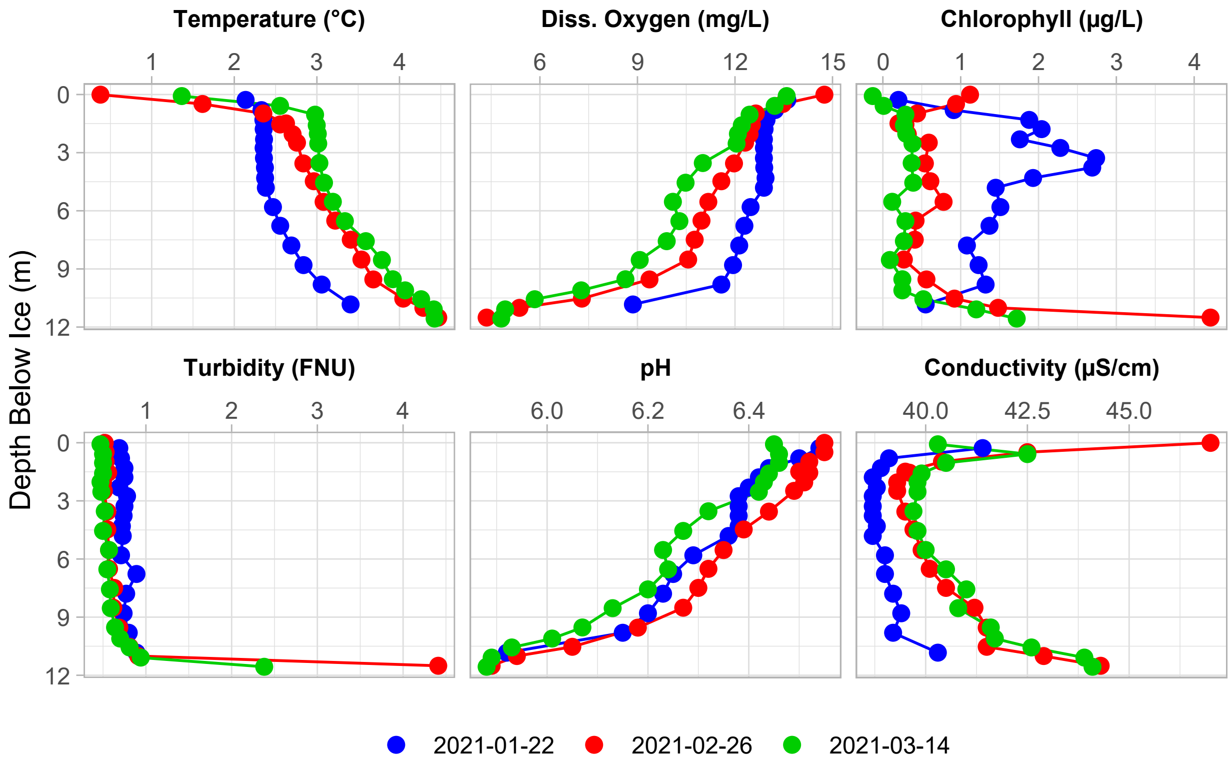


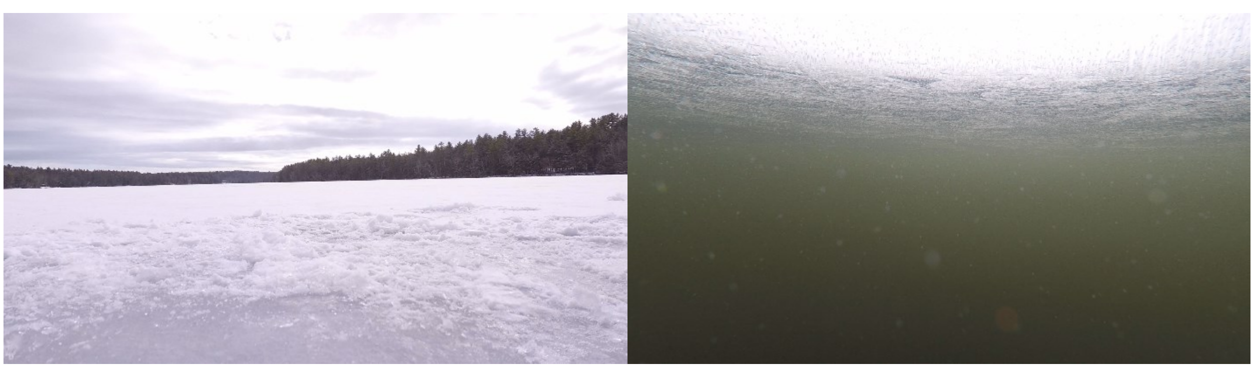


View above and below ice at Moose Pond Main Basin, February 1, 2021

McWain Pond

2021 was the first year we visited McWain Pond in winter. Temperature stayed less than 4 °C (39.2 °F) until late February in deep waters; the water warmed significantly in the month between the first two trips. DO decreased with depth and time (mirrored in the pH pattern), but the water remained oxic to the bottom. Chlorophyll was generally low except for a broad peak from two to five meters deep in late January. Chlorophyll spiked below 10 meters, which could be algal cells settled out from the surface. Turbidity remained typically low and constant over time and depth, but jumped in value at the deepest level similar to chlorophyll. After a rapid decrease from elevated values near the ice, conductivity increased with time and depth, but was generally low (notice the small range of the plot scale).

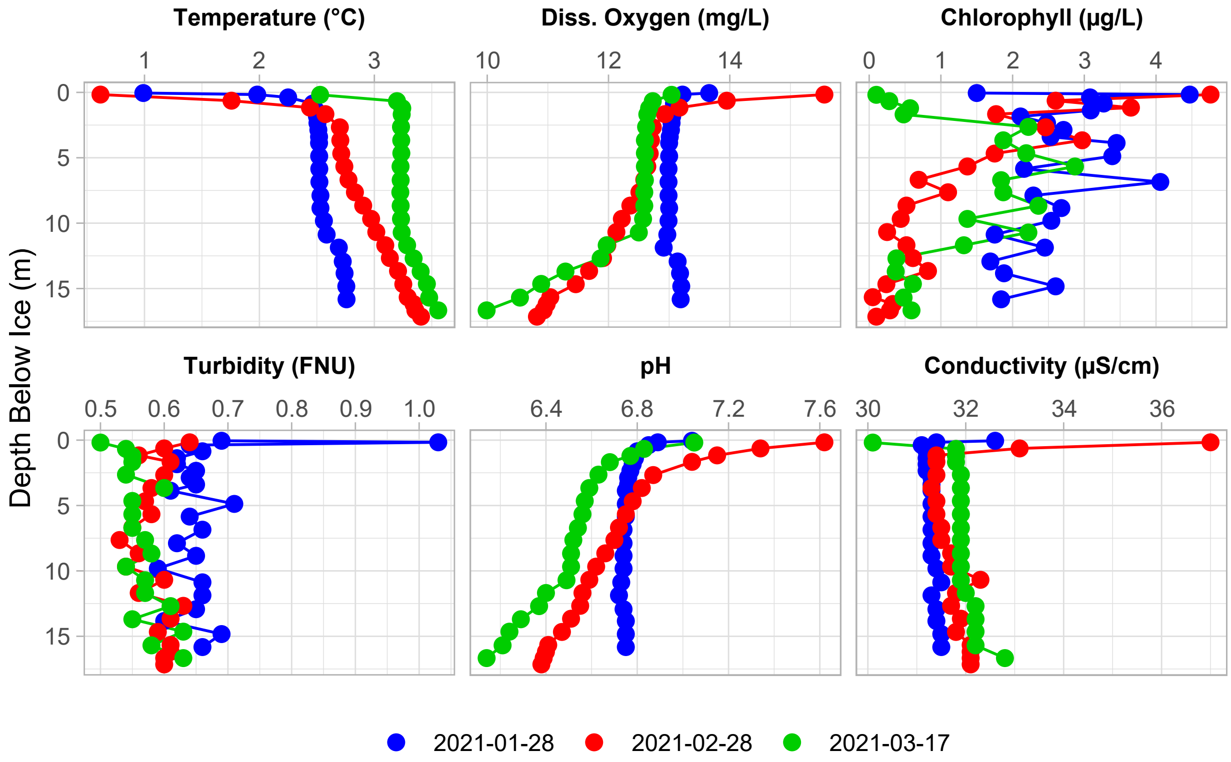


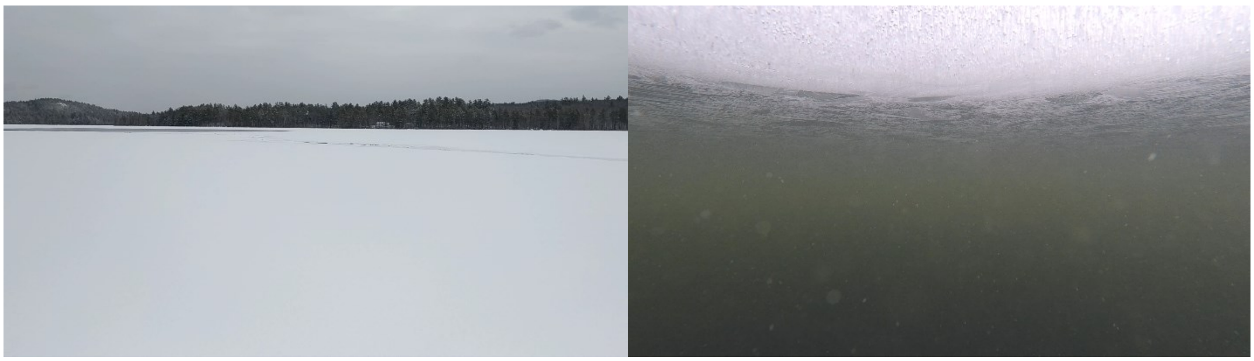


View above and below ice at McWain Pond, January 22, 2021

Peabody Pond

2021 was the first year we visited Peabody Pond in winter. Temperature never reached 4 °C (39.2 °F) during our visits, though the water warmed about 1 °C by the last trip. A large patch of open water was present on the first trip, which may have influenced temperatures. DO decreased somewhat with depth and time (mirrored in the pH pattern), but the water remained oxic to the bottom. Chlorophyll was moderate and quite variable on the first trip, followed by a more focused, shallow layer in February and a broader mid-depth peak in March. Turbidity remained typically low and constant over time and depth (notice the small range on the plot scale) except for a small, near-ice spike in January. Conductivity was slightly elevated near the ice for the first two visits, but decreased on the last visit (possibly from melt water), although the range was quite narrow. Otherwise, conductivity remained generally low and constant with depth and time.

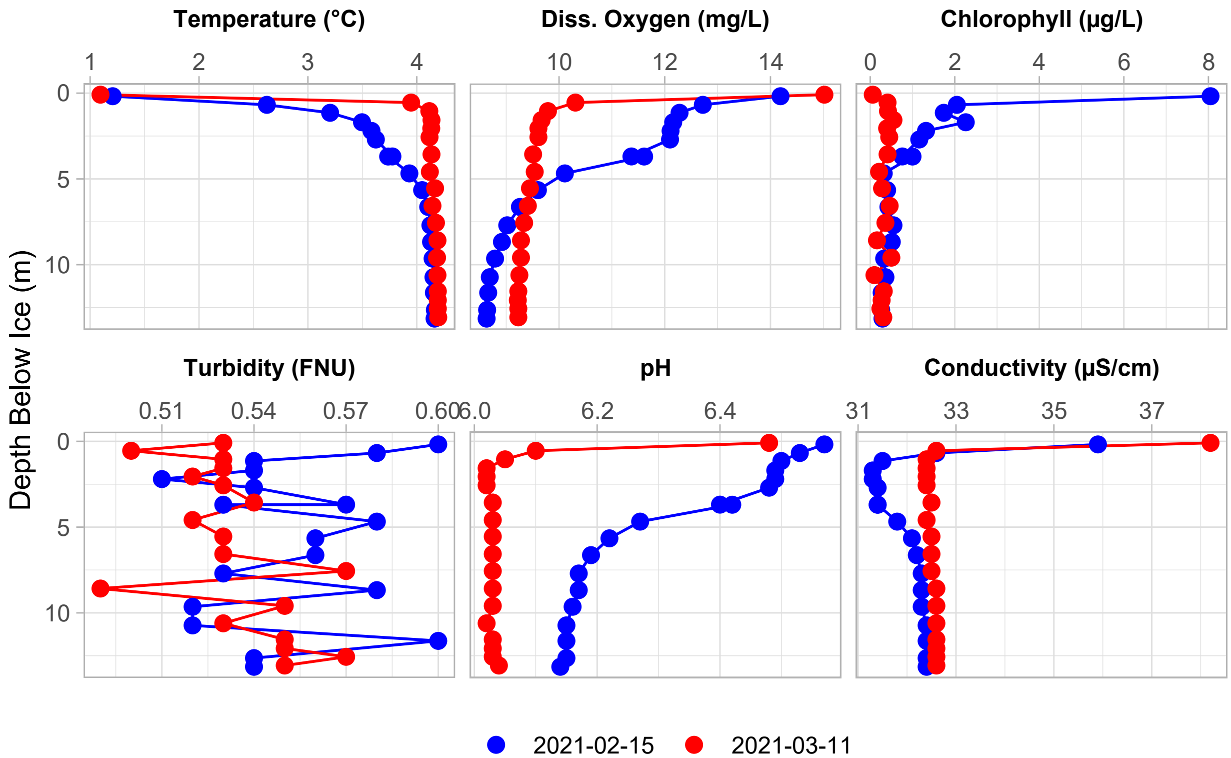




View above and below ice at Peabody Pond, January 28, 2021; an open water patch is just visible on the lake.

Sand Pond

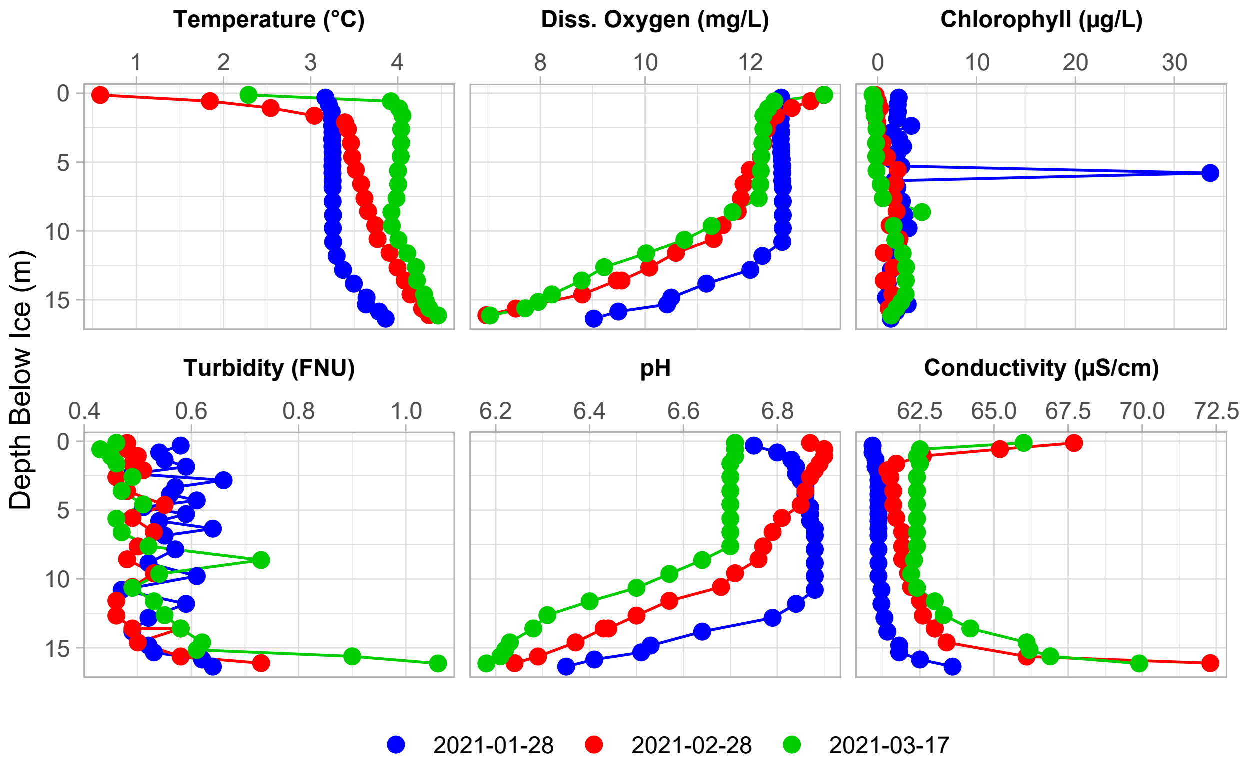
2021 was the fourth consecutive year of winter trips for Sand Pond and many of the patterns stayed the same. Temperature increased quickly with depth to 4 °C (39.2 °F) at about five meters and by March almost the entire water column was at that temperature. DO decreased with depth and time in the first five meters (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 two meters in February. 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. After a rapid decrease from elevated values near the ice, conductivity remained low and relatively constant (note the small plot scale range) with depth and time.



View above and below ice at Sand Pond, February 15, 2021

Trickey Pond

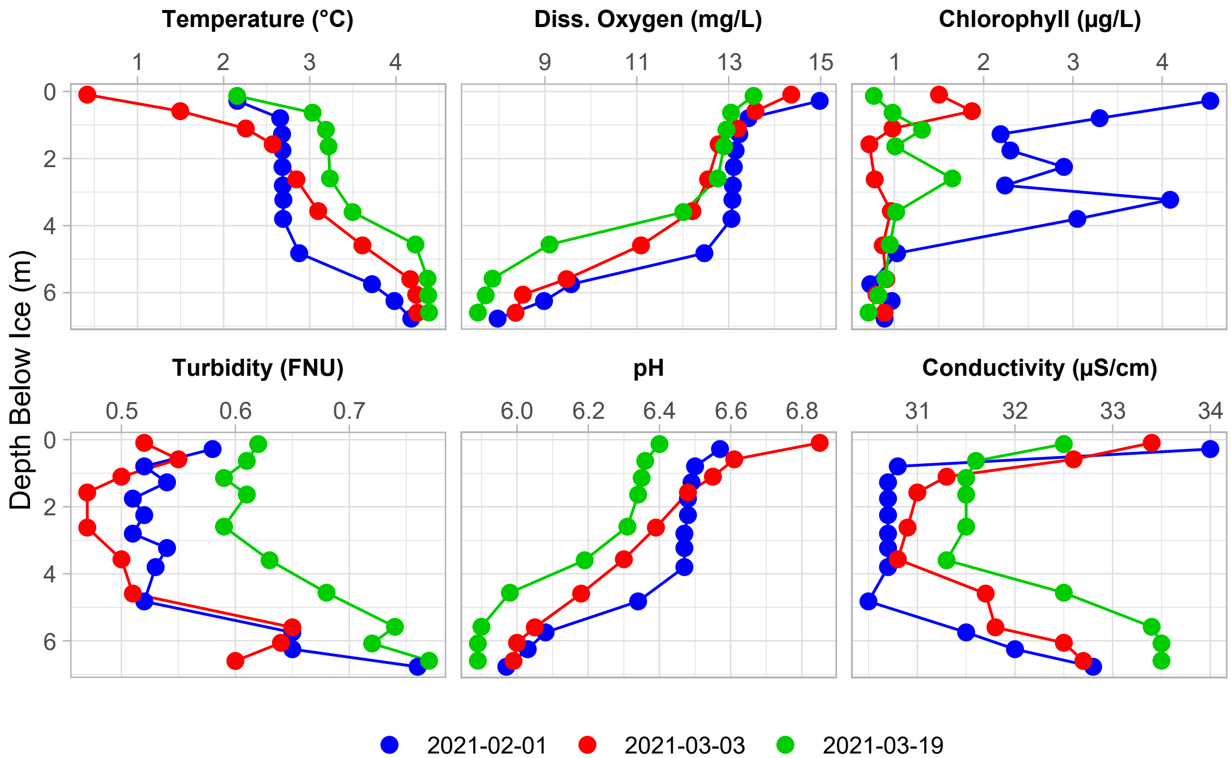
2021 was the third consecutive year of winter trips for Trickey Pond and many of the patterns stayed the same. Temperatures increased with depth and time, but remained below 4 °C (39.2 °F) until about 12 meters depth in February; by March almost the whole water column was at 4 °C. DO decreased with depth and time (mirrored somewhat in the pH profiles), but the water column remained completely oxic on all visits. Chlorophyll was mostly low to moderate except for a significant spike at about six meters in January. 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 for the first two visits, but otherwise it increased slightly with time and increased with depth in the lower five meters of the water column.

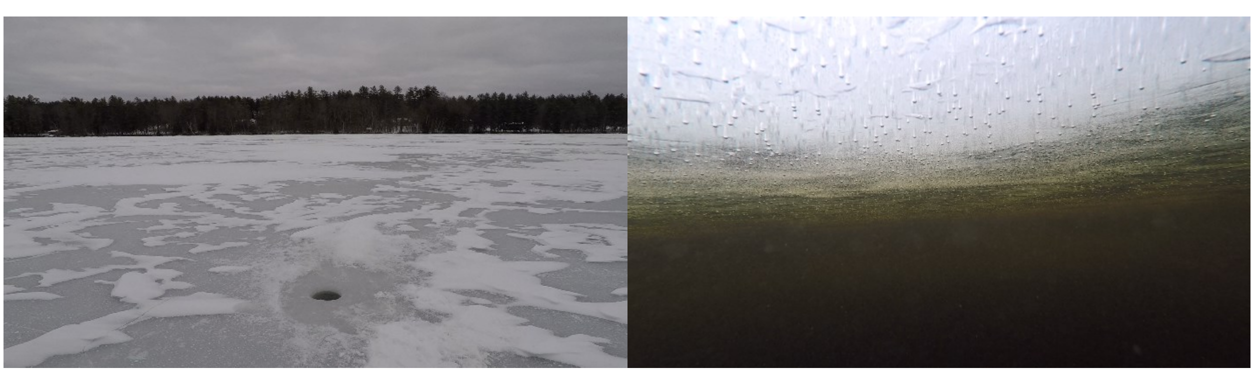


View above and below ice at Trickey Pond, January 28, 2021

Woods Pond

2021 was the second year of winter trips for Woods Pond and many of the patterns stayed the same. Temperatures increased with depth and time, but remained below 4 °C (39.2 °F) except for the deepest waters. DO decreased with depth and time (mirrored in the pH profiles), but the water column remained completely oxic on all visits. Chlorophyll was mostly low to moderate except for elevated levels throughout the upper four meters in February. Turbidity was typically low, though levels increased slightly with depth and between the last two trips (note the small plot scale range, however). After a rapid decrease from slightly elevated values near the ice, conductivity increased slightly with time and with depth, especially in the deepest five meters; note that the small plot scale range exaggerates these differences.





View above and below ice at Woods Pond, February 1, 2021