Lake RMN Protocol Document.
Ice cover & thickness (12/28/2022)

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Why measure ice cover?

Increases in lake temperature and decreases in ice cover have been observed in recent decades, which correspond with historical increases in regional air temperature (Assel 2005, Austin and Colman 2007, Dobiesz and Lester 2009). Air temperatures are projected to continue increasing over time (Vose et al. 2017), which will have cascading effects in lake ecosystems. For example, earlier thawing of winter ice can contribute to earlier onset of lake stratification, which in turn could exacerbate the extent and duration of hypoxic or anoxic conditions in the hypolimnion (Jankowski et al. 2006, Jane et al. 2022).

We are hoping to obtain both ice cover and vertical profile temperature data from some stratified lakes to help answer questions like:

- If ice off is occurring earlier, is the onset of stratification also occurring earlier?
- If the lake goes through several freeze/thaw cycles during the course of the winter, is that reflected in the vertical profile data?

Another question we've been gathering data on is the timing of mixing events vs ice on and off (based on sensor array data and time lapse images). So far we've been able to analyze data from two dimictic lakes (one in Vermont and one in Wisconsin). In 2021, at the Vermont lake, onset of summer stratification occurred 34 days after ice out and full ice cover occurred 57 days after fall mixing. At the Wisconsin lake, onset of summer stratification occurred 42 days after ice out and full ice cover occurred 55 days after fall mixing.

1 Level of effort

The RMN framework allows for different levels of effort to maximize participation. Table 1 contains a 'menu' of options for ice cover observations, divided into three levels of participation: 'minimum', 'target' and 'better'. The minimum level calls for recording the ice out date (within one week).
If resources permit, participants are encouraged to collect data at the 'target' or 'better' levels. The target level calls for percent ice cover observations recorded frequently enough to capture initial ice on, final ice off and freeze/thaw cycles in-between. Or, instead of visual observations, some people are relying on measurements from temperature sensors attached to surface buoys that freeze into the surface ice over the winter.

Having these types of data would allow us to answer questions like:

- Is ice off occurring earlier?
- Is ice on occurring later?
- Is the duration of ice cover changing?
- How many ice on and ice off (freeze/thaw) cycles occur? Is this changing over time?

In addition, this document includes ice thickness protocols, which were provided by the 1854 Treaty Authority. These are optional but encouraged where feasible.

Table 1. Ice cover observations divided into three levels of participation: ‘minimum’, ‘target’ and ‘better’. Participants are encouraged to collect data at the ‘target’ or ‘better’ levels. *Note that there may be participation levels that fall in-between those suggested in this table.*

Location	Parameter	Level of participation		
		Minimum	Target	Better
Typically taken from the shoreline; should be taken from exact same location each time	Ice cover	Ice out date* (within 1 week)	Visual estimates of percent ice cover recorded frequently enough to capture initial ice on, final ice off and freeze/thaw cycles in-between; or temperature sensor measurements from the lake surface	Daily percent ice cover
Near lake access point**	Ice thickness	--	--	Monthly ice thickness measurements pending ice conditions/safety

*for RMNs, ice out is when the lake, as viewed from the designated location, is completely ice free; or,
**In addition to proximity to lake access (nearest to access point if possible), consider lake depth (at least 5' if possible to avoid areas where ice could freeze down to lake bottom). Avoid areas with inlets/outlets/current, ice roads, high traffic and other disturbances.

2 Ice cover protocols

The use of consistent and comparable methods is very important for the RMNs, as different methodologies may introduce analytical constraints and contribute to variability, which reduces the sensitivity of indicators and increases trend detection times.

Definitions -
One of the challenges of working with historic ice observation data is that definitions of ice on and ice off vary across observers. For example, at some lakes, ice out is defined as the date when a structure drops into the water (see example in Figure 1). Other observers may define ice out as the date on which only small patches of ice remain along the shoreline, or when no ice remains. Ice on and off is also ill-defined in situations where the ice thaws and refreezes more than once during winter.

To avoid these types of inconsistencies, RMN protocols call for reporting percent ice cover (0-100%). Quantitative measures of ice cover give the end user the flexibility to define ice on and ice off in whatever way suits his or her purposes (for example, in some cases, they might use 0%, in others, 5%). If you can only collect ice out date, for the RMNs, ice out is when the lake, as viewed from the designated location, is completely ice free.

Figure 1. At Joe's Pond in Vermont, ice out has been defined as the date/time on which this structure (a cinder block tethered to a wooden pallet) enters the water. Definitions vary widely across lakes.

Site documentation -
Another challenge of working with historic ice observation data is that the observation site and area may be poorly defined (e.g., in larger lakes, the observations may only cover one bay or a portion of a bay, while in other situations, the observer may be able to view the entire lake). For regional projects like the RMNs, it is critical that the exact location at which the observation is being taken and the area being observed are clearly documented. Thus, the first step is to document the site. Observations should be taken from the exact same location each time.

Timing of observations -
If possible, report daily observations throughout the ice season. For remote lakes, consider deploying time lapse cameras to document ice cover on a daily basis. This has successfully been done at several RMN lakes and we now have two options for housing photos: Flow Photo Explorer or LakeObserver[1]. EPA regional leads will be applying for a grant in 2023 to add a computer artificial intelligence (AI) component to Flow Photo Explorer to train computers to interpret percent ice cover from the lake images.

If daily measurements are not possible, but multiple visits are possible throughout the winter, concentrate the visits when ice cover is typically changing the most (usually during the start and end of the ice season), and if there are winter warm-ups/thaws, try to capture those periods as well. At a minimum, try to capture the ice out date within a week. Timing of ice out can be difficult to predict, as it varies from year to year and lake to lake, but some patterns are fairly predictable (e.g., lakes at higher latitudes and elevations tend to hold ice later; patterns are also affected by lake size).

Estimating percent ice cover –
We encourage the use of time lapse cameras to take daily ice cover photos throughout the winter at remote lakes. We have two years of time lapse images at some RMN lakes. At this time, daily ice cover

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[1]Flow photo explorer - https://www.usgs.gov/apps/ecosheds/fpe/#/
LakeObserver (https://www.lakeobserver.org/)

estimates are manually interpreted from the images and recorded into a spreadsheet (Appendix A). We hope to be able to add a computer AI component in coming years.

Ice cover photo albums from each lake that span a range of ice cover conditions are being compiled so that teams of observers can calibrate each other to reduce subjectivity. We encourage group calibration exercises where everyone is asked to make independent ice cover estimates, then compare the results and work on reaching a consensus. When discussing the results, find out what they are basing their assessments on and write up guidance that captures this.

As an alternate to the visual observations, some people are relying on measurements from temperature sensors attached to surface buoys that freeze into the surface ice over the winter.

Lakes with existing long-term ice observation data -
If there are existing ice cover data for a RMN lake, and those data were collected using different protocols (e.g., ice out was defined based on an object dropping through the ice, as shown in Figure 1), the long-term record should be continued using the same protocols as before (and a documentation form should be filled out so that people who use the data will know exactly how ice on/off has been defined over the period of record, and exactly where the observations have been taken from). In addition, percent ice cover (0-100%) should be recorded in accordance with RMN protocols. Both sets of records should be maintained.

The two sub-sections below describe step-by-step protocols for ice cover observations based on: 1) on-site observations; and 2) time lapse cameras.

2.1 On-site observations

1. Go to the observation site.
2. Record percent ice cover (0-100%)
3. Take photo(s) as appropriate. We recommend taking more photos during periods of partial ice cover and occasional photos when ice cover is 0 or 100%.
4. Write comments and take photos when there are unusual events (such as rain-on-ice events, during which rain pools up on the surface of the ice).

2.2 Time Lapse Cameras

1. Familiarize yourself with the camera
    a. We recommend doing practice/trial run(s) locally (e.g., at home or at the office) before deploying in the field
2. Configure the camera
    a. If you have a long ice-on season (5-6 months) with very cold temperatures, and can only visit the site at the beginning and end of the ice-on season, to conserve battery life, we recommend the time lapse setting for 2x/day (e.g., 10am and 3pm), *without* the motion detect option.
        i. Two photos are preferred over one because sometimes clouds or rain obscure the photos at certain times of the day. Having the extra photo does not add

much time to photo interpretation, especially in northern areas where 100% ice cover is prevalent for most of the season.

ii. If you are concerned about running out of space on the camera's data card, look into the options on photo quality settings; medium or high resolution images (vs enhanced) will likely suit our purposes fine.

3. Install camera
    a. Siting considerations
        i. Don't point it directly into the sun (north or south-facing generally works well)
        ii. Field of view - make sure it's taking a picture of the desired area (note: we recommend that you get a camera that has an internal picture viewer; this makes camera setup easy and eliminates the guesswork in setting up for the perfect shot). Good rules of thumb: fill 80% or more of the image frame with the target (in this case, lake water); ideally capture the area where the sensor array is deployed; if you can also include a reference marker (such as a boulder in the water that is unlikely to move) in the frame as well, during the ice-free season it may be possible to estimate water level from the images in addition to ice cover.
        iii. Accessibility – off the beaten path (avoid high traffic areas if possible to lower the chance of vandalism) but not too far off the beaten path (make sure you or someone else can find it!)
        iv. Initially we thought the higher up/more 'aerial' of a view you can get, the better (since it will allow for easier comparisons with images from Google Earth, and potentially will allow for ice cover area calculations in Google Earth). But the jury is still out on this and it doesn't seem important from a computer AI perspective.
    b. Use a cable[2] and lock to secure the camera. A security box is nice to have as well but is optional. This makes the camera less likely to be stolen or vandalized. It also it ensures the camera will be returned to the exact same position after it is removed to download images.
    c. Tag – some programs have had success putting tags on their equipment with their contact information and a note like 'please do not disturb; this camera is being used to study ice dynamics'
4. Download images
    a. Frequency – there is no requirement; visiting the site at the beginning and end of the ice season should work if you follow the recommendations on configuration settings (major considerations = battery life and capacity of the camera data card). That being said, if you are able to download images more than once during the ice season, this lowers the chance of losing long periods of data.
    b. Repositioning - make sure the camera is returned to the exact same location after images are downloaded
5. Camera maintenance
    a. If you are going to keep the camera deployed
        i. Check battery life; change out batteries as needed
        ii. Change out or reformat the camera data card as needed
        iii. Clean the lens if needed

[2] If you are using a python lock on smaller trees, check for tension each visit and adjust if needed (tree growth can create tension and make them hard to unlock)

   b. When the camera is not deployed, remove the batteries (it will likely drain the batteries, plus may cause corrosion)
6. Interpret images
   a. Go through the images and record daily percent ice cover (0-100%) in a spreadsheet like the one shown in Appendix B. If you have multiple images per day and they differ, take the average.
7. Data storage
   a. You are the custodian of these data. Keep your files in a safe, secure location that is backed up regularly[3].
   b. LakeObserver now has a batch upload feature; if you enter percent ice cover data into an Excel file and follow the format shown in Attachment B, it can be uploaded to LakeObserver with minimal effort (the batch upload saves you from having to manually enter percent ice cover for each day). You can upload photos as well (this is done in a separate step).
   c. If server space is an issue with the photos, only keep one image per day; if more space is needed, delete photos of long periods of 0 or 100% ice cover.

2.3 Ice cover equipment

If you are performing visual observations, bring a notepad to enter your data onto, binoculars and a camera. If you plan to enter the data while you are in the field and are using LakeObserver, bring a smartphone or tablet with the LakeObserver app. If you are using the time lapse camera protocols, Table 2 and Figure 2 provide information on basic equipment needs. There is also a camera user guide page on the Flow Explorer website - https://www.usgs.gov/apps/ecosheds/fpe/#/user-guide.

Table 2. The cost and features of the cameras varies widely. Here are some basic considerations and estimated costs.

Item	Specifications	Recommendations	Estimated Costs*
Camera	Should be able to take time lapse photos ('still' photos*). Should be durable/able to withstand moisture and cold temperatures. Should have sufficient battery life to make it through the winter.	Pick one that is easy to set up (some are not user friendly). Pick one that has an internal picture viewer; this makes camera setup easy and eliminates the guesswork in setting up for the perfect shot	Price varies widely; lower end cameras that suit our needs generally run $90-$150**; higher end cameras like Reconyx Hyperfire are ~$400
Camera data card (SD)	At least 16 GB	32 GB is even better and is about the same price	$5-10 (usually cheaper if multiple are purchased)
Batteries	Varies; many cameras take 8 double A's (alkalines)	Lithium batteries may work better in harsh weather conditions	8 AA batteries $5-10 (cheaper if purchased in bulk); lithium ion

[3] If server space is an issue, consider purchasing an external hard drive and/or uploading your images to the Flow Photo Explorer - https://www.usgs.gov/apps/ecosheds/fpe/#/

			batteries are a bit more
Cable and lock	Nothing fancy; cable should be cut-resistant	Easy to work with; lock should be able to withstand exposure to the elements	$15-20
Security box (optional)	Fits whatever camera you are using	Inconspicuous, easy to install and easy on trees (it’s nice if you don’t have to drill into a tree with lag bolts)	$30-35

*some time lapse cameras only output videos – e.g., Brinno
**this is not an endorsement, just some examples of popular models in this price range - Browning Strike Force XD, Moultrie A-series, Stealth Cam G42 No-Glo Trail Game Camera STC-G42NG.

Figure 2. Examples of equipment options for cameras (upper left - example of a camera; lower left – example of a security box; right – batteries, SD card and cable and lock).

2.4 Ice cover field forms

For visual observations, record the following information at a minimum:

- SiteID
- Observer
- Date
- Time
- Percent ice cover (0-100%)

- Photo (yes/no)
- Notes

Also, if using time lapse cameras, carefully document the location of the camera with GPS coordinates. Also draw a map and describe nearby landmarks.

Ideally the location from which observations are taken will not change over time, as this will interrupt the long-term record. But if for some reason the site needs to be moved, keep a log documenting any changes over time.

3 Ice thickness protocols

The following protocol was provided by Hilarie Sorensen and Tyler Kaspar from the 1854 Treaty Authority, who have been recording ice thickness at ten lakes in Minnesota for several years.

Select the monitoring location based on lake depth (at least 5' if possible to avoid areas where ice could freeze down to lake bottom) and proximity to lake access (nearest to access point if possible). Avoid areas with inlets/outlets/current, ice roads, high traffic and other disturbances.

Mark the location with a GPS and with a branch (in the ice hole) and check monthly December-March/April each year pending ice conditions/safety. Drill one hole via ice auger (8", might recommend smaller hole for ease of drilling) in the same location (near but not in the previous hole) each month/year of monitoring to get trend of relative ice thickness (not to represent ice thickness across the entire waterbody). Clear the ice shavings, snow, slush from the hole and surface so the measurement is taken from the bottom of the ice to the ice surface.

Record the following information:

- water depth (feet, taken with depth finder)
- on shore snow depth (inches, in undisturbed areas near access point)
- on ice snow depth (inches, in undisturbed area near/around the ice hole)
- total ice thickness (inches)
- grey ice (inches, is usually the top layer measured from ice surface to start of clear ice)
- clear/solid ice (inches)
- weather conditions (temp, wind, etc.)
- crust/slush/water layers present on ice surface.

All ice/snow measurements are to the nearest 1/4 inch. Snow depths are the median of several measurements (no set number, depends on variation and size of location).

Equipment: Ice auger, measuring stick (add bolt to hook on bottom of ice, need to account for this in measurement; also use this measuring stick for snow depth), ice scoop, otter sled, Kestrel weather meter (temp, wind speed), data sheets on write in the rain paper, shovel and GPS. Snowmobiles are used for monitoring locations far from the access point and/or lakes that are not accessible via truck in the winter.

4 Data management

Ice cover estimates for each lake should be entered into spreadsheets like the example shown in Appendix B and stored in a safe, secure location that is backed up regularly. In addition, we encourage you to also keep current versions of these files posted on the RMN Sharepoint site (for assistance, contact Jen.Stamp@tetratech.com). The spreadsheets can also be uploaded to LakeObserver via its batch upload feature.

If you are using time lapse cameras, given the large size of the photo files, you may want to purchase an external hard drive, which are relatively inexpensive (e.g., a 1TB drive costs about $55). You also have two options for housing your photos, both of which are free and accessible to the public:

- Flow Photo Explorer: https://www.usgs.gov/apps/ecosheds/fpe/#/
- LakeObserver: https://www.lakeobserver.org/

EPA regional leads will be applying for a grant in 2023 to add a computer artificial intelligence (AI) component to Flow Photo Explorer to train computers to interpret percent ice cover from the lake images. In the meantime, RMN partners can start uploading images to this database as soon as they desire.

If you prefer to use LakeObserver, you will need to set up a siteID and link the site to the RMN projectID (for instructions, see their website; if you have problems, contact Lisa Borre - borrel@caryinstitute.org). You can enter data via their mobile app (which works on Apple and Android platforms) or via the online computer interface. You do not need cell phone coverage at the time of the submission. The app will store the data until you are back in a coverage area. Submitted data is stored on the LakeObserver server, which is located at the Cary Institute in New York. You can download your data from the LakeObserver website at any time. Lake Observer is currently supported by grants and the developers are continually trying to make improvements. Contact Lisa Borre if you have questions and/or suggestions on ways to improve Lake Observer (borrel@caryinstitute.org).

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