



How Will Northern Lakes Respond to Climate Change?

Regular water quality monitoring provides snapshots of what is happening in a lake on a given day and, over time, lends itself to identifying the trajectory a lake is following. Diatoms—algae collected from sediment cores extracted from lake bottoms—provide a photo album from which we can infer what water quality conditions were like in the past.

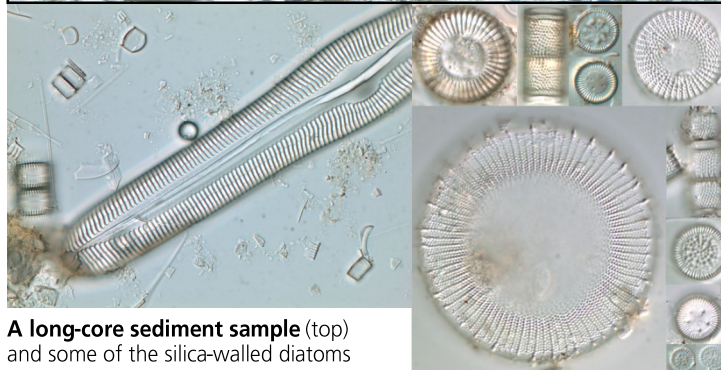
Different species of algae have particular conditions they need to survive—a certain temperature range, a certain amount of light or oxygen. Diatoms are a type of algae with cell walls made of silica. When the alga dies, its glass-like “skeleton” falls to the bottom of the lake. Extracting a sediment core from a lake yields collections of diatoms that can be identified to the species-level, telling us the composition of a lake’s algae communities going back hundreds of years. The species composition of those historic communities lends insight to past environmental conditions in a lake (e.g., temperature, acidity, oxygen levels).

In the Great Lakes region, studies of sediment cores collected from park lakes are revealing dramatic changes in diatom communities, especially in the past few decades. **Can the information diatoms provide about how lakes responded to past environmental changes give us an indication of how lakes will respond to future climate changes?**

We used basic biological, chemical, and physical (depth, shape, size) information about each lake, along with historic weather data to create daily temperature models over a 50-year period (1960 to 2011) for four lakes in Voyageurs National Park (Minnesota) and four lakes in Isle Royale National Park (Michigan). The lakes ranged from small, shallow, and eutrophic (nutrient-rich), supporting an abundance of plants and animals, to large, deep, and oligotrophic (nutrient-poor) with fewer plants and animals. Water temperature profiles gathered during routine monitoring by Great Lakes Inventory and Monitoring scientists and park staff since the mid-2000s allowed us to check modeled results against actual in-lake measurements.

Overall, there was good agreement between modeled and observed temperature profiles, especially in the deeper lakes, with a wide range of temperatures, thermoclines situated at about the correct depth, and the overall shapes of the profiles similar between simulated and observed values (*Figure 1*). The shallow lakes at Isle Royale did not fit the model quite as well, possibly due to their smaller volumes and factors related to their size.

We also used the model to look for trends in shallow- and deep-water temperatures and the timing of temperature gradient (thermocline) formation between two 25-year time periods (1962–1986 and 1987–2011). The most common significant trend was



A long-core sediment sample (top) and some of the silica-walled diatoms that are extracted from such a sample. Diatom photos by Mark Edlund.

an increase in shallow-water temperatures across all eight lakes during the summer (Figure 2). We also found an increase in how often and for how long thermoclines in deep lakes equaled or exceeded 2°C or 3°C (36°F–37°F) per meter (Figure 3). Such a change indicates a stronger separation and potentially less mixing between the warm upper and cold lower water layers in a lake, which can lead to oxygen depletion, the loss of cold-water species of fish, and alteration of biological communities at the base of the food web such as diatoms and other plankton.

We compared model output with historical biological changes in the lakes as interpreted from diatom communities extracted from dated sediment cores. Diatom community shifts in the shallow lakes at Voyageurs suggested slight increases in lake pH (i.e., declining acidity), while in Isle Royale's shallow lakes, the shifts suggested an increase in the number of days that the lakes completely mixed (turnover). Changes from habitat-specialist to habitat-generalist diatom communities were more pronounced in the deeper lakes and tracked with the modeled increase in the frequency and duration of a stronger (2°C or 3°C) thermocline.

This study is a proof of concept that we can use past meteorological data and lake characteristics to accurately model past physical responses of lakes to weather and climate conditions and to predict future responses. The ultimate aim is to use simple lake parameters to predict the sensitivity of different lake types to future climate change. Knowing how sensitive lakes are to change can help park managers identify potential management issues such as determining what lakes are most likely to support a cold-water fishery, or which lakes might be more susceptible to harmful algal blooms.

We have deployed temperature sensors in at least one inland lake at Isle Royale and Voyageurs national parks and Sleeping Bear Dunes and Pictured Rocks national lakeshores. The temperature sensors record temperature once per hour, year-round. Over time, data from these sensors will be used to assess lake response trends in the same way the modeled data were used in this pilot study.

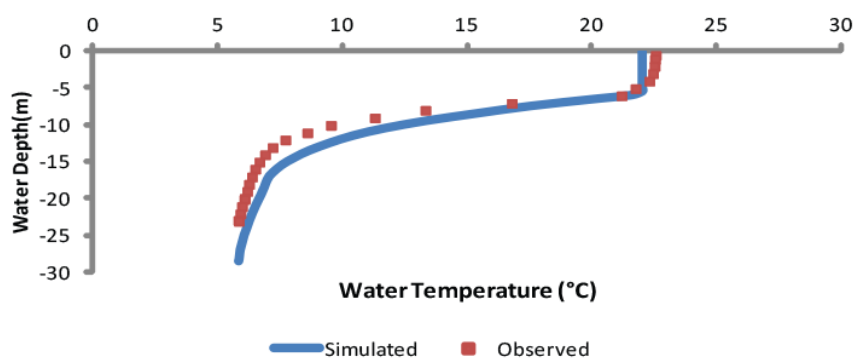


Figure 1. Simulated and observed temperature profiles (in °C) for Cruiser Lake (Voyageurs NP), 20 July 2010.

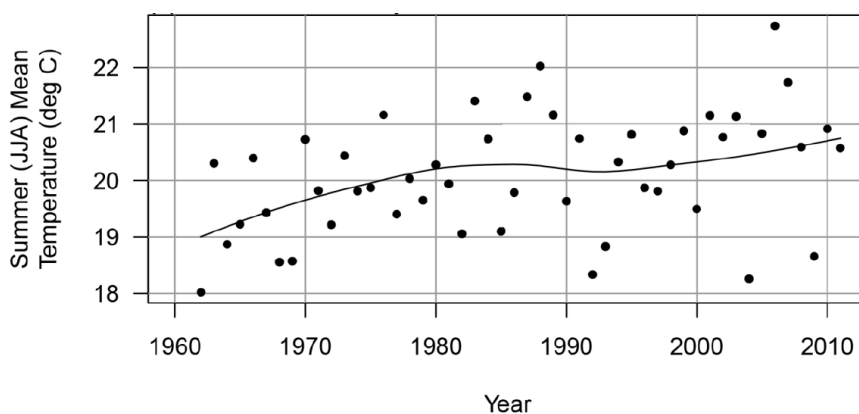


Figure 2. Modeled summer shallow water temperatures (in °C) for Lake Richie at Isle Royale National Park, 1962–2011. JJA=June, July, and August.

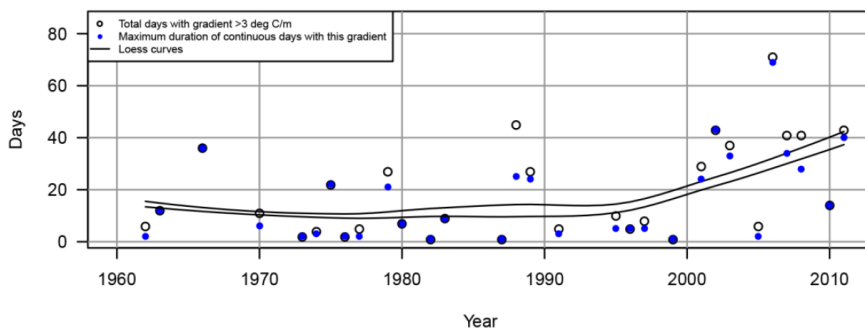


Figure 3. Modeled number of days with a thermocline >3°C (37°F) for Cruiser Lake at Voyageurs National Park, 1962–2011.



This work is a cooperative effort between the Great Lakes Inventory and Monitoring Network and the St. Croix Watershed Research Station.

For more information: <http://science.nature.nps.gov/im/units/glkn/publications.cfm> (Inland Lake Water Quality Monitoring Reports)

Edlund, M. B., J. E. Almendinger, D. R. Engstrom, X. Fang, J. Elias, and U. Gafvert. 2014. Modeling the effects of past climate change on lakes in Isle Royale and Voyageurs national parks. Natural Resource Technical Report NPS/GLKN/NRTR—2014/909. National Park Service, Fort Collins, Colorado.