



Using the Past to Predict the Future of Wilderness Lakes

Have you stood on the shore of a remote wilderness lake with no apparent sign of human influence and wondered if the lake always looked like that? Has the water always been so clear, and will it be as clear 50 years in the future? We know this area is warming, and some places are getting wetter, and we know it will likely continue to do so throughout our lifetimes. In contemplating both the past and future condition of the lake, we must consider how sensitive that lake is to a warmer and perhaps wetter climate.

Climate Effects

Climate has both direct and indirect effects on lakes.

Direct effects are the influences of air temperature, wind, and precipitation directly onto the surface of a lake. *Indirect effects* are the ways in which climate is impacting the surrounding landscape that drains into the lake, also known as the lake's watershed or catchment.

In general, lakes less than 12–15 feet deep do not *stratify*, meaning they do not develop a stable warmer layer over a colder layer in the summer. Lakes of this type are referred to as *polymictic*, meaning the water column regularly mixes throughout the ice-free season. Deeper lakes do typically stratify, with different chemical and biological processes occurring in each temperature layer.

Physical characteristics such as the size of the catchment as well as the size and depth of the lake itself may determine how sensitive the lake is to warming conditions. Further, lake sensitivity will vary depending on both direct and indirect climate effects. To test this idea, we compared a lake's propensity to stratify (direct, in-lake climate effects) to the ratio of a lake's watershed-to-lake-surface area (indirect catchment effects) (Figure 1). Using this framework, we predicted:

1. Small, *shallow lakes with large catchments* will be most susceptible to *indirect* climate warming, and
2. Small, *deep lakes with small catchments* will be most susceptible to *direct* climate warming.

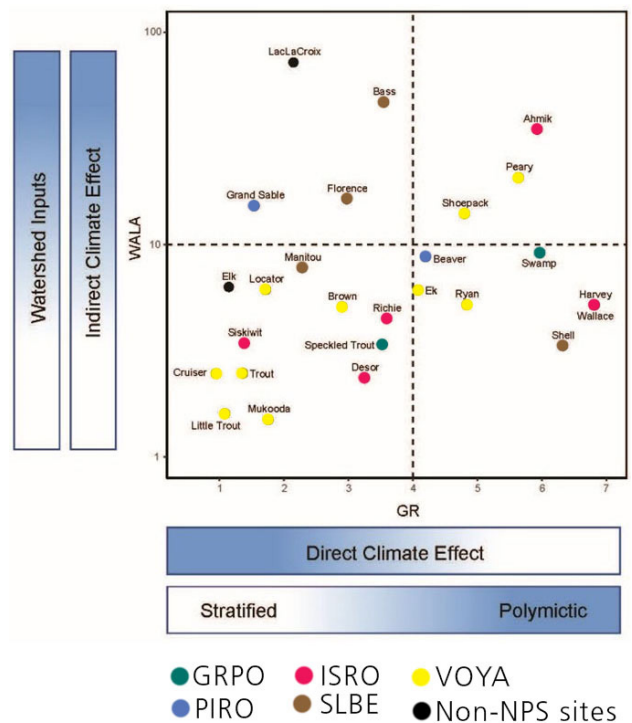


Figure 1. Twenty-seven lakes arrayed in a two-dimensional matrix comparing direct climate effects on lake stratification (summarized as the lake's geometric ratio, or GR) with indirect climate effects controlled by each lake's watershed-to-lake-surface area ratio (WALA). GRPO = Grand Portage, PIRO = Pictured Rocks, ISRO = Isle Royale, SLBE = Sleeping Bear Dunes, and VOYA = Voyageurs.

The Sediments of Time

To predict what might happen to our lakes in the future, we looked at how lakes changed in the past. To do that, we collected sediment cores from the bottoms of 27 lakes in Minnesota, Wisconsin, and Michigan (Figure 2). Most of the lakes are in Great Lakes Network national parks and have experienced minimal land use change over the last century.

Sediments in the cores dated back to more than 150 years before present, and they contained the glass-like "fossil" remains of a type of algae known as diatoms. The presence or absence of certain diatom species tells a story of past lake conditions. We looked through this time-window for evidence of diatom community change, changes in individual species and species groups, and to measure *productivity* (the rate at which individual organisms or populations gain energy) through the build-up of diatom "fossils" and carbon.

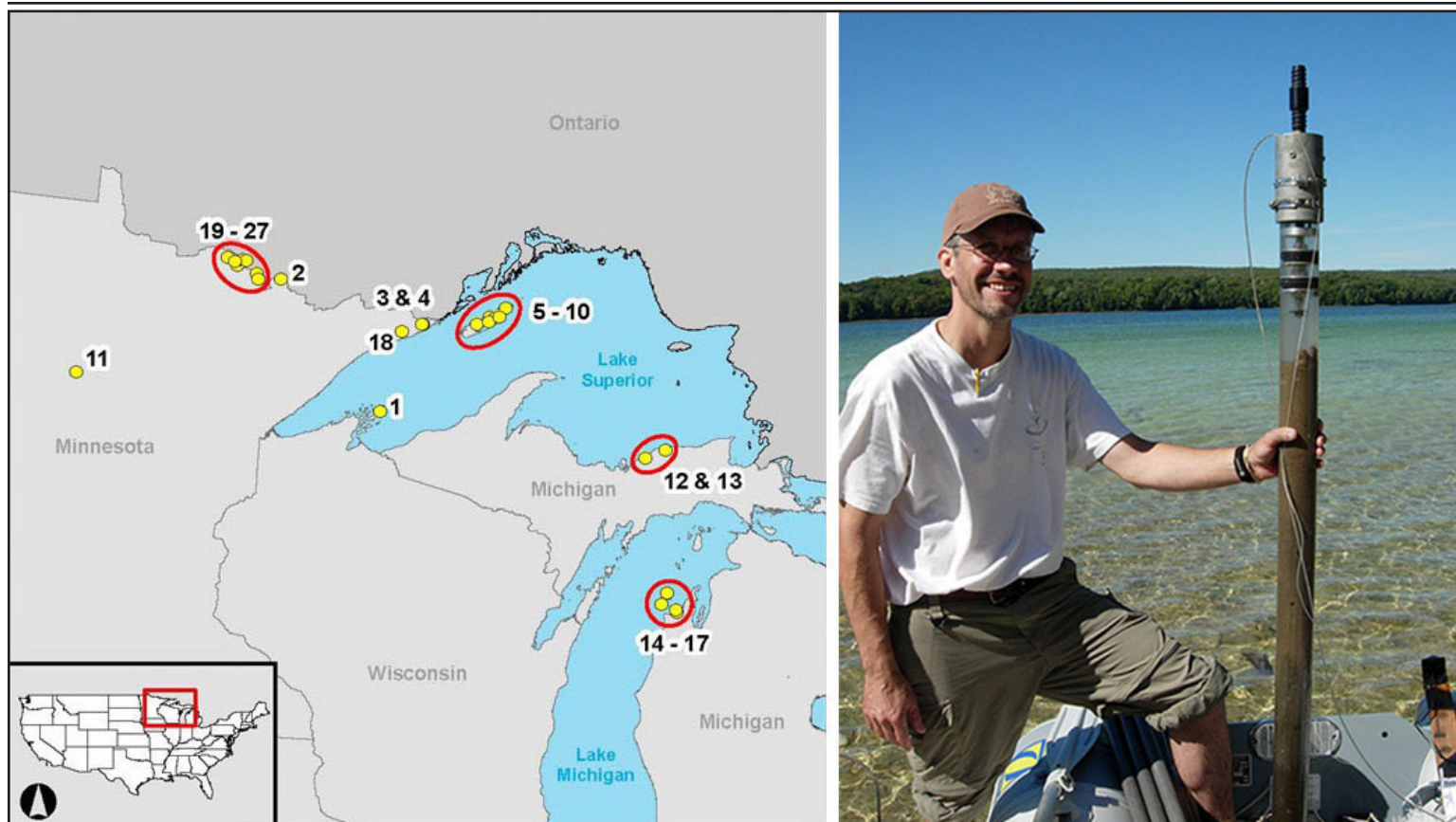


Figure 2. Sediment cores like the one shown in the photo on the right were collected from lakes at Apostle Islands (1), Isle Royale (5–10), Pictured Rocks (12, 13), Sleeping Bear Dunes (14–17), and Voyageurs (19–27). NPS PHOTO/B. LAFRANCOIS

We found significant shifts in diatom communities and increased productivity in most of our lakes. As predicted, greater diatom community change occurred in deep, stratified lakes with smaller catchments. However, diatom species groups showed variable responses along the sensitivity spectrum (Figure 3), suggesting that a warming climate may favor certain types of diatoms over others. Increased productivity, especially the build-up of carbon in the sediments, was more common in shallow lakes regardless of their catchment size, telling us that shallow lakes will become more productive as they continue to warm up due to climate change.

Different diatom species need different water conditions to survive and thrive, so the community shifts and the varied responses of individual species and species groups tell us about the physical and chemical conditions of these lakes in the past. If we can match these historic lake conditions (as indicated by the diatoms) to what we are seeing now in the physical characteristics of lakes and watersheds, we may be able to predict the sensitivity of the lakes to climate change. That is a big picture drawn from a microscopic alga. •

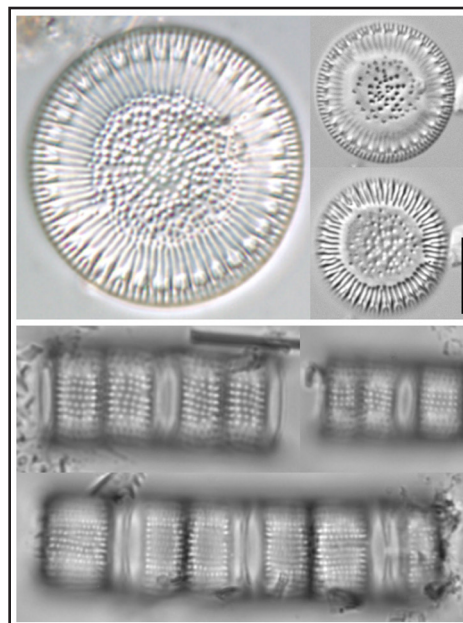


Figure 3. Large cyclotella diatoms (top) increased in abundance in deep lakes with small watersheds, while *Aulacoseira* species (bottom) declined in abundance in those same lakes due to climate-driven changes in lake stratification.