A **S**urvey of **C**limate **C**hange and **A**dirondack **L**ake **E**cosystems
Overview and research priorities

Despite decades-long efforts to protect lakes and streams in New York and elsewhere, numerous bodies of water, including in lakes throughout the Adirondack region of New York State, are now showing symptoms of climate change impacts. These cherished systems are also increasingly plagued with invasive species, salt build-up, and toxic mercury. Federal, State, and Local agencies, not-for-profits, and other organizations are unsure how best to protect these ecosystems that fuel regional economies. To address these challenges, a Survey of Climate change and Adirondack Lake Ecosystems (SCALE) is urgently needed.

The survey will address pressing scientific and management-oriented research needs to understand and guide management of Adirondack lakes, and serve a national model for freshwater research and management. Results from the lake survey will serve as a baseline to understand climate change impacts on freshwater ecosystems, including on climate-sensitive species distributions, invasive species movements, carbon accounting, and harmful algal blooms.

With funding from the New York State Energy Research and Development Authority (NYSERDA), a workshop was convened consisting of a consortium of academics, government agencies, and not-for-profits in July 2021 to articulate and prioritize the research and management needs for this survey. Workshop participants represented the Ausable River Association, the City University of New York, Cornell University, the Nature Conservancy, the New York State Museum, the New York State Department of Environmental Conservation, the New York State Energy Research and Development Authority, the State University of New York College of Environmental Science and Forestry, Paul Smith's College, Rensselaer Polytechnic Institute, Syracuse University, the US Environmental Protection Agency, and the US Geological Survey.

Workshop participants compiled a list of research and management questions that form the foundation for an Adirondack lake survey. Answering these questions would greatly improve the management of Adirondack waters to better understand current and future climate change impacts. A report from that workshop is in preparation. This document serves to highlight research priorities discussed at the workshop. These priorities may evolve as new data and insights are gained on how Adirondack lakes are responding to climate change. The overall scope of the survey will reflect the priorities of researchers, water resource managers, and funding organizations.

1. **Are warming air temperatures enhancing deep-water dissolved oxygen losses in Adirondack lakes, and what are the consequences of oxygen losses for organisms and ecosystems?**

   Oxygen is essential for all complex life. Climate change is contributing to deep-water dissolved oxygen losses, potentially threatening aquatic organisms and increasing greenhouse gas emissions (CO_2, CH_4, N_2O) from lakes. Growing anoxia may also stimulate harmful algal blooms by altering chemical reactions to liberate phosphorus from lake sediments. Yet, the magnitude of deep-water oxygen losses is unclear, as are many of the effects. What proportion of lakes exhibit deep-water anoxia (zero oxygen) conditions? Are growing differences in temperature between surface and deep waters (called "stratification") or increasing salinity contributing to a greater extent or duration of

anoxia? A survey is needed to understand the potential of widespread dissolved oxygen losses in Adirondack lakes and the effects it may have on other ecosystem properties.

2. **How is climate change affecting organisms that live in and depend on Adirondack lakes?**

   The underlying biology of all organisms is temperature dependent. Yet the fate of many species, such as climate-sensitive Adirondack cold-water fisheries (e.g., trout) remain difficult to predict due to complex feedbacks and interactions between organisms and the environment and between organisms, such as between fish and their preferred prey. Does increasing stratification increase risks of invasion by warm-water species? Will cold-water species of concern lose habitat under climate change? Has warming and deep-water oxygen losses enhanced mercury bioaccumulation, despite reduced inputs of mercury in the Adirondacks?

3. **How is climate change affecting carbon cycling and the ability of lake sediments to act as carbon sinks?**

   Lakes serve as important sites of carbon cycling. In order to create local, State, and National carbon budgets that account for both natural and human (anthropogenic) sources and sinks of carbon, it is important to measure carbon burial and dissolved gas (carbon dioxide and methane) concentrations in lakes. However, many aspects of carbon processing and flow in aquatic ecosystems are poorly characterized. What predicts carbon burial rates in the sediments of Adirondack lakes? Are lake methane emissions sensitive to warming? Are ongoing increases in dissolved organic carbon concentrations sensitive to climate change and likely to continue in future decades? A lake survey represents a key approach to measuring these important carbon fluxes.

4. **Will harmful algal blooms (HABs) become more prevalent in Adirondack lakes under climate change?**

   Some evidence indicates that harmful algal blooms, which can be toxic to humans and wildlife, are increasing in lakes across the country and around the world. Yet, it is unclear if climate change is driving the increase in harmful blooms. A survey of Adirondack lakes that are not impacted by other factors (e.g., land use change) is needed as a baseline to understand potential climate change drivers of blooms. What proportion of Adirondack lakes exhibit toxin-forming harmful algal blooms? What other factors, such as land use, best predict lake blooms? Does the ongoing increase in precipitation amplify the likelihood of blooms by increasing inputs of nutrients? This survey can serve as a needed baseline for understanding climate change drivers of harmful algal blooms nationally.

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