INNER WORKINGS

Smart-sensor network keeps close eye on lake ecosystem

Natasha Gilbert, *Science Writer*

New York's Lake George may be the most high-tech lake in the world. By year's end, a network of 41 sensor platforms will monitor the 32-mile long body of water. Its tributary stations and vertical profilers measure the chemical and physical properties of water at varying depths. Acoustic sensors measure the direction and speed of currents in three dimensions. What's known as the Jefferson Project, named after US President Thomas Jefferson who once marveled at the lake during a visit, is run by researchers at Rensselaer Polytechnic Institute (RPI) in Troy, NY. Started three years ago, the project is already collecting more data points in one week than Rensselaer researchers collected at the lake over the past three decades, says project leader Rick Relyea.

For the past 38 years, researchers from RPI have gone out onto Lake George carrying multiple handheld water meters to take stock of the state of the lake. Every fortnight or so—except in winter—they'd manually measure the water's chemistry and physical properties, such as pH and dissolved oxygen, and bring back samples for analysis in the lab. One weather station and one tributary station provided the researchers with additional data, such as wind speed and the flow and depth of streams.

Today, the researchers rarely venture out to take measurements by hand thanks to the Jefferson Project, which also includes industry and a nonprofit collaborator. With the project's array of sensors and specially devised

Using an extensive array of sensors, the Jefferson Project aims to understand in fine detail the effects of pollution, invasive species, and environmental change on freshwater ecosystems. Image courtesy of Rensselaer Polytechnic Institute.

models, no other lake is under such a carefully tuned, high-powered research microscope, says Relyea.

"The greatest value of the Jefferson Project is in assembling such a detailed dataset," says Vince Palace, head research scientist at the International Institute for Sustainable Development's Experimental Lake Area (IISD-ELA) based in Ontario, Canada. Relyea wants to apply the project's findings to lakes in other regions—although it's unclear how applicable those findings will be.

Lake Lab

The project aims to understand in fine detail the effects of pollution, invasive species, and environmental change on freshwater ecosystems. The massive data haul—more than nine terabytes already—should help sharpen four predictive models built by IBM Research, headquartered in Armonk, NY. Using data from sensors, the models generate precise weather forecasts, predict water run-off from surrounding mountains, estimate road salt inputs into the lake, and track water circulation throughout the lake.

It's all part of an effort to help researchers understand the state of the lake in real time and forecast how the ecosystem might respond to changing conditions—and perhaps how other lake ecosystems will respond as well. More data should translate into better predictions, especially in difficult-to-measure dynamics, such as the effect of climate change on lake productivity, Palace says.

Lake-monitoring efforts have been ongoing for decades. Palace and his team monitor 58 small lakes in northwestern Ontario, a project first started in 1968. They study the impacts of environmental perturbations, such as pollution, or those related to climate change on whole lake ecosystems by manipulating the environment. For example, in one project, researchers added controlled amounts of mercury to a lake known as Lake 658 from 2001 to 2007 and monitored the pollutant's build-up in fish tissue (1). Now the team is monitoring how long it will take for the ecosystem to recover. The IISD-ELA projects include some of the few facilities that can manipulate whole environments to get an accurate picture of how entire ecosystems are affected.

But Palace's team still use mainly hand-held probes to measure water quality, and they're capable of takings readings at only one location at a time. Sometimes the researchers incorporate satellite data to develop predictive models of when the lakes will freeze and melt. Even so, Palace's systems don't talk to each other like the smart sensors at Lake George—those sensing heavy rainfall might, for example, tell others to increase sampling for road salt.

Palace says he would love to unpack the factors that most influence fish population growth, but it's very difficult to measure lake productivity. The bevy of sensors used in the Jefferson Project could help. "Their dataset will allow them to establish what are the best predictors of fish production with a big degree of certainty," Palace says.

Jefferson project researchers deploy an Acoustic Doppler Current Profiler through the ice to track the direction and speed of the water current. Image courtesy of Rensselaer Polytechnic Institute.

Salty Insights

Although the project is not yet fully operational, it is already yielding some intriguing results. Measurements through 2009 had suggested that road salt content had nearly tripled to 15.7 parts per million over nearly 30 years. Although a common pollutant, salt used to de-ice roads is rarely studied, despite its effects on freshwater ecosystems, says Relyea.

The team put together a suite of experiments to examine the impacts of road salt on organisms such as wood frogs (*Lithobates sylvaticus*) and zooplankton (*Daphnia pulex*)—an important food source for larger aquatic organisms. The researchers added varying concentrations of road salt to water tanks designed to mimic lake ecosystems and monitored the organisms. The most startling effect: Road salt changed the sex of tadpoles from female to male. Researchers know that pollutants such as pharmaceuticals can alter the sex of frogs, but the effect is usually the change from male to female.

In tanks with sodium chloride concentrations of 800 milligrams per liter—levels that are found in water close to treated roads—the number of female tadpoles in the population fell by 10% compared with the number in control tanks, the team reported earlier this year (2). The researchers suggest that salt molecules mimic testosterone, causing the tadpoles to switch from female to male and, hence, potentially decreasing the frog population.

But in a separate experiment, the team reported some potentially good news for zooplankton (3). They found that the tiny organisms can evolve tolerance to road salt in just 5 to 10 generations, or about 2.5 months. First the researchers exposed zooplankton to varying concentrations of salt ranging from 15 to 1,000 milligrams per liter. After 2.5 months, the team collected the organisms and raised three successive generations in low-salt conditions of 15 milligrams per liter. The resulting populations were then divided into groups and exposed to a variety of salt concentrations ranging from 30 to 1,900 milligrams per liter to see how they fared. All zooplankton survived well when exposed to the low salt levels. However, those exposed to moderate salt levels (around 1,300 milligrams per liter) survived better if their ancestors had previously been exposed to high salt levels. In contrast, around half the population died when its ancestors experienced low salt levels.

It's too early to call the zooplankton safe just yet, warns Relyea. Organisms can pay a price, such as increased susceptibility to diseases, when they rapidly evolve resistance to other pollutants such as pesticides. Relyea's team is finishing up a project that investigates what the tradeoff might be for zooplankton.

The project is also looking at what conditions will favor invasive species, such as Asian clams (*Corbicula fluminea*) and zebra mussels (*Dreissena polymorpha*). So-called environmentally friendly road salt alternatives might actually promote invasive species. Calcium chloride and magnesium chloride, for example, help the invasive crustaceans strengthen their shells, which could improve their survival.

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Relyea hopes the results of the Jefferson Project will "serve as a scalable ecosystem solution for fresh waters worldwide." The project is already garnering interest from elsewhere. The Latin American Conservation Council and the United States Environmental Protection Agency have visited the project to see what insights they might gain for their own conservation efforts, says Relyea.

Leery of Limitations

Not everyone believes more sensors will necessarily bring better insights. David Schindler, emeritus professor of biological science at University of Alberta, Canada, and founding director of the ELA, is cautious about the field moving toward a more high-tech future. "I have seen sophisticated equipment malfunction too often to trust it," he says, adding that hand-held meters can measure important characteristics, such as salinity, "with all necessary accuracy."

The human eye is often a superior scientific instrument for observing, Schindler says. And he warns that training researchers to observe important changes in the field is not best achieved "by staring at computer screens."

There's also the issue of just how much researchers will be able to extrapolate data from one lake to others. "There is a lot of variability across the world's lakes and streams," says Caren Scott, an aquatic ecologist at Battelle, which runs the National Ecological Observatory Network (NEON).

In fact, data from NEON could help. A massive project collecting data from 81 field sites across the United States, including 7 lakes and 27 other aquatic sites, NEON will have the capacity to compare multiple ecosystems using its own array of high-tech sensors. Started in 2012, the $469 million National Science Foundation-funded project is due for completion next year.

Scott likes the idea of taking the predictive models devised for the Jefferson Project and applying them to NEON data. "Because both projects are focused on long-term data, it would be pretty awesome if the same tools that they've developed for their lake would be able to be used on NEON data as a way of expanding the spatial applicability of the conclusions of the Jefferson Project," she says.

That seems a distinct possibility. Harry Kolar, an environmental engineer at IBM Research who leads the company's collaboration in the Jefferson Project, says the models can be adapted to other bodies of water and that IBM Research has plans to do so. For his part, Relyea sees ample parallels between Lake George and the lakes encompassed in NEON's surveillance. "Many of those projects are just getting off the ground," he says, "and I am certain there will be interest in future collaborations."

1 Harris RC, et al. (2007) Whole-ecosystem study shows rapid fish-mercury response to changes in mercury deposition. *Proc Natl Acad Sci USA* 104:16586–16591.

2 Lambert MR, Stoler AB, Smylie MS, Relyea RA, Skelly DK (2017) Interactive effects of road salt and leaf litter on wood frog sex ratios and sexual size dimorphism. *Can J Fish Aquat Sci* 74:141–146.

3 Coldsnow KD, Mattes BM, Hintz WD, Relyea RA (2017) Rapid evolution of tolerance to road salt in zooplankton. *Environ Pollut* 222:367–373.