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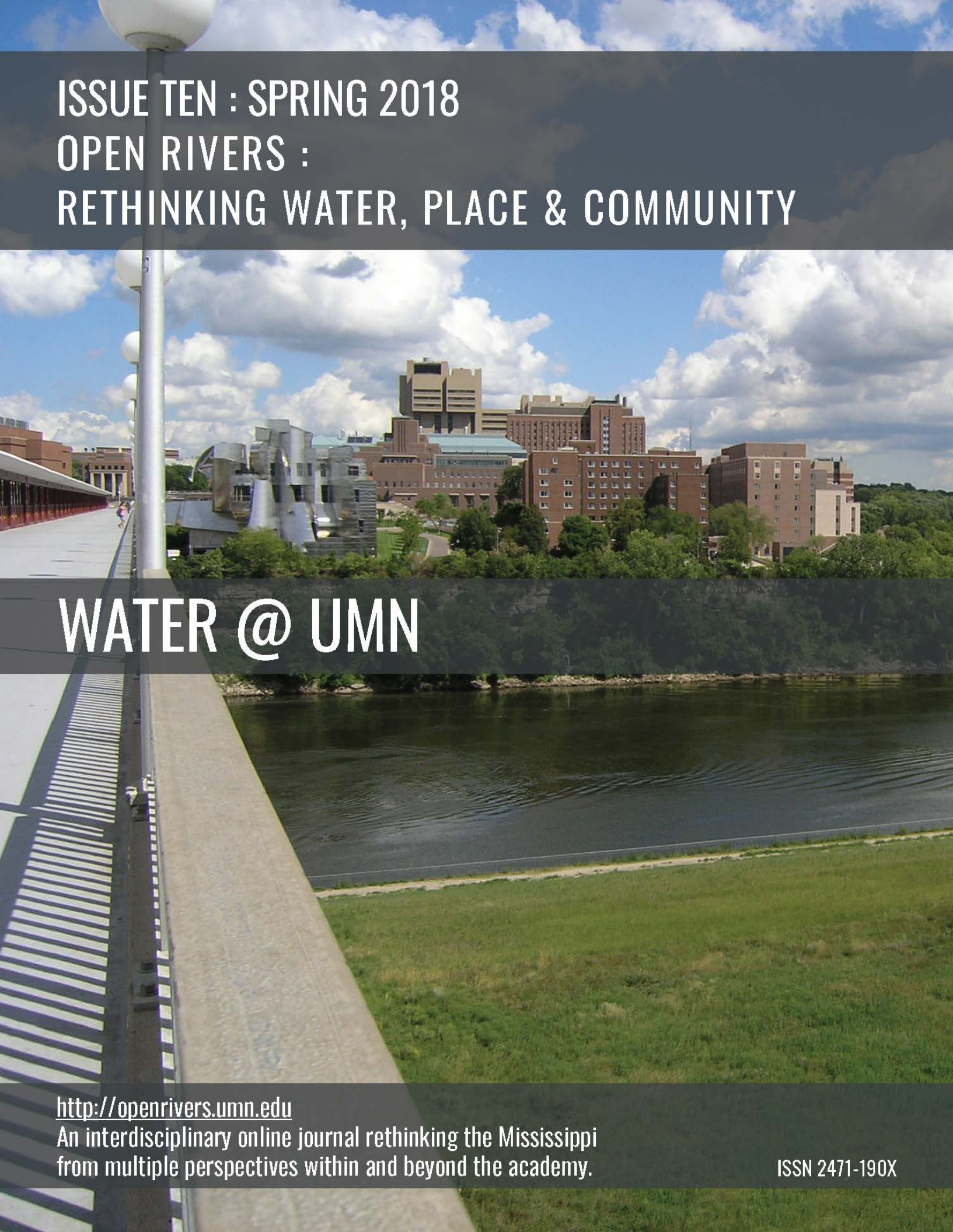

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The cover image is of The East Bank of the Minneapolis campus of the University of Minnesota and the Mississippi River from the Washington Avenue Bridge. Image courtesy of Patrick Nunnally.

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FEATURE

NRRI'S SYSTEMS APPROACH TO MINNESOTA WATER CHALLENGES

By June Breneman

Water equals life, and in Minnesota especially, clean water equals quality of life. As one of our state's most prized resources, the Natural Resources Research Institute (NRRI) at the University of Minnesota Duluth (UMD) takes water seriously. Founded in 1983 by the state legislature, NRRI was established to balance economic development of natural resources with environmental sustainability. Applied research solutions for water challenges are part of almost every problem addressed. From dealing with excess rainfall to trying to minimize human impacts on water resources, the NRRI uses a "systems approach" to solving issues such as stormwater runoff, sulfate contamination, aquatic invasive species and climate change, then delivering tools

NRRI researchers sort through samples collected at Lake Mille Lacs last summer to understand how invasive species are impacting the food web of walleye. Image courtesy of the author.

and information needed for informed decision making.

NRRI's Water Initiative is keenly focused on these issues, while other initiatives support and inform the work. They are Minerals, Metallurgy & Mining; Renewable Energy; Forestry & Land; Wood Products & Bioeconomy; and Business & Entrepreneurial support. The interplay among the scientists, engineers, and geologists makes NRRI uniquely positioned to deliver solutions for resilient communities. Water-based problems are tackled from the watershed and followed to the end of the pipe, an approach that saves money and protects the environment.

"To fully understand and then develop appropriate solutions to the challenges facing Minnesota's water resources, we need controlled, small-scale experiments as well as large landscape-scaled experiments," says Lucinda Johnson, director of NRRI's Water Initiative. "What's great about NRRI is that we partner with colleagues from multiple scientific disciplines to develop new approaches to the challenges."

NRRI research and administrative staff is housed in a recycled Air Force air defense building in Duluth, Minnesota, with a second facility on the Iron Range in Coleraine, Minnesota, focused on minerals and renewable energy. Image courtesy of the author.

TACKLING STORMWATER

Green infrastructure

In 2012, Duluth received 10-plus inches of rain in just a few hours and the flooding caused over $100 million in damages to the city's infrastructure. It also triggered concern about how to develop community resiliency in the face of future storm events.

NRRI took the birds-eye view with computer modeling. How much rain could be absorbed by converting half of the city's buildings to green roofs, adding rain barrels and rain gardens? Once the green infrastructure was mapped out, the scientists brought the scenarios to a citizens meeting where they ranked them for feasibility.

"It was a great chance to educate people, too, and get down to the nitty gritty of cost and what is actually doable from their perspective, which is absolutely essential," said George Host, NRRI Forest & Land Initiative director. The University's Center for Changing Landscapes used the information to develop a fact sheet for climate preparedness and prioritize strategies.

Ditches 101

Other important, but often overlooked, players in stormwater protection are the county and state workers who build and maintain rural ditches. If the ditch banks are built incorrectly or not maintained, the roads can erode and won't shed rainwater efficiently. Ditches also carry water directly to streams and lakes, and the water is not treated or cleaned in any way. When asked what these maintenance professionals needed most to help them do this important job correctly the answer was simple. A guidebook.

But pulling it together was quite a project. NRRI Aquatic Ecologist Valerie Brady led the effort with Minnesota Sea Grant's Jesse Schomberg to develop the "Field Guide for Maintaining Rural Roadside Ditches," published in 2014.

The Field Guide addresses problems like beavers, preventing erosion, and managing vegetation, including invasive species. Workers can quickly reference when to change culvert size or when to involve an engineer. The format is straightforward, specifically written for northeastern Minnesota's county and township maintenance crews for easy reference in the cab of the excavator. An advisory committee provided input and engineering consultants made sure the technical details were covered.

In the front of the book is a "Ditch Problem Checklist" with drawings, photos, and clues making it user friendly. The guide even comes with a slope measuring template to visually guide the excavator in creating proper ditch bank slopes to prevent erosion.

"The goal is to do ditch maintenance in a way that is most protective of our aquatic resources while still protecting the road and traffic," said Brady. "We printed 1,100 copies and distributed to every township and road maintenance group in northeastern Minnesota and northwestern Wisconsin. We need to print more because we are still getting requests."

NRRI Field Technician Mary Heise inspects a large culvert in rural Duluth, Minn., as part of an effort to develop ditch and culvert best practices leading to protecting water quality. Image courtesy of Andrea Crouse.

Unique roadside filters

Even with stable ditches, there are pollutants running off the roads—salt, dirt and heavy metals—especially in the first flush of rain. In 2013, the Pollution Control Agency established a regulation requiring onsite treatment of the first inch of stormwater off roads. Since then, compost and sand have become standard filter materials. But a better idea is being tested at NRRI that uses local waste resources and helps the state meet regulations.

NRRI Scientists Kurt Johnson and Meijun Cai are experimenting with varying mixtures of three ingredients: 1) a clay and organic material mix called "muck," 2) peat that was stockpiled after a road construction project, and 3) taconite tailings waste rock. Each material has its advantages and disadvantages, so the researchers are experimenting with which "recipe" works.

"It has to support vegetation and it has to filter chemicals in the stormwater," said Johnson. "And, of course, they have to be native plants, so I'm looking at the biology and plant growth potential."

Cai is an environmental engineer, so she's working on the efficiency of the pollution removal. Another member of the team is David Saftner in UMD's Civil Engineering Department, who will develop the water storage requirements for the materials.

NRRI Researcher Meijun Cai filters water in her lab as part of an experiment to use local waste resources to remove pollutants from road runoff. Image courtesy of the author.

"We're comparing our mixes to the standard compost/sand mix," said Cai. "If it works and the performance is good, we can make use of these local waste resources for local projects."

Powerful peat

Another effort is underway to address parking lot runoff in a partnership with American Peat Technologies in Aitkin, Minnesota. NRRI Chemist Igor Kolomitsyn is helping them take advantage of the natural attributes of peat to remove heavy metals. Kolomitsyn developed a process to chemically alter the surface of granulized peat to increase its adsorption properties for target removal of cadmium, zinc, cobalt, copper, and sulfate.

A demonstration project to test its efficacy is in place in Aitkin at the far end of the Paulbeck's County Market parking lot. An underground vault is positioned to catch and filter out trash, and then two levels of the peat-based filters capture heavy metals before the water moves to a nearby wetland.

Peat resources are harvested at American Peat Technologies in Aitkin, Minn. NRRI is working with the company to develop unique, peat-based water filters that target specific heavy metals. Image courtesy of the author.

The "S" word: Sulfate

Sulfate in water systems is a statewide problem related to human activities. Innovation is needed to find low cost and efficient options to augment/complement more expensive reverse osmosis. NRRI is tackling this challenge with chemistry, microbes, and filtration aids.

Currently underway at NRRI are promising lab-scale tests of a process that transforms soluble sulfate into a dense solid that settles in a water system so that it can be removed with filters. The goal is to bring sulfate levels ranging from 60-300 parts per million – levels often associated with municipal wastewater treatment facilities – down to the current target of 10 parts per million, the current standard for areas with wild rice in Northeastern Minnesota. This lab work will be scaled up to a first generation pilot demonstration this summer.

Another process uses microbes that naturally convert sulfate to sulfides. NRRI is now working on a biological treatment that allows these sulfides to be permanently removed from the system as another compound.

"It's clear that we need to address with problem multiple approaches, which may or may not include reverse osmosis technology," explained Rolf Weberg, NRRI Executive Director. "These projects are directed at providing another set of tools to address sulfate and related water challenges in Minnesota."

PREVENTING AND MITIGATING AQUATIC INVASIVE SPECIES

Testing ballast technologies

It's well known that aquatic invasive species are a proliferating problem for Minnesota's native species. And we know that one way they're getting here is in ballast water transported by ocean-going vessels travelling through the Great Lakes. For the past decade, NRRI Senior Researcher Euan Reavie has been leading a project to take the guesswork out of finding technologies that kill off invasives before ballast water is released. The research is part of the Great Waters Research Collaborative at the Lake Superior Research Institute in Superior, Wisconsin.

The final step in this lab-to-pilot-to-onboard research was completed in 2017. Reavie and his crew chased a working commercial bulk carrier to ports around the world testing a promising technology, commercialized by JFE Engineering Corporation, in real world situations. The combined filtration and chemical injection treatment keeps species out of the ballast tanks while also killing any organisms that enter. NRRI systematically and scientifically tested the technology so that vendor and policy makers can deploy the equipment with confidence.

"The engineers who build equipment like this have good intentions," Reavie explained. "But they don't necessarily grasp the complex biology of water around the world. A vendor may have done preliminary testing in Europe, and then comes to Lake Superior and gets completely different results."

Fishing gear study

It is well documented that the half-inch barbed spine of the spiny water flea, a tiny invasive zooplankton, gets caught on fishing lines. The non-native species can then inadvertently be transported from lake to lake. But what other gear might it be catching on? NRRI Aquatic Ecologist Valerie Brady and UMD Biology's Donn Branstrator are studying the role of a variety of fishing gear in the spread of aquatic invasive species.

"Are the frayed anchor ropes a problem? What about the bait bucket? The downrigger? Are they hiding in the live wells in the boat? Would a different type of fishing line entangle fewer of them?" Brady said, explaining the project. Insights about the ways that invasive species are transported provide managers with tools for preventing their further spread.

NRRI researchers on Island Lake in northern Minnesota test three different types of fishing line, buoys holding anchor lines and a downrigger to see if spiny water fleas attach to them. Image courtesy of the author.

This research took place on Island Lake near Duluth in 2017 with funding from St. Louis County. In summer 2018, the research moves to Lake Mille Lacs, with funding from the Minnesota Aquatic Invasive Species Research Center and the Environment and Natural Resources Trust Fund. Mille Lacs water is much clearer than Island Lake, which may affect how spiny water fleas interact with fishing gear. Comparing results from both lakes will provide information to anglers to help stem the spread.

Using better information gleaned from this project, waterproof stickers will be made available at bait and fishing supply stores with best practices information for anglers.

On Island Lake in northern Minnesota, one boat of NRRI researchers pulls nets searching for spiny water fleas while a second boat trolls equipment through the water to see if the invasive species attaches itself to the gear. Image courtesy of the author.

What about walleye?

Even though anglers are being educated in checking and draining their boats, aquatic invasive species are still spreading to popular sport fishing lakes. NRRI Aquatic Researcher Katya Kovalenko is leading a team to understand the impacts of spiny water fleas and zebra mussels on walleye populations in Lake Mille Lacs.

"I'm interested in the entire food web and how the lakes are changing," said Kovalenko. "But walleye are especially interesting because they are the top predator. They can give you a picture of everything below them on the food chain."

The overall project is led by the Minnesota Department of Natural Resources (DNR) to understand the walleye food webs in the state's nine largest walleye lakes. Three lakes (Cass, Winnibigoshish, and Leech) have varying levels of zebra mussel invasions. Four lakes (Kabetogama, Lake of the Woods, Rainy, and Vermilion) have spiny water fleas. One lake (Mille Lacs) has both invaders. And another (Red Lake) has neither. Historical data collected by the Minnesota DNR will also allow for comparisons of walleye populations pre- and post-invasion.

NRRI Researcher Katya Kovalenko holds a water sample with amphipods (scuds) and caddisflies take from Lake Mille Lacs in July 2017. Image courtesy of the author.

And while the two unwelcomed critters are very different, they both reduce zooplankton, the tiny food source at the bottom of the food chain. That means less food for young walleye and for yellow perch, which is the food source of grown walleye. The question is: Are walleye adapting to the changes in the food web? If so, what are they eating?

ASSESSING THE IMPACTS

Indicators of environmental change

So how do all these challenges actually impact the environment? NRRI has a number of assessment projects underway to inform future decisions about protection and restoration.

At the turn of the last century, the complexity of the Great Lakes coastal zones was little understood. In 2000, the Environmental Protection Agency (EPA) tapped NRRI to develop indicators to assess the ecological condition and point to problem areas. The resulting labor-intensive and unprecedented report, Great Lakes Environmental Indicators, was delivered in 2015. It serves as a guide for comprehensive studies of the U.S. freshwater coastal zones from Lake Superior's North Shore to Lake Ontario in New York.

The EPA granted NRRI $6 million for the initial project, and the Great Lakes Restoration Initiative provided an additional $1.7 million in 2010 for more data and analysis.

Keys to a successful project of this magnitude were collaboration, tight coordination, and a way to collect data across all watersheds. Principal investigators were assigned to five different indicator groups: 1) Algae and Water Quality, 2) Fish and Macro-invertebrates, 3) Wetland Vegetation, 4) Birds and Amphibians, and 5) Chemical Contaminants.

Out of the terabytes of data collected, nearly 100 peer-reviewed papers and countless metrics and methodologies emerged indexes and benchmarks that provide the capacity to both postulate and confirm the condition of the entire Great Lakes shoreline.

"Basically, we wanted to know how the biological communities related with human disturbances across the Great Lakes coastal region," said Johnson. "Our final products provide a rationale for defining new approaches to solving problems on the Great Lakes and are being implemented in various forms in both Canada and the U.S."

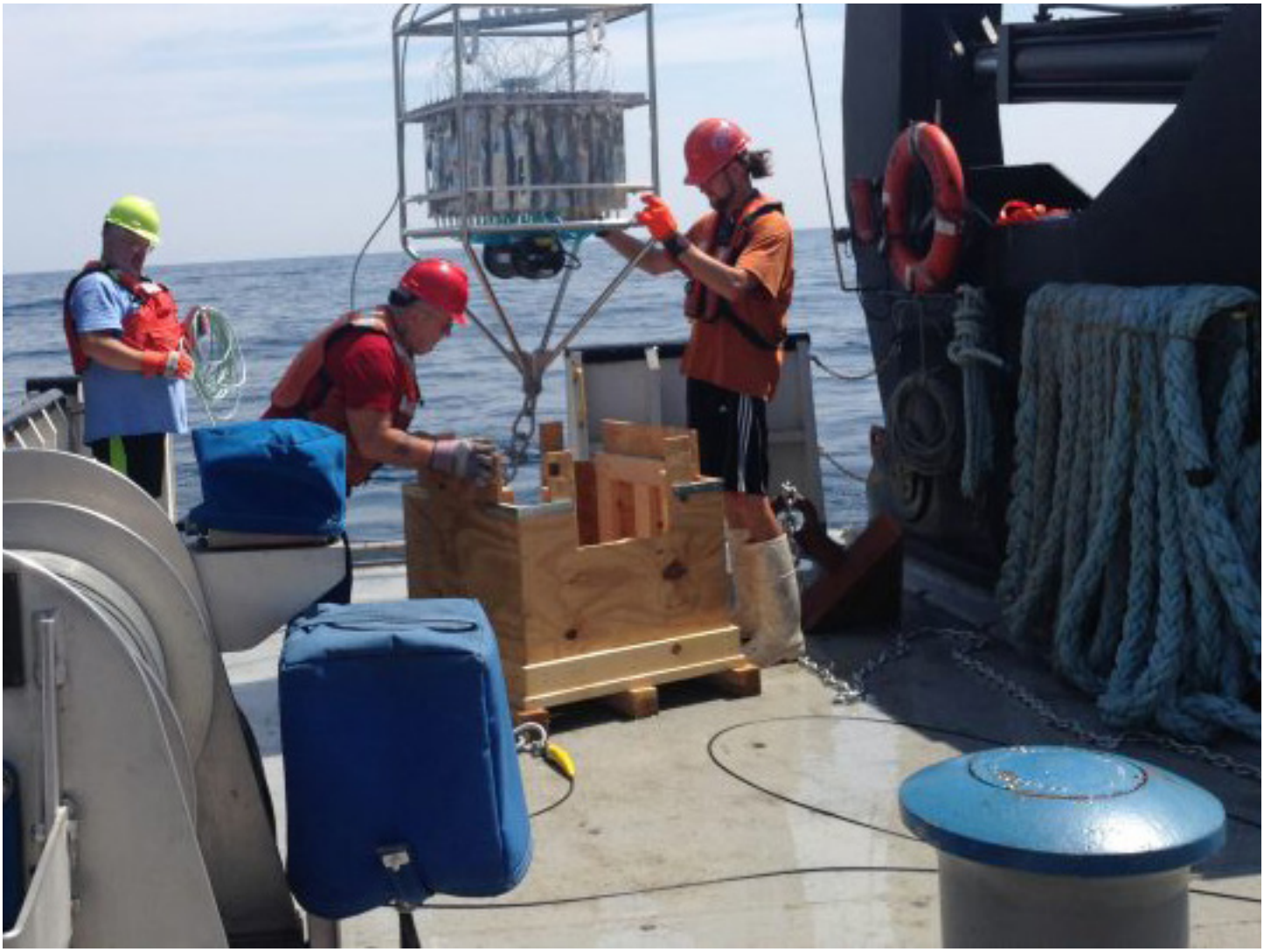
Focusing on the food web

Since 2007, NRRI scientists have been providing data to the U.S. EPA about the status of microscopic organisms at the bottom of the food chain in the deep, open waters of the Great Lakes. Then in 2016, NRRI received additional EPA funding to expand the data gathering to areas near the shore and to use robots that collect data year-round, including under ice in the winter.

"Because of the discoveries we've made so far revealing profound food web impacts, this is a natural progression for the research," explained

Euan Reavie, NRRI senior researcher and program lead. “We need data from more seasons, beyond spring and summer to make predictions, especially with climate change impacts.”

Two submerged buoys with remote sampling devices will be stationed in each of the lakes to collect and preserve phytoplankton samples and store them until retrieved a full year later. The winter data will identify what species are active under the ice and what happens as the ice thaws, a period that is little understood but critical as annual biological cycles begin. The nearshore area, which sits between the shallow coastal waters and the deep open waters, is a very poorly sampled zone that could tell us more about impacts associated with human activities on the land.



Deploying one of the buoy systems with remote sampling devices to collect year-round data on the Great Lakes. Image courtesy of Euan Reavie.

Keeping it cool for trout

The need to better understand North Shore streams that might stand the best chance of staying cool for trout resulted in funding from the Environment and Natural Resources Trust Fund in 2016.

Volunteers from Trout Unlimited and NRRI researchers teamed up to find cool groundwater inputs in about 120 stream segments from south of Duluth, up the North Shore and to the Canadian border.

In 2016 and 2017, researchers mapped cold water seeps and tributaries and correlated the data with each location's geology, creating a computer model to predict the probability of encountering cooler groundwater. Management agencies and fishing groups can then target trout habitat

NRRI Field Technicians Nick Pierce and Kari Hansen walk through rural streams to get temperature readings, documenting where cool water inputs might make them more resilient against climate change impacts. Image courtesy of the author.

restoration and protection efforts on locations where groundwater helps keep streams cool during hot summers.

Field surveys revealed 83 stream segments containing cool water locations, and the resulting computer model was accurate for predicting other groundwater locations. The Minnesota DNR considers warming water to be the greatest threat to trout and steelhead fisheries.

Where the river meets the inland sea

In addition to these many research efforts, NRRI is especially known for ongoing data gathering for long-term monitoring. A significant effort is informing restoration efforts on the St. Louis River estuary as the state works to remove its status as an Area of Concern. In all, more than $400 million has been invested with the goal to complete the work by 2025.

NRRI scientists with specialties in aquatic vegetation, macroinvertebrates, fish and wetland birds species, as well as toxicology and paleolimnology, are able to document change over time. Data showing both historical and pre-restoration condition are used to set goals for what the post-restoration estuary will look like.

The St. Louis River estuary is shown here as it joins Lake Superior. Image courtesy of the author.

Delivering solutions for resilient communities

NRRI was given a unique mission in 1983 when it was established through legislation by state leaders who understood the need for sustainable use of Minnesota's natural resources. Thirty-five years later, the staff of approximately 150 continues that important work with renewed vigor as new challenges emerge and the balancing act becomes more complex.

Large uncertainties exist with respect to the future of Minnesota's water resources. While Minnesota is generally a water-rich state, there are regions that are likely to experience stress as a result of climate and land use change.

"We are facing both threats and opportunities as society strives to adapt to changing conditions and become more resilient," said Johnson. "What is clear is that a systems approach will continue to be necessary to increase efficiencies, and where possible, prevent problems before they demand expensive remediation."

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About the Author

June Breneman is NRRI External Affairs Manager and has been telling the stories of this unique research institute for 18 years. June holds a master's degree in journalism and English from the University of Minnesota Duluth. Prior to her career at NRRI, she worked seven years in both print and television journalism, as well as some magazine freelance writing. She and her husband live on the Wisconsin side of the St. Louis River Estuary and enjoy canoeing and hiking.