Fresh Water

Understanding and Solving Freshwater Problems Facing the World

University of Minnesota Duluth

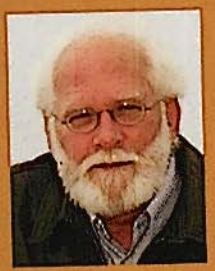
The University of Minnesota Duluth is known as "A Great University on a Great Lake." We know the availability of fresh water will be one of our most important national and global issues in the 21st Century.

UMD is a leader in freshwater research, and we are aware of the work ahead of us in the coming decades. The fragility of the world's supply of fresh water has been a concern of this university for many years. Since 1975, when we brought Minnesota Sea Grant's extension program to campus, we have added centers including the Natural Resources Research Institute (NRRI), which holds the Center for Water and the Environment, the Large Lakes Observatory, and the Center for Freshwater Research and Policy. In addition, UMD provides opportunities for undergraduates and graduate students to participate in classroom, laboratory, and field study in the aquatic sciences.

We have assembled one of the finest — possibly *the* finest — team of freshwater researchers in the world. Our researchers not only respond to research and education needs, they often are the first to identify freshwater issues facing our community, our country and other nations.

I can guarantee that UMD is doing everything within our power to address crucial freshwater problems and improve the quality and availability of water for future generations.

Chancellor Kathryn A. Martin
University of Minnesota Duluth



Northern Minnesota is strong with superior aquatic science. The University of Minnesota Duluth's Center for Freshwater Research and Policy proudly presents a sampling of the multifaceted aquatic research being conducted by scientists at UMD and other organizations on aquatic ecosystems and resources in our region, the nation, and across the globe.

Because of the high caliber of aquatic scientists and specialists here, funds from a multitude of sources have been well spent. Programs described in these pages have received millions of dollars from sources such as the National Science Foundation, the Environmental Protection Agency, the National Oceanic and Atmospheric Administration, the Minnesota Sea Grant Program, and private foundations, as well as businesses and individuals to discover, understand, manage, and protect our aquatic resources.

One strength is the large critical mass of scientists, educators, outreach specialists, and regulators who work cooperatively for the betterment of wetlands, streams, rivers, lakes, and great lakes in our region and the world. We hope you enjoy reading about the aquatic programs from an area of our nation that is not only known for its vast aquatic resources but also one of the largest concentrations of outstanding aquatic professionals.

Randall E. Hicks, Director
Center for Freshwater Research and Policy
University of Minnesota Duluth

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Published by the Center for Freshwater Research and Policy, University of Minnesota Duluth (UMD)

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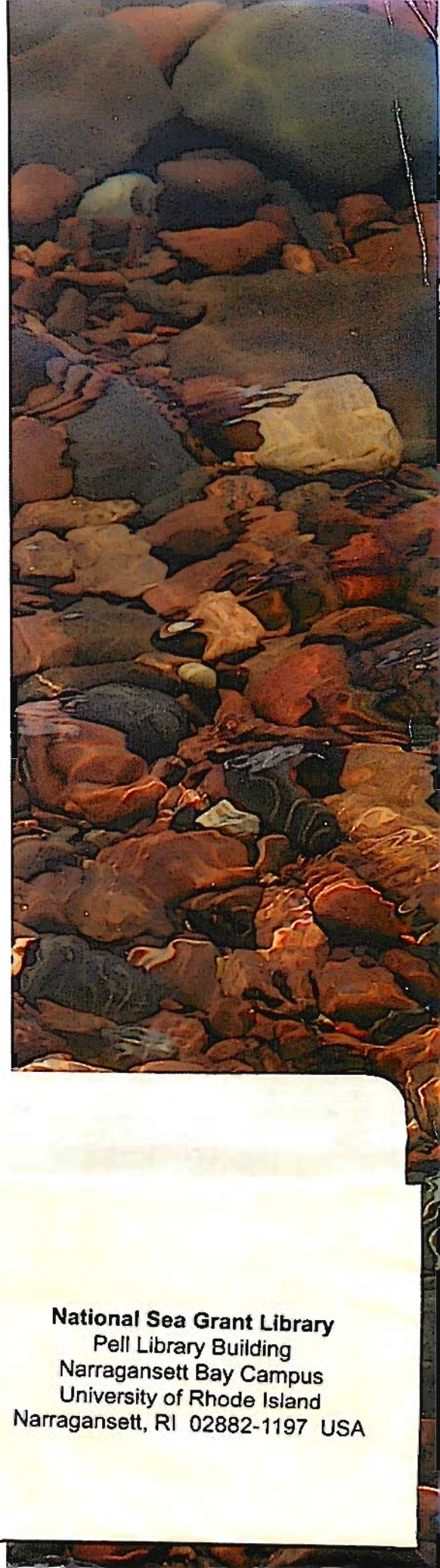


"Our reseachers not only respond to research and education needs, they often are the first to identify freshwater issues facing our community, our country and other nations."
— Chancellor Kathryn A. Martin

Brett Groehler

Critical mass: over 500 aquatic scientists, educators, and professionals interact and share resources. Their innovative insight and solutions are creating an impact on the way the world understands fresh water.

Tapping Fresh Water:
Research, Education, and Outreach

"Climate change, droughts, growing population and increasing industrial demand are straining the available supplies of fresh water. More than one billion people live in areas where water is scarce, according to the United Nations, and that number could increase to 1.8 billion by 2025." Economist, *June 2008.*

The University of Minnesota Duluth (UMD) leads one of the largest groups of freshwater researchers in the world. Faculty, students, and scientists study lakes, wetlands, rivers and Great Lakes in the United States and across the globe. From observing the behavior of lake currents and searching for clues about climate change, to changing the way people think about what goes down their drains, UMD's work is driven by a passion to protect and preserve the world's fresh water for generations to come.

UMD is not alone in this endeavor. Our partners, educational institutions, research institutes, and federal and state agencies form a community of over 500 dedicated individuals whose careers are related to freshwater research. Together these groups form a thriving web of research and dissemination of knowledge on freshwater issues. They are located within a few miles of each other, all based on the shores of Lake Superior, the largest of the Great Lakes. The region is near the Boundary Water Canoe Area Wilderness and Minnesota's lake country. The area features a wide variety of groundwater aquifers, glacial lakes, kettleholes, bogs, rivers and freshwater wetlands.

This publication shares some of the projects undertaken by UMD and our aquatic science partners. The topics range from wetlands to streams, inland lakes, Lake Superior, the Great Lakes, and lakes of the world. Stories about the people behind the science are featured prominently.

Science Changes the Way We Think

UMD and its partners are conducting research of national and international significance and consequence.

One highlighted project includes the discovery in freshwater lakes of an unusual microbial group, the Archaea, an entire third kingdom of living organisms. Archaea were initially thought to be relegated to extreme environments, but after the discovery in oceans of Crenarchaeota, a type of Archaea, research by UMD has revealed the prevalence of Archaea in the Great Lakes, Midwestern lakes, and great lakes on three continents.

The climate records generated by the Large Lakes Observatory's study of African lake sediment cores are providing new insights into the timing and magnitude of climate change in tropical Africa, and its relationship to the climate dynamics of far away places such as Antarctica, Greenland, and the tropical Pacific Ocean.

Another of the many projects with international significance is the work done by Large Lakes Observatory scientists Jay Austin and Steven Colman. They have determined Lake Superior's summer surface temperatures have increased at about twice the rate of the atmosphere. As winter air temperatures become warmer, the amount of ice cover diminishes, causing even warmer water.

Area aquatic professionals take the path from pure research, to applied science, to public outreach, and to policy making.

The study of Lake Superior temperature started with a purely academic interest. The surprising discovery that the lake is warming faster than the land, is helping scientists better understand the impact climate change has on a huge body of fresh water. The data has historical, national, and international importance and may lead to further climate change discoveries.

Collaboration is Key

The aquatic professionals on the shores of Lake Superior are proud of their shared high standards of excellence. With scientific leadership from UMD, researchers and educators choose to network with each other and cooperate on projects. In addition to formal research collaboration, up to 100 professionals gather at Twin Ports Freshwater Folk, a monthly topic luncheon.

Compared to research centers and research universities in other parts of the world, the incidence of area cooperative ventures between agencies and individuals in academic research is extremely high. UMD's undergraduate and graduate researchers enjoy not only the phenomenal opportunity to participate in projects with national and international impact, but also to learn from UMD's research partners about practical applications.

Furthermore, as scientists better understand systems, they share their findings with educators and policy makers. Area scientists and communications staff help translate the information for the public. They actively help decision makers attempting to solve freshwater problems.

From Pure Research to Public Response

In situation after situation, area aquatic professionals take the path from pure research to applied science, to public outreach, and to policy making.

The work of Tom Hrabik is a case in point. He shared the hydroacoustic data he collected on the rehabilitated Lake Superior cisco population with the Department of Natural Resources. That led to a longer fishing season, and economic relief for the commercial fishing industry.

Many additional projects follow the path from research to application. The Weber Stream Restoration Initiative resulted in a series of efforts to address excessive sediment in the river and to raise public awareness and cooperation in solving the problem. Studies of aquatic invasive species undertaken by Minnesota Sea Grant have led to regional programs for recreational boaters that encourage them to clean off any clinging invasives from their boats, as well as educational programs featured in pet stores nationwide that persuade aquarium owners and water gardeners not to release non-native plants and fish. The Minnesota Pollution Control Agency (MPCA) collected and analyzed samples from 39 Lake Superior beaches for bacteria and informed swimmers about the risk of contracting water-borne diseases from contaminated waters.

From the Great Lakes Environmental Indicators Project (GLEI), which developed environmental indicators to assess the condition of the shores of the Great Lakes, to LakeSuperiorStreams.org, a Web-based delivery of real-time Lake Superior watershed data, UMD and its partners are moving science out of the lab and into the community. This critical mass of aquatic scientists, educators, and professionals are impacting the way the world understands fresh water.

These individuals know all too well that the freshwater crisis lies at the center of our continued existence and that of planet Earth, as well.

Freshwater Research
University of Minnesota Duluth

- Center for Freshwater Research and Policy
- Large Lakes Observatory
- Natural Resources Research Institute
- Minnesota Sea Grant
- Departments: biology, chemistry, geology, physics, and engineering

PARTNERS

- Minnesota Pollution Control Agency
- Minnesota and Wisconsin Department of Natural Resources
- University of Wisconsin-Superior
- Great Lakes Maritime Research Institute
- U.S. Environmental Protection Agency
- National Park Service
- U.S. Forest Service
- U.S. Fish and Wildlife Service
- Tribal groups in Minnesota and Wisconsin

Focus on Frogs:
Life and Changes in Prairie Ponds

Roughly a million years ago, glaciers carved an amazing and diverse freshwater resource into the Great Plains landscape — the prairie potholes.

These scattered pockets of shallow wetlands are alive with plant and animal life. The shallow pools also play an important role in managing the hydrology of the area, storing excess water during heavy rains and spring snowmelt. This already-sensitive ecological region faces pressures from agriculture, development and pollutants.

Impact of Climate Change

Now a new challenge looms — climate change — which can affect how some potholes function and eliminate others altogether.

Predicted higher temperatures and reduced precipitation join the potholes' already diminished water quality, declining groundwater resources and an overload of pesticides and nutrients. How will these stressors affect the amphibious life in these ponds? Frogs, from eggs to adulthood, are crucial to many of the processes in the ecosystem — from the bugs and algae they eat to being an essential food source for other critters.

Three Years of Wetland Research

With funding from the Environmental Protection Agency's competitive Science to Achieve Results (STAR) program, NRRI designed a comprehensive three-year study that includes a mesocosm experiment, a wetland-scale (small area study) and a landscape-scale (large area study) surveying 150 of more than three million potential wetlands in the Great Plains region.

First, scientists needed to know specifically how the predicted warmer, drier climate would affect these wetlands. Using a computer simulation model developed by collaborators at the U.S. Geological Survey and South Dakota State University, various scenarios of climate change were applied to the entire range of wetland types in the region. The computer results showed that even modest changes in temperature and precipitation will affect the hydrogeology of these sensitive aquatic ecosystems.

Further research examined the region's amphibian species (primarily leopard frogs) to determine whether they prefer temporary, seasonal ponds or deeper, year-round wetlands for breeding and larval development.

Then, NRRI's geographic information systems technology mapped the larger context of where the different wetlands are in the landscape and land use around the region.

Ultimately, this information will lead to the goal of the project, explained NRRI aquatic ecologist Lucinda Johnson. "We want to be able to make predictions about the future persistence of the frog populations based on what we know about both the frogs and the landscape. If their preferred habitat goes away, what will they do?" she asked.

Jennifer Olker

June Kallestad

Left: Studying the effects of predicted climate change scenarios and nutrient stressors on the amphibian populations in shallow ponds helps scientists understand their possibilities for survival. Right: NRRI scientist dissects frogs to study endocrine disrupting atrazine found in frogs.

Agricultural Effects

Another important part of the study looked at atrazine, a herbicide widely used in the U.S. on corn crops, which can be found at high levels in some prairie potholes. Atrazine is known to act as an endocrine disrupter in some systems, mimicking or blocking hormones and disrupting normal development. NRRI ecotoxicologist Pat Schoff designed a research project to collect water samples before, during, and after herbicide applications, testing the water for atrazine. Later, frogs were collected and dissected to see if they had abnormal gonads. Scientists also conducted exposure studies in mesocosms.

"We expected to find atrazine but we didn't know the concentration levels," said Schoff. "No one had studied it this closely before."

Duck Haven

The prairie pothole region is often called North America's "duck factory," providing conditions that produce over 50 percent of the continent's ducks. The amphibious life in these wetlands is an important food source for ducks as well as other critters in the region. Under future climate scenarios, it will be important to understand where managers and landowners should place their scarce resources.

Wetlands that are predicted to disappear or are too isolated may not be suitable for frogs and other small critters in the future. NRRI mapping, modeling, and data collection skills are at the heart of understanding human impacts to wetlands wildlife in America's heartland.

Brett Groehler

PROFILE

Lucinda Johnson:

Understanding and Guarding the Environment

Lucinda Johnson is one of the founding fellows of the University of Minnesota's Institute on the Environment, yet when she discusses her scientific career, she starts and ends with words about mentors.

"I was interested in biology," she began. "But as a kid I worked for a family friend who was a veterinarian, which is originally what I thought I wanted to be.

"In college, one of the first science classes I took was a botany course. The professor who taught it would pose unanswered questions, then spend whole lectures building up to what was known about the topic," said Johnson. "It was the first time I really understood how much we don't know about the world. That got me very interested in botany and scientific research."

As a summer technician, Johnson worked for pioneering aquatic invertebrate researcher Warren U. Brigham at the Illinois Natural History Survey. "He really influenced me," she said. "He gave me responsibility for a big taxonomic survey of algae. It was the first time I'd ever been given total responsibility for planning and completing a scientific project. That had a huge impact on my life."

After earning a Bachelor of Arts and Science degree in botany from Duke University, Johnson completed a Master's degree in entomology at the State University of New York College of Environmental Science and Forestry, and then more than a decade later she earned a Ph.D. in zoology from Michigan State University

By 1990, she had become the associate director of the Natural Resources Research Institute's Center for Water and the Environment. In her research, teaching, and administrative work she reminds lab employees and students to "find someone you respect who will listen to you and help you bounce ideas around."

"I was lucky to have mentors who gave me leeway — enough to hang myself multiple times over," Johnson laughed. "I try to give my students the same freedom to do their own thinking. If they run into problems, I'm happy to be there, but it's important to let people explore and make mistakes."

FOCUS

Wetlands and Wild Rice

Brett Goehler

Lauren Hildebrandt and John Pastor are examining the nitrogen content of wild rice straw for clues to the growing cycle.

The National Science Foundation funded a study with the Fond du Lac Band of Ojibwe Natural Resources Program to understand the boom-and-bust growing cycles of wild rice. This sacred and spiritual element of Ojibway culture is also an interesting ecological puzzle for the tribes. Very productive years are almost always followed the next year by a crash, followed by a slow recovery over the next three years to high production again.

Minnesota is rich in wetlands and scientists at the Natural Resources Research Institute are adding to the wealth of knowledge needed to understand and protect these soggy, valuable ecosystems.

Starting in the 1990s, NRRI ecologist and UMD biology professor John Pastor began a study on peatlands and their role in the global carbon cycle. Minnesota has some 7.5 million acres of peatlands that store, produce, and release greenhouse gases. Pastor asked the question: What happens to peatlands if the climate continues to get warmer and drier, as predicted? With funding from the National Science Foundation, Pastor designed a research project involving 54 circular bog and fen mesocosms, subjecting each to different temperatures and water levels.

This research built a foundation of knowledge about how these wetlands work. The information can help scientists advise policy makers and resource managers for informed decision-making. This is especially crucial now as Minnesota seeks ways to reduce carbon emissions.

"A lot of peatlands were drained for farming in the 1930s and when the water table drops, the peat decomposes and collapses, releasing carbon," Pastor explained. "We need to let the water table rise and, where possible, plug any ditches that drain peatlands."

The National Science Foundation also funded a study with the Fond du Lac Band of Ojibwe Natural Resources Program to understand the boom-and-bust growing cycles of wild rice. This sacred and spiritual element of Ojibway culture is also an interesting ecological puzzle for the tribes. Very productive years are almost always followed the next year by a crash, followed by a slow recovery over the next three years to high production again. Then the cycle repeats.

"What we found is that wild rice straw holds more than 90 percent of the nitrogen that the plant needs to take up from the sediments," Pastor explained. "In order to get the nitrogen, the straw needs to decompose, which it does very slowly, creating the boom-bust cycle."

Brett Groehler

PROFILE

John Pastor:
A Keen Observer of Nature

"It's convoluted," biology professor John Pastor says of his path to UMD. "I was always interested in nature and science as a kid," he said. "In sixth grade, I had a teacher who would cancel classes for two hours to take us out to observe the warbler migration."

When the same teacher told Pastor he could observe nature for a living, Pastor started thinking about seriously studying the natural sciences.

"I was fortunate in middle school and high school," Pastor said, "to have teachers who were good role models as to what a scientist is — I didn't know it at the time, but it was important to me to have them modeling what being a scientist is about."

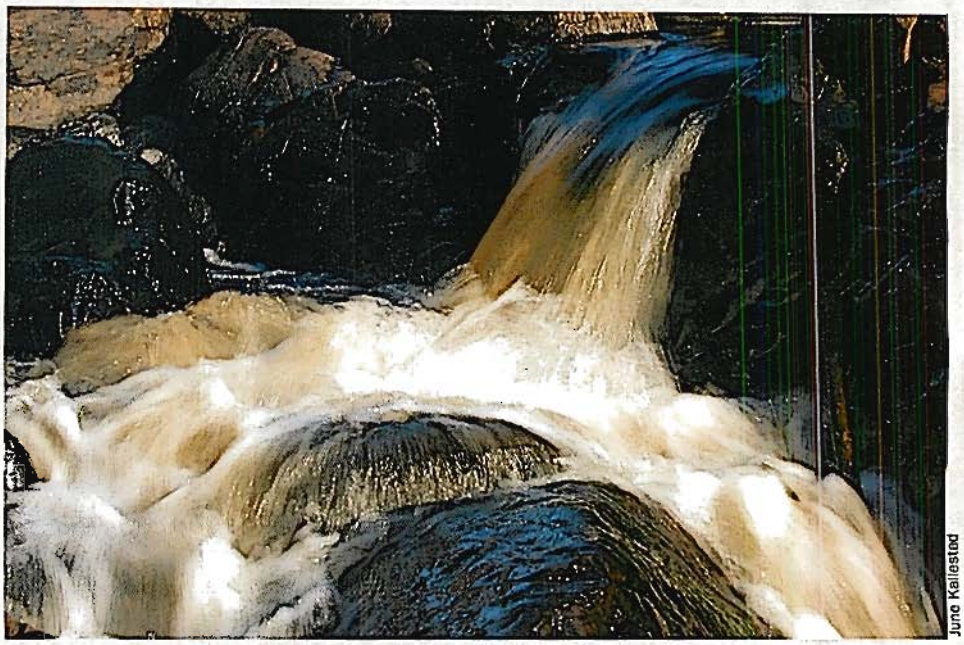
He left his tiny, rural, blue-collar New Jersey hometown, where Hungarian was spoken as much as English, to study geology at the University of Pennsylvania. "It was a wonderful department," he said. "Small, welcoming to undergraduates, and they expected us to behave like professional scientists."

From geology, Pastor wound his way to biology "through a back door opened by chemistry, geology, mathematics," and other sciences. "I haven't had a lot of standard biology classes," he said.

He received Master of Science and Doctorate degrees from the University of Wisconsin Madison, and two postdoctoral fellowships in forestry, including one at Oak Ridge National Laboratory, where he used mathematical and computer modeling to study forest ecosystems. He was then hired at UMD's Natural Resources Research Institute and became a tenured UMD professor in 1996.

Pastor enjoys the combination of research and teaching. "Those pursuits should all be part of the same cloth," he said. "I don't see them as taking away from each other. If I'm not going to talk about something in a classroom, why would I work on it in a lab?"

Web Watch: Learning about Streams



The public uses LakeSuperiorStreams.org to learn more about human impacts to water quality.

LakeSuperiorStreams.org is science education and outreach at its world-class best. It started as DuluthStreams.org in 2002 as a project funded by the Environmental Protection Agency's EMPACT program, whose mission is buried in its acronymic name: Environmental Monitoring for Public Access and Community Tracking. Now, it has expanded to LakeSuperiorStreams.org, radiating water quality information from Duluth to audiences far and wide.

The Web site project is managed by scientists at the Natural Resources Research Institute, incorporating the talents and know-how from the City of Duluth, the Minnesota Sea Grant Program, the Minnesota Pollution Control Agency, Western Lake Superior Sanitary District, and Minnesota's Lake Superior Coastal Program.

Inquiries from the LakeSuperior Streams.org Web site include questions like: Why aren't there trout in my creek any longer? Can we use your rain barrel information in our community? Can I add plants or shrubs to keep my riverbank stable?

"At first we focused on reaching the general public and municipality officials," said Rich Axler, NRRI aquatic scientist and principal investigator. "We want to raise awareness of how land use affects our streams and potentially Lake Superior. And more, to show the true costs of poor land use management."

From there, the audience for LakeSuperiorStreams.org expanded to include teachers and students, contractors and the development industry, resource agency staff, and extension educators — in essence, everyone who needs to know anything about the interactions between people and water quality. The site has been used in over 120 countries. It generates over 400,000 requests per month, especially high in the spring and fall when schools are in session.

Learning in Real Time

At the heart of the Web site is real-time data that is transmitted from six streams. This means that researchers can see and interpret the dynamic changes in water quality due to storms and changing seasons. And everyone can join in the observations from their home computers. The data comes in many shapes and forms — from animated temperature graphs recorded by automated sensors, to a map showing streams and roadways in a watershed located in Duluth.

Every 15-minutes, the sensors also record flow, salt concentration, and the muddiness of the water, then transmit the day's data via cell phone to the base computer and Web site the next morning, along with any precipitation data. Scientists and other viewers can see how quickly the water heats up from parking lot runoff, how pollutants get washed in from rainstorms, and how stormwater runoff can accelerate stream bank and channel erosion.

Information for Many Uses

The Web site is deep and the information broad, but it's organized into five categories for easy browsing:

Communities: From Grand Marais, Minn., to Ashland, Wisc., what do you want to know about the streams, recreational opportunities and stormwater challenges in your town?

Understanding: The nuts and bolts of stream ecology, impacts to water quality, wastewater issues and other science issues related to water.

Streams: This section is interactive and unique. Information on 67 different streams is available, with six showing real- time water quality data. Interactive animation and mapping tools can be found here, along with an index of historical data, photos and watershed information.

Citizens & Schools: A wealth of information is provided for individuals who want to know what they can do to reduce stormwater pollution. Resources and curricula for teachers are available that focus on the Lake Superior region when possible.

Stormwater: This section gets to the nitty-gritty of municipal stormwater plans and issues. Contractors, developers and planners use the Site Design Toolkit to access case studies of local conservation designs, training materials, and local ordinance options to reduce stormwater impacts.

Across the nation and around the world, LakeSuperiorStreams.org provides science education and outreach, minute by minute, day after day.

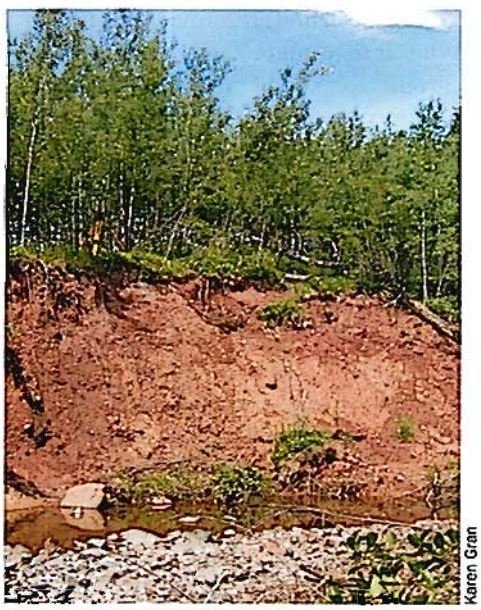
FOCUS

Keeping Water Clean through Stormwater Protection

Stormwater pollution occurs when rain runs off the land, picks up pollutants, and carries them into Lake Superior. Oil and grease from cars, sand and salt from streets and driveways, excess fertilizers or pesticides from lawns, yard waste dumped in ditches, and abandoned dog waste, all end up in local streams and eventually Lake Superior. But unlike wastewater sewer drains, stormwater runs into the lake without treatment.

Individually, small sources of pollution may not seem like a big deal, but it all adds up. And as more land is developed, more impervious surfaces (like parking lots, rooftops, and sidewalks) are built, increasing the volume of stormwater runoff. Everyone contributes to stormwater pollution, and everyone must help keep our streams and Lake Superior clean.

To spread this message, the Regional Stormwater Protection Team was formed in 2003 to protect and enhance the region's shared water resources by coordinating educational programs and technical assistance. This partnership of 26 local and regional governments, agencies, colleges and universities was formed because stormwater pollution does not stop at city boundaries, and neither should the solution.



Karen Gran

The Stormwater Team supports relationships between communities in the Lake Superior watershed that are connected by their streams, wetlands, and lakes. A watershed is the area of land that drains to a lake or stream — following the contours of the land. Whether a person lives next to the lake, high atop Duluth's hill, or on the clay plains of Superior, Wisc., they are all part of the Lake Superior watershed.

An Innovative Regional Partnership

Many of the team members are regulated by the state to control stormwater in their communities, and their permits require outreach and education. With funding and staff limitations, local organizations agreed to share resources to send a consistent message: Our high-quality waters require protection to keep them clean. "Consolidating resources doesn't just save time and money," said Chris Kleist, Duluth's Stormwater Coordinator, "it allows us to work faster and share ideas more effectively."

To protect the exceptional quality of our region's water, the Stormwater Team focuses on protection strategies that will prevent the high costs of trying to restore these resources later. The team developed a media campaign including three 30-second "Watershed Moment" public service announcements for television. The group also hosts Lake Superior Watershed Festivals, training workshops for construction and maintenance crews, and a live mascot, Rex, who hands out doggy bags to pet owners at various events. Grant funding has helped the group carry out many of these ideas, including over $100,000 in funding from Minnesota's Lake Superior Coastal Program.

The Regional Stormwater Protection Team evolved along with LakeSuperiorStreams.org as a tool to provide in-depth information on regional water quality issues, regional permitting, and local stormwater management techniques through the Web site's Site Design Toolkit. The team regularly supplies technical and outreach information for this Web site.

UMD: Leading by Example

Team members from the University of Minnesota Duluth bring their experiences in stormwater management to the group, including Facilities Management staff Erik Larson and Candice Richards.

"As an educational institution we believe that we should not only protect our lakes and streams, but educate our students, staff, and community on what they can do to protect these resources as well," said Larson.

Larson promotes the use of alternative stormwater treatments, such as pervious or grassy pavers, underground storage of stormwater, and a thriving campus rain garden. From the beginning, UMD knew that they would benefit from being a part of the team.

"This is an advantage for us," added Richards. "This team, and LakeSuperiorStreams.org, provides a focus for stormwater efforts in the region, and gives UMD avenues to share what we are learning through our campus stormwater projects.

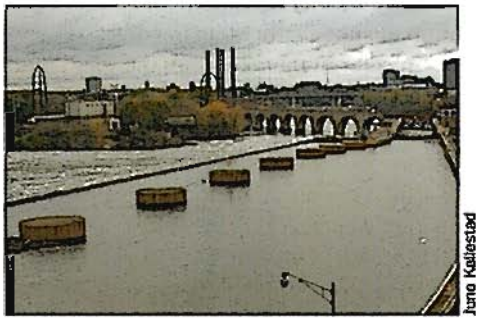
How Well Are We Doing?

Assessing the Nation's Great Rivers

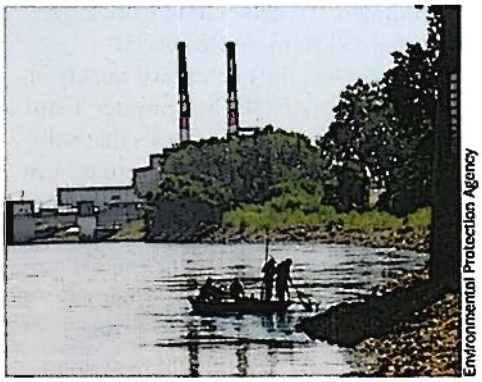
If you want to know what America is thinking, you conduct a survey of enough people to get a statistically strong estimate. If scientists want to determine the health of large and complex ecosystems — such as the Great Lakes and Great Rivers — they do much the same thing.

They collect information from a relatively few well-chosen sites to estimate the condition of the entire system. This is how the U.S. Environmental Protection Agency's Mid-Continent Ecology Division in Duluth is improving the science and practice of understanding the current state of the nation's great rivers.

Since 2003, the Mid-Continent Ecology Division has worked with many state and federal partners, including the University of Minnesota Duluth, to investigate how to monitor and assess the Mississippi River and its major tributaries, the Missouri and Ohio Rivers, to be able to report on the current state of the rivers. These methods will eventually help management agencies conduct assessments to show whether conditions are getting better or worse.



June Kallestad



Environmental Protection Agency

How do algae respond to habitat conditions, nutrient concentrations, hydrology, and a variety of human disturbances associated with the rivers? The Natural Resources Research Institute is collaborating in the research by assessing the algae growing in the water and on snags in the river. Snags of logs are important habitats in large rivers but most have been removed to improve navigation, flood control, and power generation. Some invertebrate animals depend on these snags. That's why the Mid-Continent Ecology Division is also studying benthic invertebrates, zooplankton, and fish in the rivers to understand how these animals and the environment interact.

This research is leading to new ways to set expectations regarding river health. While it may not be useful to compare current river conditions to historic, pre-settlement conditions that can never be attained, advancements in assessment methods will be useful to determine whether investments in pollution control and habitat restoration make measurable improvements in river ecosystem health. The EPA's Mid-Continent Ecology Division is researching efficient ways to generate more and better data for better informed management decisions. One measure of the success of this research will be how the methods under development will be adopted for broader use in states' Clean Water Act reports and the EPA's recurring national assessments of rivers and streams.

The U.S. Environmental Protection Agency's Mid-Continent Ecology Division in Duluth is collecting information from well-chosen sites to better understand the current state of the nation's great rivers.

Environmental Protection Agency

EPA research is investigating the health of both the Laurentian Great Lakes and the Great Lakes of the Central Plains, such as Fort Peck Reservoir of the Missouri River in Montana (pictured here). This interdisciplinary research depends upon a network of collaborators.

Aquatic Invasion:
A Beast in Our Lakes

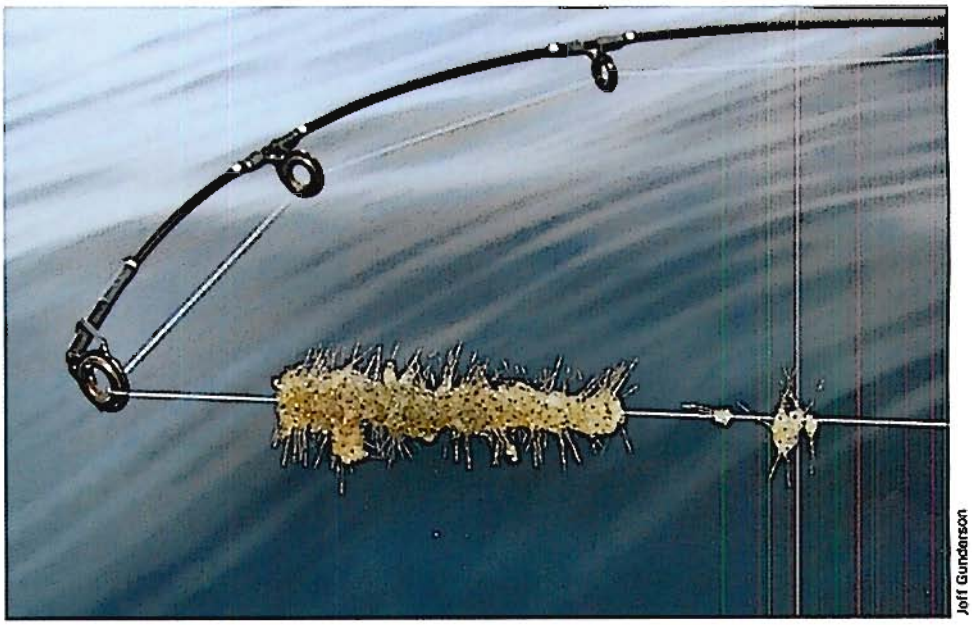
A new beast prowls the border lakes between Canada and the United States. The predator has a single enormous black eye and a hunger for its own kith and kin. Its long spike of a tail could pass for barbed wire at a different scale. Worse than fiction, the spiny waterflea is a troubling reality that occupies Donn Branstrator's thoughts and freezer.

Anyone who has opened a biologist's freezer knows that it is generally not the place to look for dinner. Donn's is no exception. Branstrator, an associate professor of biology, is one of the scientists at UMD studying aquatic invasive species. In his freezer in the Swenson Science Building, you're apt to find the hardy resting eggs of spiny waterfleas among suspicious looking containers and bags marked with cryptic notes.

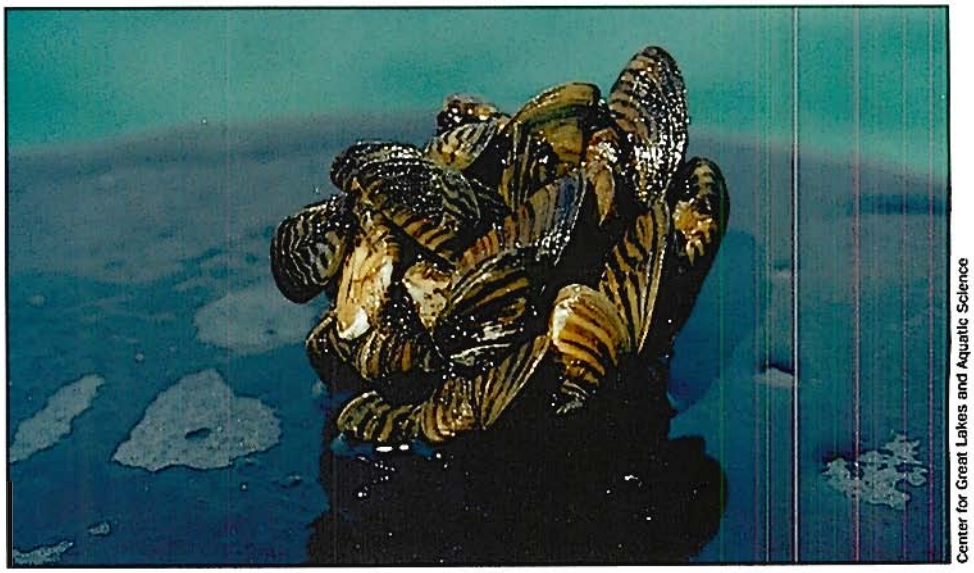
Although cryogenics inspires many experiments related to bringing organisms back to life, it's the thought of killing spiny waterflea eggs that interests Branstrator and his colleagues. They've tried freezing, cooking, bleaching, and salting the durable eggs, in the process discovering a significant number survive such chemical and temperature assaults. It seems the reasonable options for slaying the minuscule eggs of the nearly invisible creatures have come down to one: desiccation.

"Drying is the best way, maybe the only feasible way to kill a spiny waterflea in its resting egg phase," said Branstrator, a cautious optimist about our ability to keep aquatic invasive species from further damaging the waters of North America.

"Killing an adult is easy; it's the eggs that are difficult. They're the most resilient and toughest stage in a waterflea's life cycle, but they perish if they have dried for more than six hours individually or more than 12 hours in a more typical clutch of eggs."



Jeff Gunderson

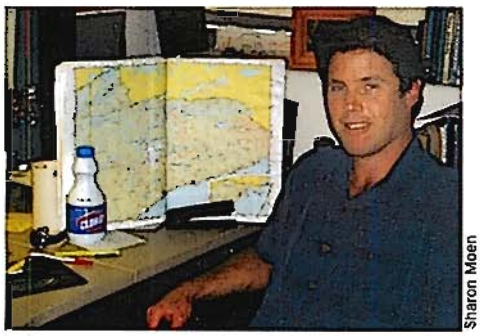


Center for Great Lakes and Aquatic Science

Top: UMD researchers are working to discover ways to interrupt the life cycles of invasive animals, like these spiny waterfleas, which are clumped together on a fishing line. The waterfleas have cost many an angler their catch because they clog the eyelets of the fishing pole. Bottom: Zebra mussels, another aquatic invasive species, overgrow and smother a native mussel.

A Speck of a Species

Like biologists scanning the Serengeti for lions and wildebeests, Branstrator, his colleagues, and his



Sharon Moen

UMD Associate Professor Donn Branstrator is tracking the movements of invasive species.

contemporaries plumb the vast and wild expanses of the Great Lakes to estimate the population sizes of zooplankton species. Their results indicate all is not peaceful in this animal kingdom.

"In Lake Superior, changes are afoot in the makeup of the zooplankton assemblage that could reduce the energy flow from primary producers to the top predators," said Branstrator.

Spiny waterfleas, aquatic animals not much larger than the size of the "zoo" in zooplankton, became ensconced in the New World during the 1980s. Experts think many of the non-native species found throughout the Great Lakes, including spiny waterfleas, arrived in ballast water, which stabilizes ships in rough seas.

These modern-day pilgrims from Eurasia have thrived in the Great Lakes (and in increasing numbers of nearby lakes) using a strategy of cloning and sexual reproduction to achieve densities that interfere with fishing and aquatic food webs.

Spiny waterfleas eat each other as well as other tiny aquatic animals. After spiny waterfleas move in, research indicates that some species of native zooplankton become scarce while others become unusually common. In recent years, for example, exceptional numbers of globby "shells" have washed ashore around Lake Superior, making some people wonder, "Did a barge carrying tapioca capsize?" The buzz circulating amongst ecologists is that these transparent globs are the abandoned homes of the fleck-sized *Holopedium gibberum*, a veritable elephant of a zooplankton that grazes on algae. They think that the reason *Holopedium*, a native animal, has become recently abundant is because spiny waterfleas disrupt the aquatic food web in a way that allows the better armored and evasive zooplankton to thrive.

"Shifts in the lower parts of the food web have the potential to change the abundance or diversity of the species farther up the line," said Branstrator. "The time frame is, thus far, too short to know how the addition of spiny waterfleas will alter the natural balance of species in northern aquatic ecosystems, but we shouldn't allow ourselves to be too cavalier about these little things that matter."

Branstrator said these invasive waterfleas present a dual problem for young fish: 1) their lengthy tail spines make them undesirable as food, and 2) they compete for the same zooplankton meals.

Infiltrates and Invaders

In addition to defining ways to exterminate invasive waterfleas, and what their presence could mean to the aquatic food web, Branstrator puts considerable energy into tracking their movements. This involves sending students out to follow them in Lake Superior and chase them through the Boundary Waters Canoe Area Wilderness (BWCAW). Spiny waterfleas are presumably eaten by fish before they get a chance to conquer warmer and more fertile lakes. But in cold, clear, glacially carved lakes, they've found traction.

"Spiny waterfleas are moving inland, particularly into Canadian lakes but also increasingly into lakes in the Arrowhead Region of Minnesota," said Branstrator. "Lake Superior is a likely source for these inland invasions but we don't precisely know how these small creatures are getting across the land. Of course we have suspicions and that is part of what we're studying in the BWCAW. Recreational equipment and aquatic birds are our prime suspects."

Related to movement across oceans or across portages, Branstrator is collaborating to investigate the number of zooplankton required to seed successful populations. Although the research setting (a laboratory) is tamer than the open waters of Lake Superior and canoe-country wilderness, the question is just as resounding.

The International Maritime Organization, which is setting biological standards for ballast water discharge, suggests that ten living animals per meter are permissible. Given its lack of scientific teeth, their suggestion is arbitrary. It is also unrealistic; available ballast water treatment systems are not 100 percent effective at removing all life. Branstrator's work promises to contribute to decisions and discussions about ballast water treatment.

Research Gets Personal

Spiny waterfleas are only one of many aliens occupying North American waters, ranging from infinitesimal viruses to magnificent trees. Each makes a unique environmental mark and all make a serious economic dent. No one understands this better than UMD's Doug Jensen, coordinator of Minnesota Sea Grant's aquatic invasive species program.

Spiny waterfleas are only one of many aliens occupying North American waters, ranging from infinitesimal viruses to magnificent trees.

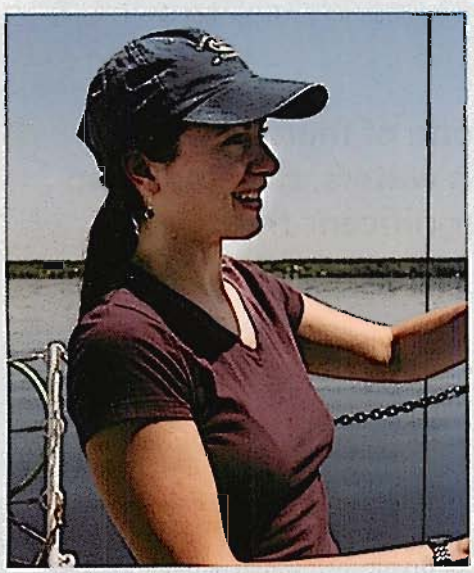
Jensen applies research like Branstrator's to protect the economic and environmental integrity of Minnesota's waters. One of the largest groups he serves is boaters and anglers. His aim is to help people understand that properly cleaning or drying their watercrafts and gear is a critical step in preventing the spread of aquatic invasive species.

"It is not accidental that Minnesota has fewer zebra mussel infestations than other Great Lakes states," said Jensen. "Minnesota invests in maintaining its aquatic resources. The state and its partners have made it a priority to use scientifically-based information, like Donn Branstrator is providing, to help recreational boaters and anglers, aquaculture facilities, and the maritime industry respond to aquatic invasive species challenges. It is fulfilling and exciting to see research being applied."

PROFILE

Meghan Brown:

Seeing the World's Lakes



Kevin Colton

As a child, Meghan (Smith) Brown had powerful limnology teachers: Lake Michigan and her family.

"I grew up on the lake [in Traverse City, Mich.]," she said. "My career path was fostered by my parents and grandparents, who didn't have a scientific understanding of the water, but who did have a deep love of it. I still find it very calming to be on a lake shore."

After graduating from the University of Michigan and briefly teaching high school science, Brown finished her Ph.D. in Water Resources Science at UMD in 2005. Now, she is a professor at Hobart and William Smith Colleges in Geneva, NY, on the shore of Seneca Lake, and is becoming a powerful instructor and example to others.

"When I entered graduate school, I envisioned myself someday working at a big research university. But at UMD, I mentored undergraduate research students and watched the intimate interactions of UMD professors and their students. I realized I wanted more contact with students than is typically possible at a research-focused university."

Brown said she took the job at Hobart and William Smith — a high-caliber liberal arts school — because she was "interested in teaching and being at a place that values it while continuing to do high-quality science." In addition to being on a lake, the colleges own a 60-foot research vessel similar to UMD's *Blue Heron*. "That's a unique combination," Brown said. "It creates opportunities for both teaching and research."

While continuing the research on invasive zooplankton she started at UMD, Brown also has "some pretty exciting projects" initiated and planned. She and her students are studying a series of ponds on the Hobart and William Smith campus to understand community development. She's also studying spiny waterfleas in Italian lakes where they're native, and not invasive as in U.S. lakes, and in spring 2009, Brown will use a Fulbright Hayes grant to take a group of students to Lake Baikal in Russia, the world's deepest, oldest, and most diverse lake.

Teaching Communities to Combat Invasive Species

The Minnesota Sea Grant Program is a nationally recognized leader that focuses on public education programs to prevent the spread of aquatic invasive species. These programs are on the cutting edge of human dimensions of invasive species management.

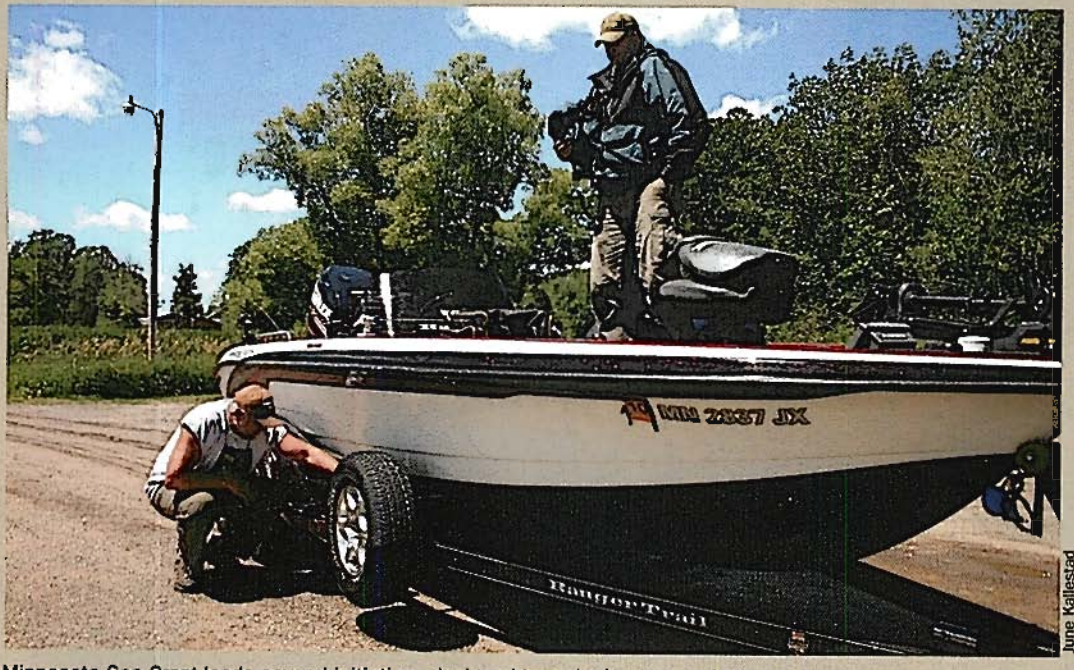
To persuade aquarium owners and water gardeners not to release unwanted fish and plants, Minnesota Sea Grant encourages them to get "Habitattitude."

Besides being tricky to say, Habitattitude™ is a national campaign led by Sea Grant with the pet industry and the U.S. Fish and Wildlife Service. Industry partners have committed over $1.1 million to the campaign. Millions of consumers have been reached and evaluations suggest the campaign can prevent releases.

The popularity of water gardening brings another set of problems. Minnesota Sea Grant's water garden and shoreline restoration project reduces the potential for these activities to spread invasive plants or animals in the Great Lakes Region. Sea Grant personnel surveyed nursery professionals and water gardeners then developed educational messages and materials through focus groups. Nurseries and garden centers now distribute posters, tip cards, plant sticks, and tags.

Stop Aquatic Hitchhikers! is a national campaign aimed at preventing the spread of invasive species by boaters and anglers. Sea Grant leads efforts to evaluate and extend the campaign along key invasion corridors in Minnesota, Wisconsin and Iowa. Along with many partners, a multimedia campaign was launched in 2006 to reach boaters and anglers. Millions of people have been exposed to the educational messages and 97 percent of survey respondents said the exposure will influence them to take action.

Aquatic Invasive Species-Hazard Analysis and Critical Control Point Curriculum training is a successful program developed by Sea Grant. It is aimed at preventing the spread of aquatic invasive species and to provide aquatic invasive species-free certification. The curriculum is being adopted by a variety of organizations, tribes, and agencies across the country.



June Kallestad

Minnesota Sea Grant leads several initiatives designed to make boaters and other audiences more aware of how they can prevent the spread of aquatic invasive species.

FOCUS

Cleaning Up the Inland Sea through Ballast Water Treatment

"This is an exciting time for waterborne commerce," said Dale Bergeron, Minnesota Sea Grant's maritime specialist. "Fuel costs and the urgency of reducing emissions have people rethinking transportation corridors and rediscovering the value of shipping."

The Great Lakes/St. Lawrence Seaway, a significant transportation corridor connecting the center of North American industry to the global marketplace, becomes earth-bound in the Duluth-Superior Harbor. It's incredible, but true — one of the most active ports in the United States lies 1,500 miles from the nearest ocean but just four miles from UMD.

Proximity makes it easy for faculty and staff to work on shipping concerns. Accessibility makes it even easier; UMD and the University of Wisconsin-Superior jointly manage the Great Lakes Maritime Research Institute and the world's first freshwater testing facility for ballast water treatment technologies.

The institute, concerned with sustainable maritime commerce on the Great Lakes, is affiliated with UMD's Swenson College of Science and Engineering and Labovitz School of Business and Economics. Funding from the Institute allows UMD researchers like Daniel Pope to examine whether biodiesel blends can reduce greenhouse gas emissions and cut fuel consumption on ships. The Large Lakes Observatory's research vessel, *Blue Heron*, is Pope's guinea pig.

The Freshwater Ballast Treatment Testing Facility opened in the harbor in 2007. Constructed by the Great Ships Initiative with funding from government organizations, local universities, Great Lakes ports, and private businesses, it is a set of tanks, pipes, and gear-laden trailers. This machine represents an integral step between the laboratory and 1,000-foot ore boats as well as ocean going vessels and the commercial and academic efforts to clear potentially invasive species from ballast water. Ballast stabilizes ships but also creates a way for organisms to escape their home ranges.

Several UMD faculty and staff are world leaders in understanding relationships between ballast water and species invasions. Other area scientists and engineers work on recycling dredge material, harbor corrosion, mapping the lake's floor, and maritime taxes and legal affairs. They find it hard to resist the call of a sea, even a freshwater one.

Minnesota Sea Grant

UMD leads efforts to understand the relationship between ballast water and aquatic invasive species. Although ballast water is vital for stabilizing ships, it can carry unwanted plants and animals from overseas and around the Great Lakes.

Taking the Pulse:
Great Lakes Environmental Indicators

The shores of the great lake Gichigami have long attracted humans and diverse communities of plants and animals. Today, much of the industry — and its point source pollution — is declining on the shores. However, the watershed of Lake Superior continues to see housing and commercial developments. So even though industrial discharges have been eliminated or reduced, diffused pollution from agriculture, roads, storm sewers, and failed septic systems have increased.

These non-point sources of pollution are more difficult to mitigate. Realizing this, the U.S. Environmental Protection Agency posed an important question: What is the most efficient, economic and effective way to manage the long-term integrity of the coastal areas of the Great Lakes? In 2000, the Natural Resources Research Institute (NRRI) was awarded a highly competitive grant to help answer those questions by developing indicators of condition for the entire U.S. side of the Great Lakes region's coastal waters. Thus, the Great Lakes Environmental Indicators project was born.

A Starting Point for the Future

With a $6 million grant from the EPA in 2001, the massive five-year study, covering almost 5,000 miles of shoreline and nearly 112,000 square miles of land, ended in 2006. During those years, teams of investigators from cooperating universities sampled over 1,000 carefully selected sites from the rocky shores of Lake Superior to upstate New York.

The entire effort was built on the development of methods for measuring disturbance across the entire basin. Over 200 separate measures that reflect changes people have made to the landscape, as well as natural features, were compiled into a "human disturbance gradient." This allowed researchers to identify the "least disturbed" as well as the "most disturbed"

June Kallestad

UMD graduate students collected data around the Great Lakes basin. Research assistant Christie Miller helped to monitor breeding success of wetland birds in the near shore areas of Lake Superior.

The success of the Indicators project led to a million-dollar grant from the EPA's Biological Open Water Surveillance Program to gather algae in the deeper areas of the Great Lakes for water quality research.

areas of the coast — an unprecedented effort. The gradient is now assisting managers in the design of monitoring programs on a state-by-state and lake-by-lake basis.

The results of the Great Lakes Environmental Indicators project are now in the hands of the EPA to manage the complexity of uses — and ecological challenges — of the largest freshwater system in the world. The portfolio of biological indicators includes birds and amphibians, algae, fish and macroinvertebrates, plants, and toxic chemicals such as polycyclic aromatic hydrocarbons (PAHs). Each indicator uniquely responds to changes in the lake basin ecosystem, helping scientists and resource managers understand human impacts on water quality.

Some New Knowledge

- Some 2,000 algal species were documented and categorized for their sensitivity to water clarity, nutrients, acidification and other stressors in the Great Lakes.
- The variety of invertebrates in the lake coastal zones — each with their own tolerance level for habitat degradation — helped scientists "grade" the conditions of sites around the basin from "least impaired" to "most degraded" due to human-related stress.
- Tiny spring peeper frogs, found throughout the U.S. Great Lakes coastal zone, show signs of specific land use impacts.
- A plant species "dominance index" was developed to indicate the ecological integrity of a wetland by identifying dominant species and categorizing how they dominate over other species.
- PAH compounds were measured in lake sediments to evaluate ultraviolet A (UV-A) light exposure.

Zeroing in on Lake Superior

Many of the research techniques honed during this study are now being applied specifically to Lake Superior, found to be the most "pristine" of the five Great Lakes. It has more "intolerant" species (and more individuals of species that are considered intolerant) than all of the other lakes combined. There is, however, evidence of severe degradation at specific locations and the bio-indicators will help determine where and why those sites are degraded.

The success of the indicators project led to a million-dollar grant from the EPA's Biological Open Water Surveillance Program to gather algae in the deeper areas of the Great Lakes for water quality research. The five-year project will provide long-term information on the impacts of invasive species, excessive nutrients, and possibly, climate change in the lakes.

International Recognition

As NRRI Director of the Center for Water and the Environment, Jerry Niemi received accolades for his leadership of the indicators project by the International Joint Commission. Niemi received the 2006-2007 Outstanding Great Lakes Scientist of the Biennium award. The commission is an independent bi-national organization that helps prevent and resolve disputes related to the use and quality of the boundary waters between the U.S. and Canada.

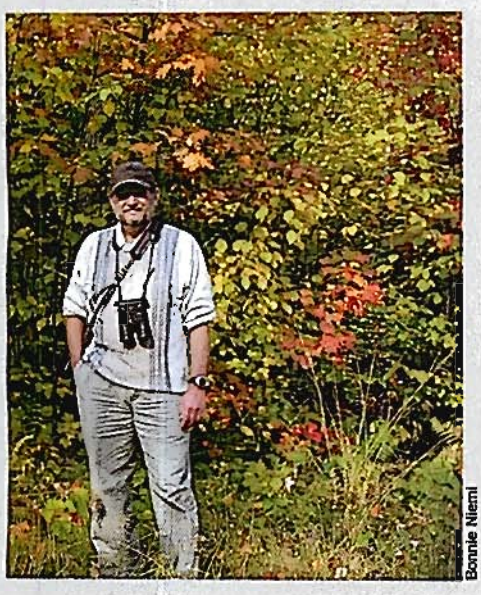
One of the commission's responsibilities is to regulate water levels and flows through the St. Lawrence Seaway. New information and technologies, as well as expanded interests in water levels, have required that new regulations be developed. The commission will tap Duluth area scientists and techniques developed during the indicators project to monitor the near-coast areas of the Great Lakes for signs of environmental stress due to changes in water levels.

Many of the methods and indicators developed are being evaluated by several Lakewide Area Management Plan organizations in the Great Lakes (especially Lake Erie and Lake Superior) for inclusion in their ongoing monitoring plans. The "human disturbance gradient" approach is being incorporated into EPA methods for conducting biological assessments of freshwaters.

Most of all, the Great Lakes Environmental Indicators project has provided a base-line study for researchers to use for decades to come.

June Kallestad

NRRI scientists Dan Breneman and Jeff Schuldt collected bug and fish samples during the pilot year of the Great Lakes Environmental Indicators project. Teams of investigators sampled over 1,000 sites from the shores of Lake Superior to upstate New York.



Bonnie Niemi

PROFILE

Gerald Niemi:
A Passion for Birds and Conservation

Jerry Niemi grew up in Duluth, Minnesota, went to Central High School, matriculated to UMD, and, he said, "wasn't drawn to science at all" beyond being interested in hunting and fishing.

Yet, he wound up earning a Ph.D. in biology from Florida State University, winning a Fulbright scholarship to Finland (where he's been many times since), and becoming director of the Center for Water and the Environment at the Natural Resources Research Institute (a position from which he recently stepped down).

"I started out as a physical education major," Niemi said. "I switched to biology after taking an ornithology course from Pershing (Jack) Hofslund in 1971. On our first class field trip, we saw an osprey come down and grab a large fish. It was fabulous. I asked Jack if someone could make a living studying birds, and he told me that I could do anything in which I have a passion.

"I was a very mediocre student during my first couple years of college," said Niemi. "Then, when I found something I believed in, everything fell into place. I know many scientists who have the same story. College courses like genetics, physiology, anatomy, physics, and organic chemistry made much more sense when I could see why they were important to a better understanding of birds."

Niemi says learning about birds helped him develop a deep and broad interest in ecology and the environment. "Birds led me to conservation biology and the loss of species — one of the major biological crises today. We are in a major, unprecedented, extinction period caused by human activity. It is truly sad."

"Teaching conservation biology to college students is a great connection with my research, and a good reality check — it's eye-opening," Niemi said. "Scientists often get caught up in our own little world. Teaching forces us to convey information from our research in terms students can understand and students are stimulating to work with — very beneficial and motivational."

FOCUS

Ecotoxicology Research

A leader in freshwater toxicology, the EPA Mid-Continent Ecology Division in Duluth conducts research and provides expertise to the regulatory programs of the U. S. Environmental Protection Agency (EPA) and its partners in local, regional, national and international organizations

Over the years, research has led to improved toxicology tests to establish safe versus harmful levels of chemicals and involved extensive *in vivo* (whole organism) endpoints in a variety of indicator organisms. Fathead minnows and other fish species, water fleas, freshwater shrimp, and frogs are typically used because of their importance in aquatic ecosystems. Chemicals typically studied include metals, pesticides, waste chemical products, and other hazardous pollutants that find their way into the environment.

Environmental Protection Agency

The EPA is developing predictive models and tools to efficiently and effectively assess chemical risks to organisms in aquatic systems that are vital to the health of the natural environment.

The EPA is faced with a vast number of chemicals in production and many being registered for use. Developing predictive models and tools to efficiently and effectively assess chemical risks to organisms in aquatic systems is vital to protecting the natural environment. To better understand a chemical's mechanism of toxic action, scientists are developing and using advanced models to understand chemical behavior in aquatic organisms. This information is then used to predict toxicological effects across fish species and in other wildlife including birds, to assess risk but also seek to reduce animal testing. In recent years, information on molecular responses in organisms to prioritize and screen chemicals for toxic effects is achieved through computational toxicology and modeling. Toxic effects associated with chemical structure are being integrated with advanced techniques in molecular biology (e.g., study of genes, proteins, and metabolism) and systems biology to provide alternatives to *in vivo* testing. These models and techniques, combined with *in vitro* testing (tests using cells instead of whole organisms) are used to identify compounds that are likely to disrupt hormone function and potentially alter the natural reproduction of organisms.

The EPA's ECOTOX Knowledge System (cfpub.epa.gov/ecotox), developed and maintained at the Duluth laboratory, provides toxicologists with a cost-effective means of locating high quality toxicological effects data for a wide range of terrestrial and aquatic organisms as well as chemicals. ECOTOX is used by researchers to form and test hypotheses using data from literature, and by risk assessors to investigate and determine a chemical's risk of toxicity to aquatic and terrestrial species.

Beneath the Waves:
Acoustic Technologies Help Manage Fishing

In the nearly 70 years he's been working on Lake Superior, commercial fisherman Dick Eckel has seen times when cisco were as abundant as ants at a picnic. He's also seen times when populations were dramatically down, and changes in regulations to protect them dealt a tough blow to the fishermen who relied on sales of the tasty fish and its eggs to make ends meet.

Today both the cisco and commercial cisco fishing are doing much better. And Department of Natural Resources fisheries managers expect it to stay that way, thanks to a research trawler, enlightening sound waves, and an innovative collaboration with the University of Minnesota Duluth.

"It has huge implications," DNR Lake Superior area fisheries supervisor Don Schreiner said of the timely collaboration between researchers and fisheries managers. "It's helping us to design our program for the next 10 years."

How Big Is the Pie?

Cisco, also known as lake herring, are lanky, submarine-sandwich-sized fish that live in the open water of Lake Superior. Lake trout love to eat them. So do people: In the 1920s and '30s, commercial fishermen — some 400 of them — pulled more than five million pounds a year from Minnesota waters to feed a growing population.

In the 1960s, that changed. Stressed by fishing, habitat degradation, and competition from exotic species, cisco populations plummeted. In the 1970s, the DNR closed cisco fishing in Minnesota waters during the November spawning season, effectively shutting down the production of caviar, a major source of fishing income in the area.

Frustrating as the new rules were to the commercial industry, they — along with efforts to control exotic species and clean up the lake — seemed to do the job. Gradually the cisco came back, eventually sustaining an annual catch of 300,000 to 500,000 pounds.

Was the new population healthy enough to allow November harvest once again? When fishermen began to ask that, the DNR didn't have the answer. Catches were improving, but so were populations of predators such as native lake trout and Pacific salmon. Nobody wanted to over fish, but if it wasn't harmful, modifying the regulations would be a huge boon to those who depended on cisco for their livelihood. There was a

Brian Roth

Tom Hrabik (shown here in Mongolia with a *Hucho taimen*) studies the factors influencing fish diversity and dispersal within small and large lake ecosystems around the world. His interest in interactions between exotic and native fishes and the accumulation of toxic chemicals in fish tissue is vital to Mongolia water quality as well as to economic interests in sport and commercial fisheries.

need to see under the surface.

"We're trying to allocate the cisco harvest amongst commercial netters and amongst the predator fish that are out there, and then we have to make sure we leave enough in the lake so we can sustain and grow their populations. ... We need to know how big the pie is before we start slicing it up," Schreiner said. "People who study deer, foxes, bugs, and that sort of thing, they can make direct counts. We can't."

Enter One Technological Advance and One Great Collaboration

In 2001, UMD hired fisheries scientist Tom Hrabik, an expert in using sound to see what's beneath the waves. The approach, called hydroacoustics, had been developed in the 1980s, and advanced through the 1990s as a tool for estimating the size and number of fish for research purposes. Hrabik and Schreiner agreed to combine their resources and see if they could develop a protocol for using hydroacoustics to estimate the cisco supply in Minnesota waters — a move that would give the DNR a good enough handle on the resource to institute a total allowable catch regulation and open cisco fishing in November once again.

Sophisticated Fish Finder

If you like your sleep, Hrabik's approach to searching Lake Superior for cisco is probably not going to be your idea of fun. From a hydroacoustic angle, these little fish are easiest to get a read on in the middle of the night, when they move up from the bottom and spread out from their schools.

"It's a lot of sleep deprivation," Hrabik said. "You get on the ship and you work until you're pretty well out of gas ... you usually have been up over 24 hours the first day. But it gets better after that."

In August 2003, the researchers took the hydroacoustic equipment — what Schreiner calls "a very sophisticated fish finder hooked to a computer" — out on DNR's research vessel, beamed sound waves into the water in a cone shape, and observed and recorded the patterns the waves made as they bounced off objects — fish — below. In October 2003 and late summer 2004, the equipment moved to the larger R/V *Blue Heron*, UMD's 87-foot research vessel, for use in deeper waters. To learn how the echoes they saw on their sonar screen corresponded to actual pounds of cisco, the research team members collected midwater trawl samples at the same time they assessed fish electronically. By comparing the size and species of what they hauled up in the trawl with the sound data, Hrabik was able to figure out a formula for translating hydroacoustic readouts into herring abundance, density, biomass, and composition.

"Since we now have a technique to be able to set total allowable catches, we can allow some harvest during the spawning season," Schreiner said. "It's a huge deal for our commercial fishermen. They can choose when they want to fish."

Research to Reality

The researchers plan to continue working together to gain additional insights that will enhance the application of hydroacoustics to fish management on Lake Superior. One goal is to determine the best time of year to do hydroacoustic surveying to inform ongoing cisco management. Another is to learn how much the results vary with time, location, and technique.

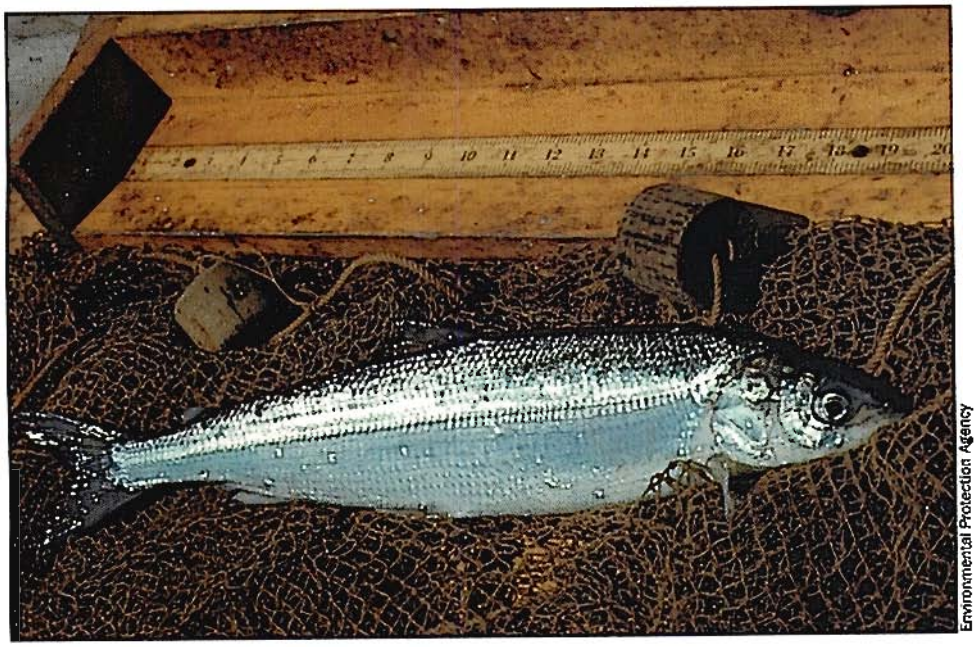
Schreiner expects results of this study, and those that follow, will have major ripple effects through the rest of Lake Superior and beyond.

"This is a really good pilot project to answer how variable our findings are," Schreiner said. "I can see it probably occurring in the rest of Lake Superior and in the other Great Lakes down the road."

Perhaps just as important, the effort demonstrated the bang-for-the-buck value of creative collaboration.

"It's been a great thing for them and a great thing for us," Schreiner said. The DNR gained information it could use to set new regulations benefiting the commercial fishing businesses, food production, and fish consumers, while also protecting the resource. On the basic science front, Hrabik gained valuable information about fish behavior. Graduate students — future hydroacoustics experts — gained career-enriching experience. And the rest of the world gained validation for a technique that can be used by others to improve management in other fisheries.

"It's a great example of how the university and the DNR interact," Hrabik said.



Environmental Protection Agency

Tom Hrabik uses hydroacoustics, a tool that uses the speed of sound, sound propagation, sound absorption, reverberation, reflection from the lake bottom, and underwater noise, for estimating the size and number of fish.

Hrabik observing sea lamprey transformers in a Lake Superior tributary.

PROFILE

Tom Hrabik:
Making Fish Count

While growing up as part of the Lac du Flambeau Band of Lake Superior Chippewa, Tom Hrabik hunted and fished a lot with his dad. His relatives were fishing guides. He was given — and could handle — a boat while still young, and had, as he says, "10,000 acres of water at my disposal."

Hrabik earned scuba diving certification at age 14. He frequently went snorkeling in the same lakes he fished. "It opened up a whole other world," he said. "It was about observing the underwater environment. Not just about catching fish, but figuring out where they were."

He also started working in his dad's hardware store when he was 10 or 11. That formative combination of learning how to handle responsibility and observe lakes led him to even more valuable opportunities. He started with shadowing the Lac du Flambeau natural resources manager and continued with undergraduate research opportunities while at the University of Wisconsin-Stevens Point.

"Doing that research helped it sink in that if scientists do quality data collection, they can find information that's of real value to people," he said.

Hrabik did some of that research at the University of Wisconsin's Trout Lake Research Station, near where he grew up. "A UW fisheries ecologist named John Magnuson said he found out I got things done well and rapidly — which was rare among undergraduates, apparently — and he asked if I'd be interested in going to graduate school in Madison."

Tom wound up staying in Madison for a Master's degree, a Ph.D., and some postdoctoral research. Eventually, Hrabik realized the post-doc work would be funded two years at a time, and since he wanted a more stable position he applied for jobs at Utah State, Maine, and UMD.

"I remember driving out of Duluth hoping to get an offer here," he said, because he was intrigued by studying Lake Superior. The big lake and small lakes in the area provide research opportunities.

He's also still connected to the lakes of his boyhood. "The same natural resources manager is still at Lac du Flambeau," he added.

Beach Bacteria:
Keeping the Public from Harm

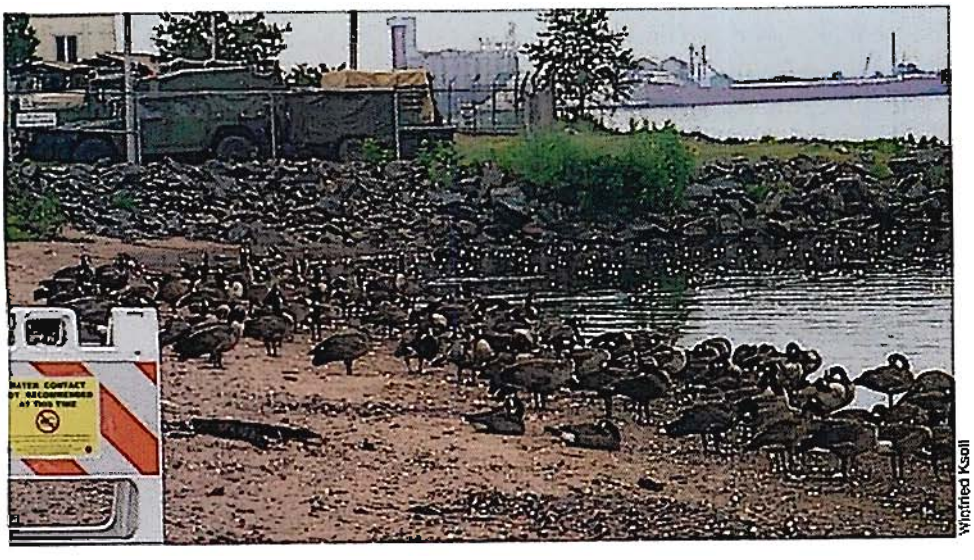
Visitors to Great Lakes beaches sometimes come across an unpleasant surprise — signs recommending no contact with the water. Not exactly what anyone craving a cool dip on a hot day wants to see. Signs like these are posted at Lake Superior beaches by the Minnesota Pollution Control Agency in an effort to protect human health.

Researchers at UMD are finding that *Escherichia coli* (*E. coli*) bacteria at beaches do not always come from harmful sources, and in fact, some can take up residence in the sand, aquatic plants, and even in the fish from lakes. They are shedding light on this issue and paving the way to develop better detection methods and more meaningful beach advisories.

The *E. coli* bacteria under the microscope live in the intestines of animals, including humans, and are used at most Great Lakes beaches as one indicator of pollution and the possible presence of other more harmful bacteria that increase the risk for illness. While most *E. coli* strains are harmless, a few types of *E. coli*, and some bacteria related to them, cause gastrointestinal illnesses. Symptoms include vomiting, diarrhea, or other more serious conditions people would not want as a reminder of a fun day at the beach.

In several projects spanning the last seven years, Randall Hicks, biology professor at UMD and Michael Sadowsky, professor of soil, water, and climate at the University of Minnesota St. Paul, have collected samples from Lake Superior streams and problem beaches in the Duluth-Superior harbor. They used a method called rep-PCR DNA fingerprinting to help determine the potential sources of *E. coli* in the environment by creating a CSI-like library of DNA fingerprints that are specific to different animals and environmental sources.

. . . . human waste pollution often accounts for only a tiny fraction of the *E. coli* contamination



Winfried Ksoll

UMD researchers have discovered that goose droppings, not human waste, are the cause of many of the beach advisories in problem areas of the Duluth-Superior Harbor. This information helps resource managers better assess the risk to people from this contamination and to determine control strategies.

Randall Hicks

UMD graduates Wendy Hieb (left) and Brendan Keogh (right) along with a Wisconsin DNR staff person (center) collect fecal samples from a ring-billed gull chick.

They discovered that human waste pollution often accounts for only a tiny fraction of the *E. coli* contamination in Lake Superior streams and Duluth-Superior beaches. By contrast, *E. coli* from waterfowl and wildlife can sometimes account for up to 100 percent of the total *E. coli* whose sources can be identified in water. Although ring-billed gulls are more abundant in this harbor, surprisingly Canada geese are usually the dominant source of the waterfowl *E. coli*.

Heidi Bauman, manager of the Lake Superior Beach Monitoring Program for the Minnesota Pollution Control Agency, says this research helps give people a better idea of what contributes to beach contamination.

Winfried Ksoll and Satoshi Ishii, past graduate students in Hicks' and Sadowsky's labs, also found that *E. coli* can survive, reproduce, and form natural populations in riverine soils within Lake Superior's watershed, in algae washed up on beaches, and on periphyton-covered (i.e., slimy) rocks in the lake.

"These natural environmental sources could increase *E. coli* counts found at beaches, especially if the counts in water are measured on windy days when the sediment and algae are churned up," said Sadowsky. "Often it's assumed that *E. coli* found in water during beach monitoring is from recent sewage overflows or washed into the water from human or animal sources on the land. We've shown that's not always the case."

So in essence, the practice of using *E. coli* to indicate recent fecal pollution and poor beach water quality is a little like using carbon dioxide — a gas also naturally given off by animals, microbes, and some plants — to indicate the source of air pol-

lution from only human activities.

Their latest discovery is that fish in the Duluth-Superior Harbor are *E. coli* carriers. Two of Hicks' former students, Dennis Hansen and John Clark, found most of the *E. coli* in the intestines of bottom-dwelling fish such as brown bullheads, Eurasian ruffe, common carp, and round gobies.

Using their DNA fingerprint library, they matched the fish *E. coli* to sources like bottom sediments, Canada geese, mallard ducks, and treated wastewater. The researchers didn't test the *E. coli* isolated from the fish to see if they were pathogenic strains that might be harmful to humans. But their previous work indicated that less than 1% of the *E. coli* at one beach might be pathogenic strains.

"We didn't look for the bacteria in the fish meat – they're carried in the fishes' intestines," said Hicks. "Anglers shouldn't worry about using the fish they catch as food. They should just be careful not to cut open a fish's intestine when they are cleaning their catch."

"Fish probably acquire *E. coli* from the water and their food sources," said Hicks. The researchers don't expect *E. coli* to flourish in cold-blooded fish, since they are more common in warm-blooded animals. "However, it is possible that fish may reintroduce *E. coli* bacteria back into waterways when they excrete their own waste."

"Currently, it's probably more appropriate to consider fish as vectors of *E. coli* from other sources, rather than a new source of contamination in our waterways," Hicks added.

Now, Hicks and Sadowsky along with Ph.D. student Jessica Eichmiller are studying how quickly the numbers of fecal bacteria from waterfowl and humans change at beaches and if they are correlated with events like large rainfalls, high winds, wave action, changes in water temperature, or recent sewage overflows. They hope a better understanding of the relationships between these types of events and the changing sources of fecal bacteria at beaches on very short time scales (daily) will lead to improved strategies to control contamination at beaches and possibly *fewer* beach advisories.

PROFILE

Winfried Ksoll:

Sharing UMD with the World

Winfried Ksoll, who earned his Water Resources Science M.S. degree from UMD in 2006, is a global water research presence, having studied fresh water in Europe and North and South America. He now works for Sachsen Wasser GmbH in Leipzig, Germany, his home country, where he coordinates water projects abroad in Asia, Eastern Europe, the Middle East, and Africa.

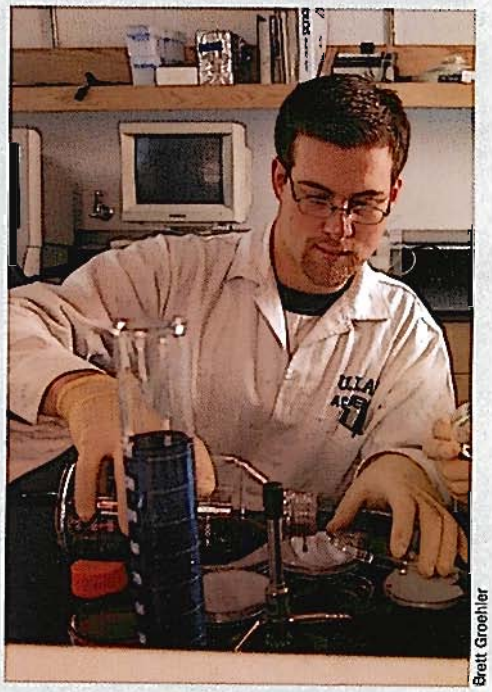
He has fond Duluth memories of "24-hour sampling sessions with undergraduate lab mates, cross-country skiing at temperatures where the snow squeaks like Styrofoam®, and trips to the Boundary Waters Canoe Area."

While studying environmental and resource management in his native Germany, Ksoll spent a year in Mexico, focusing on both classes and lab work in experimental microbiology. Back in Germany, he worked for eight months on a research experiment. Throughout this time, he was developing interest in learning about wetlands constructed for wastewater treatment, and how they might be used in the developing world.

Eventually, he received an offer from Center for Freshwater Research and Policy Director Randall Hicks to study in Duluth. "I had lived in the U.S. before," Ksoll said. "I like to travel and be abroad, and the topic matched my interests. It was an easy decision to go to Duluth."

Ksoll said he acquired valuable professional experiences with Hicks as his advisor: "I learned a lot regarding autonomous and scientific work. I had the opportunity to develop a research project with the guidance of Dr. Hicks, and also learned a lot about lab management and staff guidance. Critical to me was learning to evaluate what is important and what is not. I also learned a lot regarding microbiological techniques. It helped me to move forward toward finding my vocation."

As for the future, Ksoll hopes to continue working as project manager, have a family, and at some point, work again on constructed wetlands or other low-cost wastewater treatment systems and their proliferation in developing countries.



Brett Groehler

Jason Kish

UMD graduate, Dennis Hansen, captures a mallard duck for an *E. coli* study.

FOCUS

Beach Watch

As Minnesota's only coastal recreation waterway, Lake Superior's North Shore invites thousands of tourists and water enthusiasts to its craggy, 206-mile long shoreline. Nearly year-round, anglers, kayakers, surfers, and swimmers brave the 40-degree F water to find adventure unlike any other. Yet despite its sheer volume, and efforts to protect it, Lake Superior remains vulnerable to contamination that can literally make people sick.

Complex wind, weather and water patterns can deliver feces of warm-blooded animals, including humans, to the beaches.

Other fecal sources include stormwater runoff, failing individual septic systems, sanitary sewer system overflows and improper diaper or boat waste disposal. Recent research conducted by University of Minnesota researchers Randall Hicks and Michael Sadowsky yields yet another: *E. coli* bacteria, proven to survive in soil conditions ranging from tropical to frozen, suggests these indicator bacteria are more adaptable than once thought and are actually self-sustaining in some natural environments.

Regardless of the source, *E. coli* and fecal coliform bacteria exposure affects human health worldwide. Protective solutions, however, often remain a local responsibility.

Federal passage of the 2000 Beach Environmental Assessment and Coastal Health Act, a Clean Water Act amendment, gave the Minnesota Pollution Control Agency (MPCA) program authority in 2003 to collect water samples, publicly communicate the results, and educate beach-goers about the related health risks.

From May through September, MPCA staff and county health department partners monitor 40 public beach and access points between Duluth and the Canadian border. Next-day laboratory sample analyses indicate whether bacterial levels meet or exceed federal water quality standards.

When bacterial levels are too high, MPCA staff members e-mail "water contact not recommended" alerts, post signs at the affected site(s) and update the www.MNBeaches.org Web site and local beach hotline. The Web site offers current beach advisories, collection-site photos, historical monitoring data, beach monitoring science and research, an 800-number hotline, plus helpful tips for water enthusiasts.

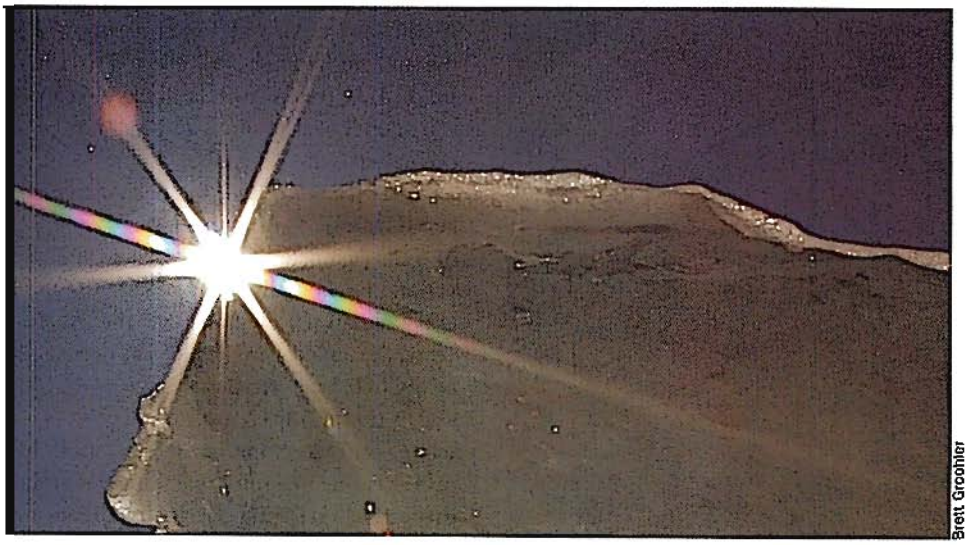
Heidi Bauman

Minnesota Pollution Control Agency (MPCA) post signs at affected sites to alert the public when water contact is not recommended due to high levels of bacteria.

Lake Superior:

Feeling the Heat

Averaging a chilly 39 degrees F, Lake Superior is not known for warmth. It is, however, known to be warming, at least on the surface.



Brett Groehler

Ice cover on Lake Superior is declining and surface water temperatures are warming up, UMD researchers have found.

"In a coldly scientific way, the changes are fascinating," said Jay Austin, assistant professor of the University of Minnesota Duluth's Large Lakes Observatory (LLO) and the Department of Physics. Austin and Steven Colman, the director of LLO, broke the news of the ways climate change has manifested in Lake Superior in *Geophysical Research Letters*.

The researchers reported that Lake Superior has been:

- surface warming twice as fast as air
- exhibiting longer summer stratification
- experiencing diminished ice cover
- showing increasing wind speeds over the surface

The scientific world and the media paid attention. Even Austin's parents took note, but for a slightly different reason. They were watching the evening news at their home in California when, much to their surprise, their son appeared on the screen. As one newspaper phrased it, Austin has become a "reluctant star" for his investigations into Lake Superior's response to climate.

The observation that inspired the LLO researchers was a byproduct of Austin's quest to know the lake. As an oceanographer and newcomer to the area with an interest in the behavior of large lakes, Austin wanted to ascertain what and how much data were available on Lake Superior's physical attributes and propensities.

Eureka!

While mining for data (looking for old files and reports), Austin struck gold. He unearthed trends by examining daily water temperature readings dating back to 1906. The information, one of the longest directly measured water temperature records in the world, comes from near the St. Mary's Falls hydroelectric power plant on the eastern end of Lake Superior.

Compared to air temperature readings provided by the Goddard Institute for Space Studies (the source for much of the data used to illustrate global climate change), Austin noticed that Lake Superior behaved with typical variability until the early 1980s. After that, things started to heat up.

"The striking thing was that the long-term upward temperature trend in Superior was so much stronger than the global average," said Austin. "We knew that the upper Great Lakes region was

"Winter ice cover is the primary indicator of how warm the lake will be the following summer. If you have a year with lots of ice, most of the sunlight hitting it gets reflected back into space. Take the ice away, and the sun can warm up the lake, similar to what may be occurring in the Arctic." — Jay Austin

Marie Zhuikov

UMD researcher, Jay Austin (top), and his crew carefully lower a research buoy into Lake Superior. The buoy collects weather and water information that will further understanding of the lake's patterns and currents.

warming more rapidly than the global average, but not this rapidly."

Curious, Austin analyzed more detailed data collected over the past 30 years by three National Oceanic and Atmospheric Administration (NOAA) buoys. From the moment they are placed in the water in April until they are pulled in November, these buoys measure water temperature, air temperature, and wind velocity. Comparing the buoy information and regional air temperature from stations within 300 miles of Lake Superior's center, Austin saw past the wide annual variability.

"There's a lot of scatter," said Austin. "But on average the water is clearly getting warmer."

How much warmer? Austin and Colman report that since 1980 Lake Superior's surface water temperature in summer has increased about two-degrees F per decade, while regional air temperature has increased one-degree F.

The incongruity begs for an explanation. Ever up to a challenge, Austin pulled out more buoy data and a set of new numbers concerning ice. These new data came from NOAA's Great Lakes Environmental Research Laboratory.

Decreasing Ice

"Here's the kicker," said Austin. "Winter ice cover is the primary indicator of how warm the lake will be the following summer. If you have a year with lots of ice, most of the sunlight hitting it gets reflected back into space. Take the ice away, and the sun can warm up the lake, similar to what may be occurring in the Arctic."

Lake Superior's ice has been scarcer of late. There is less of it for shorter amounts of time. Again, looking past sizable annual variation to find an underlying trend, Austin and Colman reported that over the last 30 years, the area covered by ice has decreased by about 0.5 percent per year.

A domino-like cascade starts in winter on Lake Superior. Ice sets it off. Ice prevents the lake from warming. Warming dictates when spring overturn happens (when the water hits a maximum density at 39 degrees F and can mix from top to bottom), which determines when the lake stratifies (when a warm layer develops over the surface). The researchers found that spring overturn is becoming earlier by about one-half day per year, leading to earlier summer stratification. The earlier stratification means the sun-warmed upper layer can accumulate more heat and extend more deeply, making fall water mix later. In the end, the combination of diminishing ice cover and warmer summer temperatures have accelerated Lake Superior's temperature trend.

The researchers also found that winds are whipping by about 25 percent faster than they did three decades ago. Potentially, more forceful winds push the surface layer deeper, adding even more heat to the water.

Scientists are reluctant to pin down climate change as the sole cause of the diminishing ice on Lake Superior because of confounding factors such as nutrient enrichment. Austin said it's a case where you answer one question and uncover two more. He and his team are investigating the loss of ice cover by peering more deeply into the lake.

"We're starting to measure more than just surface temperatures," said

Austin. "We've set out four buoys that take temperature readings from the surface down to 800 feet. This will allow us to examine the heat content of the lake and ask questions like, 'How far does the surface layer extend?' and, 'How does it vary from year to year?'"

Austin believes this research could give them new insights on what physical and climate parameters most affect Lake Superior and other bodies of water across the globe. He'll be calling one of the buoys, which has its own cell phone number, for regular updates.

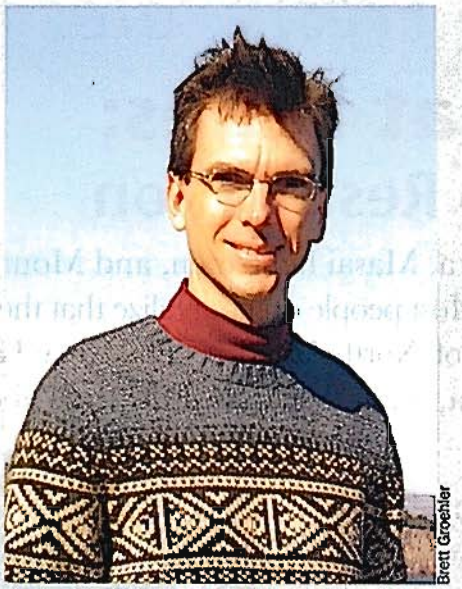
And the Forecast is...

The Minnesota Sea Grant Program uses research like Austin and Colman's to help people plan for a future in the face of a changing climate. They report that out of a dozen computer models simulating Lake Superior's climate in the next century, all indicate we should expect continued warming. More frequent and intense storms, climate variability, and extremes are also in the offing. Although the details of regional climate predictions are tricky and model-dependent, it seems likely that by 2100 the Lake Superior Basin will have:

- Kansas summers (up to 20 degrees F warmer; drier with soil moisture possibly decreasing by 30 percent).
- Wisconsin - Illinois winters (up to 12 degrees F warmer; similar precipitation but more falling as rain, and more mid-season melting).

Even for scenarios that forecast increased precipitation, lower water levels are predicted for Lake Superior. That's because evaporation could increase from 7 to 17 percent by 2030.

Adapting to the changing climate will involve the efforts of communities, industries, and individuals. Aspects worth considering include the capacity of stormwater drains and breakwalls to withstand violent storms. Communities might need to battle more fires since forest fires correlate closely with temperature, precipitation, and soil moisture. The Great Lakes fleet might make use of an extended shipping season, which would offset the lighter loads ships will be carrying if water levels drop. Natural resource managers predict changes in coldwater fisheries.


Brett Groehler

PROFILE

Jay Austin:
Aquatics and a Splash of Math

As an undergraduate mathematics student, Jay Austin applied — "just for hoots" — to a Woods Hole Oceanographic Institution summer research program. He was accepted, given a fellowship and the chance to work with a research scientist, and then he had a bit of an epiphany.

"People were addressing critical problems by applying math and physics to them," Austin said. "It was very interesting."

After a year of graduate math studies at Cornell, Austin said, "math clearly was not what I was cut out for. I wound up writing to Woods Hole and asking if I could come back and be a graduate student. The students there were so enthusiastic and passionate about what they did."

Math still plays a significant role in Austin's research, but he says he appreciates his many multi-disciplinary opportunities.

"I'm required to be a good mathematician, to handle myself on a boat, to talk to engineers and electronics experts. I might sit and do math for a whole day, but it's not like I do that every day. The work I do requires reasonable competence in a range of different fields."

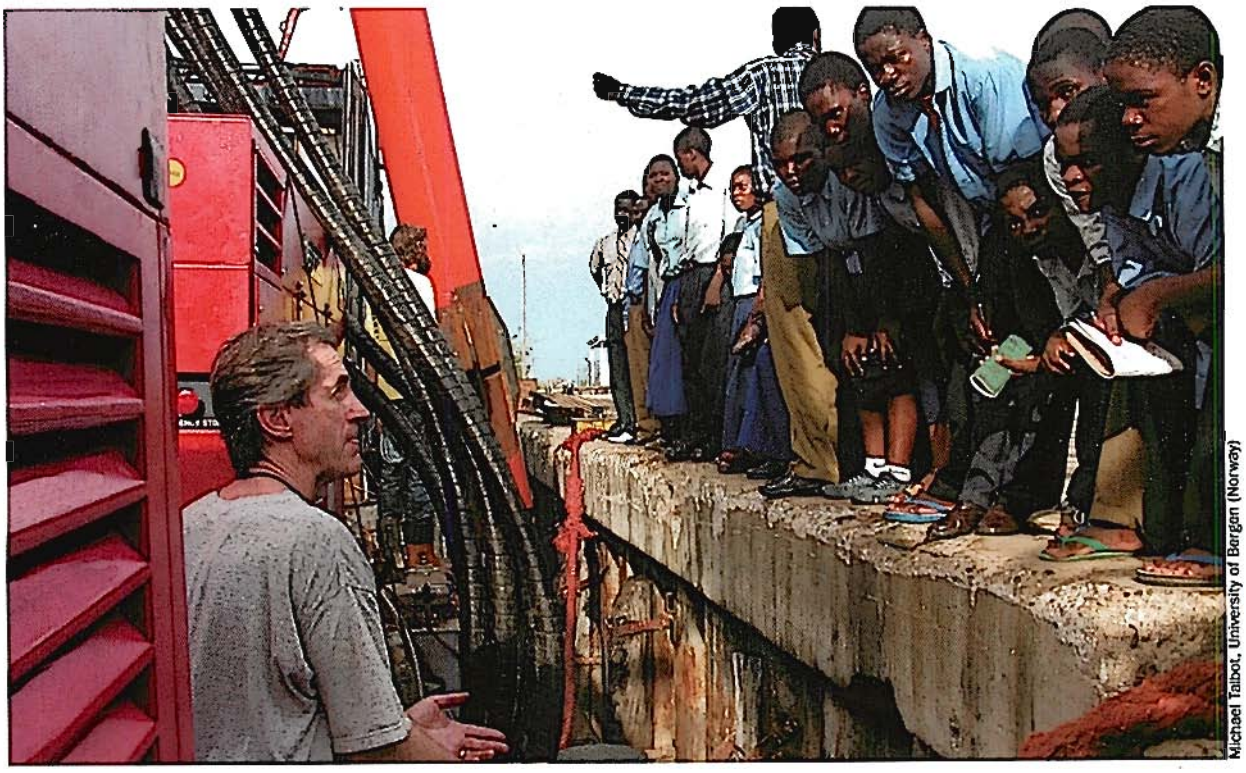
One of those fields is teaching a basic physics undergraduate course. "It's a big sophomore-level course, which doesn't necessarily apply to my research, but I'm a bit unusual." Austin enjoys the introductory course and "trying to explain basic concepts and helping students understand how systems work and apply to their own interests. I find that task extremely fascinating."

Working with graduate students has its own challenges and rewards, Austin said. "It's a lot of work. I suddenly appreciated my graduate advisor's ability to balance research and mentoring," he added.

Austin believes in balance. "The primary purpose of a professor," he said, "is to instruct others."

African Great Lakes:
Paleoclimate to Restoration

Africa. Visions of lions, zebra, Masai herdsmen, and Mount Kilimanjaro. How about freshwater lakes? Indeed. Most people do not realize that there is more fresh water than the Laurentian Great Lakes of North America. (The Great Lakes of the East African Rift Valley, Malawi, Tanganyika, Kivu, Victoria, Edward, Albert and Turkana.)



Michael Talbot, University of Bergen (Norway)

Drilling in Lake Malawi in Eastern Africa presented many of the most difficult aspects of both continental and ocean scientific drilling, including a remote location lacking infrastructure and very deep drilling operations. In 2005, 26 members of the science and drilling teams (including Tom Johnson, shown here on the left) lived and worked aboard a converted fuel barge while recovering sediment cores from the lake.

The largest of these, Lake Tanganyika, is nearly a mile deep and 12 million years old, with a 3-mile-thick sediment basin underlying the lake floor. Lake Malawi holds more than 1,000 species of fish, the vast majority of them having evolved within its confines and found nowhere else on earth. These lakes have served as magnets to human development since the evolution of early man, with their provision of fresh water, fish protein, amelioration of climate, and transport waterways.

Scientists from UMD's Large Lakes Observatory (LLO) have been conducting research on the African Great Lakes since the inception of LLO in 1994. Most of this work has centered on geological aspects of the lakes, including charting the lake depths, mapping the distribution of different kinds of sediment across the lake floor, and analyzing sediment cores for the history of climate in tropical Africa. The results of this work are published in major scientific journals and are well known in the international arena of lakes research.

The products of the research are of interest to oil companies, for they currently extract about 20 percent of the world's oil and natural gas from ancient rift lake basins that once held lakes like those of present-day East Africa, and indeed the modern lakes now host oil exploration and extraction. The climate records that are being generated from the sediment cores are providing new insights into the timing and magnitude of climate change in tropical Africa, and its relationship to the climate dynamics of far away places such as Antarctica, Greenland, and the tropical Pacific Ocean.

LLO scientists were among the leaders of a major drilling project on

Lake Malawi in 2005 – the first of its kind in Africa – that led to the recovery of a sediment core more than a thousand feet long from a site in 2,000 feet of water. This required a massive international effort, including the conversion of a 140-foot barge into a drilling vessel with computerized dynamic positioning and living facilities for 25 scientists. Drillers and mariners were hired to stay aboard for five weeks, working around the clock to meet the operational goals. The core, which is archived in Minnesota, holds a 500,000-year record of past climate change that will be analyzed by scientists from throughout the world over the next several years.

The recent additions of professors Stephanie Guildford and Bob Hecky to the LLO faculty in August 2007 have increased the biological presence of UMD's research program in East Africa. Guildford and Hecky have conducted research on all the East African Great Lakes with current emphasis on two. They have worked on Lake Victoria, which has the largest lake fishery in the world with over one million metric tons landed in recent years, and Lake Malawi, which has more species of fish than any lake in the world. On Victoria, they and their graduate students have examined why the lake has become increasingly oxygen depleted in the last several decades and which nutrients need to be controlled to prevent further degradation of the lake environment. Victoria is an important drinking water source for millions of people and protecting the valuable fisheries is important.

Collaborating with European and African researchers, Guildford and

PROFILE

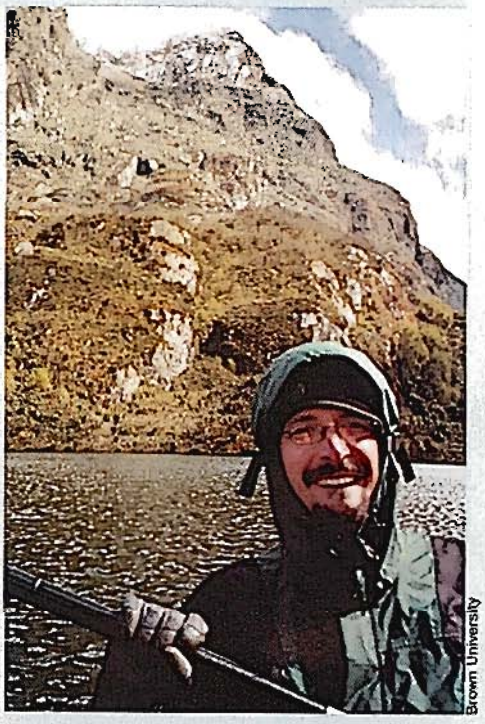
Jim Russell:
Large to Small Lakes

"The best place to study big African lakes," Jim Russell said, "is Duluth." Few folks who aren't large-lake limnologists would take him seriously; then again, most of those haven't worked with people in Duluth.

"It's the best place to study big lakes in general," said Russell, who earned his University of Minnesota Ph.D. in ecology — splitting time between Minneapolis and Duluth, and now teaches at Brown University. "It's the best place in the country for research on large lakes, both because of the people that have been assembled there and the work they're doing."

Like many folks who study large lakes, Russell said he found his way to UMD through "the buddy system." As an undergraduate geology student at Wesleyan University, he came into contact with a Minnesota doctoral graduate. "She worked on big African lakes," he said. "I got interested and started working with her. She knew the Minnesota program, and that's how I learned about it."

After one year of postdoctoral work at the Large Lakes Observatory, Russell became a professor at Brown University. "The emphasis of my position is



Brown University

on research," Russell says, "but I enjoy teaching. I try to integrate my research into the classroom as much as possible, to get undergraduate students involved.

"I can't get them involved in large-lake research here in Rhode Island — there are no big ones around here — but they're working on a lot of small New England lakes. They like that because they can often see the whole lake, and get a good handle on how the lake works as a system."

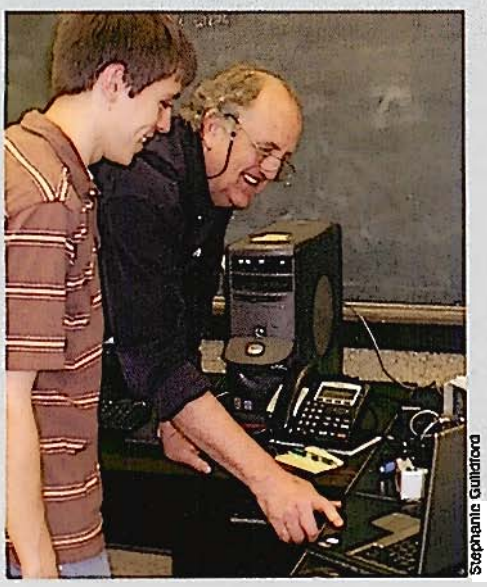
Michael Talbot, University of Bergen (Norway)

UMD's research has found that the African Great Lakes Tanganyika, Malawi, Victoria and Kivu, have been warming over the last century, causing fish production declines.

Hecky are also examining how oxygen depletion has altered food webs in the lake and disrupted complex breeding behavior of the fishes in the lake.

In Lake Malawi, intensive cage culturing of fish has begun on a commercial scale and is growing rapidly. The study examines how the intensive feeding operations required for successful cage culturing impacts the nutrient conditions in surrounding waters and any effects in feeding relationships of the highly diverse native fishes.

In West Africa, Hecky and Guildford, with their graduate students and Ghanaian scientists, are studying the ecology of Lake Bosumtwe, the sacred lake of the Ashanti people. This crater lake was formed by a meteor impact one million years ago. Its water level and ecology are very sensitive to climate



Stephanie Guildford

PROFILE

Robert Hecky:
Keeping Research Real

"Students keep me going," said Robert Hecky. "It's good to see their drive and curiosity."

Fishing with family started Hecky's interest in lakes. He spent two years at the Illinois Institute of Technology — studying to become an engineer — before transferring to Kent State. "I missed the outdoors," he said. "I finished my biology degree at Kent State, where I had some relatively influential professors who recognized talents in me that I wasn't aware of." Hecky suspects his professors gave him good recommendations. "I went to Duke University for my Ph.D. work in marine biology, and I'm pretty sure I wouldn't have gotten there on my own."

From Duke he found his way to the Freshwater Institute in Winnipeg, Manitoba where he worked for 23 years, and then onto the National Water Research Institute and the University of Waterloo in Ontario where he worked with his first graduate students in the early 1990s. Hecky studied lakes in North America and Africa at those institutions and a variety of governmental agencies. Recently, he and his colleague and wife, Stephanie Guildford, joined the Large Lakes Observatory.

"I've seen both worlds." Hecky said, referring to agencies and academia. "I did government work for almost three decades, and I understand the challenge of working on real problems — having to be reasonably focused and applied in research. I often find that my perspective is different from those who have spent their entire careers in the academy.

"If I surveyed my graduate students, I think they'd say they appreciate the background and contacts I bring to the academic world. I think it helps them see real connections to the work we do — it's more than an academic exercise."

Collaborating with European and African researchers, Guildford and Hecky are also examining how oxygen depletion has altered food webs in the lake and disrupted complex breeding behavior of the fishes in the lake.

change in the Sahel, a semi-arid tropical savanna ecoregion, which is undergoing desertification as well as local deforestation in the crater watershed. Sediment cores taken by an international drilling project on Bosumtwe have recovered a one million-year record of climate change in West Africa, and the studies on the modern ecology of the lake will support the interpretation of this unique record.

Among the major discoveries by LLO scientists:

• Lake Victoria, second only to Lake Superior in surface area, dried up completely at the end of the last ice age, and re-filled just 15,000 years ago. Most of the 500 endemic species of cichlid fish in the lake had to evolve since that time, an astounding rate of speciation among vertebrate animals.

• Lake Victoria has become highly eutrophic because of excessive nutrients entering the lake over the last several decades causing the extinction of several hundred fish species – the highest vertebrate extinction rate known. If the other African lakes also become more eutrophic, similarly high rates of extinction may result and devastate a large portion of the world's fish diversity.

• Lake Malawi experienced severe drought at roughly 20,000-year intervals up until 60,000 years ago. The lake level dropped several hundred meters during these dry periods, raising water salinity in the lake basin and causing major change in the local ecology. The end of severe drought in this part of Africa coincides with the timing of major expansion in the population of our human ancestors and their dispersal across and out of Africa. Whether this is cause or coincidence is presently under investigation by an international team of paleoclimatologists and paleoanthropologists.

• The African Great Lakes, Tanganyika, Malawi, Victoria and Kivu have been warming over the last century, and this has led to reduced productivity in the deepest Rift Valley lakes. Current climate model projections predict even greater changes in temperature over the coming century, which may result in major declines in fish production on the lakes. The African lakes are the most productive lake fisheries in the world and provide a critical food source to millions of Africans.

PROFILE

Stephanie Guildford:

Making Global Connections

Stephanie Guildford said she was lucky. "I grew up in Nova Scotia. My parents had a summer cottage on the ocean, and we were always swimming, fishing, boating and being around the water. I went into marine biology, and I didn't think too hard about going into other things."

Right after earning her undergraduate degree in the early 1970s, Guildford took a temporary position at the Bedford Institute of Oceanography before hearing about "this great new institute in Winnipeg" — the Freshwater Institute.

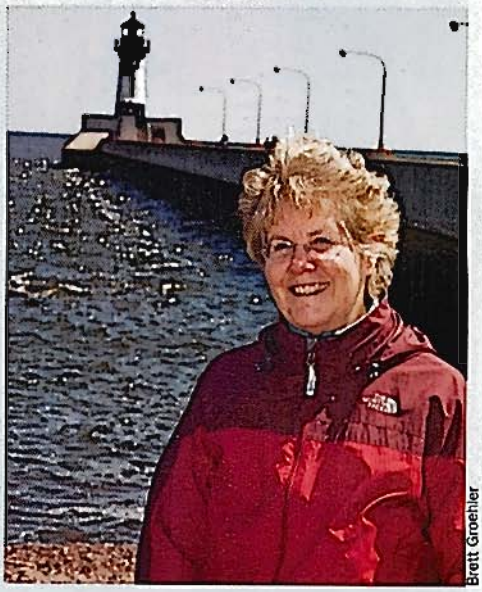
"It was brand new, and there were people there from all over the world doing and presenting cutting-edge research," she said. "I didn't realize, at that age and at that point in my career, how unusual an opportunity that was. I loved having the job, being in that exciting environment and doing field work — being in the north country all summer."

Like her husband and LLO collaborator, Robert Hecky, Guildford started teaching after exclusively researching for more than a decade.

"I always really enjoyed research," she said. "It seemed like a natural extension of research to teach. Scientists love to talk about their work, and students provide a captive audience.

"I know why my research seems fun and interesting to me, but I hope it is important to people who live and work on lakes, and people in general as well.

"It's important to be able to explain your work at different levels.



Brett Groehler

Talking about it with peers or graduate students is one thing, undergraduates require something different, and the general public is different still. People invariably ask interesting questions that can make you think."

A New Branch of Life:
The Mystery of Crenarchaeota

Randall Hicks

Deploying a sequencing sediment trap in Lake Superior, which will collect particles that sink to the bottom of the lake for six months.

Since 2005, a funnel-like device has been anchored in the middle of Lake Superior, quietly trapping microscopic particles as they drift through the water column. The particles contain mysterious single-celled microorganisms called Archaea, which caught scientists by surprise in the 1990s when they were first found to be present in the cool, oxygen-rich waters and sediments of oceans and great lakes.

A proposal in 1977 that the Archaea were different from bacteria caused nothing less than a paradigm shift in the biological world, and a major redrawing of the tree of life in 1990. Archaeal microorganisms were found, through studying their RNA, to be nothing less than a major new "branch" of life. (The other two major branches or "domains" are the Bacteria and the Eukarya — the branch that leads to plants and animals.)

"It was first thought that Archaea could only live in freakish environments, very hot water, super saline habitats, or places devoid of oxygen on our planet," said Josef Werne, associate professor at the Large Lakes Observatory (LLO) and UMD's Department of Chemistry and Biochemistry. They were pegged the "extremists" of the natural world.

The Crenarchaeota, a kingdom within the Archaea dominated by thermophilic cells that thrive at very high temperatures, caused another ripple across the scientific world in 1992 when DNA from non-thermophilic forms of these microbes was discovered in the world's oceans, then in large freshwater lakes, and eventually, in many aquatic and terrestrial ecosystems. "Now we know that they live everywhere." Werne said.

The non-thermophilic Crenarchaeota species, especially their living cells, are elusive. So far, only one laboratory in the world has been able to isolate a single species representative of these microorganisms and keep it alive. "Basically, the only things we know about them are from molecules we find

Postdoctoral investigator Brent Dalzell filters water collected from different depths that will be used to extract DNA from aquatic microorganisms.

in the environment like their DNA or compounds they leave behind when they die," said Randall Hicks, director of UMD's Center for Freshwater Research and a professor of biology. "It's as if a new animal were discovered, but it is invisible."

Werne and Hicks are seeking answers to several important questions about the Crenarchaeota in Lake Superior and other large lakes. Their studies are showing that these microorganisms contain a gold mine of information: their "fossils" hold information about temperature change over millennia, and some of the living microbes appear to play a key role in cycling nitrogen.

UMD, the Netherlands, and Large Lakes of the World

UMD is at the forefront in the research about these elusive microorganisms in great lakes. Both Werne and Hicks are on a quest to find answers.

Werne participated in early research on chemical compounds produced by crenarchaeons at the Netherlands Institute for Sea Research. After arriving at UMD in 2002, he was eager to continue his biogeochemical research into the "paleoenvironmental questions that can enhance our understanding of the evolution of the earth." Scientists have known that chemical clues can provide a way to measure climate change, but the quest has been to find a reliable temperature "proxy" — something that reacts to temperature change and leaves behind a record. From Werne's research, it looked like lipids found in the cell membranes of the Crenarchaeota might provide that proxy.

"The compounds in the membrane surrounding archaeal cells have been called 'molecular fossils,' " Werne explained. "They allow us to look at life that we can't look at any other way — both ancient and modern."

Partnering again with the Netherlands Institute, Werne and Ph.D. student Lindsay Powers conducted a preliminary study that analyzed sediments from four large lakes: Superior, Michigan, Malawi in East Africa, and Issyk-Kul in Kyrgyzstan. Lipids from crenarchaeotal cell membranes were found in the sediments of all four lakes. They published the results of this research in 2004, reporting that the diversity of these microbial compounds in sediments — the proxy — were found to correlate "very strongly" with the annual mean surface temperatures of lakes. They suggested that these compounds might provide a way to reconstruct past temperatures in continental systems around the globe.

Crenarchaea: The studies of Werne and Hicks are showing that these microorganisms contain a gold mine of information: their "fossils" hold information about temperature change over millennia, and some of the living microbes appear to play a key role in cycling nitrogen.

Werne has been studying the Crenarchaeota in Lake Malawi, East Africa, and Elk Lake in Itasca State Park, Minnesota. The Lake Malawi work has already resulted in a reconstruction of temperatures 700 years ago, 25,000 years ago, and 70,000 years ago.

"We're pushing this back 200,000 years to compare the temperatures with the history of human evolution and migration in the East African Rift Valley," he said. Studies continue in other East African lakes such as Lake Turkana, Lake Victoria, and Lake Albert, as well as some lakes in Mexico, but the Lake Superior location is the only place where sediment traps are being used.

Back to Lake Superior's Crenarchaeota

In the fall of 2004, Werne teamed up with Hicks to conduct research exploring Crenarchaeota ecology in Lake Superior to learn more about why and how the molecular fossils left behind by these microbes reflect lake surface temperatures from the past. They also want to find out what roles these microbes play in freshwater environments — in other words, what are their "jobs?" They hope to answer important, basic questions about these microbes: When during the year are they produced? Where do they live and grow in lakes — in the surface water, in the middle, or near the bottom? Do cold bodies of water contain as great a diversity of the Crenarchaeota as warm

water ecosystems?

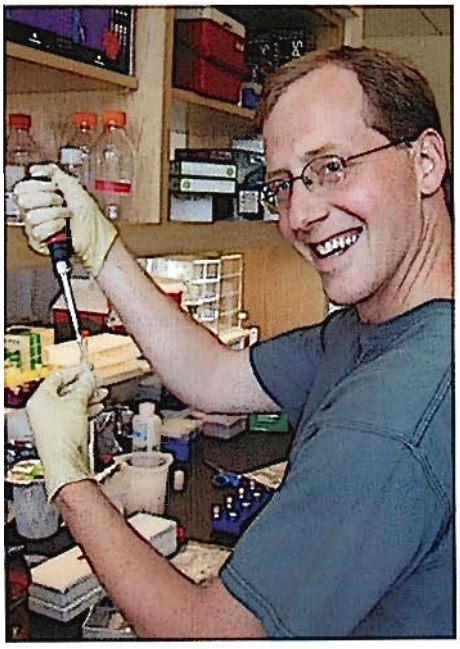
Werne and Hicks began an NSF-funded research project, Linking Archaeal Membrane Lipids and Ecology in Great Lakes, in 2005. Each May and September, a group of six scientists, including undergraduate science majors, master's and doctoral candidates, and professors from UMD, visit their research site in the middle of Lake Superior — a spot halfway between the Apostle Islands and Isle Royale — to collect microbes from the water and materials from the sediment traps.

"The sediment traps are essentially big funnels," Werne said. One sediment trap is submerged in the lake at 145 meters (about 475 feet), while another is sent down to 60 meters (about 197 feet) and left there to collect samples. Eighty-four samples are collected each year by the sediment traps.

Once the samples are brought back to the lab, portions of each are prepared for different analyses. A doctoral candidate, Martijn Woltering, travels to the Netherlands twice a year to process samples through their liquid chromatograph/mass spectrometer, which generates data about the lipid compounds found in the cell membranes. While back at UMD, graduate student Jason Kish and undergraduates process DNA samples in Hicks' lab that were extracted from microbes in the water and trap samples.

A breakthrough in understanding the Crenarchaeota's role or "job" came in 2005, according to Hicks. Evidence from studies in three different marine ecosystems suggested that at least some of these microbes might be oxidizing ammonia — catalyzing the conversion of ammonia to nitrate. Hicks and his students have found the crenarchaeotal gene that catalyzes this conversion in their Lake Superior samples.

"That's a pathway we didn't know about because this conversion was something scientists once thought only bacteria could do," he said. "We need to understand how the Crenarchaeota are influencing the lake nitrogen cycle, and ultimately, their role in the global nitrogen cycle." All organisms on earth use nitrogen to create proteins, a major chemical building block of their bodies.



Randall Hicks

Graduate student Jason Kish extracts microbial DNA from filters to identify crenarchaeal micro-organisms and compare archaeal communities from different depths in Lake Superior.

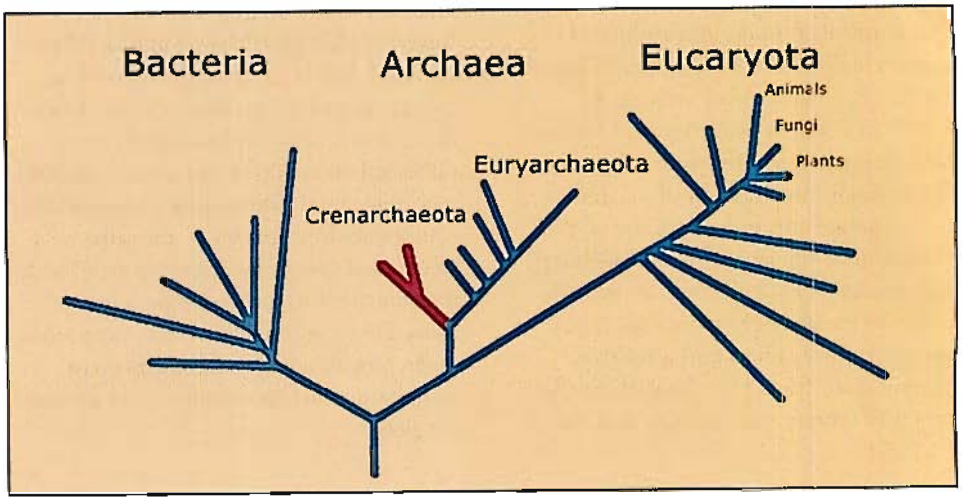
A continuous, century-long increase of nitrate in Lake Superior's waters was discovered by other researchers and a recent study suggested that most of the nitrate may be accumulating from biological processes within the lake and not from new inputs of nitrogen. UMD and LLO scientists hope continued research will show why.

Ground-Truthing Stage

The discovery of Crenarchaeota in colder aquatic systems has opened abundant opportunities for research within the scientific disciplines of geology, chemistry, and biology.

"We're been searching for a good temperature proxy for lakes, and we think we've found it. Right now, we're at the early, 'ground truthing' stage," Werne said.

"One of the signs of a good science project is you generate as many questions as answers. There's more than a career's worth of work here," Hicks added.



UMD's Large Lakes Observatory made scientific news when it found Crenarchaeota in Lake Superior and other large lakes in the U.S., Africa and Kyrgyzstan. Archaeal microorganisms were found, through studying their RNA, to be nothing less than a major new "branch" of life. The other two major branches or "domains" are the Bacteria and the Eukarya — the branch that leads to plants and animals.

PROFILE

Joe Werne:

Curiosity about Earth's Systems

When Josef P. Werne spent two years at the Royal Netherlands Institute for Sea Research (NIOZ), he didn't know the connection would lead to one of the Large Lakes Observatory's (LLO) most significant discoveries. Joe stayed in touch with his Netherland colleagues and when they published their findings about oceanic microbial biogeochemistry, Joe passed the information on to LLO's Tom Johnson.

So, on a cold day in Duluth, Tom Johnson burst into Joe's office with the NIOZ paper and exclaimed, "We've got to try this!" It was a moment that would direct the major focus of Joe's research for the next five years. NIOZ had determined temperature variations over millennia by collecting and testing microbes from the bottom of the ocean. Werne and Johnson, along with UMD grad student Lindsay Powers, sent collected microbe samples from Lake Superior, Lake Michigan, Lake Issyk Kul in Central Asia, and Lake Malawi in Africa to the team in The Netherlands for testing. The samples came back positive with reasonable readings for each lake. The readings formed the first fuel for the research conducted by Joe and LLO and resulted in a number of papers and research projects that continue today.

Joe's mom insists that he has aquatics in his genes because his grandfather served as a captain in the Navy. But Joe says his early scientific career influences came from his high school chemistry teacher, "She made the class really engaging," Joe said.

At Denison University in Ohio, Joe's geology professor was so influential Joe changed his major and ultimately his world view. "My overall intellectual goal is to examine how Earth's systems operate," Joe said.

Geology morphed into biogeochemistry and oceanography and the outcome was a Ph.D. from Northwestern University and a two-year postdoctoral fellowship in the Netherlands.

He's been at UMD since 2002 and said, "The LLO is one of the most collegial places I've ever been. Faculty and researchers have diverse interests: paleography, biology, chemistry, physics. There's so much collaboration because we're all in the same hallway, and we bounce ideas off each other all the time."

Cheryl Reitan

PROFILE

Martijn Woltering:

UMD Connections

"My biggest problem with being around only chemistry people," said Netherlands native and former UMD chemistry major Martijn Woltering, "is that they always think inside the box. But if you're also around geologists, microbiologists, and other scientists, you come up with and produce much broader perspectives."

University of Minnesota

Martijn recently earned his Master's of Science degree, and is now working toward his Ph.D. in the University of Minnesota's Water Resources Science program. At UMD and the Large Lakes Observatory, Martijn gets to feed his desire for eclectic perspectives. He works with fresh water, but he's still well connected to the Netherlands Institute for Research; he works with UMD's Joe Werne and Tom Johnson on paleoclimate research, and with Randall Hicks on molecular biology studies.

"By combining all our efforts, we can have a diverse study, and many lines of evidence for our conclusions," he said.

Martijn also enjoys the multiple perspectives provided by combining research with work as a teaching assistant. "I find it quite rewarding," he said. "It's nice to see when some students get it. In the beginning, they follow directions and don't think. At the end of a semester, when they see the light and really get into what they're studying, it's nice to see they've made some connections.

"A good scientist should make connections between fields, and not focus too much on one little aspect of a field or a question. It's interesting for students to do that, too — to combine study of chemistry, biochemistry, geophysics, and other fields," Martijn explained.

And once his doctoral work is complete Martijn is open to teaching and researching anywhere. "At this point I'm wide open," he said. He studied in Finland as an undergraduate in an area that required him to learn some Swedish, which gave him confidence about living and studying abroad.

"It encouraged me," he said. "I knew I could do it."

A View From the Lake:
Lessons of the Shoreline

Minnesota Sea Grant's "A View From the Lake" boat trips are not strictly pleasure cruises. Western Lake Superior residents and visitors have opportunities to get muddy and sometimes wet, as well as enjoy the rather rare chance to see their communities from the water.

Annually for the past several summers, Sea Grant has teamed with the University of Wisconsin-Superior to offer low-cost, three-hour cruises from ports in Minnesota and Wisconsin. The programs change each year, but share a focus on proactive approaches to improving Lake Superior water quality. Topics covered in past programs include climate change, sustainable development, the importance of wetlands to fisheries, and the role of forests in protecting water quality.

"We talk about how our individual and community land use decisions impact water quality," said Jesse Schomberg, Minnesota Sea Grant coastal communities educator.

At some point, the boat stops and equipment is lowered over the side to grab water samples and mud from the lake's bottom. Once the samples are onboard, participants can poke and prod the mud to see what they find. They can also look at the tiny water plants and animals under a microscope. Some trips include board games where players must decide the best way to develop land.

About 500 people venture out on the cruises each summer and the things they learn stick. Surveys show that 60 percent of attendees gained new ideas or knowledge that would help them take action in both their homes and communities. Forty-three percent of returning participants took action between trips, including speaking about Lake Superior, sharing information, and even working on their own septic system.

Western Lake Superior residents and visitors have opportunities to get muddy and sometimes wet, as well as enjoy the rather rare chance to see their communities from the water.

Becky Norlien, a Two Harbors resident, appreciated learning about the relationship between the water and the land. "I am very strongly attached to the lake and want to learn all I can about protecting it. I'm grateful for another opportunity to learn more," she said.

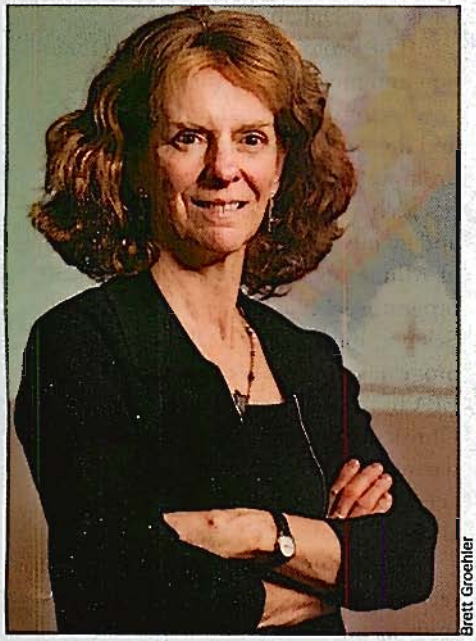
Jeff Gunderson

Lake Superior educational boat trips give residents a chance to think about land development and its impacts on the lake. Here, a View From the Lake boat trip participants play a land use game aboard the *L. L. Smith, Jr.*

PROFILE

Cindy Hagley:

From Field Researcher to Facilitator



Brett Groehler

Cindy Hagley, education coordinator for Minnesota Sea Grant, has a love affair with fresh water that started during summers spent at her family's ramshackle cabin in north central Minnesota on Deer Lake. "There was no TV, just my five brothers for playmates," Hagley said. "With a beautiful lake in front and wetlands behind us, my childhood was very much water-based."

When Hagley reached adulthood, she continued to seek water and the outdoors, even designing her own college major in field biology at the University of Minnesota Twin Cities.

After graduation, she lived in a mecca for frozen water — the Antarctic. Hagley worked for three seasons shaping sheet metal for a contractor to the U.S. Antarctic Research Program. Eventually, a graduate degree lured her to warmer water at the University of California Davis, where she studied freshwater ecology in a mountain lake.

Next Hagley hovered in helicopters over lakes across the country collecting samples for the Environmental Protection Agency's (EPA) National Surface Water Survey. After four years based in Las Vegas, Hagley wanted to return to water-rich Minnesota.

Back in Minnesota, she worked as a contractor for the EPA's Mid-Continent Ecology Laboratory in Duluth. Hagley's passion for water continued through her work on the National Wetlands Research Program.

In 1993, Hagley joined Minnesota Sea Grant, where she shares her love of water with others as an extension educator, facilitator, and education coordinator. Hagley brings real world issues into classrooms and communities through innovative programs, including educational Web sites such as Water on the Web (www.waterontheweb.org) and Lake Superior Streams (www.lakesuperiorstreams.org), the University of Minnesota Extension shoreland management program, and educational cruises through the bi-state "A View From the Lake" program.

"This is the longest I've been at any job, primarily because it's so wonderful to work in a community that's committed to researching, managing, and teaching about fresh water," Hagley said.

Training Opportunities

Aquatic Sciences

Ecological education and research, especially in the aquatic sciences, have historically been strengths at the University of Minnesota Duluth. UMD provides outstanding opportunities to train with aquatic scientists and obtain either a master of science or doctorate degree.

Central to the University of Minnesota's identity as a top research university, the graduate school provides quality graduate education and postdoctoral services. Prospective students interested in aquatic sciences and policy can obtain a graduate degree in one of two interdisciplinary degree programs at UMD.

Water Resources Science

In the Water Resources Science graduate program, students are trained in a holistic manner to prepare to solve complex problems in managing and researching aquatic systems. Excellent research and classroom opportunities and faculty from 25 departments on both the Twin Cities and Duluth campuses enhance the program. Students are able to develop the breadth of scientific knowledge needed to understand complicated aquatic ecosystems and watersheds.

Water Resources Science has three educational goals: produce scientists with strong technical skills; develop a holistic understanding of the hydrologic cycle and associated ecosystems, as well as the interconnectedness of the sciences needed to understand and manage aquatic resources; and generate an understanding of the interplay between the bio-physical sciences and the social sciences in developing and implementing public policies related to water.

In addition to understanding complicated aquatic ecosystems and watersheds, students learn the social dimensions, including ethics, public policy, and legal frameworks in which water resources are protected and managed.

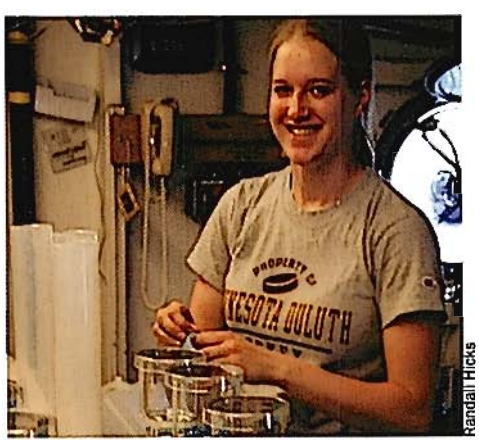
Integrated Biosciences

In the last decade, integration of the biological sciences has changed the research paradigm for the study of life. Recent advances have revealed striking interrelationships in the structure and function of biomolecules, genomes, and cells. Molecular markers are providing new tools for detailed tracking of population dynamics. The vast amount of information generated in all sectors of biology, coupled with innovations in computer technology, have created a growing demand for scientists who can generate, manage, and analyze biological information. By emphasizing the greater picture of how biological subdivisions — from molecules to ecosystems — interact with each other, the Integrated Biosciences program provides a dynamic new approach for training future scientists and educators.

The program provides training in integrative biology through the following mechanisms:

- required courses in integrated systems approaches in biology, advanced evolutionary biology, experimental design, animal and plant physiology, and professional practice and ethics;
- student research/journal clubs;
- colloquia on current topics of faculty research; and
- specialization in either a cell, molecular, and physiological biology emphasis or an ecology, organismal, and population biology emphasis.

Students investigate topics ranging from the genomic, cellular, and physiological consequences of an organism's interaction with its environment and the genetic basis of adaptation to the flow of energy and materials through ecosystems and the globe. Students receive experience with cutting-edge technology so they will be competitive in academic, industrial, and governmental settings.



Randall Hicks

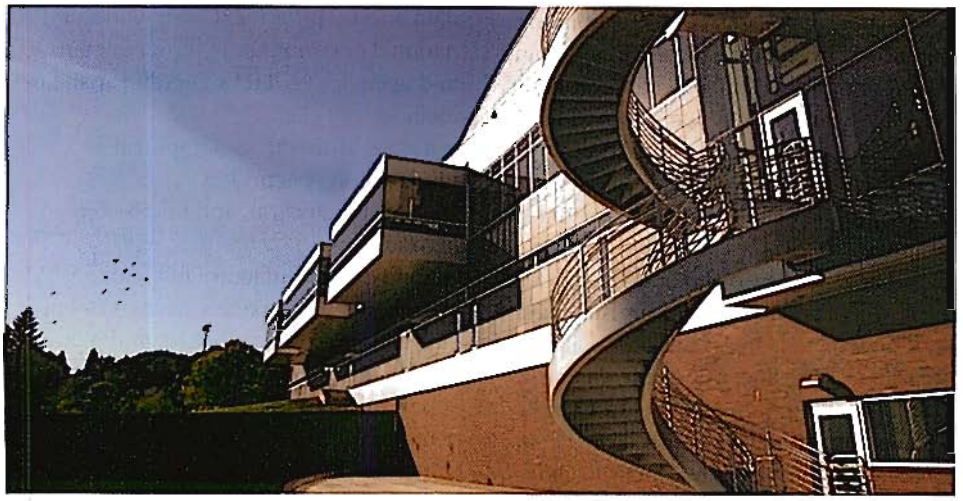
UMD biology graduate Jenna Bergin filters microbes from water as part of an ongoing study of Lake Superior microorganisms

Aquatic Toxicology and Ecosystem Research

The breadth of the University of Minnesota's research and graduate degree programs that relate to the Environmental Protection Agency's mission provides a solid foundation for a successful research training partnership. The UM-EPA Cooperative Training Partnership in Aquatic Toxicology and Ecosystem Research was created to train graduate students, postdoctoral investigators, and undergraduate researchers in aquatic toxicology and ecosystem science. UMD's excellence in aquatic sciences is one of the key reasons the partnership was established in Minnesota. There is a rich and successful history of cooperative research and student training between scientists at UMD and the EPA National Health and Environmental Effects Laboratory-Mid-Continent Ecology Division in Duluth, Minn.

The program seeks to attract the best and most diverse students and postdoctoral investigators from the nation and the world. Participants in this special program are cooperatively trained by researchers from the Duluth EPA lab and faculty members at the University of Minnesota through existing graduate programs such as the Water Resources Science and Integrated Biosciences programs. Researcher advisors from the EPA have faculty appointments in various University of Minnesota programs and the partnership provides students unparalleled access to scientists, training, and facilities at the EPA laboratory in Duluth.

The northern Minnesota and Wisconsin regions provide great opportunities for studying aquatic ecosystems but students in this training program are also involved in research projects of regional, national, and even international scope. All graduate students are supported by research assistantships with tuition waivers, although some also choose to obtain instructional experience as graduate teaching assistants. Students are encouraged, and the program partially supports travel costs, to present their research results regularly at scientific meetings. For more information about this unique program, visit the UM-EPA Cooperative Training Partnership Web page at www.d.umn.edu/cfrp/epa_ctp.htm.



University of Minnesota Duluth

Swenson College of Science and Engineering

The Swenson College of Science and Engineering (SCSE) is the largest college on the campus of the University of Minnesota Duluth (UMD). Its undergraduate and graduate enrollment is over 2,500, and 140 faculty members are associated with the college. The college offers undergraduate and graduate degrees in engineering, physical sciences, life sciences, mathematics, and computer sciences. It also houses or is associated with the following aquatic research institutes: Center for Freshwater Research and Policy, Great Lakes Maritime Research Institute, Large Lakes Observatory, Minnesota Sea Grant, and the Natural Resources Research Institute.

The Swenson College of Science and Engineering has a fourfold mission: to help each student develop a foundation for a career by learning the substance and methods of an academic discipline; to participate fully in the liberal education mission of the campus; to foster significant scholarly research; and to serve the well-being of the community, state, and region.

The SCSE faculty are active and productive in research. They bring to the university substantial sums in research grants and produce hundreds of publications each year. The undergraduates are bright, ambitious students who come from the top third of their high school classes, and upon graduation from UMD, move to successful careers or graduate study. The graduate students represent a balance of national and international scholars who enjoy close associations with their professors and opportunities for research. SCSE faculty and students both benefit from and contribute to the School of Medicine and College of Pharmacy located on the UMD campus.

Center for Freshwater Research and Policy

The UMD Center for Freshwater Research and Policy facilitates communication among scholars from various fields including the Large Lakes Observatory, Natural Resources Research Institute, and Minnesota Sea Grant, who are working on issues in freshwater research and policy, and attempts to foster communication between those working in this area at UMD and various external constituencies.

The goals of the center are to:

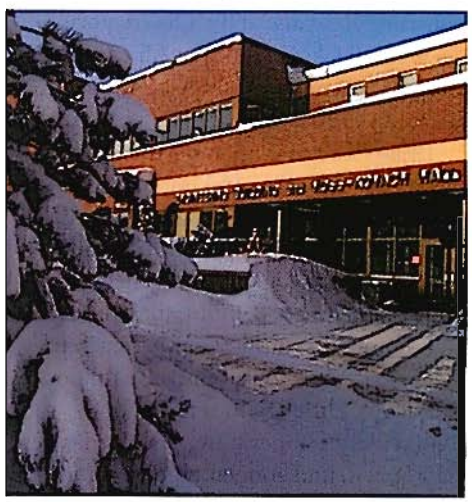
- promote freshwater research and policy work being conducted at UMD
- establish or sponsor special events that foster communication among aquatic scholars, private and governmental organizations, policy makers, and the public
- facilitate collaborative efforts in aquatic research and freshwater policy issues
- expand international cooperation in freshwater research and policy
- create national and international opportunities for training in aquatic sciences
- address inquiries by decision makers and stakeholders about freshwater issues, threats, and solutions

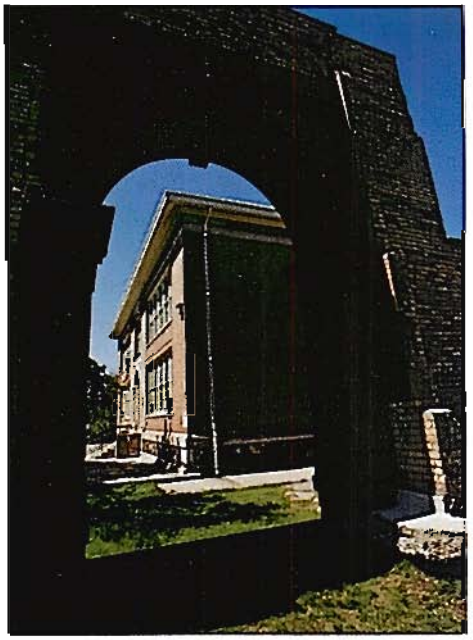
Duluth, Minn., offers an ideal natural environment for the study of fresh water. It is situated on the shores of Lake Superior, the largest of the Great Lakes, and down the road from the Boundary Water Canoe Area Wilderness, in the heart of Minnesota's 'land of 10,000 lakes.' The region also features a variety of groundwater aquifers, rivers, and wetlands.

Amid this unique landscape, Duluth has become an internationally recognized center of excellence for research in fresh water. The conjunction of universities, research institutes, federal and state agencies, and the local aquarium make Duluth a thriving center for research and dissemination of knowledge on freshwater issues. The Center for Freshwater Research and Policy is engaged in an ongoing effort to coordinate activities and promote communication among these entities.

Examples of these endeavors include the Twin Ports Freshwater Folk, a monthly informal gathering of people engaged in freshwater research, policy, or regulation issues; the Distinguished Aquatic Scholar Series; the UM-EPA Cooperative Training Program in Aquatic Toxicology and Ecosystem Science; and the attraction and support of major national and international meetings on aquatic sciences to this region.

For more about the center see: www.d.umn.edu/cfrp/.





Large Lakes Observatory

The Large Lakes Observatory (LLO) is located in the Research Laboratory Building at the University of Minnesota Duluth. It is the only institute in the country dedicated to the study of large lakes throughout the world. Scientists focus on the global implications of oceanographic-style investigations in the areas of lake ecology, aquatic chemistry, circulation dynamics, geochemistry, acoustic remote sensing, sedimentology and paleoclimatology. The 10 faculty within LLO hold joint appointments with the relevant basic science departments in the Swenson College of Science and Engineering. LLO currently has 17 graduate students who are pursuing M.S. or Ph.D. degrees in Biology, Geological Sciences, Chemistry, Physics or Water Resource Sciences, and three Postdoctoral research associates. Research at the Observatory ranges from lakes in the East African Rift Valley, China and Central Asia, to the Great Lakes of North America.

The LLO also operates the largest academic research vessel in the Great Lakes, the R/V *Blue Heron*. The *Blue Heron* carries a broad suite of instrumentation for the physical, biological, and geochemical study of the water column, including a hull-mounted acoustic Doppler current meter, a Triaxus-towed instrumentation platform outfitted with sensors for conductivity, temperature, dissolved gases, chlorophyll, and zooplankton size and abundance. Geological investigations are supported by multi-beam sonar, high- and low-resolution seismic reflection profiling, and side-scan sonar systems aboard the vessel. These instruments and several coring systems allow acoustic imaging and sampling of the lake floor and the sediments below.

The *Blue Heron* is also outfitted for the deployment and recovery of instrumented moorings on the Great Lakes, as well as for routine sampling of water, sediments, plankton, and fish. In addition, LLO has an autonomous underwater vehicle that is capable of adjusting its buoyancy to glide across broad areas of Lake Superior while diving to the lake floor and rising back to the surface, measuring water column parameters and communicating results and geographic position back to a station onshore.

The LLO has well-equipped laboratories for a diverse suite of biogeochemical analyses of water, biota, and sediments, including instrumentation for light stable isotope mass spectrometry, liquid and gas chromatography, flow cytometry, and scanning X-ray fluorescence.

Natural Resources Research Institute

Minnesota legislators in the early 1980s, realized how vitally important natural resources are to the state's economy, as well as how vulnerable those resources are to environmental degradation. In 1983, the institute was signed into legislation and in 1985, it was given a home in an abandoned air force building, the Semi-Automatic Ground Environment (SAGE) near Duluth's airport.

The 120,000 square feet of cavernous spaces were remodeled with matching funds from the U.S. Economic Development Administration, transforming it into exceptionally functional offices, laboratories and pilot plant space.

True to its mission to promote economic development, many of the versatile laboratories and testing facilities are available for use by regional businesses. Scientists also provide valuable data and tools for local, state-wide, and national environmental resource managers and agencies. NRRI's Duluth capabilities include:

- a state-of-the-art geographical information systems lab.
- water quality, soil, and microscopy laboratories.
- ability to manufacture full scale engineered wood panels, such as oriented strandboard, particle board, and plywood.
- a chemical extractives laboratory with a supercritical fluid extractor.
- minerals processing and three-dimensional mineral deposit mapping.
- four rapid prototyping technologies for cutting-edge product development.

An NRRI lab in Ely, Minn., is equipped for research on biological and chemical indicators of water quality, and analyzing sediment profiles to understand environmental trends. The research on freshwater ecosystems focuses on using algae as indicators of environmental changes.

In 1986, NRRI acquired a minerals research laboratory on Minnesota's Iron Range from U.S. Steel. With a staff of 25, the lab is one of the premier mineral processing laboratories in the nation. Many projects are underway to improve the cost efficiency of taconite processing and make quality pellets. Research is also being conducted on iron nodules for electric arc steel plants, products from taconite waste rock, as well as alternative energy technologies and resources.

Near Zim, Minn., NRRI manages 500 acres of previously drained peatlands where important sphagnum bog restoration research takes place.

Minnesota Sea Grant

Did you know that Minnesota is home to a sea? To the federal government, Lake Superior and the other Great Lakes are defined as inland seas. Because of that, they have the support of the National Oceanic and Atmospheric Administration (NOAA) through the national Sea Grant Program. This network of 30 university-based programs works to solve coastal challenges. Environmental stewardship, long-term economic development, and responsible use of coastal resources are the heart of Sea Grant's mission.

The Minnesota Sea Grant Program at UMD focuses federal and state dollars on research to help understand Lake Superior and Minnesota's other aquatic resources. The program also communicates this information to the curious and to those who most need to hear it through a combination of research, outreach, and education.

Minnesota Sea Grant projects take on complex issues such as sustainability, pollution control, and climate change. The program is breaking ground in areas like genetic engineering, persistent environmental toxins, endocrine disrupting compounds, and invasive species. Every two years, Minnesota Sea Grant provides about $1 million to fund six to eight research projects and graduate research assistants at Minnesota academic institutions.

Minnesota Sea Grant's dozen outreach and education staff members take the researchers' findings, along with other information, and convey them to resource users, managers, decision-makers, and other academic institutions. Staff members use a variety of methods including workshops, conferences, presentations, newsletters, Web sites, and the news media. Since its inception in 1975, Minnesota Sea Grant has generated over 685 publications, making the program a veritable fountain of freshwater information.

Minnesota Sea Grant staff members also facilitate public policy discussions and forums. They team with non-Sea Grant institutions, agencies, and businesses to pursue externally funded projects that fit with Sea Grant's mission.

To find about more about Lake Superior and what Minnesota Sea Grant is doing, visit: www.seagrant.umn.edu.

UMD Partners: EPA

Environmental Protection Agency, Mid-Continent Ecology Division

The U.S. EPA's Mid-Continent Ecology Division (www.epa.gov/med) is a unit of the Agency's Office of Research and Development, National Health and Environmental Effect Laboratory. The division, with laboratory facilities in Duluth, MN, and Grosse Ile, Mich., is responsible for conducting studies that serve the research and development needs of the agency's regulatory programs and regional offices.

Research themes of the division are in four primary areas: predictive ecotoxicology modeling, assessment of toxic effects, ecosystem analysis and assessment, and ecosystem modeling. These programs deliver approaches, methods, and models to advance the agency's protection of freshwater species, populations, and ecosystems. Division facilities include research laboratories, vessels for use in rivers and lakes, a research library, and computing systems. A number of division research scientists hold graduate faculty appointments with the University of Minnesota programs, including the Integrated Biosciences graduate program, the Water Resources Science Program, the Toxicology Program and Conservation Biology Program. The division supports a "Cooperative Training Partnership in Aquatic Toxicology and Ecosystem Research" with the University of Minnesota, that is a vehicle for funding and mentoring graduate students and postdoctoral scientists through these University of Minnesota programs. Division researchers frequently collaborate with faculty and graduate students of the University of Minnesota.

The division is a center of excellence within EPA's Office of Research and Development for predictive ecotoxicology modeling and assessment, and for ecological assessment and modeling of large complex freshwater systems, such as the Great Lakes and Great Rivers. Research at the division is national and international in scope and scale. Division scientists are active in various scientific societies and publish in national and international scientific literature. Research staff serve on editorial boards of a variety of international journals. They represent the agency in regional, national and international forums and work groups, such as the Ecological Risk Assessment Forum, Metals in the Human Environment Research Network, and workgroups of the International Joint Commission and the Organization for Economic Cooperation and Development.

The division operates high-quality laboratory facilities that are equipped to support state-of-the-science research. The division also seeks to minimize its own environmental footprint through conservation of energy, water, and materials.

MPCA

Minnesota Pollution Control Agency

Amid a growing awareness of the environment's vulnerability, the Minnesota Legislature created the Minnesota Pollution Control Agency in 1967 to protect the state's natural resources and serve the public's desire for clean air, land, and water.

Pollution-control efforts have since yielded stunning results: the environment is cleaner now than it was 40 years ago in spite of a growing economy and population. After years of addressing end-of-pipe "point source" pollution, the agency began tackling the next generation of "nonpoint" environmental challenges: energy, biological monitoring, greenhouse gases, and a host of newly-emerging issues.

Evolving regulatory and compliance programs and services support large and small industrial and municipal facilities; wastewater, stormwater, and solid waste operations; remedial and voluntary cleanup programs; pollution prevention and environmental education; technical and financial assistance; and, emergency response.

The MPCA-Duluth office's 60-plus staff not only serve northeastern Minnesota's seven counties, they manage binational and Great Lakes-specific programs and activities including the Lakewide Management Plan, ballast water permitting, accelerated impaired water monitoring and research, watershed capacity development, and contaminated "hot spot" remediation.

Agency partnerships with researchers, educators, environmentalists, industry, local, state, federal and tribal governments, and the public have helped make Minnesota an effective environmental-protection collaborator.

MN DNR

Fisheries

The Minnesota Department of Natural Resources (MN DNR) French River Fisheries Headquarters houses four separate entities responsible for managing the fisheries resource in much of northeast Minnesota. The Lake Superior Area is responsible for Minnesota's portion of Lake Superior from Duluth to the Canadian border. The Duluth Area is responsible for fisheries management in the streams and lakes of Carlton and southern Saint Louis counties. The Research Unit supports management by working on important projects that may impact management strategies, and the French River Cold-water Hatchery produces fish for stocking in both Lake Superior and inland waters.

The MN DNR works closely with the public and has developed a number of public outreach programs that include public advisory groups, scheduled quarterly meetings with local sportsman's groups and environmental organizations, semi-annual newsletters, specific meetings, and various workshops and conferences.

Since 1989, the Lake Superior Area has cooperated with local universities, including UMD, to employ students during the summer field season. This long-standing program allows students to work closely with Lake Superior Area staff on a variety of projects. Students also spend time with each of the other entities at the French River Headquarters so they receive a comprehensive understanding of the work performed at a state fisheries management agency. This program has been extremely valuable for both the students and the MN DNR, as a number of interns have eventually been hired by the MN DNR or continued on with graduate work in fisheries science.

MN DNR

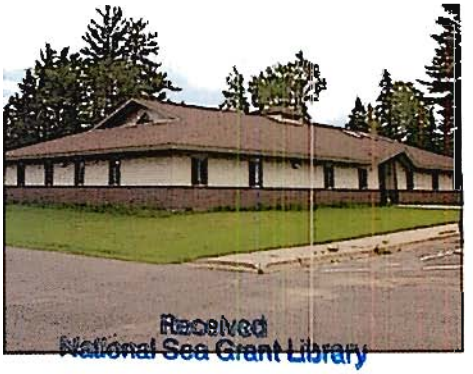
Lake Superior Coastal Program

The Minnesota Lake Superior Coastal Program's mission is to preserve, protect, restore, and enhance coastal resources for present and future generations. Since 1999, the coastal program has awarded nearly $8.3 million in grant funds to the coastal community.

The program's goal is to achieve a balance between natural resource protection and the needs of coastal communities to provide places to live, work and play. The program provides technical and financial assistance to local governments, nonprofit organizations, and other public entities to take care of Minnesota's cultural, historical, recreational, economic, and natural coastal resources.

Eligible applicants can apply for grants to fund projects addressing planning, outreach, public access, cultural, historic, and natural resource protection. The program also coordinates a Coastal Enhancement Program to address important coastal issues, including coastal hazards, cumulative and secondary impacts from development, and special area management planning. The Coastal Nonpoint Program addresses nonpoint pollution from source categories such as urban/rural development, forestry, and wetlands.

Funded by the U.S. Department of Commerce's National Oceanic and Atmospheric Administration through the Office of Ocean and Coastal Resource Management, Minnesota's Lake Superior Coastal Program is administered by the Minnesota Department of Natural Resources.



Randall Hicks

UMD undergraduate Ryan Oster collects water samples aboard UMD's research vessel, the R/V *Blue Heron*.

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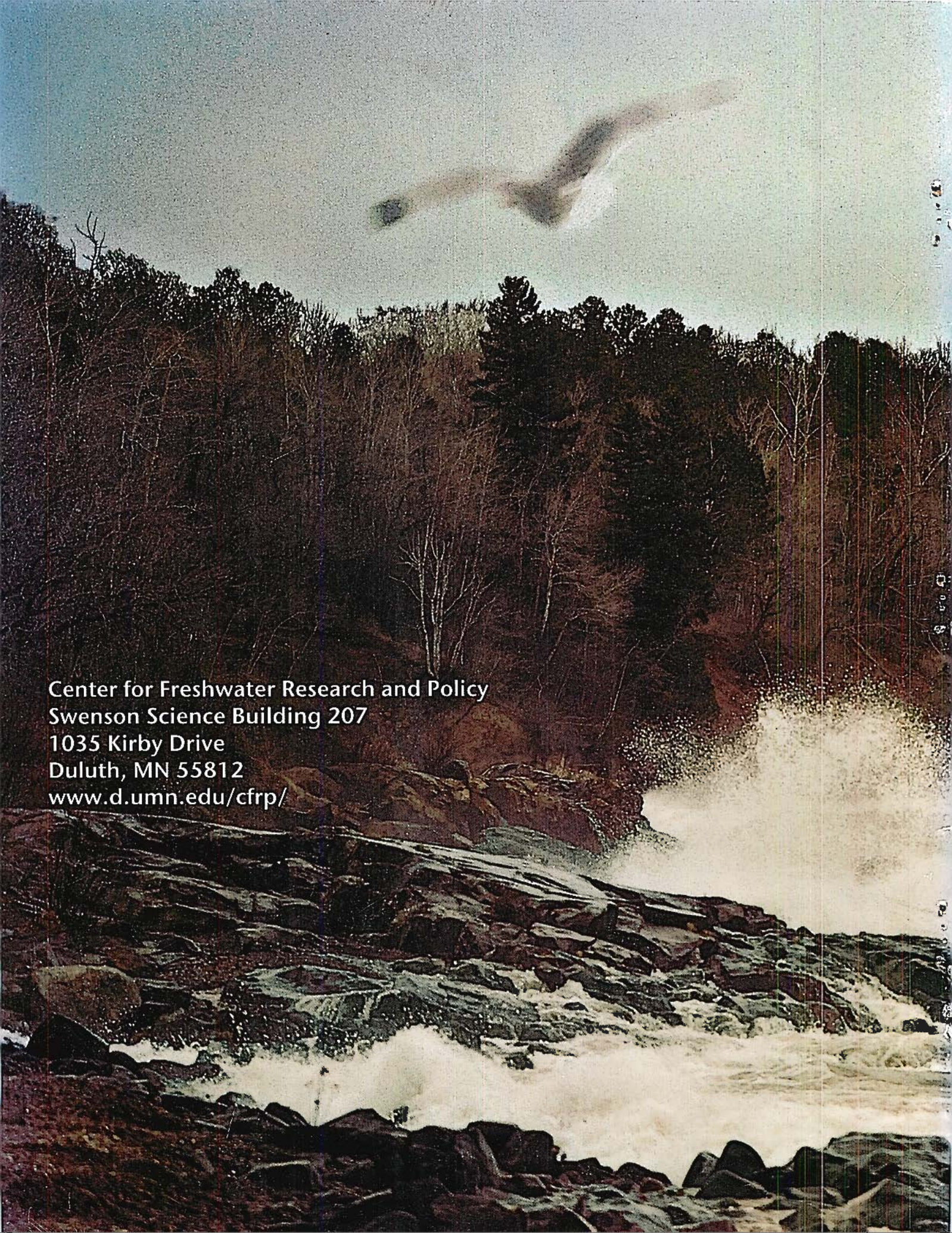

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