A GREAT UNIVERSITY ON A GREAT LAKE

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NATURAL RESOURCES RESEARCH INSTITUTE

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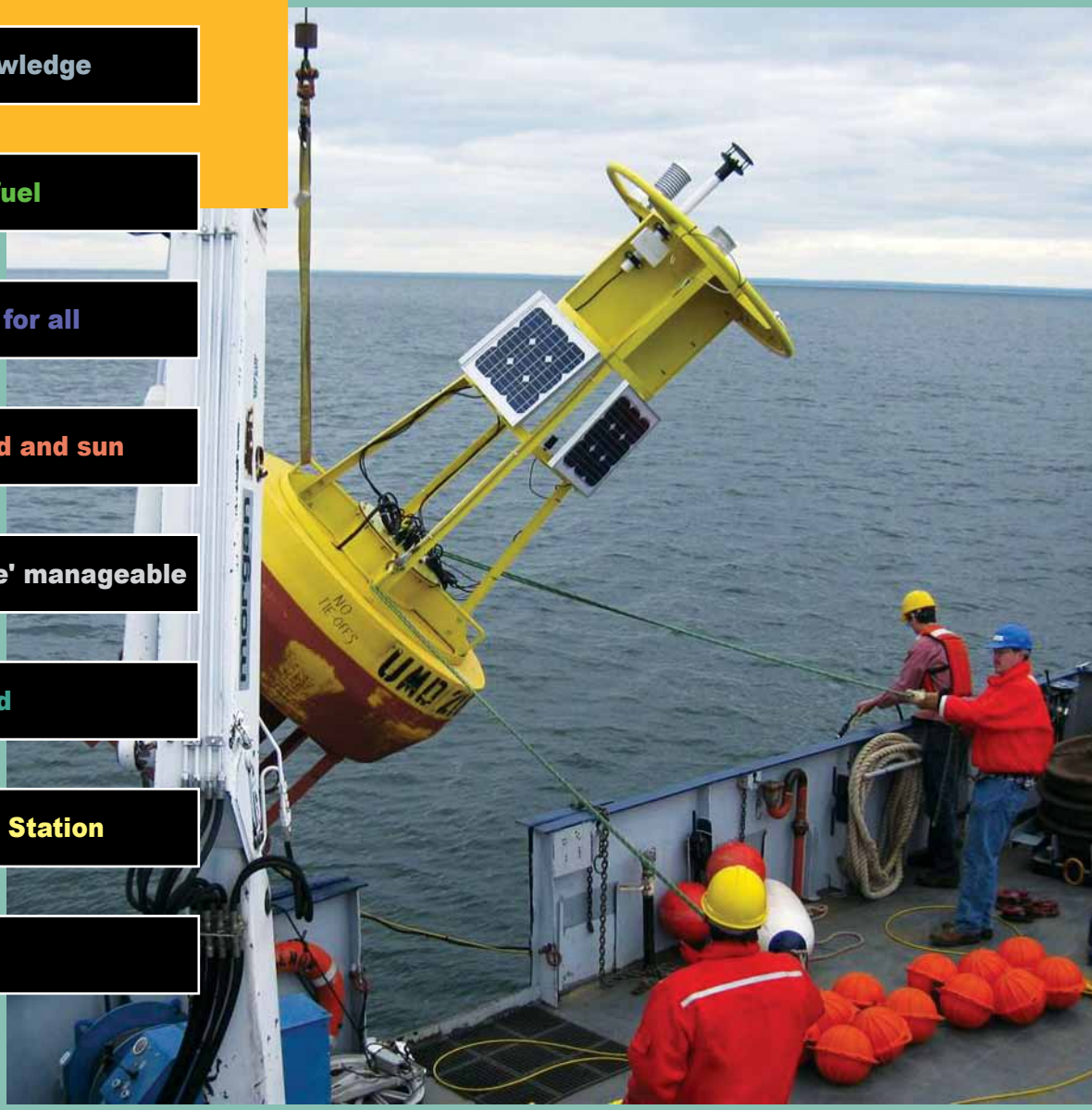


UMD's Large Lakes Observatory goes deep to complement NRRI water research.

~Growing Strong Industries
~Developing New Ideas
~Nurturing Natural Resources

Cover Story

From trickling streams to the deep inland seas

Complementary research for freshwater knowledge

The value of freshwater for industrial processing, power generation, irrigation and to sustain life is indisputable. As usable water resources become increasing scarce world-wide, some investors are calling water "the new oil" as a valuable commodity, and it is recognized as a factor in many border disputes around the world.

As a university in the "land of 10,000 lakes" and given its proximity to one of the world's great freshwater resources, it's no surprise that UMD has developed extensive expertise to understand the complexity of these valuable but diverse water bodies.

While water research takes place in other University units, two programs in particular – NRRI's Center for Water and the Environment and the Large Lakes Observatory – focus their research in complementary, but uniquely different ways.

The Center for Water and the Environment focuses on how to manage natural resources sustainably – including fresh water in rivers, wetlands and lakes of all sizes – given the pressures of human impact.

The Large Lakes Observatory, on the other hand, was established in 1994 to bring oceanographic research techniques to the deep waters of the world's large lakes. LLO has the tools and the expertise to go deep, literally and academically, to gather fundamental information about how these freshwater resources work.

Four of the world's largest lakes hold half of the world's fresh surface water. The critical importance of these large water bodies drives LLO's mission. For the most part, LLO scientists study the offshore areas of the lakes with their deep water equipment to discover new things about large lakes – from sediment studies to large-scale responses to climate change.

NRRI-CWE scientists spend their time in waders and small boats studying the biology in the near shore regions and adjoining watersheds of the Great Lakes, where people and water interact most. To assist resource managers,

NRRI studies what is coming into the water from the landscape, and how it impacts the areas closest to the shore. What plants are thriving or just surviving? How are the bug and fish communities faring? Has the water quality changed over time? What types of management practices are most effective for protecting or restoring those systems?

"Lakes exist in a watershed and receive inputs from its catchment," said Bob Hecky, LLO limnologist. "That's where NRRI has its capacity. It's fundamental to know what's coming into the lake. Our research is naturally complementary, and Lake Superior is a focus for all of us here."

So NRRI and LLO researchers often meet up on Lake Superior. To handle the often rough, open waters of the Great Lakes, LLO has the R/V Blue Heron, an 86-foot long research vessel that can carry a crew of 11, and operate 24 hours a day for 21 days between ports. Its equipment has to tackle ocean-scaled depths to gather samples for physical and geochemical analysis. It's the only university-owned oceanographic laboratory on the Great Lakes.

The two organizations work well together on many projects. For example, LLO often turns to NRRI's Geographic Information Systems lab for its extensive spatial data capabilities and experience in understanding human impacts from the watersheds surrounding Lake Superior.

NRRI's public outreach expertise is also useful to LLO on their Global Great Lakes project. Funded by the University's Institute on the Environment, the project's goal is to collect vast amounts of data on the world's large lakes to understand environmental stressors for better long-term management. (It's similar in many ways to NRRI's multi-year bio-indicator research effort on the coastal zones of the U.S. Great Lakes.) For LLO's project, a variety of data was compiled that are not easily analyzed – food webs, water quality, weather, temperature and light penetration, for example. LLO turned to NRRI's outreach expertise.

"It's very much part of NRRI's mission to synthesize data and make it accessible to managers who are the end-users of this information," explained NRRI Scientist Rich Axler, co-leader on the project. To this end, NRRI has developed web-based data visualization tools for regional water resources and adapted the tools for the Global Great Lakes project.

In turn, NRRI turned to LLO limnologist Jay Austin for a harbor restoration project. Austin's expertise in hydrodynamic modeling was needed to understand how water flow might change in the St. Louis River estuary if islands and wind break berms were constructed. NRRI is working to restore wetland vegetation, fish and wildlife communities in the estuary that have been impaired by a century of industrial and urban activities.

"The challenge with water is in trying to understand the whole cycle, how water travels from the land, through the streams, to the estuary, to the deep water," Hecky added. "Each is a very different environment with different ecological processes taking place. They're related, of course, but it takes a variety of research and research techniques to study."

Turning a pest into fuel

NRRI works to turn Africa's invasive problem plant into fuel solution

NRRI research usually stays fairly close to home, but sometimes there's a need for NRRI expertise on the other side of the globe. Such is the case with NRRI research on biocoal – roasting biomass to make an efficient fuel source – and the country of Mauritania, Africa.

The wild Atlantic coast meets the Saharan sand dunes in this North African country which has more than its fair share of problems. Drought and terrorism are drastically changing what used to be a largely quiet, nomadic life. But Mauritanians are survivors and they hold tightly to ancient traditions. Those who still try to eke out a living from the land face two problems that NRRI and its partners hope to help solve with one solution.

Problem one: The area's once plentiful wood supply became seriously depleted after the drought of the early 1980s. Traditionally, that wood was made into charcoal for the Mauritanian's three stone fires, a system perfected over millennia to cook and heat water for washing.

"The degradation of the lands from the great drought and the following rural-to-urban migration without jobs created conditions for huge social and economic problems that are yet to be resolved," explained Peter Strzok, a consultant who is working with the villagers to improve their economic conditions. "And farmers lack an economically appropriate fuel source." Strzok works in partnership with the nonprofit Agency to Facilitate the Growth of Rural Organizations (AFGRO).

Problem two: Damming of the Sengal River in upriver Mali caused accelerated spreading of African cattails (Typha australis), which are taking over water sources and precious farmland. Oxygen is depleted which severely reduces fish populations. The plant is extremely prolific with an entangled root system that spreads rapidly. The river and tributaries are so choked with the plant that fishermen can't get into the water and attempts to pull it out just makes it spread faster.

Typha coal briquettes

Harvesting Typha in Mauritania

Meanwhile, NRRI has been testing a variety of biomass – wood, switchgrass, corn stover – as possibilities for local alternative fuel sources. Minnesota cattails also showed promise as burnable biocoal. So when NRRI obtained a large bag of cattails from Africa, it wasn't difficult for Scientist Tim Hagen to apply the process to the African Typha.

"To increase the biomass efficiency as a fuel source, we are testing dry torrefaction, or roasting, techniques as well as the emerging hydrothermal torrefaction process on the cattails," explained Hagen. NRRI is forming them into a variety of sizes – pellets, briquettes, pucks – to see what size the African people prefer for their stone fires.

"We are trying to convert a plant pest that adversely impacts the local villages along the Senegal River and turn it into a useful fuel that can help create a better future for all," added Don Fosnacht, NRRI center director and project leader.

Eventually, they hope this will create cattail harvesting jobs in Mauritania and start a biocoal production facility. The fuel could be used in their village and also sold to other communities, generating much needed income. The average salary to support a family in rural Mauritania is about $300 a year, and Strozk estimates they use about 40 percent of that on fuel.

Lake Superior Coastal Atlases

Putting big data in the hands of small communities

Gerry Sjerven and George Host

In this information-overload, instantaneous-sharing and pockets-full-of-gigabytes world, NRRI is going old-school.

The Institute's Geographic Information Systems specialists have pulled layers of detailed information from their computerized technical formats and made community atlases – the kind you can actually flip through, hands-on. Why? Because while there's been tons of data compiled on the geospatial layers of the coastal areas, it's only accessible in highly technical GIS formats. Townships and small municipalities don't typically have the expertise to access the important information.

"A printed atlas will allow city planners, land managers or educators in small towns like Beaver Bay or Canosia Township easy access to information about their area," explained NRRI's George Host, project leader. "They can look up things like forest cover types, at-risk waters and watershed borders at their local town hall."

The environmental data will be especially relevant for land use permitting, including the distribution of wetlands, bluffs or steep slopes, impervious surfaces, streams and lakes. In all, 32 townships and municipalities received hardcopy atlases for their area and two complete atlas compilations were also printed to be kept on file at the NRRI library and the Coastal Program in Two Harbors. The resulting maps are also available on DVD or can be exported as PDF or JPEG files.

The project is a collaboration with Minnesota's Lake Superior Coastal Program and funded in part by the National Oceanic and Atmospheric Administration.

Harnessing the wind and sun

Research underway to store energy in underground mines and caverns

It's well known that wind and solar power are viable, but intermittent, energy sources. Systems that can store their energy when it's abundant – nighttime for wind and sunny days for solar – then make it available when it's most needed are important pieces of the alternative energy puzzle.

Last year NRRI researchers, working with other University collaborators, studied the potential use of abandoned mine pits on the Iron Range for Pumped Hydro Energy Storage. They identified a number of deep mine pits in the area that could support a 100 to 200 megawatt wind storage facility.

This year, NRRI received a grant from the University of Minnesota's Initiative for Renewable Energy and the Environment (IREE), supplemented by $70,000 in matching funds, to research a similar – but different – process. Using abandoned underground mines or newly constructed mine caverns, Compressed Air Energy Storage can also store electrical energy for later use. The system pumps air into the caverns using energy generated at non-peak hours. Then, during peak energy use, the compressed air is allowed to expand through turbo-generators as needed.

NRRI's research will identify potential existing sites on the Iron Range, determine their constructability, and the viability of Compressed Air Energy Storage in this area. NRRI will also work with a non-ferrous mining company to determine if storage caverns can be planned into future mining activities.

Making 'massiv

Visitors to Minnesota's Iron Range are often awed by the size of the trucks used to haul rock to the taconite pellet plants. They're massive. The truck's tire alone is about twice the height of a full grown person.

But everything about turning low-grade ore into steel-making feedstock is huge. The process of blasting, crushing, separating, concentrating, mixing, pelletizing and firing takes super-sized equipment to get the job done. The Mesabi Iron Range's five taconite pellet plants each churn out hundreds of tons of product an hour. A visitor might find the enormous process surreal.

NRRI, however, is right at home there. Not only have NRRI engineers and technicians previously worked in Minnesota mining operations, they were often plant problem solvers.

"We know that world," said Dave Hendrickson, lab director of Strategic Development, himself a 23-year veteran from Cliffs' Hibbing Taconite. "We've experienced their problems, know the operation and have worked with the people in the mines, plants and control rooms."

That's extremely helpful when NRRI gets called on to help a taconite plant operate more efficiently. Even better, NRRI can mimic the whole pellet-making process on a much smaller scale and figure out ways to tweak the process to make it better. When you're dealing with ore going through the grinding mills at a rate of 400 tons an hour, water flows of 100,000 gallons per minute and air flows of 500,000 cubic feet per minute, efficiency is ultra-important.

"A very small improvement can result in huge savings for the plant," Hendrickson explained.

Mined rock is sent to NRRI when the taconite plants need research and development for process improvements. The entire plant process is simulated at NRRI's minerals lab starting with the pilot-scale crushing and size reduction mills all the way to concentrating the valuable minerals from the fine powder. Like the plants, NRRI removes the magnetic iron ore with magnet separators, then produce the hard iron pellets with an agglomeration process. The original mined rock containing 25 percent

Photo Credit: Cliffs Natural Resources

ve' manageable

iron is made into blast furnace feedstock containing roughly 67 percent iron through this simulated process.

"Over the last three years, NRRI has invested heavily in new pellet induration and sintering equipment that allows us to closely match plant processing conditions," explained NRRI Center Director Don Fosnacht.

With production goals to meet each day there's simply no extra time to evaluate changes on the plant floor. "In our research lab, we can change the parameters on the bench or pilot scale and make chemical and process equipment changes, then evaluate flowsheet improvements," Hendrickson added. "We ask, is the process at peak efficiency? Are there new technologies to test?"

The taconite plants also count on NRRI's computer modeling capabilities to test "virtual" changes in air, heat and water flow through the system. Again, because of the huge scale, small changes translate to big savings.

NRRI also stays informed on changes in the steel-making industry. Back in 1990, NRRI started research to meet the current trend of steel-making with electric arc furnaces. These mini mills use scrap steel and direct-reduced iron or hot briquetted iron as feedstock, as opposed to the blast furnaces which use taconite pellets. Electric arc mini mills now produce 62 percent of the U.S. steel and some taconite plants are considering altering their processes to provide iron feedstock needed to serve this growing steel market. NRRI's uniquely designed pilot scale iron nugget furnace and gas-based direct reduced iron processing capabilities are support these developments.

"Leveraging our capabilities at NRRI can ensure that Minnesota provides the iron bearing products needed by the steel industry of the future," said Fosnacht. "We must work with current operators and new entrants to recover the iron values in our mineral base in the most economical and environmentally sound way. If we do this, we will have an industry that will last for generations to come."

NRRI scales down the taconite pellet process flowsheet for efficiency

NRRI's pilot-scale autogenous mill (pictured here) grinds taconite rock at a rate of about one ton per hour. A commercial-scale grinding mill can run from 100 up to 900 tons per hour, depending on the plant and the ore.

LOCAL & ORGANIC

Sustainable food for sustainable communities

UMD revitalizes a farm – and a passion – for locally grown food

When NRRI's Center for Water and the Environment chiseled out their strategic goals in 2012, they included the goal to "develop innovative approaches to foster a sustainable, more diversified economy and healthy environment."

And foundational to a sustainable community is a vibrant, local food system. NRRI Scientist Cindy Hale knows this intimately (she and her husband manage their own small farm) and intellectually, so she's one of the driving forces behind UMD's Sustainable Agriculture Program. It's a collaborative effort founded by Professor Randy Hanson in 2009 with the College of Liberal Arts. The project has revitalized the University's dormant experimental farm spurred by today's growing interest in locally sourced food.

"UMD students have really embraced this program," said Hale. "They're hungry – no pun intended – for the ability to get their hands in the dirt and learn gardening skills that have been lost from a generation that has been trained to get food from a grocery store."

The program pulls faculty from many University disciplines – Anthropology, Language Arts, Geography, and Ecology – to provide a variety of talents and integrate the educational experience across the campus.

As "Orchard Queen" Hale is focusing her efforts on the restoration of the old seedling trial apple orchard and a newly planted heritage fruit orchard. In an effort to reduce chemicals on the fruit and in the environment, Hale started an Integrated Pest Management program to monitor pests, diseases and weather conditions. Close monitoring can substantially reduce or even eliminate chemical use in the orchards.

"We look at the ecology of the pest or organism that's causing damage to the crop, look at its life cycle to understand when it's most vulnerable," Hale explained. "For example, using organic methods to control caterpillars just when they hatch is much more healthy and cost effective than spending lots of money on large amounts of insecticides that target adult moths."

Hale also developed a series of public workshops about pruning, grafting and pest management for local growers and backyard orchardists, as well as integrating orchard topics and activities into UMD courses.

With the Sustainable Agriculture Program, UMD is tracking with national trends for schools to include garden science and fresh food culinary skills in their curricula. People are paying attention to studies that show decreased nutrients in long-haul trucking of food. There's also a desire to support local growers and the local economy.

"We just didn't understand all of the unintended consequences of disassembling our local food system in the 1970s and commodifying what we eat," Hale said. "People are starting to appreciate the fact that, from a national and local security perspective, from a sustainable and healthy communities perspective, a local food system is critical."

One goal of the agriculture program is simply to dispel the myth that it's too cold in northeastern Minnesota to feed the community with locally grown food.

"That's just a bunch of hooey," said Hale. "The largest organic broccoli grower in the state is in Wrenshall, Minnesota. We might not be able to grow bananas or eat fresh strawberries in the middle of the winter, but historically, this region had many productive farms and the UMD farm was a vital resource for locally adapted crops and farming practices."

Back in 1912, the University developed a system of six Agriculture Experiment Stations across Minnesota, including the one at UMD, to trial regionally appropriate crops. At that time, the Northern population was expanding rapidly and locally grown food was the best way to feed the people. But as large scale, industrialized farms took over and less expensive food filled the supermarkets, need waned for the experimental farm and it was closed in 1976.

Today, local farming is coming around full circle with youthful enthusiasm.

"We're teaching students about food systems in general, how they work and have worked historically, looking at food production models and strategies," said Hale. "What kinds of things can we grow? How do we manage the system sustainably? How do we use compost to build soil nutrients, and then how to preserve the food. It's stuff our grandparents knew but we lost that skill set over the past 40 years."

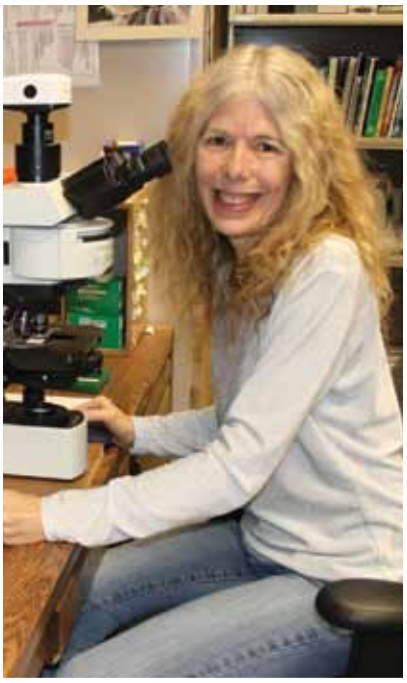
The Sustainable Agriculture Program farm now provides thousands of pounds of fresh produce to the UMD cafeteria and local groceries and restaurants. And yes, it's growing!

NRRI's Ely Field Station

Tackling big water problems from the bottom up

Euan Reavie

Amy Kireta



Lisa Allinger

Kitty Kennedy

> "There are alarming things taking place in the Great Lakes right now, and they are happening really fast."

The tubes and microscopes quickly tell a visitor to NRRI's Ely Field Station that the scientists are "doing science." And they are, indeed, engaged in the ancient and noble system of observation to acquire new knowledge.

"But our ultimate goal is to inform management," says Field Station Director Euan Reavie. "We do a lot of in-depth, nitty-gritty science but when we pull it all together it has a clear management perspective."

Like all of NRRI, the focus is on supporting a viable economy with viable ecology. The Ely Field Station, part of NRRI's Center for Water and the Environment, specifically focuses on the bottom of the freshwater aquatic food chain – from Minnesota lakes to large rivers to the entire Great Lakes system.

The team's biggest project has been running for decades and provides fundamental information for the fisheries industry. The U.S. Environmental Protection Agency has been conducting the Biological Open Water Surveillance Program on the Great Lakes since 1983. NRRI's role since 2007 has been to collect data on the abundance and composition of microscopic species that are the food source for all other species above them – ending with those of us who eat fish. Twice a year, a Field Station scientist cruises the Great Lakes

in the EPA research vessel Lake Guardian to gather samples and document what's living in the open water.

"There are alarming things taking place in the Great Lakes right now, and they are happening really fast," said Reavie.

As a freshwater "island" in the middle of the continent, the Great Lakes system is complex. The native biology evolved without much outside influence until people brought in new species at a rapid pace over the last two centuries.

So a second research effort is helping industry to slow the influx and relocation of invasive species. The Great Ships Initiative is a cooperative effort among the maritime industry, federal agencies and other regional stakeholders. Reavie and his team test technologies that are developed to kill aquatic hitchhikers in the ballasts of ships.

"We help vendors test and refine their treatment systems," said Reavie. "Our goal is to ensure that the equipment is sufficiently protective, to make sure ships aren't releasing non-native species into the environment."

The scientists meet the ships at many ports-of-call and are graciously welcomed aboard. The team collects water samples and tests the effectiveness of various treatment technologies. They also want to be sure that the technologies aren't adversely affecting ship operations.

"And it's not just us testing for algae," said Lisa Allinger, NRRI Research Fellow. "There's a huge suite of testing by other partners that also takes place."

A third research focus is to study lake histories by studying the sediment that settles on the bottom. Using paleolimnology, the scientists analyze physical,

> "Lake Superior is the largest lake by surface area and yet we've managed to change the entire lake."

chemical and biological remains preserved in the sediments to understand water quality changes going back some 300 years. A type of algae (known as diatoms) leaves distinct fossil remains. They are sensitive organisms that 'record' past water quality.

"For instance, in Lake Superior the diatoms informed us that back in the early 20th century there was a complete reorganization of the biology of Lake Superior," Reavie explained. "It's the largest lake by surface area in the world and yet we've managed to change the entire lake; the diatoms reflected the shift

Samples from around the Great Lakes fill the refrigerator in the lab.

in nutrients and biology due to human activities, like agriculture."

Reavie and his team could also see how water quality improved remarkably in the 1970s after the Clean Water Act and Great Lakes Water Quality Agreement were enacted. Now they're addressing the recent, rapid changes in algal populations that will take more research to explain.

"It seems to be related to the rapid warming of the lake, but it's only a correlation. We don't yet fully understand the mechanism for the current changes," he said.

Closer to home, the team is using paleolimnology to understand the massive algal blooms and other changes on Minnesota's Lake of the Woods. And the team is doing a historical study on the White Iron Chain of Lakes.

"This is great. It's the first time I've been involved in a study that hasn't been a response to a serious environmental problem," said Reavie of the White Iron Chain project. "The homeowners' and lake users' association took it upon themselves to do a baseline study so they have a better understanding of the sensitivity of their lakes to environmental stress.

"I think people are often surprised at the high caliber of the work underway at our field station up here in Ely," Reavie added.

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The Natural Resources Research Institute was established by the Minnesota Legislature in 1983 to foster economic development of Minnesota's natural resources in an environmentally sound manner to promote private sector employment.

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New 3-D printer helps local business improve product

Plastic parts–from squishy to firm–fast

Lee Trueblood has his dream job. Into archery as a hobby for about 12 years, he now gets to spend his days thinking about ways to improve archery products at Field Logic in Superior, Wisc. As Research and Development Engineer, Trueblood stays immersed in the technologies.

"Archery is forever old but always evolving. It's amazing what's out there now," he said. "My job is to see what might be beneficial in the industry, design new products, test them and make revisions to stay cutting-edge."

The company does much of its prototyping in their plant but they couldn't do what NRRI's new Connex three dimensional printer can do – make plastic parts of varying hardnesses for a new clamping device.

The Object Connex 3-D printer has the unique ability to make parts with both hard and soft plastics at the same time. Think of the handle of a toothbrush with a soft rubber grip overlay on a hard plastic handle. Before the parts are manufactured the durometer – a measure of hardness – must be determined. Prototyping the part can be an important first step to make sure the durometer is exactly right before manufacturing.

NRRI Prototype Center Director Steve Kossett made three parts for Field Logic, each with a different durometer.

"The turnaround for me was 24 hours, the part is realistic, and we could test it," said Trueblood. "Before we would have had a mold made, then made a part to test. If it wasn't right we'd have to start all over again. NRRI has been super helpful."

NRRI's rapid prototyping lab has five technologies to make parts for form, fit and function development. In addition to the new Connex, it has stereolithography, selective laser sintering, fused deposition modeling and standard 3-D printing capabilities. For more information visit www.nrri.umn.edu/NLTC.

Photo above: Parts made by NRRI for Field Logic.