NRRI *Now*

Spring 2016

Natural Resources Research Institute

UNIVERSITY OF MINNESOTA DULUTH

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A new lab at NRRI will tackle a pressing Minnesota problem

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From the Director: Rolf T. Weberg

> *"We must invest in innovative approaches and technology, make sound, long-lasting decisions and move forward together."*

Welcome to our Spring 2016 issue of *NRRI Now*.

The Northland had some difficulty shaking off the grip of Old Man Winter despite this being the warmest winter on record. But we're finally on our way. On several levels, this seems to be a concerning metaphor for the northeast Minnesota economy. Our industries have suffered cycles in the past, but regional leaders perceive a difference this time. The region is continuing to suffer economic hardships while the rest of the state and the country continue to move forward. Minnesota and our natural resource-based industries are facing an inflection point. Our successful response should drive innovations, define resources, diversify our industries, deliver higher value products and reduce cost to market – all while protecting our water resources and environment.

NRRI is engaging the challenge on many fronts. We are fully supporting "Recharge the Range" – an effort led by the Iron Range Resources and Rehabilitation Board to identify new ideas that can redefine the Range economy. Our relationships with regional development groups, legislators, environmental groups, industries and businesses inform our participation and contribution.

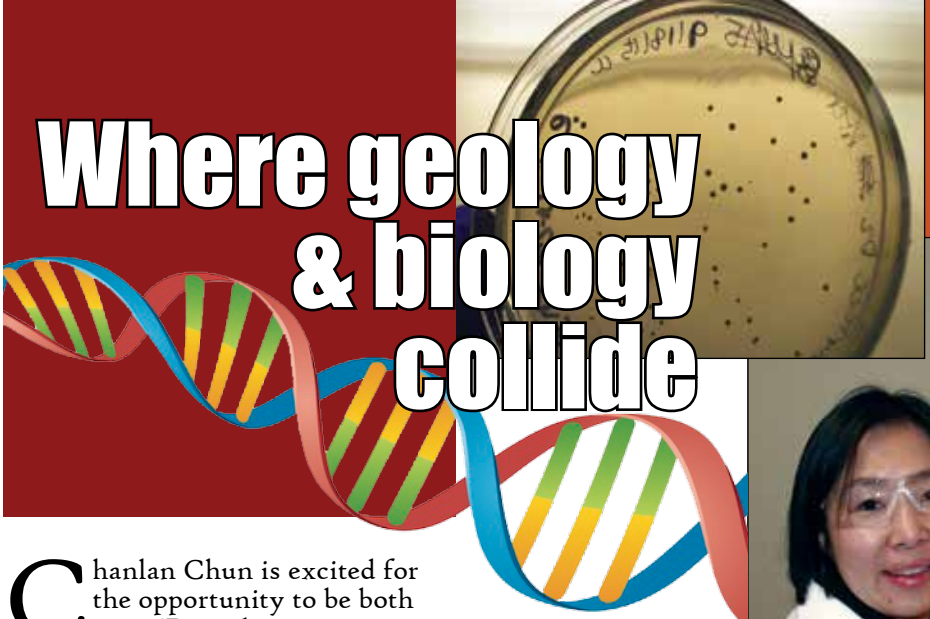
Minnesota is rich in water resources, having a tenth of the world's surface fresh water at its disposal. Availability and protection of clean, fresh water is increasingly a nationwide economic driver and quality-of-life consideration. Understanding how to safely manage increasing demands on our water resources will be critical to addressing any long-term economic planning. NRRI remains a key source for water resource science. Our scientists collaborate nationally to translate top-notch, peer-reviewed science into delivered products in water quality planning, invasive species control, trout stream revitalization, wetland restoration and ecosystem function.

On the minerals front, NRRI is helping to lead a consortium of regional experts in business, industry, agency, transportation, economics, engineering and academics to define high value opportunities for Minnesota iron ore. One example is an innovative technology to generate higher iron yields from mines. With support from University of Minnesota leadership and IRRRB, we have also initiated a project to pilot ilmenite ore processing into high value titanium dioxide and other products. At the moment, the University has a bill introduced on behalf of NRRI to support larger scale projects to develop and pilot technologies to enhance mineral yield, broaden product offerings, drive higher value and offer multiple approaches to safely address waterborne sulfate. We appreciate the support from our legislative, agency, industry and public stakeholders.

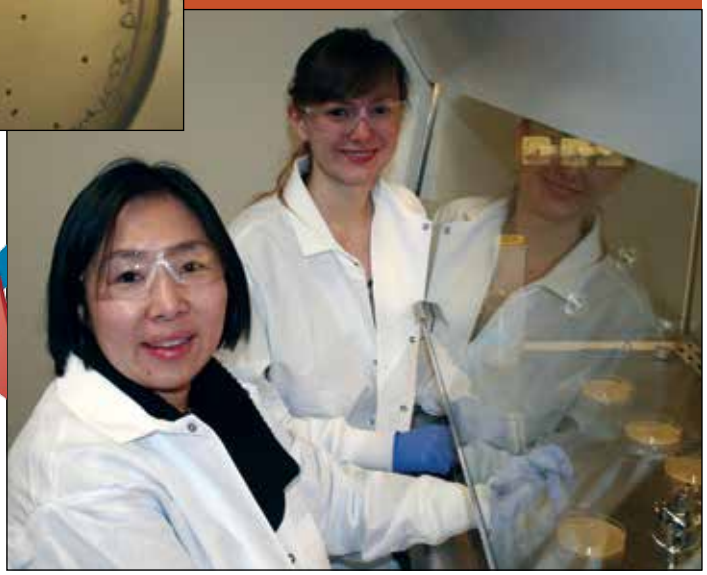
Forest resources also continue to have our attention. NRRI is collaborating across the state's industries to develop new analysis tools that more accurately define sustainable harvest of wood and biomass. This work benefits directly from the deep well of NRRI expertise regarding characterization of northern Minnesota's wildlife, forests, plants and waters. Understanding the availability of biomass helps us engage with Minnesota's desired bioeconomy while still supporting our existing wood industries. We are identifying new technologies that may transform wood pulp into to new, value-add products for the industry. With onboarding of new talent, NRRI is now collaborating around the country to define and attract investments in biomass-based energy, material, chemical and fuel opportunities.

The Minnesota "Economic Spring" will come with a lot of hard work and good thinking from many people. It will be a transition; not quick and definitely not easy. But we must get started, invest in innovative approaches and technology, make sound, long-lasting decisions and move forward together. NRRI continues to broaden our collaborations in an effort to deliver meaningful solutions for Minnesota.

Where geology & biology collide



NRRI gains new skills, new lab to enhance bioremediation research



NRRI's Chanlan Chun, left, with Research Assistant Sara Constantine.

Chanlan Chun is excited for the opportunity to be both a UMD civil engineering professor and to lead a new geomicrobiology program at NRRI. The combination means she'll get to apply scientific findings to solve real world problems.

"I'm still teaching and I love interacting with students, but my education is based on engineering, which means you look for a real solution," Chun said. "I'm happy for the joint appointment." She joined the NRRI staff in September, 2015, and started right in setting up her lab.

Admittedly, Chun's work – the science of microbial ecology using DNA sequencing – is in the "basic science" realm, but she's using that knowledge to solve real-world challenges. Her top priority is sulfate reduction in water bodies. Chun's new NRRI Duluth lab will apply microbiological and DNA sequencing methods to learn more about what she calls the "mighty microbes" that naturally convert sulfate to sulfide. In an additional step, the sulfide will be converted to solid elemental sulfur, which has economic value as a soil amendment for crops.

"Thanks to funding from the University's MnDRIVE program [see sidebar], this joint position provides expertise to NRRI that will benefit our ability to meet our mission – to be at the interface of industry and science," said NRRI Associate Director Lucinda Johnson. "Chanlan brings expertise in environmental remediation that has not been part of our skillset."

Sulfate is a combination of sulfur and oxygen that are a natural part of some minerals, but at a fairly low level in freshwater systems. When introduced to those otherwise low-sulfate waters, it's been suggested that sulfates can affect humans and ecosystem health. Those mighty microbes, which are mostly bacterial, consume sulfate as an energy source.

Using bacteria to clean up a polluted site is not new, and especially not to Chun. When she was at the Medical University of South Carolina, Chun successfully developed electro-stimulation of bacteria to clean up an especially toxic chemical: PCB, polycholorinated byphenyl. At NRRI, she'll be applying low voltage electro-stimulation to the sulfate-reducing and sulfide-oxidizing bacteria.

"Throughout our environment there are all kinds of bacteria; the diversity is very high, and they each have their function," Chun explained. "But they only do the 'job' we need them to do when the environment is right for them. So the electrical stimulation helps create suitable conditions."

Mercury in its many forms and natural mercury methylation is another environmental concern. Chun will be developing the final steps of electrostimulation to produce elemental sulfur that could potentially control the methylation of mercury.

NRRI's new Geomicrobiology Lab has been equipped with, among other tools, a real-time polymerase chain reaction (PCR) thermocycler to monitor the presence and activities of microbes by detecting and quantifying target genes, and a microplate spectrophotometer. In addition to funding her position, Chun received a MnDRIVE Seed Grant to fund an undergraduate research assistant to help to get the program up and running.

Chun began her studies in environmental science and engineering at Ewha Woman's University in Seoul, South Korea, graduating with a master's degree in 2001. She received her Ph.D. in environmental engineering from the University of Minnesota in 2006.

The University of Minnesota's MnDRIVE — Minnesota's Discovery, Research and Innovation Economy — program is a partnership between the University and the state of Minnesota to align research with the state's key and emerging industries to address grand challenges. In 2013, the Minnesota Legislature authorized an $18 million recurring annual investment in four research areas identified by University faculty. Deans and corporate partners identified the most promising areas for partnership: Robotics, Global Food, Environment and Brain Conditions.

Funding proposals for the four areas of research undergo a rigorous peer review process by a strategic advisory board consisting of representatives from academia, industry and the broader community. The Office of the Vice President for Research provides accountability measures for the initiative and serves as an advocate for the program at the Legislature.

To learn more, go to www.mndrive.umn.edu.

Great Lakes feel the heat

Sediment data show effect of climate change on organisms

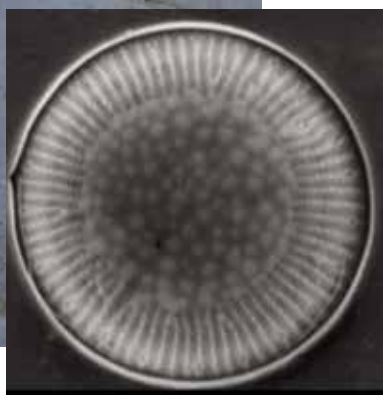
We know this to be true: Recent climate change is impacting the ecosystems of the Great Lakes. On Lake Superior especially, the season of ice cover is shorter and the water is warmer. Predictive modeling to date has shown that those changes could impact the organisms in the water.

Now we see that, indeed, they do.

NRRI scientists have the first known evidence that the physical changes resulting from a warming planet are impacting the biology in the Great Lakes. And around the world, other scientists are seeing the same thing. The smoking gun is a remarkable rise in Cyclotella – a round, microscopic species of diatom algae – over the last few decades.

Euan Reavie, NRRI's specialist in paleolimnology, has been leading a team to gather historical sediment data on all of the Great Lakes since 2011. He is surprised by how conclusively the data show the effect of climate change on the tiniest critters on the aquatic food chain.

"And we know it is climate warming, and not all the other stressors like invasive species and nutrient loading," said Reavie. "Cyclotella are also increasing in arctic and boreal lakes worldwide, lakes that have been otherwise untouched by human activity."



Basically, it's the first evidence that the living organisms in the Great Lakes are being reorganized by the warming planet.

It makes sense that changes are first being noted in the smallest of the biological life in the lakes because they are the most sensitive. That sensitivity makes diatom algae excellent indicators of environmental change, which is why Reavie studies them.

"I never thought I'd see this in the Great Lakes because of all the other stuff going on," he said, referring to the destructive effects of invasive species and nutrient pollution, especially on Lakes Huron, Michigan and Erie. "Trying to keep up with the environmental insults on the lakes, and ways to deal with them, is a constantly moving target. We're never able to catch up."

Reavie's next questions are: How important is this increase in Cyclotella? Is it a problem? Should we care? The answers depend on whether the native species will tolerate this change.

"We don't really know yet if it has food web implications, but I hypothesize that the tiny grazers that eat algae will need to adapt to these changes or will die off, which can eventually make its way up food chains," he said. "In time, as the changes increase in magnitude, will fish ultimately be affected?"

PALEOLIMNOLOGY ON THE GREAT LAKES

The Great Lakes hold a record of 11,000 years of water quality changes in the sediment that has accumulated on the lake bottoms since the last glaciers retreated. Paleolimnology is a scientific discipline that uses sedimentary samples from water bodies to meticulously analyze physical, chemical and biological remains that indicate long-term water conditions.

To obtain the valuable sedimentary materials, a paleolimnologist lowers a coring device to the bottom of the lake. The column of sediment collected for Reavie's work is typically about three feet long, but can contain up to 1,000 years of accumulated history. His research is focused on the last 300 years, called the Anthropocene epoch by scientists to indicate a timeframe when human activity is significantly impacting the Earth's ecosystems.

BEHIND THE RESEARCH

2nd in a series about how it gets done: The GIS Lab

This is a screen grab of a Knife River site displayed in an interactive 3D pointcloud viewer.

When NRRI opened its Geographical Information Systems Lab in 1989 it took six people along with some big and impressive technologies to get the work done. Like, getting a digitized map required tracing the map by hand onto Mylar film then outlining the map with a mouse, which relayed the information to the computer.

"Now you can find that information in seconds," said George Host, NRRI's GIS Lab Director. "Our fancy digitization table is just a big lunch table now."

What once took hundreds of hours can today be accomplished with just a few GIS professionals and a lot of terabytes. This is especially true since NRRI GIS Lab Manager Paul Meysembourg set up NRRI scientists to do their own basic GIS tasks at their desks. The technology is so user-friendly these days – just think of what you can do with GoogleMaps – that they can do much of the work themselves. But not all of the work. That means NRRI's GIS Lab is still a highly valued research resource. It's just that the staff is smaller, with honed expertise and unique experience.

NRRI realized early on that geoinformatics would be an important skillset to have on hand. Everything in the natural resources realm is spatial – in a time and place on the planet – which is what GIS captures.

For example, Host and NRRI Forestry Program researcher Bill Berguson are looking at the potential in remote imagery to estimate the distribution of forest resources across Minnesota's forest landscape. Many forest industries are diversifying with new products like specialized cellulose, bioplastics and biofuels.

"So that means those industries need to know where the wood supply is and how much is there," explained Host. "That's how we can assure that the new industries, along with the traditional, will have the raw materials they need."

NRRI also used GIS technology to build an interactive website that helps inform decisions about which wetlands make the most sense for restoration efforts. And during the Great Lakes Environmental Indicators project – a massive, collaborative effort reaching all the way to upstate New York – GIS pinpointed study sites to provide the most informative data for analysis. Then, once the data is collected, it takes GIS to make sense of it with a variety of spatial analyses and visualization techniques.

"And today we're working in terabytes of data, which brings new challenges in data acquisition, organization and computing power. There's a whole new world of big data to deal with," Host added.

So knowing the intricacies and capabilities of the tools still requires specialized skillsets. Staff in NRRI's GIS Lab have degrees ranging from Bachelor's to PhD levels in a broad range of disciplines, including geography, ecology, geology and computer science.

GIS Lab Manager Paul Meysembourg.

A photo of the real Knife River. See more at the Coastal GIS web site: www.nrri.umn.edu/coastalGIS.

"We're doing cutting-edge research that's on the forefront of GIS science," said Host.

New applications are continually being found. LiDAR, for example, is a remote sensor technology that uses lasers to obtain highly accurate measures of distance to build 3D digital objects. The GIS lab recently documented stream bank erosion following Duluth's devastating flood of 2012 using a LiDAR system called a Terrestrial Laser Scanner.

The project goal was to pinpoint areas on 16 North Shore streams with the most potential to erode during big rains. The laser scanner collected bluff data, photos were also taken and then Meysembourg built 3D digital models using a "point cloud viewer" of stream bluffs before and after flooding events.

"I combined the point cloud data with photos of the bluffs and applied it to a 3D cube, so they could see what it actually looks like," said Meysembourg. "Then the scientists can talk about what kind of erosion prevention needs to be installed."

The NRRI GIS lab works with a wide variety of agencies, from local to international, including many projects with the Forest Resources Council, the Minnesota Department of Natural Resources, the Chippewa and Superior National Forests, as well as local counties and

The right tools in the toolbox

NRRI delivers on Great Lakes coastal monitoring protocols

Rolf says . . . "NRRI delivers a massive team effort!"

Back in 1999, the Environmental Protection Agency needed new approaches for understanding the complexities of U.S. coastal zones. NRRI's proposal to do that work soared to the top of a very competitive heap. Of course, NRRI's interest was in the Great Lakes coasts, not the Atlantic, Pacific, or even Gulf coast lines. The resulting laborious and unprecedented report delivered in 2015 – Great Lakes Environmental Indicators – served as a guide for comprehensive studies of those other well-known coastal zones and launched NRRI to national stature.

As one might expect, where huge bodies of water meet long, vibrant areas of land, it's a complicated relationship. The freshwater coastal zones – stretching from Lake Superior's North Shore in Minnesota to Lake Ontario in New York – are as complex as any. Each lake comes with its own challenges, each state with its own priorities and (except for Lake Michigan) ownership across two countries. And back in 1999, the lakes – especially the coastal zones – were largely understudied.

Complicating this even more, the EPA wanted ways of monitoring that could be generalized across the nation, from coast to coast to coast. This was not an average research request.

"When the Request for Proposals came out, I thought this is a dream," said Jerry Niemi who, at the time, was NRRI's Director of the Center for Water and the Environment. "I knew it was something we could do, but we had to go over-and-above to outcompete organizations that wouldn't think as big. Seriously. That was our approach." Today, Niemi is winding down his career with a joint position as NRRI Senior Research Associate and UMD Biology Professor.

To tackle the proposal, Niemi pulled together NRRI's broad scientific expertise of ecologists, biologists and limnologists. Then they searched their network of esteemed scientists within the University of

GLEI Tools for Environmental Monitoring

1. Index of Ecological Condition: A method for generating the biological condition of a site using birds and frogs as indicators. An integrated index has also been developed to combine different groups of organisms such as birds, fish, and invertebrates as a multi-species indicator. This allows easier interpretation for the user because it requires less information to examine and synthesize.
2. Weighted Average: Similar to the Index of Ecological Condition, the Weighted Average is useful for indicator development with diatoms in changing environmental conditions. It can also be used for archived data from sediment cores to provide a good historic record or for setting restoration or protection targets.
3. Biological Benchmarks: Human impact (stress) thresholds are established with benchmarks such as loss of sensitive species or increased dominance by tolerant indicator species. These stress-thresholds provide useful information for environmental decision-makers.

GLEI Collaborators: Minnesota Sea Grant ♦ University of Minnesota Duluth Department o

Ann Arbor, Michigan ♦ University of Windsor, Ontario ♦ John Carroll University,

Minnesota and across the Great Lakes. The Great Lakes Environmental Indicators (GLEI) project was born.

The resulting proposal was, in the words of EPA's Michael McDonald, "amazing conceptualization and one of the few proposals I've seen that got excellent reviews." Today, McDonald is the EPA's Branch Chief for Ecological and Human Community Analysis in North Carolina. "NRRI took a new approach to looking at sub-basins and the land that fed into the streams. A lot of intense thinking went into their proposal from a lot of different disciplines," he added.

In 2000, NRRI received the $6 million grant – at that time the largest ever received at UMD – and everyone was bit nervous. Could they really pull this off? The key would be collaboration, tight coordination and a way to collect data across all watersheds. Principal investigators were assigned to five different indicator groups: 1) Diatoms and Water Quality, 2) Fish and Macro-invertebrates, 3) Wetland Vegetation, 4) Birds and Amphibians, and 5) Chemical Contaminants. [See sidebar for list of collaborating institutions.]

NRRI's Geographic Information Systems Lab got busy developing the extensive sampling protocol and field work began. Reams of data were collected in the U.S. Great Lakes basin and over 50 peer-reviewed articles and reports were completed. But the funding was terminated five years early, before all the data could be fully analyzed. Fortunately in 2010, NRRI received an additional $1.7 million through the Great Lakes Restoration Initiative for GLEI 2.

"We went back to GLEI 1, and developed different analyses to identify how different plants and animals respond to different human pressures on them," explained Lucinda Johnson, principal investigator on GLEI 2. "It's complicated, but at least we can see which species behave similarly."

More field data were collected, this time in Canada, too, but the primary goal of this second go-round was to bring all of the pieces of the project together into a coherent set of tools and products. Now both countries have the indicators they need to monitor and assess their required environmental obligations as outlined in the 1972 Great Lakes Water Quality Agreement (revised in 2012).

"Monitoring is important because it gives us the baseline for how the environment is changing," explained McDonald. "It also provides a rationale for where the biggest problems are and what we need to do to solve them. I've seen these tools in action to define new approaches to solving problems."

It took 15 years, but as 2015 came to a close the GLEI team submitted a 239-page report to the EPA describing its findings. Among the terabytes of data collected, close to 100 peer-reviewed papers, countless metrics and methodologies, three tools emerged that provide the capacity to both postulate and confirm the condition of the entire Great Lakes shoreline. [See sidebar for information about the three tools.] Overall, they found that birds, plants and fish tend to be the most consistent indicators of environmental change. Invertebrates (aquatic bugs) tend to be generalists, and diatoms are most useful as indicators of long-term changes.

"And for the first time, there are measurements that are specifically designed to identify the condition of non-wetland ecosystems, shorelines with a lot of wave action," explained Johnson. "They're challenging because there's not a lot of habitat diversity and you need a nice, calm day just to get out there."

The goal of identifying the most efficient, economical and effective biological indicators was met with a collective sigh of relief for this massive effort.

"I'm a believer in go big, or go home," said McDonald. "That's where NRRI and this project hit a homerun. I don't know if people appreciate how much GLEI advanced the science within federal and state agencies."

of Mathematics ♦ University of Wisconsin, Green Bay ♦ University of Wisconsin, Madison ♦ Cornell University, Ithaca, New York ♦ University of Michigan, Cleveland, Ohio ♦ University of Minnesota, St. Paul, Minnesota ♦ U.S. EPA Mid-Continent Ecology Division in Duluth and Grosse Ile, Michigan

AMAZING BIRCH BARK GETS BOOST

Grant will move extracts from lab scale to commercial use

Rolf says . . .
"NRRI scientists unveil more secrets from birch bark waste."

Modern science and ancient medicine have both confirmed the healing powers of the natural chemicals in birch bark. The problem has been that extracting the valuable chemicals from the outer bark is laborious and therefore expensive. In January, NRRI received a National Science Foundation Grant to work with a Minnesota producer of natural birch bark chemicals to increase production and lower price significantly.

"Natural chemicals can be produced in the lab in grams, not more," explained NRRI Chemist Pavel Krasutsky who holds 12 patents for this extraction process. "This new technology we're developing will produce tons and make these natural products industrially available."

Krasutsky and his team of chemists at NRRI will work with The Actives Factory, a small start-up business in Two Harbors, Minn., owned by Brian Garhofer. He started the business in 2013 after purchasing the license to use NRRI's patented processes for extracting beneficial triterpenoids. He learned, however, that the market for these chemicals – while certainly in demand – was limited by the process and expense. The current market price for small amounts of triterpenoids is $10,000 to $20,000 per kilogram.

The NSF Small Business Innovation Technology Transfer Research grant will be deployed in two phases to total nearly $1 million. The first phase grant of $225,000 will be used to develop the process at the lab scale, test the feasibility and conduct market research. If that proves successful, the second phase of $750,000 will begin in 2017 to scale up the process for commercialization.

The proprietary process will produce chemicals from the chemical family of triterpenoids that are well-known in certain industries for their beneficial uses: betulin, betulinic aldehyde, betulinic acid and lupeol. Research has indicated they are effective for prevention and treatment of cancer, chronic inflammation, HIV/AIDS, type 2 diabetes, tuberculosis and more.

And there's no shortage of available birch bark. These natural chemicals are extracted from a renewable, waste byproduct of the wood products industry.

"For us to meet the demand of one drug on the market, we would probably process what the average paper mill puts out in one week," Garhofer explained. "In Alaska, they debark the trees before shipping the wood overseas. There are not enough facilities to burn it all so there are mountains of birch bark in Alaska."

For now, however, Garhofer is getting his birch bark from readily available Minnesota sources, catching it before it's incinerated as cheap fuel. He is working with a number of cosmetic and personal care companies who are testing the chemicals for their products. Once The Actives Factory is able to provide large scale production, the market will expand to large pharmaceutical and biotech companies.

"And although we're looking at compounds from birch bark, this process may be feasible for products from other natural sources," Garhofer added. "But for now, there's plenty of potential in the amazing birch tree."

THE BIRDS OF THE AGASSIZ

NRRI helps forest managers and birds share unique ecosystem

There's a classic tug for resources taking place in Minnesota's Agassiz Lowlands. It's a peaty, boggy forest land that still holds remnants of the ancient glacial Lake Agassiz – today's Lake of the Woods and Upper and Lower Red Lakes. The unique acidic and wet environment produces black spruce trees (which fetch about $25 a cord) and tamarack (once among Minnesota's most common trees) harvested for wood pulp. The northern economy near the Lowlands depends on those wood resources. And so do the birds.

It's exactly the situation NRRI was formed to help address.

"This is the largest peatland in the lower 48 states and a really unique habitat that we have a stewardship responsibility for," NRRI bird scientist Edmund Zlonis explained. "So if we can make recommendations that allow people to have a livelihood but at the same time modify the way the forests are managed to protect unique species, we can balance these things. That's the ultimate goal."

From 2013 through 2014, Zlonis and graduate research assistant Josh Bednar slopped through the mosquitoey bogs for the Minnesota Department of Natural Resources to find out what feathered friends inhabit this region. They submitted their report in 2015 which includes a survey of breeding birds and predictive computer models that can help guide harvest or conservation decisions. The study is funded by a DNR State Wildlife Grant and designed specifically for foresters' use, "not just for wildlife geeks like us," Zlonis added with a grin.

The project focused on forests in the Agassiz that might be considered for timber harvest. What bird species are utilizing the variety of tree species? What age and productivity levels of forest are most appealing to those species?

"The interesting thing is that you'd think a very old forest would have really tall trees, but in these habitats, because of the acidic soil and high water table, a tree could be over a 100 years old and about as tall as me," said 5-foot-10-inch Zlonis. "So even though it's a mature forest, we found species that you'd never find in a typical mature forest with taller, closed canopies."

Added to its low productivity and the harvesting of slow-growing trees, this unique habitat has other unique pressures. Climate change models show that black spruce and tamarack are among the first that will retreat from the region over the next 100 years. The Eastern Larch Beetle has also become more widespread over the last 15 years killing 262,000 acres of tamarack, likely because warmer winters and snow cover have allowed more beetles to over-winter. And its impact has accelerated recently.

"In just the last four years, some 150,000 acres of tamarack have been affected by the beetle, that's 10 to 20 percent of the total acreage for this tree in Minnesota," Bednar added. "It's a big issue. We know that many species use those habitats and some are in decline, but we don't know yet how they're responding to the dead tamarack mixed with black spruce."

To promote a more diversified economic use of the area, NRRI hosted a meeting with interested stakeholders to discuss the potential of developing a birding trail, similar to Minnesota's world famous Sax-Zim Bog, to bring in tourists. Among the characteristic birds in the Agassiz are the Connecticut Warbler, Boreal Chickadee, and Yellow-bellied Flycatcher.

"Around $620 million was spent on wildlife viewing in Minnesota in 2010, and we think a lot of that was birding," said Bednar, quoting a 2011 National Survey by the U.S. Fish and Wildlife Service. "If we can get a trail up there and draw people, it will help these small communities economically and educate people about this magnificent habitat."

A priority bird species of concern is the Connecticut Warbler, being watched as an indicator of environmental change in the Agassiz Lowland because Minnesota's black spruce/tamarack forests are its primary breeding habitat. Zlonis and Bednar hope to get continued funding to understand why populations of the species are declining.

Photos by Ed Zlonis

The science behind rocks, water and wood

Rolf says . . .

"Science's job is to question and understand . . . which many times leads to better questions."

Or, why do the questions just keep coming?

Science is frustrating. The more we know, the more we realize how much we don't know. Nothing is 100 percent. Answers change. One day Pluto is a planet, the next it's a just another orbiting mass in the Kuiper belt.

"The public gets confused over the progress of knowledge," said Lucinda Johnson, NRRI Water Resources Initiative Director. "But science is never linear. We don't go from Point A to Point B to Point C. Every set of questions and answers brings with it another set of questions."

And yet we rely on science to find answers to important – even life or death – challenges. NRRI approaches the complexity of science by boldly defining issues and developing solutions with a multi-disciplinary approach, from small-scale to large and from many perspectives. It has to. NRRI was formed to apply rigorous science in two critical areas that are often perceived to be at odds – economic development and environmental protection. That's why over the past 30-plus years, NRRI has amassed remarkably diverse expertise.

"How do we understand society's and industry's impact on the environment, for instance, unless we have baseline data?" asked NRRI Executive Director Rolf Weberg. "Ignoring impact is much more expensive down the road. We have to be comprehensive in considering economic development with a lifecycle analysis perspective."

Unraveling Sulfate

One especially vexing problem getting a lot of attention by NRRI researchers is high levels of sulfate in water bodies across Minnesota. Previous assumptions are being examined and the scientists are moving research down the winding road that leads to new knowledge.

First, some history. The question of sulfate effects on wild rice started as an astute observation by a Department of Natural Resources water quality scientist in the 1940s. Wild rice, it seemed, was absent from lakes with sulfate levels greater than 50 milligrams per liter. Also noted was that wild rice did not thrive when levels exceeded 10 milligrams per liter. This led to industry regulation in 1973 limiting sulfate levels to 10 milligrams per liter in wild rice producing lakes.

That standard was not scrutinized until recently. Now we're wondering if it's sulfate or other chemicals in the water? Iron, maybe? What's in the sediment versus the overlying water? What stage of the plant cycle is most affected? What does a healthy wild rice population look like? Further complicating biological science are social and political complexities around water quality, wild rice and treaties with Native American tribes.

"To get at the answers, these questions need controlled, small-scale experiments as well as large lake- and landscape-scaled experiments," said Johnson.

Studies are underway. Recently, the Minnesota Pollution Control Agency shed some light on an understanding that sulfate, a rather benign chemical, can be a problem for plant roots. Competing microbes are known to convert environmental mercury to methyl mercury – a critical health threat throughout the ecosystem, including to humans.

This leads to even more questions. Can we control microbial conversion processes? Why do different water bodies have different challenges? What combination of technologies might be best suited to various sulfate challenges around Minnesota?

"What is great about NRRI is that we have the capacity to pass off questions from one group to another," Johnson said. "In our institute alone, we have multiple scientific disciplines collaborating to develop new approaches to the problem of waterborne sulfate."

Getting More from Ore

Another challenge for Minnesota is finding new ways to increase iron yield and produce higher value iron products from its ore resources. Again, NRRI is engaged in anticipating necessary technologies to help this industry compete globally and manage the impact.

As the demand for traditional taconite pellets is going down, the demand for more concentrated iron products – direct reduced iron, iron nuggets or crude pig iron – is going up. So, even if the U.S. can end the importing of cheap steel and the Iron Range rebounds, it will need to produce iron products relevant to the evolving national steel industry. Again, research questions emerge.

"Can we develop the technologies Minnesota needs to compete globally? Where are the markets? What are the impacts of a DRI plant in Minnesota? How can we manage that impact? Can we do it in a way that makes sense economically and works for the customer?"

In the Forest

Minnesota's forest managers are faced with the challenge of balancing the use of natural resources to create things of value and provide some 40,000 jobs while still maintaining healthy forest ecosystems. NRRI biologists have been studying the amphibians, birds and mammals that depend upon these resources while also providing industry expertise on how to use the resources more efficiently.

But with a slowdown in forest products manufacturing, harvesting is down about 25 percent, to approximately 2.5 million cords. Unharvested timber is a missed opportunity for economic activity and in some cases poses a threat from fire or pest damage. Pulling together expertise in both ecological and industrial forest management, NRRI can look at the broader implications to consider a viable state bioeconomy that augments existing industries while maintaining environmental health.

But first we need to know how much biomass is available and accessible. Minnesota's forest inventories aren't adequate to address that question, so NRRI is collaborating to employ modern Geographic Information Systems technologies to get answers. Using LiDAR and satellite data, NRRI can gather imagery across ownership landscapes to better characterize resource distribution.

Another challenge is that wood resources are noticeably changing; the emerald ash borer is decimating ash trees, and climate change and other factors are hampering forest regeneration. What does that mean for wildlife habitat? What forest species need to be considered for which products? How can industries adapt? Where are the highly productive forests that make sense for investment? What do we need to know for long-term, sustainable forest management?

More questions requiring more research. More answers leading to more knowledge... and, inevitably, more questions.

"Research is an investment, a bet. It rarely provides the 'silver bullet,' but the knowledge gained provides new understanding to anticipate response to changes and evolve our decision-making," said Weberg. "NRRI drives continual learning from all angles and considers long-term results and impacts. Industries and the environment are not mutually exclusive. They must support one another."

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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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