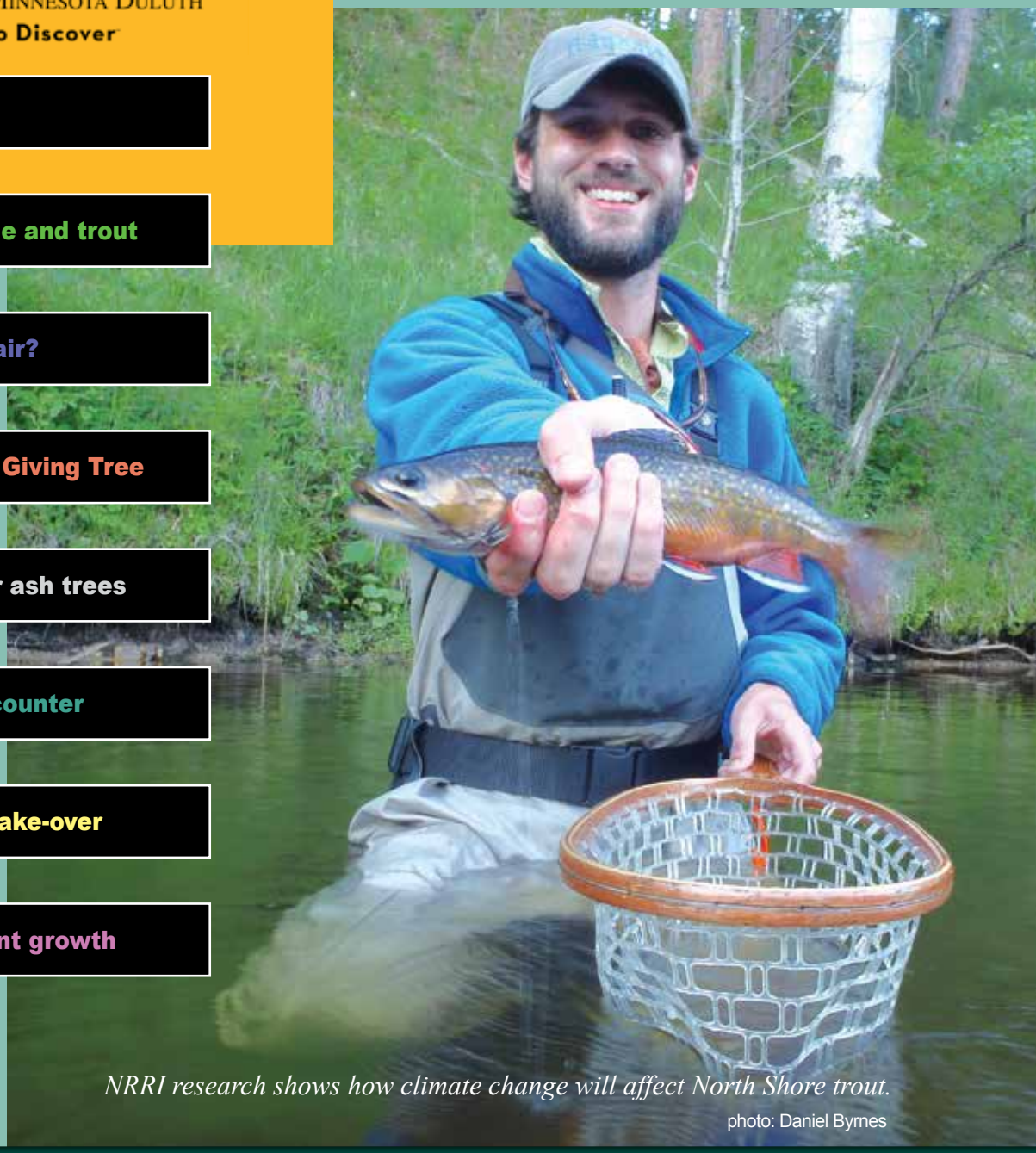
NRRI *Now*

Spring/Summer 2013

Natural Resources Research Institute
University of Minnesota Duluth
Driven to Discover



NRRI research shows how climate change will affect North Shore trout.

photo: Daniel Byrnes

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

From the Director

A month away from retirement, I was curious. When did I write my first NRRI Now column and what did I talk about? It took me only a couple of minutes to dig into my files and find that the first issue was published during the Fall of 1987, four years after the enabling legislation that established NRRI in 1983. That inaugural column indicated that NRRI was formed "by action of the Minnesota legislature on the premise that northern Minnesota has and will be dependent on its natural resources for its quality of life in terms of economic development, day-to-day living, environment and recreation." I further noted at the time that NRRI's "history has been relatively brief, but has resulted in a dynamic and progressive program." We were "gearing up – evaluating problems and opportunities in natural resources and bringing on board a highly qualified staff of scientists, engineers and business experts as well a competent support staff."

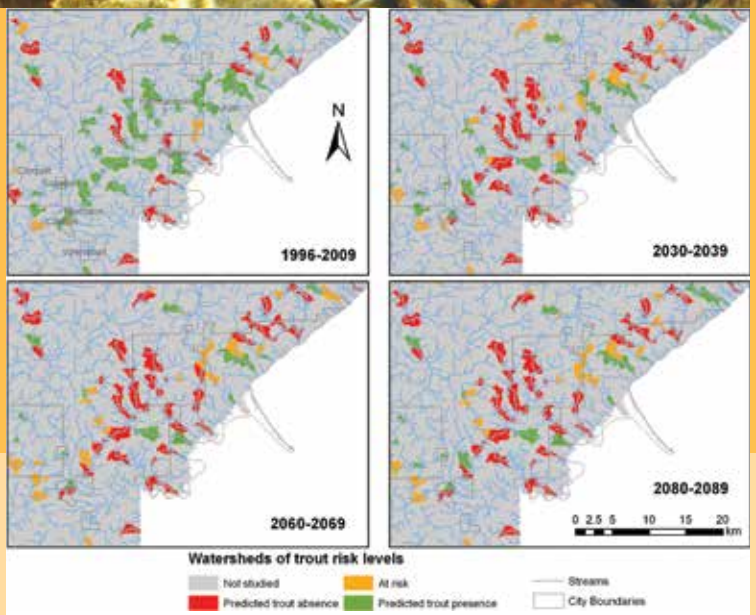
From my perspective today, I can claim that we have held course at NRRI. In retirement I leave a cadre of highly qualified and dedicated associates who are responsible for dynamic and progressive programs with impressive applied research and development track records. You have read about the tangible results of many of these in this publication, and will likely read about initiatives that are in progress now in future editions. NRRI continues to evaluate problems and opportunities – partnering with industry, government agencies, our university colleagues and public and private groups – to address opportunities and meet challenges. Clearly natural resources issues related to economic development, resource management and environmental issues are as relevant today, and will be into the future, as they were in 1983.

I'll refrain from trying to single out some of NRRI's many accomplishments. However, I do want to share my conviction that the challenges and opportunities relating to natural resources bode well for the Institute into the future. NRRI is a treasure that deserves to be supported and nurtured. If this is done, odds are that NRRI and its collaborators will continue to achieve meaningful dividends for Minnesota, our region and nation.

I look forward, with anticipation, to joining you in following the progress of NRRI in future. Thank you all for your continuing interest and the wonderful support and guidance you have provided NRRI and me personally.

Warming waters for brook trout?

NRRI helps to predict fish response to climate change



Brook trout are a popular game fish and an icon of Northern Minnesota – Lake Superior's North Shore streams once teemed with them. But it's also a sensitive fish; one that needs cool, clean water to thrive. If this region experiences warming temperatures due to climate change, how will that affect brook trout? NRRI researched an answer with the St. Anthony Falls Lab at the University of Minnesota and funding from the Minnesota Department of Natural Resources.

The team pulled together data from a variety of sources to build two models – one based on the physics of hydrology and temperature, and the other on the drivers of trout habitat. Together the information provides scientists with a peek into the future, given well-documented predictions for regional climate change. As temperatures rise, it looks like anglers might have to head further north to satisfy their passion for these beautiful native fish. Bill Herb, research associate at the St. Anthony Falls Lab, was charged with building a "deterministic" model which uses physics to precisely predict outcomes.

"As far as changes to the hydrology, the water flow in the streams, we're seeing some changes in summer low flows and spring high flows, but they are not as dramatic as I expected," explained Herb. "But the model for stream temperature shows an increase of around 3 degrees F (1-2 degrees), and that's pretty significant."

Herb also notes that his research showed that bigger streams are more vulnerable to temperature increases than smaller streams, because wider streams are less likely to have tree shade coverage, and more likely to have slower moving or standing water that absorbs more heat.

And knowing that brook trout are particular about their habitat, NRRI Statistician Meijun Cai built a predictive model showing where the fish would be most likely to live in the warmer future. Starting with data that shows where brook trout live now and temperature data from 500-plus sites, Cai was able to document the environmental conditions (air temperature, land use, geology, wetlands, water flow) associated with current brook trout habitats. Factoring in future air temperature and flow conditions Cai's model showed future habitat conditions and predictions of brook trout presence or absence in North Shore streams in decades to come.

"As we look into the future, we know that brook trout have a particular range of temperatures that they can survive in," explained Lucinda Johnson, NRRI center director and project leader. "We know there are temperatures where they persist, but don't thrive, or where they simply can't survive. This allowed us to say which streams are at risk for declining brook trout by the end of the century."

The combined models show that the streams closest to Duluth are most at risk and those furthest north show the least effect from climate change. But more research is needed.

"To get a robust prediction of the future, it's always better to have an ensemble of many, ten to 20, climate change models and we just used two," said Johnson. "One critical element we don't have is future forest cover, which is an important indicator of brook trout distribution. We're looking for more funding to do a more indepth assessment."

WHAT'S IN THE AIR?

NRRI studies air quality in mines and communities on Iron Range

In April, some long-awaited findings from the Taconite Workers Health Study Partnership were presented to the public and media in Mountain Iron. NRRI researcher Larry Zanko presented findings for the Environmental Study of Airborne Particulate Matter – an air sampling and characterization project that set out to find what is in the air on the Iron Range.

NRRI's particulate matter study is one of five underway by the research team that also includes the University of Minnesota School of Public Health and the University of Minnesota Medical School. The last major study of occupational health among taconite workers was conducted in the early 1990s. Since then residents of the Range have wondered if something in the taconite mining and pellet-making processes can be linked to the development of mesothelioma, a rare form of cancer that occurs in the thin layer of cells lining the body's internal organs.

The five-year study will be complete by the end of this year, but the researchers shared their findings to-date with a room of intent listeners, many who are or were part of the mining industry. The study's overall goal is to understand the relationship between working in the taconite industry and living on the Iron Range and mesothelioma, which is shown to be more prevalent there than in other parts of Minnesota.

"This study will provide us with fundamental information that can be used in current and future studies to evaluate possible health effects of mineral dust," said George Hudak, NRRI Director of Minerals and particulates study leader. "To do this, it's vital to understand the physical, mineralogical, chemical, and concentration attributes of mineral dust associated with taconite processing plants and communities near taconite mining and processing operations."

First, it's important to understand some basic terminology. Asbestos is a commercial term used to describe a group of silicate minerals (see list of "Regulated Asbestos Minerals") that have crystal shapes resembling fibers. These fibers are chemically inert, heat resistant and flexible, making them suitable for a wide variety of commercial uses. Crystals that have this fibrous

To read about the presented results of the Occupational Exposure Assessment, Mortality Study, Incidence Studies and Respiratory Health Survey of Taconite Workers and Spouses, go to www.taconiteworkers.umn.edu.

The Iron Range community and regional media (left) gather to hear from the research team (right).

structure are called "asbestiform." It is important to note that minerals that make up asbestos can form in crystal shapes other than asbestiform, for example bladed, columnar or blocky.

Exposure to asbestos has been linked to mesothelioma. NRRI researchers used a unique instrument called a MOUDI (Micro-Orifice Uniform Deposit Impactor) developed at the University of Minnesota Department of Mechanical Engineering. The MOUDI collects particulate matter of different aerodynamic diameters to be identified so that the characteristics of the respirable mineral dust can be evaluated. The instrument was placed in five communities across the Mesabi Iron Range, three control sites (Ely, Duluth and Minneapolis), as well as at four specific process areas within each of the six taconite plants. The particles generating the most concern are "Elongate Mineral Particles" (called EMPs) of the asbestos minerals listed.

"What we found is that the community air is very clean on the Range, compared to other communities," Zanko told the crowd. Particulate concentrations in all of the communities sampled are below the National Ambient Air Quality Standards set by the U.S. EPA, and lower than what was found in Minneapolis. Not surprisingly, they also found that the particulate matter found on the Iron Range reflects the mineralogy of the Biwabik Iron Formation and other geological materials in this part of northeastern Minnesota, as well as minerals commonly used in commercial asbestos. Particles and fragments of amphibole minerals identified to-date have blocky to acicular-shaped grains (see graphic).

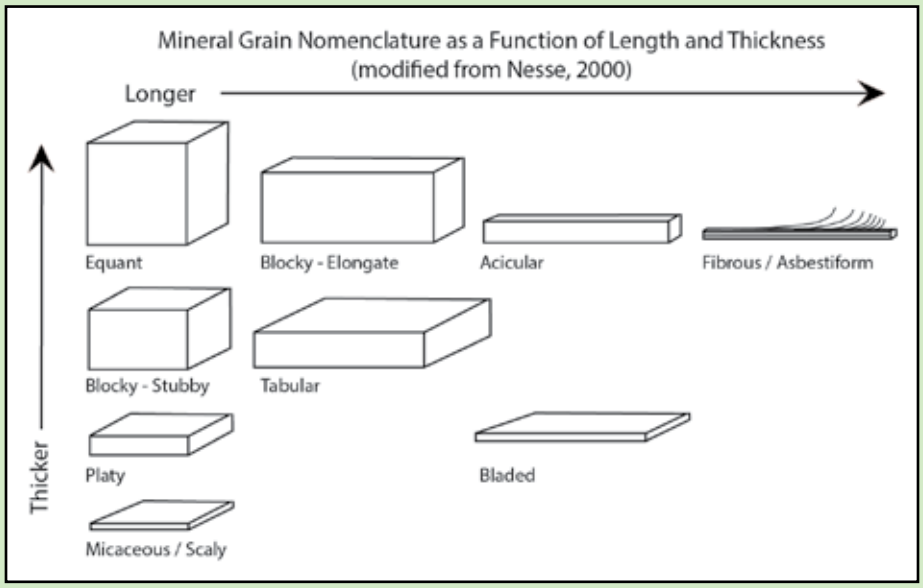
The MOUDIs placed in the taconite plants confirmed what people already know – the plant environment can be very dusty, with the agglomerator and kiln discharge areas being the dustiest. They also note that dust control efforts appear to be keeping the majority of dust from escaping the plants into the communities. EMPs were detected in very small amounts at the Northshore and MinnTac plants.

"Don't wait for us to complete our study to protect yourself at work," said study Principal Investigator Jeff Mandel. "Mining is a dusty job and protective gear should be worn at all times."

Still ahead, the researchers are going to look at whether commercial asbestos, widely used in the 1960s and 1970s, could explain the excess cases of this deadly form of cancer.

The $5 million study was commissioned in 2008 by the Minnesota Legislature. Representatives Tom Bakk, David Tomassoni, Jason Metsa, along with former Senator Ron Dicklich and former Representative Tom Rukavina, were present at the public meeting.

"I see a lot of familiar faces out there," said Rukavina to the crowd. "It was all of you people who worked so hard to get this going, to get the truth."



REGULATED ASBESTOS MINERALS

- Cummingtonite – Grunerite (a.k.a. "Amosite", an amphibole mineral)
- Actinolite (an amphibole)
- Anthophyllite (an amphibole mineral)
- Tremolite (an amphibole minerals)
- Riebeckite (a.k.a. "Crocidolite", an amphibole mineral)
- Chrysotile (a serpentine/phyllosilicate mineral)

Source: OSHA and MSHA

Gifts from the Giv

NRRI's birch bark extractives get another chance at the health care market

There's a warehouse space in Two Harbors that is quite literally full of potential. It is filled with machinery and super-sacks of product that is garnering enthusiastic interest from personal care industries. This start-up company is called The Actives Factory and the next steps are to get the machinery running and the product out the door to potential markets. Brian Garhofer, president/salesman/bookkeeper, is gearing up to do just that this spring.

The products are at once common and unique – the extracted chemicals from the bark of birch trees. NRRI has been developing and patenting processes for these extractives for 15-some years so that the long-known health benefits in the bark can be used in lotions, soaps and dietary supplements. The bark pelletizing plant in Two Harbors was established by NaturNorth LLC, a company that the University of Minnesota (NRRI), Potlatch Corp., and Minnesota Power jointly launched in 2000 to market the birch extractives. But there were hurdles yet to overcome, according to Garhofer. The first hurdle was cost of the extractives.

"Initially, there was no commercial-scale process to extract the chemicals from the bark. It was only being done in small batches in labs, making it a very expensive product," said Garhofer. "NaturNorth spent a lot of money and effort to ramp up the production process and bring that cost down."

The second hurdle was solubility. The chemicals do not dissolve in water, nor do they absorb into the skin, both of which are necessary to derive the healthful benefits in topical applications. Working with NRRI chemist Pavel Krasutsky, however, they have developed new processes to allow incorporation of the extracts into a wide variety of personal care products.

"Now, utilizing standard industry practices, we can get the natural chemicals right into products," said Garhofer. "Pavel and his team have found solutions to the roadblocks to getting this product adopted into the cosmetics industry."

Birch trees are a common sight in northern Minnesota and the wood is used for a variety of products – from paper to cabinets – leaving the bark behind. For his start-up this spring, Garhofer will be gathering that bark by the truckload and processing it for the cosmetics and natural supplements industries. The betulin and the bark's more active derivative, betulinic acid, have long been known to have healthful benefits. Many studies on betulin have shown it to have anti-bacterial, anti-fungal and anti-inflammatory benefits. Even more, the preserved body of a 5,000 year old "iceman" in Europe was found with a pouch containing birch fungus, assumed for medicinal purposes. Native Americans have also long used a variety of tree barks for healing treatments.

With the help of NRRI's ongoing chemistry research and an industry advisory panel, Garhofer believes the foundation is in place to move these natural chemicals to the personal care market. Not only does he have a large inventory of pelletized birch bark and pure betulin powder ready for shipment, he has a ready supply of raw birch bark from sustainably managed and harvested sources.

"The market for this is growing and it's a long process to build the market," said Garhofer. "We are starting with cosmetics and supplements and as people become familiar with it in their products, they'll come to expect it. I can't hire yet, but I anticipate when we are operational, I'll be able to keep five to six people working."

So far, 20 patents have been issued to the University of Minnesota for the work at NRRI in developing the processes and different uses for the natural chemicals in birch bark and their derivatives, with more on the way.

"We know that birch trees are one of the oldest tree species on earth and that it thrives in some of the harshest of environments," explained Krasutsky. "It has evolved over the millennia to have protective chemicals in its bark that can be very beneficial for people."

ving Tree

There is a lot of potential in birch bark extractives. Some of the possibilities include:

- Cosmetic ingredients to provide healthy skin and hair, as well anti-aging benefits.
- Natural anti-bacterial additives to soaps and shampoos.
- Renewable and organic plant protection products.
- Natural polyesters for biodegradable "plastic" material.
- Pharmaceuticals derived from nature instead of synthetics.

Working with UMD's School of Medicine, the Hormel Institute and Eli Lilly (through their Open Innovation Drug Discovery), NRRI's Chemical Extractives Laboratory is screening a library of new chemicals.

"This is an exciting opportunity for the University of Minnesota to take part in innovative drug creation to improve health care," said NRRI's lab director Pavel Krasutsky. "Our efforts are focused on combining the benefits provided by nature with the skills of our experienced chemists for natural, healthy product development."

Images: (Top) Pelletized birch bark extractives. (Center) Actives Factory owner Brian Garhofer in his Two Harbor warehouse. (Bottom) Natural chemicals identified in NRRI's laboratory.

Dead ash trees get second life

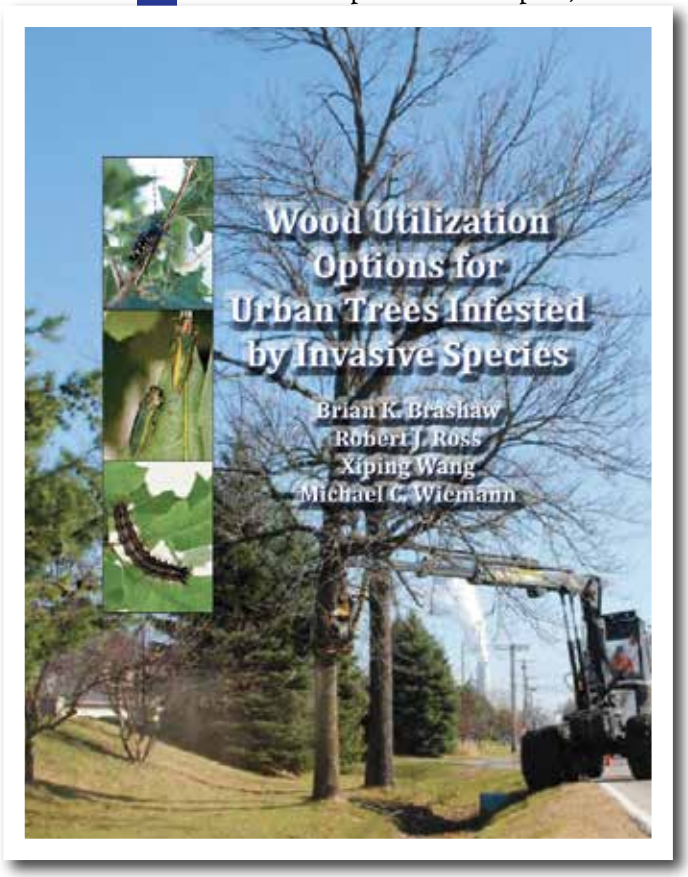
Book shows marketable uses for diseased, infested trees

Retired forester Jack Rajala recalls the devastating Dutch elm disease that swept through Minnesota in the mid-1970s. "We had to scramble to find markets for all of that elm wood," he said. "We ended up shipping a lot of it to Japan and Europe where there's a strong market for elm. It all happened very quickly."

Ironically, most of those lost boulevard elms were replaced with ash trees, and urban trees are under attack again. Since it was first discovered in 2002, the emerald ash borer has killed tens of millions of ash trees in Michigan and has spread to other states, including now quarantined areas of Minnesota.

In a proactive move, the U.S. Forest Service wanted to prepare our domestic wood products manufacturers for the surplus of ash and other infested wood coming their way. With grant money from the Wood Education and Resource Center, NRRI's Brian Brashaw worked with the Forest Products Lab in Madison, Wisc., to develop a free guide on options for wood harvested after an infestation.

"If emerald ash borer breaks out of its quarantined areas, Minnesota will have up to one billion ash trees with no natural defense against this invasive species," explained Brian Brashaw, NRRI wood products program director. "While ash has not been a highly utilized species in the past, it is a high quality hardwood with a lot of potential uses."



Other threats include the Asian long-horned beetle to maple and other hardwoods, the gypsy moth most commonly found in oaks and aspen, and thousand canker disease which kills eastern walnut trees.

"Our goal with the grant was to help maintain the economic competiveness of the wood products industry by tapping this huge volume of urban trees that need to be removed," explained Ed Cesa, utilization and marketing specialist at the Forest Service. "The book is easy to understand and should be useful for years into the future. It provides realistic, marketable uses."

The one-stop-shop manual covers uses "from biomass to baseball bats," according to Brashaw. It outlines wood properties, processing characteristics and market opportunities, as well as extensive research on sterilization options for treating infested firewood.

The information is available for free on the web at www.emeraldashborer.info, under the Wood Use Options tab. A limited number of hardcopies are available by emailing Brian Brashaw at bbrashaw@nrri.umn.edu.

Quick critter counter

NRRI develops easy way to document earthworm invasions in forests

Now that the word is out that European earthworms are an invasive species in Minnesota's northern hardwood forests, the task at hand is to understand how widespread the problem is. One way is to physically extract them from the soil and identify them, which means hauling hundreds of gallons of a mustard/water mixture deep into the woods to coax the wily wigglers out of the ground. It's very labor intensive.

NRRI Junior Scientist Ryan Hueffmeier collaborated with multiple regional researchers to develop a better way. Now, with just two hours of training and a notebook, anyone can gather information about the extent of earthworm infestation. The Invasive Earthworm Rapid Assessment Tool makes it possible to visually identify specific clues in the forest that indicate the presence of earthworms.

"Now we can train anyone – land managers, biologists out doing other studies, bird watchers or foresters cruising timber – to spend an additional few minutes to help us collect data on earthworms," explained Hueffmeier. "This process can tell us the stage of earthworm invasion, level of ecological impact and the associated earthworm species most likely present."

This moves NRRI's Great Lakes Worm Watch research forward exponentially. The more people who can contribute data on earthworm distribution in Minnesota's hardwood forests, the better managers can allocate fiscal resources.

"When land managers know how heavily invaded an area is with earthworm, it helps them decide how to best protect an area," said Hueffmeier. "For example, they'll know to first put their effort and resources into a less earthworm impacted area as opposed to trying to protect a larger portion. It helps them be more effective and efficient."

So how does it work?

An earthworm-free native, hardwood forest has a spongy feel under your boots because of the slow decay of seasonal leaf fall. Pulling back the top leafy layer, an observer will find two more distinctive, organic layers – a partially decomposed layer, and under that a very decomposed layer where fine root systems are taking hold. Those important, nutrient-rich organic layers are ideal growing conditions for Minnesota's native forest plants, like sugar maple seedlings, ferns and trillium.

In hardwood forests that are heavily infested with European earthworms, however, a trained eye can easily see the difference. Leaf litter is munched away and relocated into the soil – nightcrawlers are especially voracious when it comes to sugar maple leaves – and what's left is a thick, black, compacted layer of mineral soil that is hard for seedlings and many native plants to take root in.

"Once someone is trained they can assign a number, one through five, to the area. One being almost earthworm-free and five is heavily infested." Hueffmeier said. "The more points we get over the landscape, the better information land managers have for conservation planning."

The Great Lakes Worm Watch team assessed 1,500 points with the Rapid Assessment Tool in 2009 in northeastern Minnesota and then returned to 20 percent of those points to reassess them with the labor-intensive earthworm sampling method to compare. The tool has been very accurate in Minnesota's north woods. Now Hueffmeier wants to train people in eastern states.

"We designed the tool for collecting data in Minnesota and Wisconsin, but we'd like to run assessments in Ohio, Pennsylvania, New York... What does a level three or four look like there? What different plant and earthworm species are they dealing with?" he said.

Rudimentary data-gathering of earthworms in northern Minnesota began in the 1980s (Reynolds, et. al, 2002) with a single sampling in St. Louis County. Now, with the help of trained researchers and volunteers, NRRI is compiling the largest database of earthworm presence of any state in the United States.

Ancient ores get modern make-over

NRRI helps industry keep pace with changing technologies for steel making

Minnesota's Iron Range has long been an important economic driver for the state, as well as the primary source of ore for U.S. steelmakers. But Minnesota's iron ore products have evolved over time. First was the switch from high grade ores to taconite pellets which continue to serve the regional steel industry. But at the same time, there's growing interest in more refined feedstocks – direct reduced iron (DRI) and pure iron nuggets.

NRRI stays tuned to the needs of steel producers so that Minnesota's iron ore industry has the tools it needs to stay in the game. The evolution has been – and continues to be – interesting.

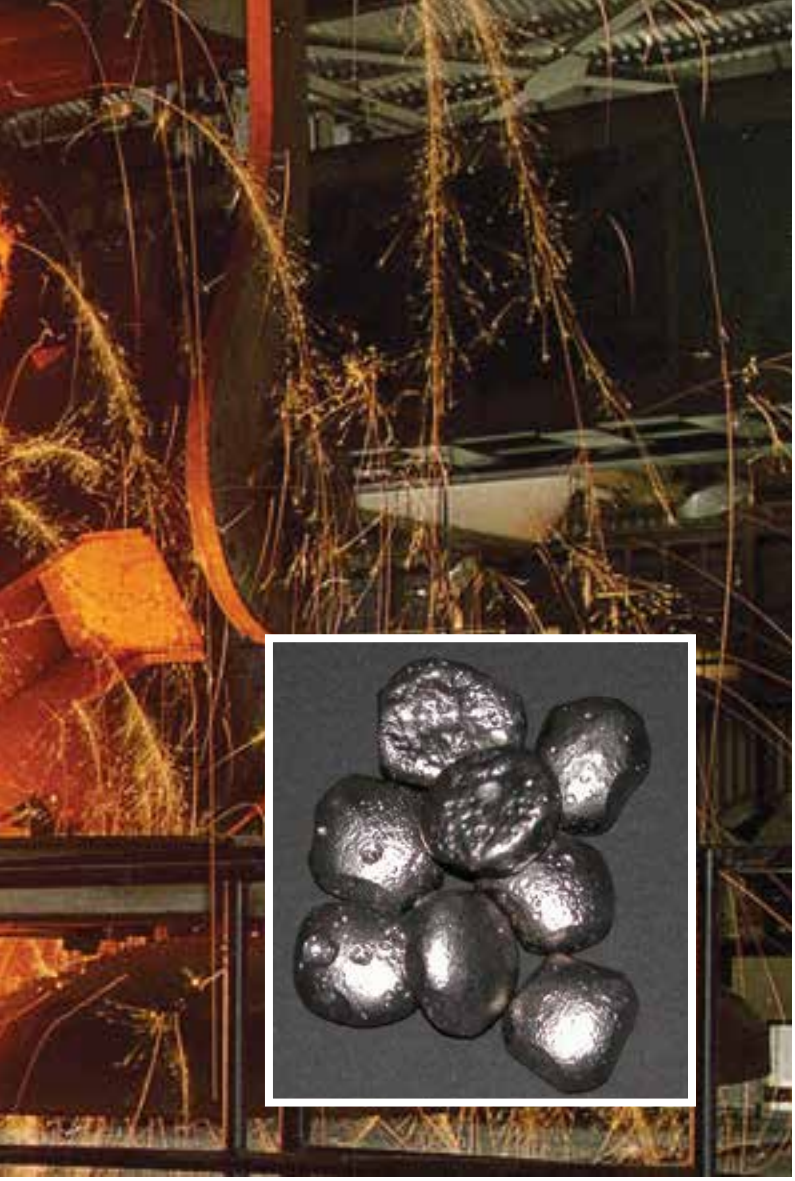
Traditional blast furnaces, still prominent in the U.S. Great Lakes region, produce a decreasing 37 percent of domestic steel, while electric arc furnace "mini mills" are on the rise. It's an understandable evolution. Electric arc furnaces can make steel very efficiently using a combination of pure iron and readily available scrap steel.

"I went to Germany in 1991 and visited a plant that used 100 percent direct reduced iron to make strong, ductile products like piano wire," said NRRI center director Don Fosnacht. "To do that in an electric arc furnace, they had very low residual nitrogen levels in the steel and alterations to the furnace. This has led to the whole gamut of products we can now make in an electric arc furnace."

Since the newer furnaces cannot use taconite pellets for feedstock, NRRI began researching the process of making 97 percent pure iron nuggets and DRI (up to 95 percent iron) from taconite concentrate. After a series of seminars, NRRI hosted a visit to Japan in 2001 to see the rotary hearth method for making iron nuggets at Kobe Steel. NRRI engineers also developed a linear hearth method for making the pure iron nuggets.

To make Minnesota ore compatible for DRI, the silica in the concentrate has to be reduced to less than 1.5 percent. NRRI researched the optimum flotation/separation circuit to achieve that. And because the DRI process is fueled by natural gas, the final hurdle was for the fuel price to come down. Thanks to inexpensive Canadian sources and new natural gas recovery methods, the cost of this fuel has come down quite a bit.

"Electric arc furnace production is growing and we expect the need for blast furnace pellets to decline in the years ahead," said Fosnacht. "It's vital for the taconite industry



to develop another product for the steel market that will serve the mini mill sector."

Early this year, three Minnesota taconite facilities (United Taconite, Northshore Mining and most recently, U.S. Steel) announced plans to produce low-silica pellets for the direct reduced iron market. And Essar Steel is ramping up to actually produce DRI in a new plant in Nashwauk, Minn.

Iron nuggets take the DRI process one step further to achieve a 97 percent pure iron feedstock for electric arc furnaces. Most of the oxygen is removed using carbon/coal to smelt DRI and reduce the ore even further. And the trip to Japan 12 years ago has now led to Mesabi Nugget which has led the way for nugget production in 2010 with a facility in Hoyt Lakes, Minn. It's the first commercial-scale iron nugget facility in the world.

"If we're going to have an iron mining industry here, it has to reflect that our chief customer [blast furnace steel makers] has become a declining part of the overall steel industry," said Fosnacht. "We also have to understand the impact of lower natural gas prices and bringing natural gas-based DRI production to our region. If we do nothing, the prospects for the future of iron mining may not be so rosy."

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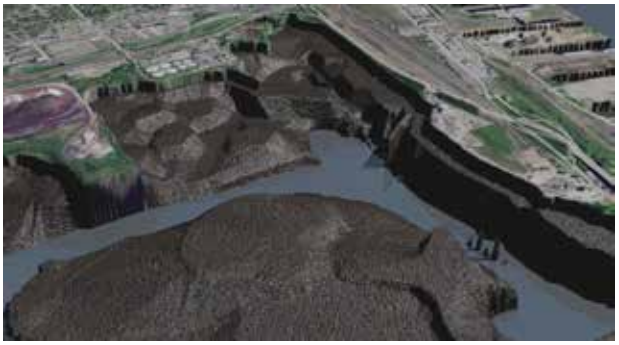
Predicting aquatic plant growth in the St. Louis River Estuary

There's a place in the Duluth-Superior St. Louis River Estuary some call "Coffee Ground Flats" because the bottom of this aquatic ecosystem is covered with a deep layer of century old dark brown wood chips. In the 1800s, thriving sawmill owners used the estuary as a convenient place to dispose of wood waste.



Today's effort is to reverse the damage from past industrial practices that have made some areas of the estuary unsuitable for marine life. NRRI is putting their computer modeling talents to work to help the cause. Funded by the U.S. Fish and Wildlife Service, NRRI scientists are generating simulation models to predict where aquatic vegetation will regrow if certain restoration practices – like islands or artificial reefs – are applied.

If the plants come back, so will the bugs and the fish and the birds... the goal is to develop an 'ecological design' for restoration after the sediments have been cleaned up.

NRRI researchers have collected data at former industrial sites at 21st and 40th Avenues West in Duluth. Their survey includes plants, bugs and birds currently living there, as well as the area's underwater topography and wave energy. A variety of computer simulated islands will be modeled to predict if large scale engineering in the so-called "area of concern" will help break up the wave action and allow more wetland and other aquatic plants to grow.

"This will give the planners an idea of what to expect under different restoration scenarios," George Host, NRRI GIS Lab Director, explained. "It adds solid science to the decision making process."