



# NATURAL RESOURCES RESEARCH INSTITUTE

# NRRI *Now*

Spring/Summer 2008

2

**The afterlife of mattresses**

4

**Birds in the riparian zone**

6

**Pellet industry heats up**

7

**Watchdogs for change**

8

**Biology & ecology come together**

10

**Sampling Iron Range air**

11

**Rapid answers right now**

12

**Earthworms of the Great Lakes**

NRRI researcher Tim Hagen examines cotton removed from old mattresses that are part of an extensive recycling effort in Duluth.



## problems into recycling solutions



Old mattresses are the bane of the landfill. Mostly, it's the steel springs that landfill managers curse. The springy metal won't crush. It bounces back, gets stuck in the bulldozers, and takes up a lot of precious space.

"In landfills, it's all about compaction," says NRRI researcher Tim Hagen. "And bed springs just won't compact. It's a huge problem."

Hagen is working on solving the mattress problem with an innovative and aggressive recycling program in Duluth, one of only two like it in the country. Now in its fourth year, the mattresses are coming in from all over the northern half of the state—by the truckloads.

The public impetus to recycle took off in 2005 when the Western Lake Superior Sanitary District, Carlton and St. Louis Counties instituted a "differential tipping fee" at their landfills and transfer stations, raising the rate to landfill a mattress match the space they take up, and set the recycling rate much lower. The first year 3,139 mattresses and box springs were recycled and this year they expect to recycle over 17,000. The mattresses go to Duluth's Goodwill Industries site where they are cut apart and the materials are separated.

Keeping mattresses out of landfills is the main goal, but the side benefits are a handful of new jobs at Goodwill and a bit of revenue selling the recycled materials.

NRRI funded a local effort to find markets for the materials. The foam is easily sold to companies that make carpet underlayment. The wood frames are chipped up and used as a biomass fuel source. Two other resources from the mattresses—cotton and steel—require research. Hagen's knowledge of fibers and fiber markets, and a small textile plant, has now led to a rebirth for some of the cotton.

Hagen knew that oil filters on diesel engines are commonly made with a combination of cotton and wood fiber, and he knew that Mat, Inc. in Floodwood, Minn., had serviced this market sector. Now the graded cotton goes to Mat, Inc. where it's mixed with wood fibers and prepared for carding. Carding pulls the fibers apart and then it's rolled into lightweight matting which is sold to the local oil filter manufacturer.

"The filter company tested the post consumer cotton against using new cotton and there was absolutely no difference in performance," said Hagen. "In the long run, this application saves raw materials costs and preserves valuable landfill space for future generations."

It seems to be a good fit. The filter manufacturer consumes about 50,000 pounds of cotton a year and that's about how much Goodwill Industries supplies at the present time.



# of mattresses



But what about the pesky steel springs? The value of steel is at an all-time high but as mattress springs, they're too bulky to efficiently truck to a recycler. So Hagen's new challenge is to find a way to compress the steel springs for shipment. He is working with a company that makes baling equipment to see if rolling the steel like hay bales is a viable option.

"We're close to figuring this out," says Hagen, "but that steel is difficult, even though it represents the highest value in the mattress. We need to get it densified so recyclers will take it."

There is one other material that comes out of mattress that Hagen isn't sure he'll ever find a home for—they call it "shoddy." It's

made of shredded old clothes and jeans, and heat-bonded synthetics that are "air-laid" into a dense non-woven mat. Shoddy provides the insulation barrier between the steel springs and the mattresses' fluffy cotton topper. It's what Hagen calls "the worst material known to man" because it cannot be recycled. He is, however, researching its possibilities as a fuel source.

## *Hennepin County to follow*

Research into recycling alternatives began with a grant from the Office of Environmental Assistance (now merged with the MPCA). This funding allowed Regional Planner Hank Fisher to bring together a roundtable of participants to brainstorm mattress solutions—including Terry McDonald with the St. Vincent DePaul Society who ran a successful non-profit mattress recycling program in Eugene, Oregon.

Now, funding from Hennepin County and the Municipal Solid Waste Management Board will allow NRRI to find value-added markets for a similar program in the metro area by early summer. Broader yet, the International Sleep Products Association has also been supporting Duluth's program and is looking at it as a national model for mattress recycling.

"The really neat thing about this program is that any not-for-profit organization can adopt this model, put people to work, and we can all feel good about the environmental gains," says Fisher. "It's so gratifying to me that we're not only saving landfill space and utilizing a resource, but also creating jobs for an organization that helps people with handicaps."

## *About Mat, Inc.*

Mat, Inc. has been making natural fiber mats and blankets for 25 years in Floodwood, Minn., selling a variety of products all over the world—from poultry floor liners to oil absorbent blankets for oil spills. This small textile operation found a unique niche when U.S. textile operations started going overseas.

# Steel Cotton Wood



## BY THE NUMBERS

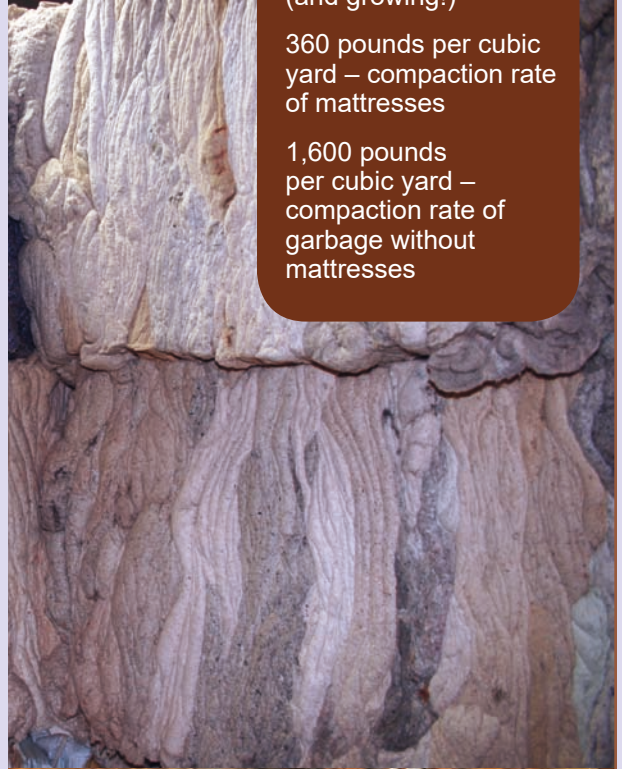
9 pounds of cotton in a mattress (average)

25 pounds of steel in a mattress (average)

1,500 mattresses a month to Duluth Goodwill Industries (and growing!)

360 pounds per cubic yard – compaction rate of mattresses

1,600 pounds per cubic yard – compaction rate of garbage without mattresses



# Bird watching in the forest riparian zone



"Teacher! Teacher! Teacher!" came the shrill cry from the woods.

"The birds talk to me," said Anna Peterson with a big grin. "That's an Ovenbird. Oh! And do you hear the squeaky wheel? That's a black and white warbler. Cool!"

Her enthusiasm was catching for the audience of about 10 forest professionals, gathered around her to learn about breeding birds' response to forest harvesting in tree buffer zones near streams. Peterson is a University of Minnesota biology doctorate candidate finishing up a long-term NRRI research project on birds in forest riparian zones.

Loggers leave a buffer of trees near streams to protect the water quality, but sometimes those buffers hold valuable timber. Can some harvesting of trees take place in those riparian zones without degrading water quality or negatively impacting wildlife? NRRI has been taking part in an 11-year-study on Pokegama



Creek near Grand Rapids to understand the effect of two harvesting methods on bird populations—especially those considered "priority" species.

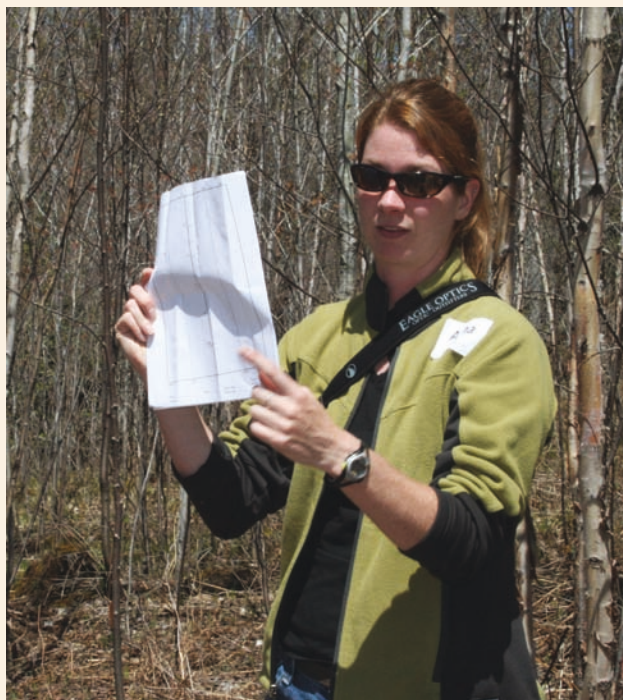
Two harvesting techniques are being studied: tree length cuts where the whole tree is taken from the site, branches and all, and cut-to-length harvesting where the branches are cut off at the site and only the log is taken.

What they've learned is that any harvesting of trees affects the bird community for as much as nine years after the harvest when the more particular birds start moving back into the harvested riparian zones.

"After a harvest, birds that migrate long distances come back to find their nests sites but if they're gone they move on," said Peterson. "But some birds do very well in early successional forests, like the Chestnut-sided Warbler."

A separate but similar study at eight sites in northern Minnesota is also underway with funding from the Legislative-Citizen Commission on Minnesota's Resources (LCCMR). This study began in 2001 to understand the effects of new riparian zone guidelines that allow some harvesting of timber in these buffer zones.

In particular, the study focused on how differences in tree density (residual basal area) would affect populations of



---

Biology Ph.D. candidate Anna Peterson explains to forest professionals how bird monitoring is done.

---

birds. By harvesting riparian zones at different tree densities they could determine which bird species were associated with the different basal areas. They learned that with increasing tree densities, short-distance migrant species (like the American Robin) decreased and birds that prefer early successional forests like Mourning Warblers also decreased.

The May workshop, “At Water’s Edge: Current state of riparian forest management research in Minnesota” was well attended by over 100 natural resources professionals and loggers over the course of three days. UPM/Kymmene paper company allowed researchers the use of 144 acres for the Pokegama Creek studies. The company’s foresters took part in the workshop to continue to improve their management strategies.



## Gathering bird information

Monitoring bird populations in any given area usually starts around 5:00 a.m., when the birds begin their morning calls. The bird researchers must be able to identify the sounds of over 100 different bird species. From their pre-assigned points in the woods, the researchers listen for all the different species they can hear from the point.

Because the forest professionals were out midday when birds are typically quiet, Peterson demonstrated a technique for bringing birds in—chickadee mobbing. She set out an iPod with speakers on a stump in the woods that played the sounds of angry chickadees. These common birds often gang up on larger birds and when they do, it’s like a playground fight. Other birds come in to see what’s going on.

Using the chickadee mobbing sounds, Peterson brought in the Ovenbird, the black and white warbler, and other chickadees. She looked for signs that they might be nesting and breeding, such as carrying nesting materials or food in their beaks.



The conference was sponsored by the Legislative-Citizen Commission on Minnesota Resources, Minnesota Logger Education Program, Minnesota Forest Resources Council, Society of American Foresters, University of Minnesota: Department of Fisheries, Wildlife and Conservation Biology, Department of Forest Resources, Extension-Itasca County, Natural Resources Research Institute, Sustainable Forests Education Cooperative, the USFS Northern Research Station, and the U.S. Geological Survey.





# PELLETIZING INDUSTRY TAKES OFF A GAIN

**NRRI's early involvement helped begin standardization**

One might think a pellet is a pellet is a pellet, if one thinks about pellets at all. But wood pellets are getting increased attention as a zero carbon footprint alternative energy source. And a poor quality pellet—made with inferior biomass or too much ash—can wreak havoc on a pellet heating system.

Pellet stoves burn about 20 percent more efficiently than regular wood burning stoves and about as efficiently as both propane and natural gas furnaces, according to NRRI forestry program director Bill Berguson. But they have another advantage. Pellets are made with wood waste from sawmills and forest harvest residues—resources that are plentiful in northern Minnesota.

This idea isn't new. Back in the mid-1980s NRRI's Energy Division (defunct since 1987) helped nurture along the Fiber Fuels Institute. The industry was young then, and the group wanted to promote the production and use of wood, agricultural residues and other fibrous waste materials as fuels. The reason was good then and it's good today—to reduce dependence on gas, oil and coal. But when fossil fuel prices began to retreat, the effort began to lose momentum.

NRRI's role was to support the Fiber Fuels Institute and provide research for some of the pelletizing projects. For a time, that meant providing an Executive Director and office support for the fledgling organization.

"We were a way station, of sorts," says NRRI's peat program director Tom Malterer. "Fiber Fuels needed a home. We also supported the industrial players so they could launch their pelletized wood products. It grew from being a local effort to a national organization."

In the mid-1990s Fiber Fuels merged with the American Pellet Fuels Institute to form the Pellet Fuels Institute, a non-profit organization that serves pellet mills, pellet appliance manufacturers, industry suppliers and retailers. It continued to grow. And now the early roots planted by NRRI and Fiber Fuels have come full circle back to NRRI through a local engineering/laboratory company, Twin Ports Testing, Inc. This company has also been active in the pellet industry since the mid-80s, verifying the quality of pelletized fuels created by Fiber Fuels members. More recently, Twin Ports Testing is helping to develop new industry-wide standards for residential and commercial densified fuels. NRRI is working with Twin Ports Testing to further develop this industry that will ensure quality pellet performance.

"Considering service issues that have arisen in the past for stove/boiler owners, pellet users will be pleased to know that if the new pellet standards pass, they are buying pellets subject to a rigorous quality assurance and quality control program," said Chris Wiberg, Chief Operations Officer of Twin Ports Testing. "They will know that their pellets truly meet the grade advertised on the bag."

## **Current Pellet Fuels Industry Standards (developed in 1995)**

Two grades of fuel: Premium and Standard. The only difference between the two is ash content. Standard grade fuel is usually up to 3 percent ash content, while premium grade is less than 1 percent. This difference is a result of the pellet contents. Standard pellets are derived from materials that produce more residual ash, such as tree bark or agricultural residues. Premium pellets are usually produced from hardwood or softwood sawdust containing no tree bark. Premium pellets make up 95 percent of current pellet production and can be burned in all appliances. Standard pellets should only be burned in appliances designed to burn the higher ash content pellets. (Source: [pelletheat.org](http://pelletheat.org))

## **New Standards on the way**

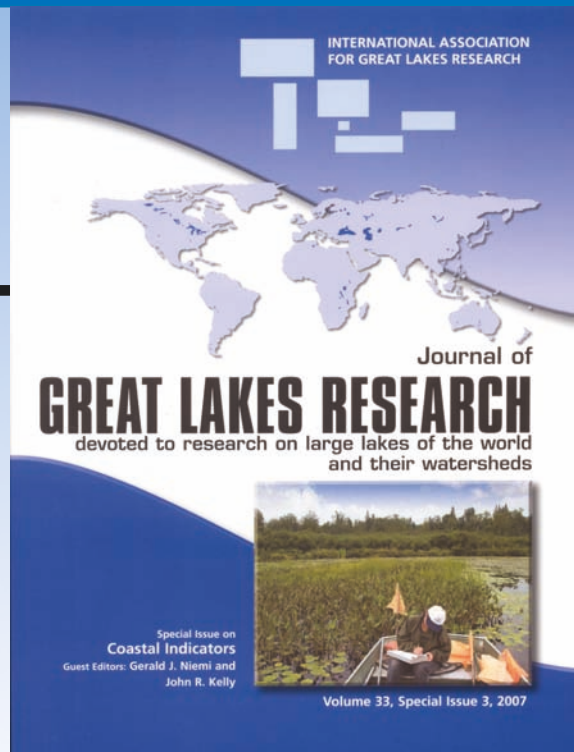
Four grades of pellets: Super Premium, Premium, Standard and Utility. The grade will be determined based on routine analysis of various chemical and physical properties—moisture, ash content, heating value, diameter, length, fines, bulk density, Pellet Durability Index, chloride content, and ash fusion characteristics. An industry-wide Quality Assurance/Quality Control program will verify that the products make the grade. Members will vote on adopting the standards by early summer.

# Watchdogs for change

Incremental changes to the environment may not be noticeable to most people. But the domino effect of those little changes can snowball into a big problem that gets noticed only after it's too late.

A special edition of the *Journal for Great Lakes Research* is focusing on those little indicators of change in the Great Lakes ecosystems. These environmental indicators are benchmarks for the current conditions of the lakes coastal region and provide measurable endpoints to assess the success of future management, conservation, protection and restoration of this important freshwater resource.

"These indicators are vitally important now," said Jerry Niemi, lead researcher for the extensive Great Lakes Environmental Indicators project and NRRI center director. "Information on indicators is legislatively mandated by the governments of the U.S. and Canada



## Journal highlights Great Lakes Environmental Indicators research

because of public demand to know the status of the Great Lakes ecosystems."

Resource management agencies with familiar acronymic names—the EPA, MPCA, DNR, and others—also need information on indicators to make sound decisions on the maintenance, conservation and protection of the lakes.

The list of stressors on our freshwater systems is long: fluctuating and declining

lake levels, warming climate, expanding agricultural activity, invading exotic species, and increasing human population density. What are the ongoing effects of these stressors on water quality, native amphibians, birds, diatoms, fish, bugs and wetland vegetation?

Understanding the link between a response in an indicator and the cause of that response will strengthen the case for restoration or for more thoughtful future planning decisions.

## NRRI researchers contributed to 16 of the 22 research articles in the *Journal of Great Lakes Research 33* (Special Issue 3) 2007:

*Foreword: Environmental indicators for the coastal region of the North American Great Lakes: Introduction and prospectus* by Gerald Niemi, J.R. Kelly, and Nick Danz.

*Testing a fish index of biotic integrity for responses to different stressors in Great Lakes coastal wetlands* by Y. Bhagat, J.J.H. Ciborowski, Lucinda Johnson, D.G. Uzarski, T.M. Burton, S.T.A. Timmermans, and M.J. Cooper.

*Optimizing fishing time: one vs. two-night fyke net sets in Great Lakes coastal systems* by Valerie Brady, J.J.H. Ciborowski, Lucinda Johnson, Nick Danz, J.D. Holland, Dan Breneman, and J.P. Gathman.

*Responsiveness of Great Lakes wetland indicators to human disturbances at multiple spatial scales: a multi-assemblage assessment* by J.C. Brazner, Nick Danz, A.S. Trebitz, Gerald Niemi, Ronald Regal, Tom Hollenhorst, George Host, Euan Reavie, Terry Brown, JoAnn Hanowski, Carol Johnston, Lucinda Johnson, R.W. Howe, and J.J.H. Ciborowski.

*Local and landscape influence on red-winged blackbird (*Agelaius phoeniceus*) nest success in Great Lakes coastal wetlands* by David Grandmaison and Gerald Niemi.

*Considerations for monitoring breeding birds in Great Lakes coastal wetlands* by JoAnn Hanowski, Nick Danz, R.W. Howe, Ronald Regal, and Gerald Niemi.

*Methods for generating multi-scale watershed delineations for indicator development in Great Lake Coastal ecosystems* by Tom Hollenhorst, Terry Brown, Lucinda Johnson, J.J.H. Ciborowski, and George Host.

*An index of ecological condition based on bird assemblages in Great Lakes coastal wetlands* by R.W. Howe, Ronald Regal, JoAnn Hanowski, Gerald Niemi, Nick Danz, and C.R. Smith.

*Sixty-three years of land alteration in Erie Township* by Carol Johnston, T. Watson, and Peter Wolter.

*Plant species indicators of physical environment in Great Lakes coastal wetlands* by Carol Johnston, B. Bedford, Michael Bourdaghs, Terry Brown, C. Frieswyk, M. Tulbure, L. Vaccaro, and J.B. Zedler.

*The influence of anthropogenic disturbance and environmental suitability on the distribution of the nonindigenous amphipod *Echinogammarus**

*ischnus at Laurentian Great Lakes coastal margins* by M. Kang, J.J.H. Ciborowski, and Lucinda Johnson.

*Coastal geomorphic and lake variability in the Laurentian Great Lakes: implications for a diatom-based monitoring tool* by Amy Kireta, Euan Reavie, Nick Danz, Richard Axler, G.V. Sgro, John Kingston, Terry Brown, and Tom Hollenhorst.

*Breeding bird communities across an upland disturbance gradient in the western Lake Superior region* by C. Miller, Gerald Niemi, JoAnn Hanowski, and Ronald Regal.

*Evaluation of the Ohio Rapid Assessment Method for wetlands in the western Great Lakes: an analysis using bird communities* by Anna Peterson and Gerald Niemi.

*Are anurans of Great Lakes coastal wetlands reliable indicators of ecological condition?* By S.J. Price, R.W. Howe, JoAnn Hanowski, Ronald Regal, Gerald Niemi, and C.R. Smith.

*A diatom-based water quality index for Great Lakes coastlines* by Euan Reavie.

# UMD's Integrated Biological Sciences Program

Biology and ecology students come together for a broader science education

Your grandfather's science program just doesn't cut it anymore. Today's scientists are trying to solve broader understanding of multiple disciplines, which is key to unraveling solutions.

The University of Minnesota Duluth is tapping its talents at NRRI, and other disciplines, to integrate cellular and molecular biology with ecology to form a nationally unique undergraduate and graduate program. The Integrated Biological Sciences program merges graduate faculty in the Departments of Biology, Biochemistry, Pharmacology,

the Medical School, NRRI and Duluth's U.S. Environmental Protection Agency. Many scientists at NRRI, including professor John Pastor (formerly an NRRI scientist) helped formulate the early aspirations for this program. Matthew Andrews is founding director of the new program.

"It has become increasing clear that graduate education in the 21<sup>st</sup> century demands that students have a broad, integrated background for working in the sciences," said Andrews. "Most institutions focus on

one particular area. We feel it's important that the students have a broader science background."

The program will allow for emphases in cellular/molecular biology and in ecology, but during the first year the students all study together.

"Typically you wouldn't have students studying ecological systems in the same program as students from the School of Medicine studying molecules. But this way they can study together, teach each other and get to know each other," said Andrews.



NRRI's Jerry Niemi with IBS graduate student Heidi Seeland.




---

IBS graduate student  
Brice Hanson holds  
a sleeping Canada  
L  
research

---

This is the first Ph.D. program administered through UMD where the bulk of the faculty are also at UMD. And even though they haven't graduated anyone yet, its unique approach is attracting attention.

"There are three other universities that have integrated biology/ecology programs, but our program is the most equally balanced and the broadest," said Pastor. "If you asked me which university has a truly integrated program, we're the one."

Pastor offered the current avian flu problem as an example of the interconnections of ecology and molecular/cellular biology.

"To understand avian flu, the cellular biologist has to understand bird migration. You're not going to understand how this flu spreads without understanding bird ecology," he said.

Heidi Seeland is working on her master's degree in integrated biological sciences and hopes to graduate in the spring of 2009. Her master's project is studying fall raptor migrations where they're most concentrated along the north shore of Lake Superior to avoid proposed wind generation turbines. Seeland is being advised by NRRI's Jerry Niemi.

"I am really interested in the public/science interface," said Seeland. "I was attracted to the idea of getting a broad background first, and then specializing. I have a strong background in ecology, but not so much in cellular biology, so I'm learning a lot."

For Master's candidate Brian Black, working with and near people of different academic backgrounds has introduced him to projects, techniques and terminology he otherwise would not be exposed to. Black is being

advised by NRRI's Lucinda Johnson.

"I would eventually like to teach in a university," said Black. "This program allows me to 'fit in' wherever I end up. I will likely be comfortable in any program in biology."

Master's candidate Brice Hansen is also hoping to teach, but at the middle or high school level. Hansen is being advised by NRRI's Ron Moen and plans to graduate in May 2009.

"Having close access to the Superior National Forest and Voyageurs National Park made it possible for me to conduct field work throughout the school year while still teaching and attending classes," said Hansen. "I'd like to continue the field studies and incorporate secondary students into the research... show students there is more to science than white lab coats."

# Airborne particle collecting gets underway on Minnesota's Iron Range

The first samples of airborne particulates were collected in early June from the rooftop of the Virginia City Hall on the Iron Range.

The air samples were collected as part of the Minnesota Taconite Workers Lung Health Partnership. UMD-NRRI and the University of Minnesota School of Public Health are lead participants in the five-year study that will ultimately answer questions about whether the dust caused by mining operations causes health problems for the miners on the Iron Range.

The samples were collected with a specially designed device called a Micro-Orifice Uniform Deposit Impactor, or MOUDI, developed by University of Minnesota professor Virgil Marple, Institute of Technology, Department of Mechanical Engineering. The MOUDI collects the samples separates them by size. It pulls one cubic foot of air each minute through a series of stages comprised of plates with progressively smaller orifices, or openings. The size of the orifices determines the flow rate. Smaller particles with less momentum flow to the lower stages while the larger particles are deposited on a filter at that stage.



NRRI scientist Tamara Diedrich and U of M professor Virgil Marple prepare the MOUDI for another round of airborne particle collection from the rooftop of Virginia City Hall.

“This is important because the size of the particle determines where it’s deposited in the lung,” explained NRRI research associate Tamara Diedrich, principal investigator for this portion of the study. “The nice thing about the MOUDI is that we can extract the information we need to target particles that are deposited in specific areas of lung, and also have a dataset that is flexible for any future studies.”

Earlier versions Marple’s device has been used for several air quality studies in mines since the 1970s.

Initial analysis of the filters will take place at the University’s Department of Mechanical Engineering. They will then be further analyzed with the scanning electron microscope and X-ray diffractometer at UMD.

This is the first step in the research team’s effort to develop a comprehensive work plan for surveying particulate characteristics from the east end of the Range to the west. Three MOUDI’s will be rotated to collect air samples from Hibbing, Silver Bay, Babbitt, Grand Rapids, Ely, Keewatin and Chisholm throughout the summer and continuing on for the next two to three years.

The State of Minnesota and NRRI’s Permanent University Trust Fund provided funding for the study.

# Rapid Answers Right Now

Prototype center offers new materials with real world solutions

Story and photos by Nora Kubazewski,  
NLTC Marketing

**E**ngineering problems are solved with new materials available from NRRI's Northern Lights Technology Center (NLTC). Need to test your prototype under real-world conditions? Need a material that can work for a snap-fit design or a movable hinge, not once but over and over again? Need an air-tight or liquid-tight part? Need a flame retardant part for testing? No problem for the new materials being tested at the Northern Lights Technology Center.

Often prototypes are used as the final test before manufacturing and can eliminate costly production mistakes. Choice of materials and properties become the driver for the best method, which is especially true in the medical or aeronautics fields.

Recently, program director and chief engineer, Steve Kossett, displayed the Center's strengths in using the new materials at the 3D User Conference. "NLTC showcased two materials at the conference: DuraForm EX as a rapid manufacturing material that can be highly finished for products as well as used for traditional, functional prototypes," said Kossett. "And we also showcased FR-106, a self-extinguishing flame retardant nylon typically used in the aircraft industry."

DuraForm EX plastic offers the toughness of injection-molded ABS and polypropylene parts. These parts can withstand aggressive, functional testing and be finished to a high gloss by using specialized techniques. The EX material is capable of complex, thin-walled ductwork, snap-fit designs or living hinges for functional prototypes that require end-use performance properties. After all, it's difficult to check your prototype in a real-world situation if the materials don't hold up.

Sample football helmets were made using DuraForm EX and finished only by applying a clear-

coat, then sanding and buffing. Even the interior pads on the helmet were rapid prototyped using DuraForm Flex, another specialized material used by NLTC.

Another new material is FR-106, a flame retardant nylon which doesn't compromise mechanical properties. This material was especially of interest to Cirrus Designs as it was originally developed for aircraft interiors by Advanced Laser Materials, LLC for Boeing specifications with rapid manufacturing capabilities in mind.

Todd Strait, of Advanced Laser Materials, LLC, said FR-106 is particularly attractive for more than just prototyping and is excellent for rapid manufacturing because it maintains superior toughness and impact resistance coupled with self-extinguishing properties.

"This is our flagship material and is the first of its kind in the aerospace industry. They typically don't need thousands of parts in one order so this material fills the need of creating parts to be used in real world situations. FR-106 was developed from specifications of Boeing Corporation and is used on their 787 aircraft," said Strait. "We know of five to six major companies in the aerospace industry using our FR-106 right now."

The Northern Lights Technology Center features four rapid prototyping technologies with a wide selection of materials available. Since 2003, the lab has offered stereolithography, selective laser sintering, 3 D printing, and fused deposition modeling using solid model and 3D CAD programs such as Solidworks.

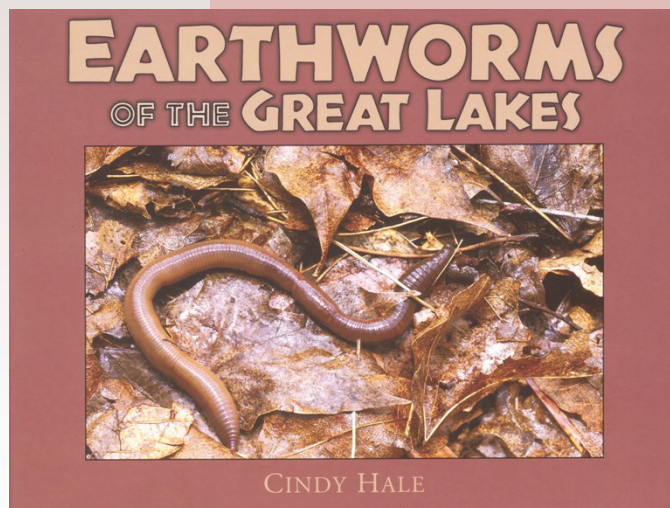


# NRRI scientist publishes book about invasive earthworms

All it took was one shipload of immigrants—although it was probably many—toting plants rooted in European soil, or dumping soil used as ship ballast, to start the invasion. Little did these early immigrants to America know, the earthworms in that soil were an invasive species to this continent, and their slow spread would eventually change the face of native U.S. forests.

NRRI research scientist and environmental educator Cindy Hale has published “Earthworms of the Great Lakes” (Kollath+Stensaas Publishing, Duluth, MN) which describes how northern forests are impacted by exotic earthworms and how citizens can get involved in documenting earthworm invasions. The field guide format provides pictures and detailed anatomical descriptions of 16 species of exotic earthworms found in the Great Lakes region along with information to prevent further human dispersal of earthworms. This book is the result of Hale’s 15 years studying forest ecology with a special interest in exotic earthworms and their impact on the forest ecosystem.

Hale has trained over 500 teachers and environmental educators in sampling and identifying earthworms and started the Great Lakes Worm Watch program to communicate her findings to the public. For more information go to [www.greatlakeswormwatch.org](http://www.greatlakeswormwatch.org).



## Check us out: [www.nrri.umn.edu](http://www.nrri.umn.edu)

*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.*

**Michael Lalich, director**

**Center for Water & the Environment**

Gerald Niemi, director

**Center for Applied Research & Technology Development**

Donald Fosnacht, director

**Center for Economic Development**

Elaine Hansen, director

*NRRI Now*

June Kallestad, editor/writer

Trish Sodahl, graphic design

*NRRI Now is published to provide information about our programs and projects. For details call (218) 720-4294.*

### **NRRI Now**

Natural Resources Research Institute

University of Minnesota, Duluth

5013 Miller Trunk Highway

Duluth Minnesota 55811-1442

### **Address Service Requested**

Non-Profit  
Organization  
**U.S. Postage  
Paid**  
Permit No. 705  
Duluth, Minnesota



*Printed on recycled paper made from 10 percent post-consumer waste with soy ink.  
The University of Minnesota is an equal opportunity educator and employer.*