Research

MICHIGAN TECHNOLOGICAL UNIVERSITY › 2012

Cladophora

The comeback ooze

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On the cover
Aaron Dayton dives over a Cladophora *bed in Lake Michigan's Good Harbor Bay, conducting research for his master's thesis. The native alga is running rampant throughout the Great Lakes, fouling beaches and coating hundreds of square miles of lake bottom.*
PHOTO: CHRIS DOYLE

Michigan Tech

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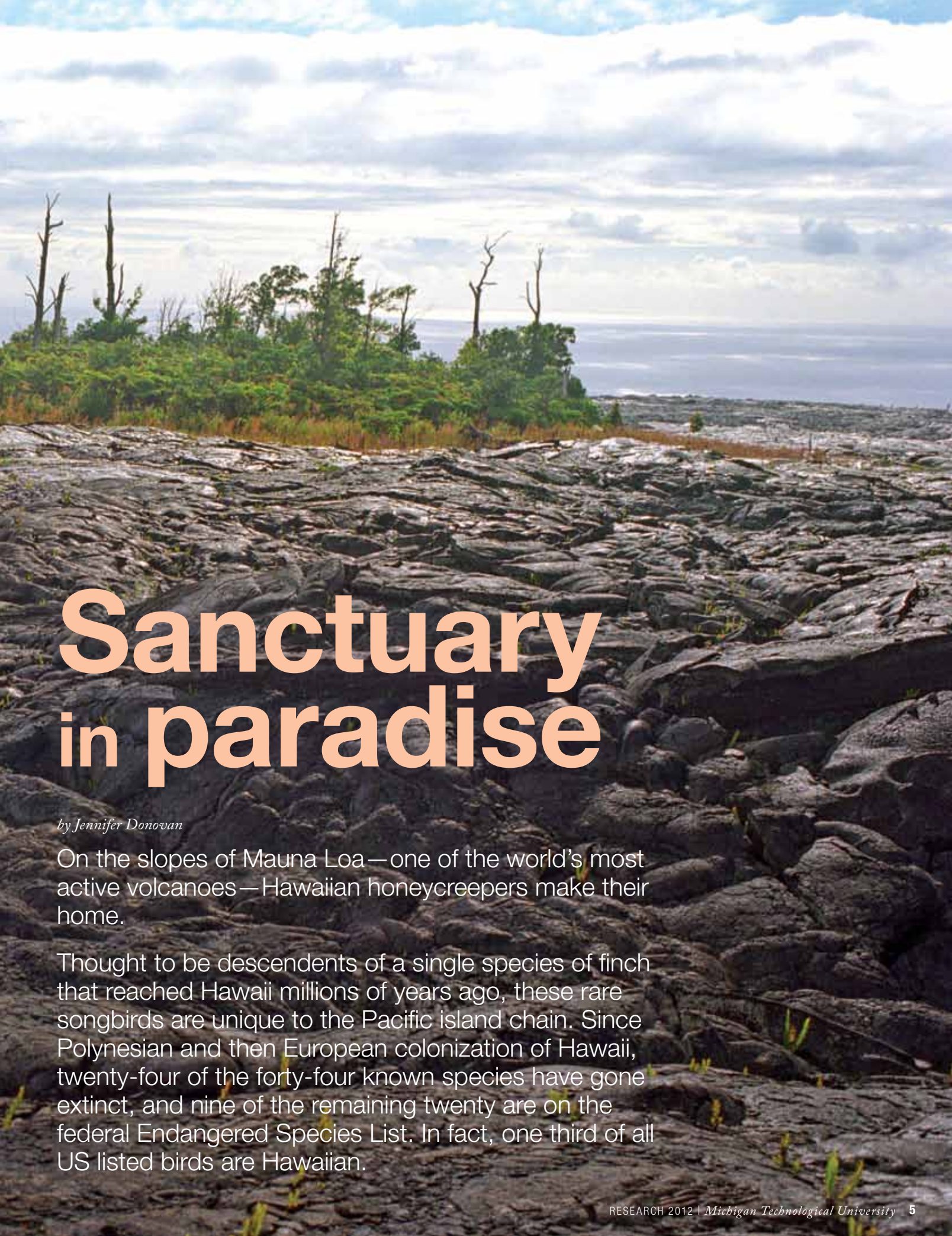
The kipuka landscape is one of the last strongholds of the native i'iwi. This nectar-feeding honeycreeper is very sensitive to avian malaria, but it is safe for now from disease-carrying mosquitoes on these high, cool, forested islands surrounded by lava flows.

KIPUKA PHOTO: MICHAEL STEWART
BIRD PHOTO: DAVID FLASPOHLER



Sanctuary in paradise

by Jennifer Donovan

On the slopes of Mauna Loa—one of the world's most active volcanoes—Hawaiian honeycreepers make their home.

Thought to be descendents of a single species of finch that reached Hawaii millions of years ago, these rare songbirds are unique to the Pacific island chain. Since Polynesian and then European colonization of Hawaii, twenty-four of the forty-four known species have gone extinct, and nine of the remaining twenty are on the federal Endangered Species List. In fact, one third of all US listed birds are Hawaiian.

Honeycreepers not only survive in the fragmented forest caused by lava flows more than 150 years ago, some also seem to have found ways to thrive there.

David Flaspohler, a professor in the School of Forest Resources and Environmental Science, and Jessie Knowlton, a postdoctoral researcher in his lab, are trying to figure out why. What helps—or harms—these birds in the "kipukas," a Hawaiian word for the forested patches created by lava flowing through densely treed land?

Funded by the National Science Foundation, the researchers are examining thirty-four kipukas ranging in size from one-quarter acre to 150 acres in a remote, protected area on the Big Island of Hawaii, where the human footprint has been minimal.

Kipukas are home to native vegetation, insects, rare birds like the honeycreepers, and rats introduced by man. This relatively simple forest ecosystem offers an ideal living laboratory, enabling scientists to study the interactions and adaptations of the creatures that call the forest fragments home.

"Most fragmentation studies look at species response to fragmentation over a few to maybe ten years," Flaspohler says. "Here we can examine the ecological legacy of a century and a half of fragmentation."

These forests are particularly important to the survival of native Hawaiian birds because they are above the 4,000-foot elevation threshold. Below that, introduced tropical mosquitoes carry introduced avian malaria, which has devastated native lowland bird populations.

A conservation biologist, Flaspohler studies how organisms interact with their environment, particularly ecosystems altered by human activity and species that are most sensitive to such changes.

"Honeycreepers are exquisitely suited to these dynamic native forests and the rich resources they provide, including nectar, insects, and seeds," he says. "They survived millions of years of volcanism as a succession of islands rose and then eroded into the sea. In fact, these geologic forces were the engines that drove adaptive radiation, giving rise to the spectacular diversity of

color and bill shape that make this group of birds one of the most famous in the world."

Using delicate nylon mist nets designed especially for humane live capture and release of birds, Flaspohler and Knowlton gently capture the honeycreepers and band them. Each bird gets a uniquely colored combination of ankle bands so the scientists can identify them later. They have already banded more than 800 birds.

The impact of black rats on the honeycreepers' survival is one of the scientists' particular concerns. Not natives of Hawaii, the rats probably arrived on ships centuries ago. The tree-climbing rodents have become the most significant predator of birds and their eggs in the kipukas. Rats also eat insects, directly competing with birds for food.

"Hawaii can tell us how birds cope and evolve and persist. This may help us prevent more endangered species from becoming extinct."

Rats are being trapped and removed from half of the kipukas. The scientists will then compare the survival rate and abundance of the honeycreepers and the success of their nests in rat-infested kipukas and those that are virtually rat-free.

Flaspohler and Knowlton hope their research on the honeycreepers in the kipukas of Hawaii will teach us how to maintain biodiversity there and elsewhere in the face of increasing habitat fragmentation and climate change. Rising global temperatures are expected to allow malaria-carrying tropical mosquitoes to move upslope, threatening the birds in these forest refuges. "Hawaii can tell us how birds cope and evolve and persist, and these insights can inform our understanding of how birds cope with habitat change in other parts of the world," he says. "This may help prevent more endangered species from becoming extinct."

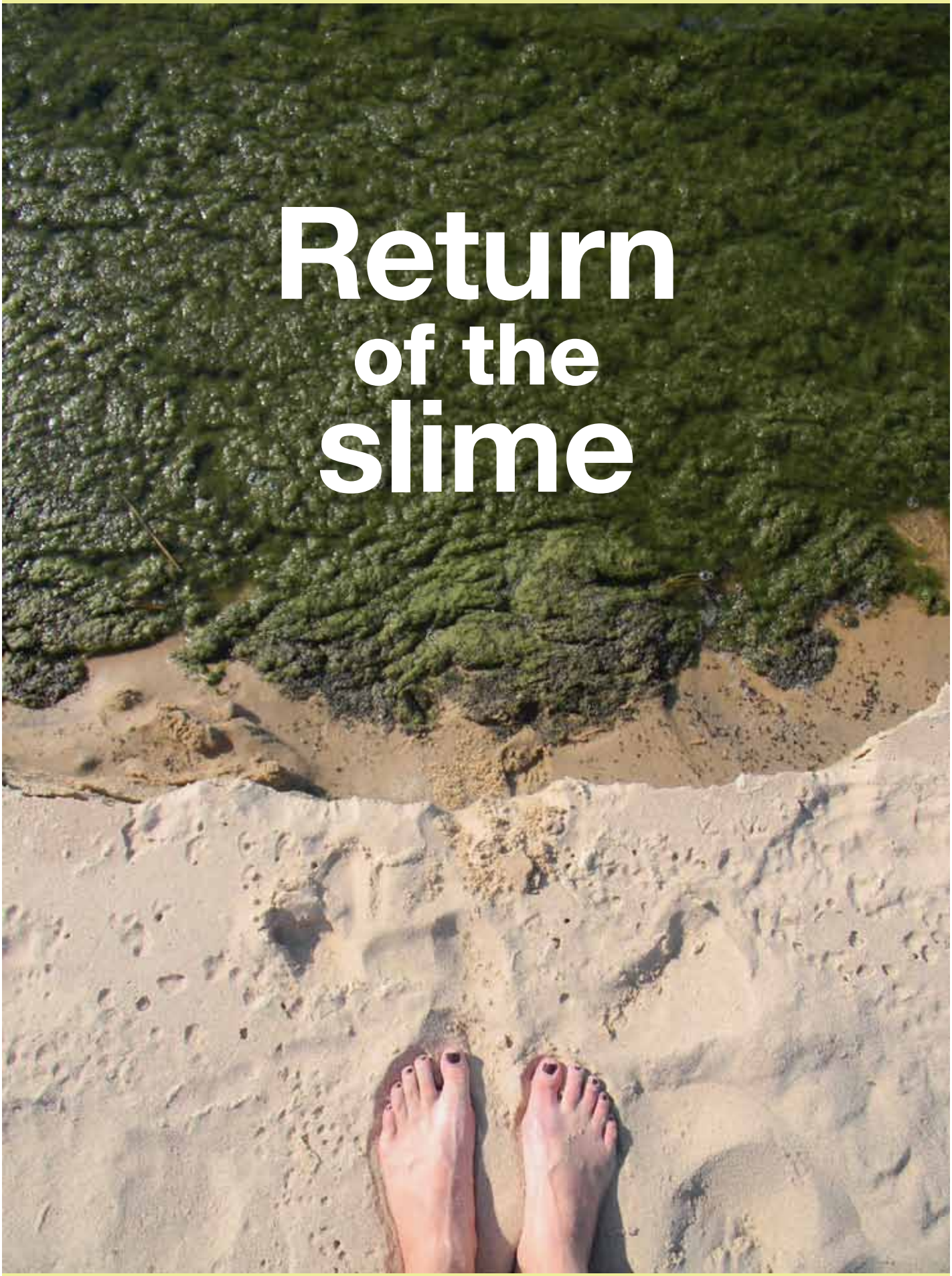
Their research is a collaborative effort with Stanford University, the University of Maryland, the US Forest Service Institute for Pacific Islands Forestry, and the Carnegie Institution. ■

For more information
http://forest.mtu.edu/research/cbae

Far upper left, a kipuka in the midst of a lava flow; lower left, an o'mao, a native thrush, with distinctive bands that allow for easy identification; near left, researchers measure the bill of an i'iwi, a native honeycreeper. Above, David Flaspohler's field crew measures and bands birds before releasing them; upper right, Flaspohler with a nonnative Japanese white-eye; lower right, male (left) and female (right) Hawaii amakihis, native honeycreepers that feed on insects and nectar.

PHOTOS: TOP LEFT, USGS/J.D. GRIGGS. TOP RIGHT, CARRIE FLASPOHLER. ALL OTHER PHOTOS, DAVID FLASPOHLER

Return of the slime



KRYSTAL JOHNS

by Marcia Goodrich

The oozy, green, bottom-dwelling alga called *Cladophora glomerata* has squished around toes about as long as people have been wading in the Great Lakes. It was never a serious nuisance, however, until the mid-twentieth century. That's when an unprecedented number of huge, gooey mats of *Cladophora* (pronounced klah-DAH-for-uh) blooms uprooted and drifted ashore, fouling entire beaches with a thick layer of rotting muck.

Then came the Great Lakes Water Quality Agreement, and the mats of *Cladophora* all but disappeared. Says Robert Shuchman, codirector of the Michigan Tech Research Institute, "It was a great success story." It was also a short one. After thirty years in the wings, *Cladophora* is back on center stage.

The story begins in the 1970s, when Martin Auer was a PhD candidate at the University of Michigan. His advisor asked him to check out the relationship between the phosphorus-rich effluent flowing from a sewage treatment plant and the jungle-like growth of *Cladophora* thriving nearby. Auer, now a professor of civil and environmental engineering at Michigan Tech, was able to demonstrate that lowering phosphorus levels from the effluent got rid of nearly all the *Cladophora*. Through this work, Auer became a respected expert on one of the biggest problems afflicting the Great Lakes.

Guided by Auer's findings, the US and Canada developed regulations that would slash the amount of phosphorus entering the Great Lakes. Soon, the massive algal blooms faded away.

"People said, 'We're done,'" Auer remembers. "'There's nothing else to do. That's the end of it.'" They appeared to be right. Auer calls 1985 to 2005 "the Dark Age of *Cladophora*." "It seemed," he said, "like there was no more *Cladophora* work to be done."

Of course, *Cladophora* was still around; it just wasn't a nuisance. "It's not an invader," Auer notes. "It's always been in all of the Great Lakes except Superior." A filamentous green alga, it attaches to anything solid, like rocks, and floats upward toward the sun. "If I were to pick you up and dunk you in the lake, your hair would hang like *Cladophora*," he says.

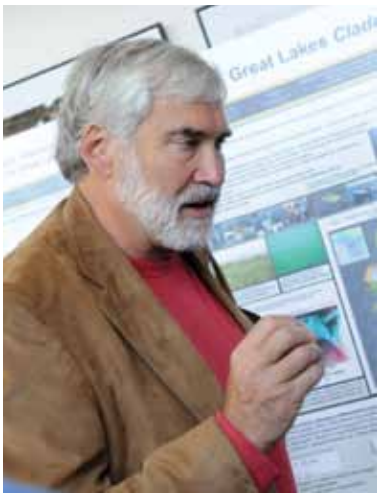
Then, a generation after the *Cladophora* problem had supposedly taken its final bow, it was back with a vengeance. Vast stretches of lake bottom in Lakes Erie, Huron, Ontario, and Michigan were coated. "The stuff was washing up and clogging the cooling water intakes for nuclear power plants," Auer says. "The power plants had to shut down."

Initially, no one understood what was going on. "We'd been removing phosphorus, and everything was supposed to be getting better," Auer says. As it turned out, the reason everything was now getting worse came in the form of another pesky species.

Practically no one in the Great Lakes region had even heard of zebra mussels during the first *Cladophora* explosion. But in the intervening years, the oceanic invaders hitched rides in the ballast tanks of sea-going vessels and established themselves in all of the Great Lakes, save Superior.

They not only clogged water intake pipes and disrupted the food chain, "they changed the Great Lakes in three ways that benefit *Cladophora*," says Auer. "It's not your grandmother's ecosystem anymore."

First, zebra mussels filter particles out of the lakes, clarifying the water and letting sunlight penetrate deeper. It's like turning on a grow light. "Now,



MICHAEL BLANCHARD

Robert Shuchman, left, uses satellite data to pinpoint the location of* Cladophora *in the Great Lakes. Martin Auer was among the first to establish a link between phosphorus and an overgrowth of the nuisance alga.

where *Cladophora* used to grow at depths of ten feet, they now grow at forty-five," said Auer. "You have *Cladophora* growing where it never could before."

Second, the mussels are whipping up *Cladophora's* favorite food. "Rivers carry a type of phosphorus that *Cladophora* can't use, which used to go out to the center of the Great Lakes," Auer said. "Now come the zebra mussels, and they filter out that phosphorus and spit it back in a form that's perfect for *Cladophora*. It's like living upstairs of the bakery."

Finally, the zebras are creating new real estate. Billions of zebra mussel shells coat the once-sandy lake bottom, providing a hard surface where *Cladophora* filaments can attach.

"So you have a triple whammy," says Shuchman. And thus far, no one has found a way to evict zebra mussels from the Great Lakes. Controlling twenty-first century *Cladophora* is turning out to be far more complicated than keeping excess phosphorus out of the ecosystem.

In 2009, the US Environmental Protection Agency took aim at the myriad problems plaguing the Great Lakes through the Great Lakes Restoration Initiative. With funding from the initiative, Shuchman and his research team are helping resource managers get their arms around the *Cladophora* problem.

"The EPA asked us to find out where *Cladophora* is concentrated," Shuchman said. It seems like an easy enough question if your boat's propeller is encapsulated in slime, but with thousands of miles of Great Lakes shoreline, no one had a good estimate of the extent of the *Cladophora* beds.

To find out, Shuchman and his team are using remote-sensing data from satellites. They measure "radiance," or reflective brightness, to distinguish *Cladophora* beds from areas where the lake bottom is clear. That's relatively easy at a constant depth, but radiance drops as water gets deeper.

To account for the difference, Shuchman integrated the satellite data with information on the lake bottoms and developed an elegant algorithm that compensates for the depth of the water.

"By doing this, we can map *Cladophora* in a straightforward way," he said. To verify their results, they use ground truth, i.e., up-close sensing: researchers boat along the shoreline and visually check for *Cladophora*, often using a

In addition to its Cladophora *efforts, the Michigan Tech Research Institute is working on three other projects as part of the federally funded Great Lakes Restoration Initiative.*

Everything you wanted to know about the Great Lakes

"The goal of this project is to make one place where everyone can get data on the Great Lakes," says Nate Jessee, an assistant research scientist. "It's the synthesis of many products we've produced."

Known formally as the Great Lakes Observation System Area

of Concern Tributary Monitoring program, the project gives visitors the latest information on a variety of topics at the website. Anyone from anglers to the Department of Natural Resources can check out Great Lakes maps for data on lake surface temperature; sediment plumes; color-producing agents (chlorophyll, dissolved organic carbon, and suspended minerals); harmful algal blooms; the type of land cover, such as forests, agriculture, wetlands, and urban; and lake-bottom type (sand or algae).

The site is updated from May through November using satellite data and is frequented regularly by government resource managers. "We have terabytes and terabytes of data," says Jessee. "We hope to help others bring back diversity and the finest possible recreation to the Great Lakes." Learn more at www.glosaocmapping.org.

Finding *Phragmites*

Great Lakes *Phragmites* (pronounced frag-MY-tees) comes in two types: good and bad. The good type is a native reed that plays well with others, says research scientist Colin Brooks. "The bad type is an invasive exotic that gets fifteen feet tall, crowds out native plants, and takes over wetlands," he says. "In *Phragmites* marshes, the only things we've seen are slugs and aphids. Even mosquitoes don't like *Phragmites* habitats."

Brooks's research lab is using satellite imagery to map the bad *Phragmites* in the US coastal regions of the Great Lakes, so resource managers trying to control it can find it. Laura Bourgeau-Chavez, also of MTRI, leads the *Phragmites* mapping project.

Quagga mussels have gobbled up the food supply for Asian carp in mid-Lake Michigan, "but there's plenty of *Cladophora* near shore for them to eat."

remote-controlled mini-submarine camera. These surveys showed their remote-sensing analysis to be about 90 percent accurate.

Shuchman's team will also track the historical ebb and flow of *Cladophora* by applying the algorithm to satellite images that go back decades.

Armed with this information, resource managers will be able to locate *Cladophora* beds and tell if their cleanup efforts are working. The EPA is already using their data to track the health of the Great Lakes. Auer and Shuchman are also considering ways to track the algal mats, which typically slough off the lake bottom in midsummer, and possibly block them before they land on beaches or in the cooling water intakes of nuclear power plants.

The team members will map all US waters in the Great Lakes that are optically visible—those parts where light can be reflected off the bottom. Already they have determined that sunlight is reaching much more of the lake bottom than in years past, thanks to the mussels' insatiable appetite for water-clouding plankton. "I hate zebra mussels, but they have made it possible for us to look into deeper water," Shuchman said.

The team has already finished mapping Lake Michigan. They have found *Cladophora* on 591 square miles, or about a third of the optically visible area. Ironically, *Cladophora* is superabundant near Sleeping Bear Dunes National Lakeshore, where twenty-inch-thick algal mats lie just a few yards off shore. "That place is full of *Cladophora*," Auer said. "But *Good Morning America* named Sleeping Bear Dunes the most beautiful place in America."

It wouldn't be so beautiful if those mats washed up on the miles of white sand beaches, he added. In addition to creating a repulsive viewing experience, rotting *Cladophora* provides ripe conditions for avian botulism and has been implicated in the poisoning deaths of thousands of shorebirds.

The abundance of *Cladophora* could have even broader implications. "It's a little bit scary," Shuchman said, in part because the Michigan Department of Natural Resources reports that the exotic Asian carp can eat *Cladophora*. The voracious fish have infested the Mississippi River system, and many fear they will expand their range into the Great Lakes via the Chicago Shipping Canal.

The filter-feeding quagga mussels have essentially wiped out their potential food supply in the middle of Lake Michigan, "so the carp will never survive in deep water," said Shuchman. "But there's plenty of *Cladophora* near the shore for them to eat." ■

For more information
http://mtri.org

JOSEPH MCCAULEY, USFSW

Phragmites may be on the move. The invasive form now grows mostly south of a line that runs roughly between Lake Huron's Thunder Bay, Traverse City, and Green Bay. Farther north, mostly the native version of *Phragmites* is found. But if it gets warmer and lake levels drop, the invasive form may come north, and the US Geological Survey and the US Fish and Wildlife Service want to know where it is and where it might show up because of climate change. "Our product will help with decision making. It's great to have a map, and it's even better if people use it," said Bourgeau-Chavez.

Maps of *Phragmites* in the US coastal Great Lakes region and MTRI's field data are available at www.mtri.org/phragmites.html.

Beyond *Cladophora*: Toxic algal blooms

Cladophora isn't the only problem alga in the Great Lakes. Western Lake Erie is undergoing one of the worst algal blooms of *Microcystis* in decades. Harmful algal blooms, or HABs, have also shown up in Green Bay and Saginaw Bay.

"This is a record year for HABs," says research engineer Michael Sayers. Concentrations have skyrocketed in portions of Lake Erie, from 35 micrograms per liter to 1,000. The blue-green algae are toxic, killing fish and endangering other wildlife and human health. They thrive in nutrient-rich, stagnant water.

Sayers and other members of the MTRI team are developing algorithms that describe the extent of HABs dating back to the early 2000s. "The trick is to tell blue-green algae from regular algae, but we're coming up with a nice algorithm using satellite data," he says. "It's very robust. Our goal is to help the people who are trying to remediate this."

HEV engineering goes over-the-road

Advanced powertrain lab rolls on 18 wheels

by Jennifer Donovan

Eric Foote had been working in automotive emissions for seventeen years when the auto industry's economic meltdown caught up with him. Laid off from AVL, a giant powertrain systems developer, Foote had been out of work for eight months when he heard about Michigan Tech's course in hybrid electric vehicle engineering. The University had partnered with General Motors and the Engineering Society of Detroit to offer the free course to displaced engineers in the Detroit area.

Foote signed up in the spring of 2010. Now he is employed as a correlation engineer at Ford Motor Company, a job he doubts he could have gotten without the hybrid electric vehicle training.

"Hybrid electric vehicles are the latest technology, and in my field—emissions—I really needed to understand the emissions evaluation aspects of hybrid electrics," Foote explains.

The course was a precursor of Michigan Tech's pioneering program in hybrid electric vehicle engineering. One of the first of its kind in the nation, Tech's HEV program is funded by a $3 million US Department of Energy grant and $750,000 of in-kind contributions from industry sponsors and partners. It's offered on campus, online, and—thanks to the showpiece of the program—on the road.

That showpiece is a huge, handsome mobile lab and classroom that enables the University to take hands-on hybrid electric vehicle education right to working and displaced engineers, company employees, students, and communities, wherever they may be.

A Chevy Volt charges its batteries outside the mobile HEV lab, Michigan Tech's latest tool in advanced powertrain engineering research and education.

In the mobile lab, Jeremy Worm teaches the finer points of hardware-in-the-loop powertrain testing.

Designed and built at Michigan Tech by an interdisciplinary team of engineering students under the industry-savvy guidance of Research Engineer Jeremy Worm, the mobile HEV lab is housed in an expandable, double-wide trailer. It's pulled by a class 8 diesel semi with a Detroit Diesel DD15 engine, the latest in heavy-duty diesel technology. The semi tractor was provided by Detroit Diesel on a no-charge, ten-year consignment.

The mobile lab is wi-fi accessible throughout, and everything inside is as mobile as the trailer itself, with desks, chairs, and workspaces that can be reconfigured to suit. The bunk space for an over-the-road driver is being converted to a high-tech office, where the lab's road team of four can work when they aren't teaching or driving.

Another unique feature is two powertrain "hardware-in-the-loop" test cells, a cutting-edge developmental tool that enables students to learn how the HEV components work, including the batteries, engines, electric motors, and power electronics. Then, using the test cells, they can experiment with how every part of the system reacts to changes in any other part.

"The powertrain test cell sits in the trailer and thinks it's on the road," Worm explains. "Students can change gears, change batteries, change engines, change hardware and software of every kind, and see what effect it has on fuel economy, emissions, top speed, and cost."

Reconfigure and go figure

Then they get to test their solutions in another unique component of the mobile lab, a configurable hybrid electric vehicle. Built by students, faculty, and staff in the Department of Mechanical Engineering–Engineering Mechanics, the heart of the configurable HEV is a Kohler industrial engine on a dune-buggy frame. Everything on it—rear axle, engine controls, motor, battery—can be changed and changed quickly. "We can switch out gears in three minutes, something that would take three days on a regular vehicle in a shop," says Worm.

And finally, after the students have evaluated up to 14,000 possible combinations through testing or simulation, they prepare their vehicle for final validation testing. They also get to experience the state-of-the-art in three four-wheel gifts from

“A lot of people are teaching a short course in HEV here, a class there, but this is the first effort we know of to pull it all together in a hands-on curriculum.”

General Motors: a real, live Chevy Malibu hybrid, a Saturn Vue, and a Chevy Volt. The HEV students drive them on public roads and compare the effects of various parameters on fuel economy and driveability.

Students at Michigan Tech are already using the mobile lab in half a dozen courses, part of the HEV/engineering sustainable transportation curriculum. The program includes classes selected by the Michigan Academy of Green Mobility for training automotive engineers, a certificate program, and a professional master’s degree.

Chris Morgan, who graduated from Tech last spring with an MS in Mechanical Engineering, credits the HEV courses he took with helping him land his job in hybrid electric vehicle software and calibration at GM.

“This technology is driving many of the major fuel efficiency improvements in vehicle power systems,” says Morgan. “It is the leading edge of engineering in the automotive world.” Auto manufacturers are looking for engineers with knowledge of hybrid electric vehicles, because HEV education is new to mechanical engineering programs, he adds.

HEV to the people

The mobile lab will be on the road this spring. Worm and his colleagues are developing HEV short courses for engineers at automotive companies and agencies like TARDEC, the US Army’s tank research center. They are also partnering with companies such as Wineman Technologies and National Instruments, whose substantial gifts made the lab possible, to use the mobile lab to conduct educational programs for the public and schoolchildren. They hope to join the Michigan Tech Mind Trekkers on the National Mall in Washington, DC, at the USA Science and Engineering Festival in April.

Jeremy Worm, right, helps a student develop a protocol for fuel-economy testing.

“A lot of people are teaching a short course in hybrid electric vehicles here, a university class there,” Worm says, “but this is the first effort we know of to pull it all together into a hands-on curriculum equally accessible to students on campus and far away, filled with technology that is constantly reinventing itself, that also incorporates a long arm of outreach to the public who will drive these vehicles and the schoolchildren who will design and build them down the road. That’s why the Department of Energy is looking to Michigan Tech to build a model for the nation.” ■

For more information
www.me.mtu.edu/researchAreas/aice

The hybrid electric vehicle mobile lab on the road in Houghton County, followed by three test cars donated by General Motors: a Saturn Vue, a Chevy Malibu, and a Chevy Volt.

Good cop, better cop

It's a life-or-death world out there, and experience can make all the difference. Can we teach street smarts?

by Frank Stephenson

Three days after Christmas 2010, 24-year-old rookie police officer Jillian Smith of the Arlington, Texas, Police Department responded to a call from a distraught woman claiming to have just been sexually assaulted by her ex-boyfriend and wanting to file a report. Smith, only two weeks out of field training, showed up alone at the apartment shared by the 38-year-old woman and her 11-year-old daughter.

Within minutes, the woman's ex-boyfriend—a registered sex offender—burst into the apartment with a handgun and killed Smith with a shot to the head. He then shot and killed his ex-girlfriend before turning the gun on himself. In the mayhem, the terrified 11-year-old girl escaped to a nearby friend's apartment.

In an average year, more than fifty police officers in the US are killed in the line of duty. Most are in their prime (in 2010 the average age was 38) and most are experienced officers with an average of at least ten years on the force. Every death is tragic, yet the death of a rookie officer somehow always seems more so. When young cops die, inevitably the same questions are raised: Did the officer make a "rookie" mistake? Did he or she suddenly confront a situation that their training failed to address—either adequately or at all?

Statistics on the circumstances surrounding novice police officers killed or wounded in the line of duty aren't easy to come by, nor is there much evidence that the ways recruits are trained in any of the country's hundreds of law enforcement academies each year are fundamentally flawed. But implicit in an almost universal requirement by police agencies that rookies be partnered with veteran officers suggests a well-understood maxim in law enforcement administration, namely that no amount of classroom instruction or field training—regardless of its quality or duration—can match on-the-street experience for creating an expert cop.

Whatever it is about real-world experience in any field that requires quick and accurate decision-making—from law enforcement to professional sports—is endlessly fascinating to cognitive psychologists, scientists who study how we think. Michigan Tech's Paul Ward is one such researcher who has made a career pursuing the elusive elements that make up the thought processes of people who are remarkably good at making correct, split-second decisions—and doing it consistently.

Ward is an associate professor in the University's Department of Cognitive and Learning Sciences. His latest work uses a series of highly controlled video simulations designed to contrast the performance of rookie policemen with that of their fellow officers with years of experience. He, along with his grad student Joel Suss and other colleagues, recently published findings that they believe offer some of the best insights yet uncovered in the study of expert decision-making under stress.

"From the start, our No. 1 goal in this research has been to develop a comprehensive understanding of skilled decision-making in complex law enforcement situations," Ward said. "We believe we can use this knowledge to test and improve training methods [in law enforcement] that can help save lives."

As it stands now, most law enforcement recruits go through about twelve weeks of training that incorporates classroom instruction, practice on the firing range, and exposure to a series of highly realistic video simulation exercises. Ward said that such simulations—which are commercially produced and can cost up to $100,000 apiece—can offer a powerful way to test and improve recruits' decision-making skills. These interactive programs present novices with experiences that mimic real-world

Paul Ward, right, adjusts the eye-tracking device on graduate student Joel Suss as he runs through a law enforcement simulation.

MARIUSZ NOWAK

situations closer than any other training technique available. Most training centers have them as part of their standard curricula, but how these sophisticated tools are used is spotty, Ward said.

"Some centers use these tools extensively, but others just don't have the manpower to put all their students through these exercises," he said. "Some tend to use them as video games and just tell the recruits to do the best they can. Frankly, you don't learn much from that. So, I think it's fair to say that the training centers aren't always getting the kind of feedback from these simulations that they could be."

Ward's team has designed techniques for using these training videos as a means of getting inside participants' heads. They use what they call a "think out loud" protocol, in which participants tell what they're thinking at every step as they progress through simulations that often involve the use of lethal force. When the video ends, the officers immediately report on what just happened and try as best they can to explain exactly how they reacted and why.

"We're getting about as close as we can to the stream of thought of these officers without having a video recorder in their minds' eye," Ward said. "In these tests, it's truly astounding to see the differences between skilled SWAT officers and rookies."

For his latest study, twenty-eight police officers volunteered for Ward's experiments run in his campus lab. Half the officers were rookies, fresh from basic training in the academy. Their average age was 24.7 years. The other fourteen were highly skilled tactical officers, who averaged 38.7 years in age with an average of 15.4 years of service. All officers were run through a series of twenty video scenarios, projected on a 9-by-12-foot screen, which

"Some tend to use them as video games and just tell the recruits to do the best they can. Frankly, you don't learn much from that."

included situations ranging from simple traffic stops to dangerous hostage stand-offs. Eleven of the videos ended in confrontations that forced the officers to fire their weapons or risk getting "killed."

As Ward predicted, in every run-through the skilled officers significantly out-performed their younger, less-experienced counterparts. These officers not only reacted faster (on average, by about 1.4 seconds) but also used their weapons more effectively, hitting the right targets more often than did the novices. How were they doing that?

Through their careful interviewing techniques and detailed analysis of the simulated scenarios, Ward and his colleagues were able to prove that skilled officers are much better at picking up on environmental cues and faster at analyzing them than the rookies. In test after test, the veteran officers showed a keener ability to assess situations, develop and analyze their options, and successfully intervene—e.g., either shoot the perpetrator or otherwise diffuse the situation peacefully.

In parsing the officers' do-or-die decision-making process—which typically spans only a fraction of a second—the researchers found that the more experienced officers generated a higher number of critical options before taking action than did their counterparts. This lightning-fast mental calculus suggests that over the years, officers acquire skills that enable them to encode critical information in long-term memory and in a way that is instantly available to them on the fly when it's most needed. Rookies simply don't have this amazing retrieval system and as a result risk injury to themselves or others before they acquire it the only way they can—through on-the-beat trial and error.

Is it possible to somehow distill the very essence of expert decision-making under stress, quantify it, and put it to use in a training program? Ward says that's exactly what he is trying to do. He envisions dramatically improved training in any profession that demands rapid and accurate life-or-death decisions, from law enforcement and the military to health care.

"The ultimate goal for us is to improve the performance of those who make really critical decisions on a daily basis," Ward said. "We see it as a way to build a better, safer world." ■

For more information
http://web.me.com/pw70/ACE_lab

Better machines for bigger people

When it comes to rowing machines, one size does not fit all.

by Dennis Walikainen

Those ubiquitous rowing machines that populate every gym are popular for a number of reasons. They are supposed to be low impact, allow for full body movement, and increase cardiovascular endurance.

But those advantages don't hold true for everyone, according to Karen Roemer, an assistant professor of biomechanics in the Department of Kinesiology and Integrative Physiology at Michigan Tech. Her research is demonstrating that the typical rowing machine may be a poor fit for people with a high body mass index (BMI), particularly those who are obese.

Manufacturers do make special equipment that is strong enough to support very heavy people, but Roemer has found that sturdy construction is not enough. Design is important too.

She has studied four types of subjects: overweight, obese, normal weight, and skilled rowers. To follow their movements as they worked out, she attached nearly fifty reflective markers to the rowers and to the rowing machines, then filmed them from six angles, freezing the motion using strobe lights. In particular, she looked at the rowers' hips, knees, and ankles.

Subjects who were obese had to move their knees outward to row, increasing the load on part of the joint. She believes the machines' restricted foot position may increase their risk of knee pain in the same way arthritis does.

"Previous studies have shown that increased loads of the medial compartment [inner portion] of the knee joint are related to osteoarthritis. The studies have shown that obese people suffer from high loads on the medial compartment during weight-bearing activities, which is similar to our results," Roemer said. "Therefore, there is a risk for knee pain here, too."

Karen Roemer oversees PhD student Erich Petushek exercising on a rowing machine. He is dotted with reflective markers used to track his movements as he works out.

"It's interesting to me that an exercise that is supposed to be beneficial to obese people may actually cause them pain," says Stephanie Hamilton, a biomedical engineering PhD student working on the study. "It underscores the importance of a research foundation in developing exercise equipment."

In a follow-up study, the research team is modifying the foot position to see how a wider placement affects the loading at the joints. "It's exciting to see direct applications come from research that can affect many people," says Hamilton.

Roemer's work could open the door to better exercise equipment for the people who need it the most. "Equipment should be adaptable to meet the needs of people with a higher BMI," she said. ■

Rising sun

Photovoltaic panels are plummeting in price and can power your home for a generation. Are we at the dawn of the solar age?

by Marcia Goodrich

It's time to stop thinking of solar energy as a boutique source of power, says Joshua Pearce.

Sure, solar only generates about 1 percent of the electricity in the US. But that will change in a few years, says Pearce, an associate professor of electrical engineering and materials science at Michigan Tech. The ultimate in renewable energy is about to go mainstream.

It's a matter of economics. A new analysis by Pearce and his colleagues at Queen's University in Kingston, Ontario, published in the journal *Renewable and Sustainable Energy Reviews,* shows that solar photovoltaic systems are nearing the tipping point. In other words, they can make electricity that's as cheap as what consumers pay their utilities—sometimes cheaper.

Here's why. First, the price of solar panels has plummeted. "Since 2009, the cost has dropped 70 percent," says Pearce. Secondly, the assumptions used in previous studies have not given solar an even break.

"Historically, when comparing the economics of solar and conventional energy, people have been very conservative," says Pearce.

To figure out the true cost of photovoltaic energy, analysts need to consider several variables, including the cost to install and maintain the system, finance charges, how long the system lasts, and how much

electricity it generates. Pearce and his colleagues performed an exhaustive review of the previous studies and concluded that the values given those variables were out of whack.

For example, most analyses assume that the productivity of solar panels will drop at an annual rate of 1 percent or more, a huge overestimation, according to Pearce. "If you buy a top-of-the-line solar panel, it's much less, between 0.1 and 0.2 percent."

In addition, "The price of solar equipment has been dropping, so you'd think that the older papers would have higher cost estimates," Pearce says. "That's not necessarily the case."

Equipment costs are determined based on dollars per watt of electricity produced. One 2010 study estimated the cost per watt at $7.61, while a 2003 study set the amount at $4.16. The true cost in 2011, says Pearce, is under $1 per watt for solar panels purchased in bulk on the global market, though system and installation costs vary widely. In some places, solar is already cheaper than power from conventional sources, and the study predicts that it will become increasingly attractive throughout the world.

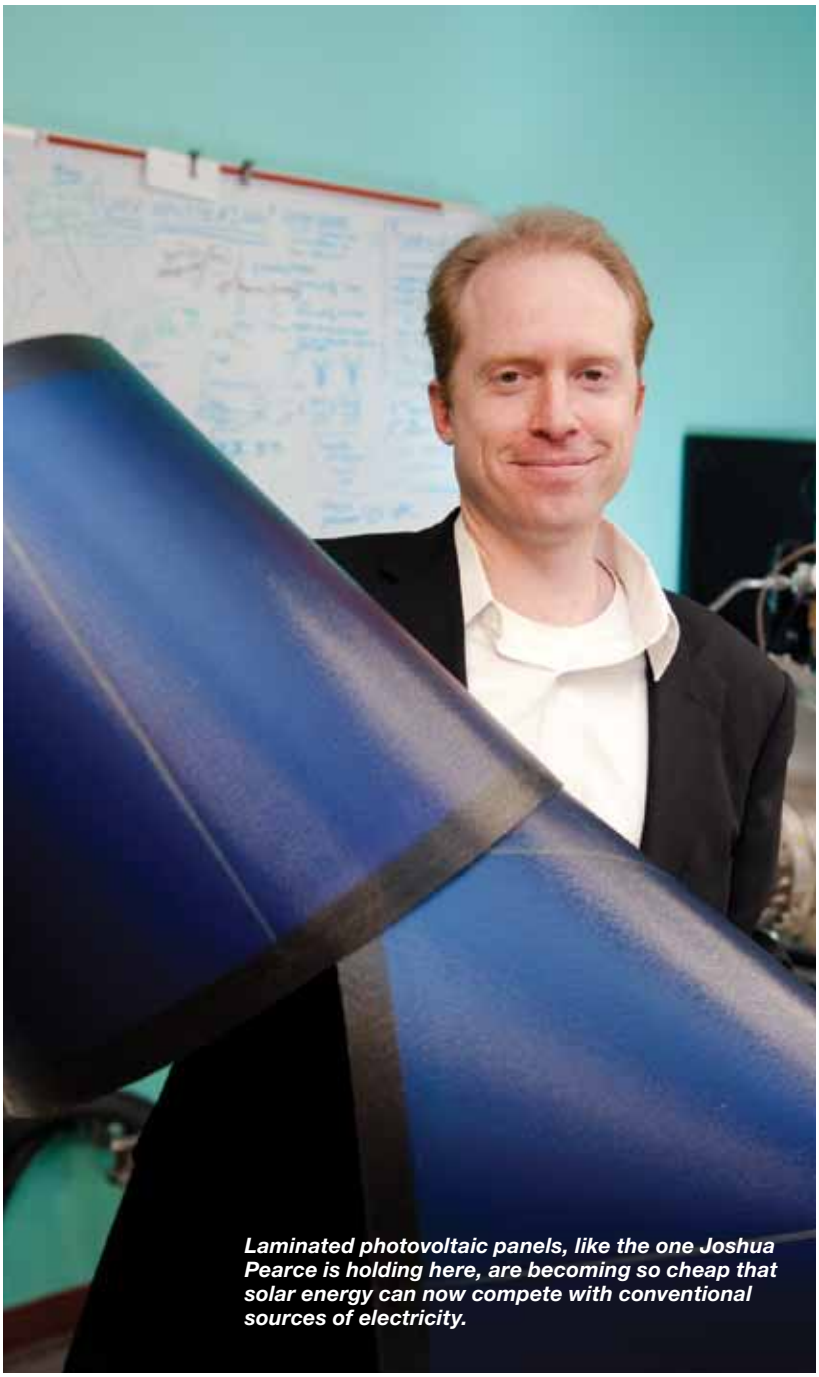
In regions with a burgeoning solar industry, often due to favorable government policies, there are lots of solar panel installers, which heats up the market.

"Elsewhere, installation costs have been high because contractors will do just one job a month," says Pearce. Increasing demand and competition would drop installation costs. "If you had ten installers in Upper Michigan and enough work to keep them busy, the price would drop considerably."

Furthermore, economic studies don't generally taken into account solar energy's intangible benefits, including reduced pollution and carbon emissions. And while silicon-based solar panels do rely on a nonrenewable resource—sand—they are no threat to the world's beaches. It only takes about a sandwich baggie of sand to make a roof's worth of thin-film photovoltaic cells, Pearce says.

Based on the study, and on the fact that the cost of conventional power continues to creep upward, Pearce believes that solar energy will soon be a major player in the energy game. "It's just a matter of time before market economics catches up with it," he says.

For Pearce, solar power isn't simply a matter of money. He was drawn to the field as an undergraduate at Pennsylvania State University, when he took an engineering science class from solar energy pioneer Christopher Wronski. "He asked what we wanted to do after we graduated, and I said 'solar,'" Pearce recalls. "He said, 'See me after class.'"



Laminated photovoltaic panels, like the one Joshua Pearce is holding here, are becoming so cheap that solar energy can now compete with conventional sources of electricity.

Back then, "I wanted to do something good for the world tackling our most pressing problems," Pearce says, and solar was just the ticket. Throughout graduate school and his academic career, he has immersed himself in the technology, economics, and politics of photovoltaic energy.

"I actually believe in this stuff," he says. "You have a device that, worst case scenario, pays for itself in five years in terms of the energy needed to produce it, or in under a year in the best case scenario. It lasts thirty years or more. It's made out of abundant, easily accessible materials. And its fuel source is free.

"Who wouldn't want that?" ■

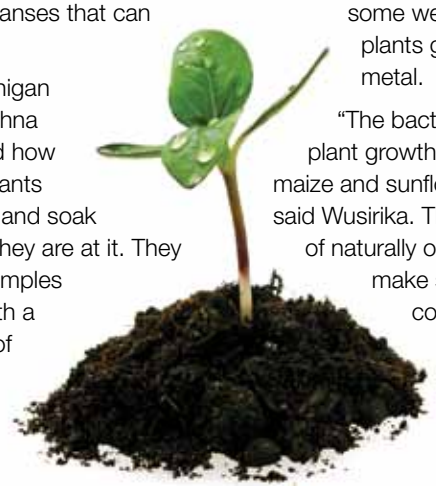
For more information
www.mse.mtu.edu/~pearce/Index.html

Research *in brief*

Bacteria key to copper clean-up

When miners abandoned Michigan's Copper Country, they left a lot of the red metal behind. Waste from the mining operations still contains so much copper that almost nothing can grow on it, leaving behind moonscape expanses that can stretch for acres.

Now a team led by Michigan Tech biologist Ramakrishna Wusirika has discovered how to make two types of plants grow in the mine waste and soak up some copper while they are at it. They added copper to soil samples and inoculated them with a copper-resistant strain of bacteria. They planted maize and sunflower seeds and waited.



As expected, seeds planted in copper-free soil thrived, and seeds planted in the copper-tainted soil without bacteria were stunted. But seeds planted in the coppery soil enriched with bacteria did much better; some were nearly as vigorous as plants grown without the toxic metal.

"The bacteria seem to help with plant growth, and they also help maize and sunflower uptake copper," said Wusirika. That means some kinds of naturally occurring bacteria could make soil more fertile and, in concert with the plants, remove at least some of the copper.

Alaskan forests: From carbon sink to carbon source

Alaskan forests used to take up carbon dioxide and give off oxygen. But now, researchers at Michigan Tech and the University of Guelph, in Ontario, report that climate change is causing wildfires to burn larger swaths of Alaskan trees, turning black spruce forests from repositories of carbon to generators of it.

"Since the proliferation of black spruce, Alaskan soils have acted as huge carbon sinks," says Evan Kane, a research assistant professor in the School of Forest Resources and Environmental Science. "But with more frequent and more extensive burning in recent decades, these forests now lose more carbon in any fire event than they have historically been able to take up between fires."

The researchers found that the annual carbon losses from forest fires from 2000 to 2009 were more than twice the carbon lost during each of the previous five decades.

In addition, the new forest types likely to replace the black spruce act as much weaker carbon sinks. And the researchers say that these fires are likely to increase permafrost loss, in turn accelerating climate change by exposing deeper carbon pools to burning.

Bringing back the grayling?

Overfishing and habitat destruction drove the Arctic grayling from most of its native Michigan waters a century ago. Now the Little River Band of Ottawa Indians and Michigan Tech biologists Nancy Auer and Casey Huckins are looking to bring them back.

The research team is studying the viability of reintroducing Arctic grayling in the Big Manistee River watershed, where, Auer says, "in days of old, they used to be very abundant."

With a $200,000 grant from the US Fish and Wildlife Service, the Little River Band of Ottawa Indians is supporting their work, which includes electro-fishing on the Manistee to record the resident fish and evaluating the river to see if it could support these iridescent fish with their sail-like dorsal fin.

The Manistee flows southwest for about 230 twisty miles, from near Alba to Manistee, where it empties into Lake Michigan. The Little River Band and Michigan Tech are focusing on an eleven-mile section of the river between the Tippy and Hodenpyl dams.

After the study is completed, the Little River Band and partners will decide whether to attempt a reintroduction. "It's exciting to think that it might be possible," Auer says. "We hope to get people aware of how beautiful these fish are and how wonderful these ecosystems are. These big rivers are our lifeblood."

Solving a genetic puzzle

Molecular biologist Hairong Wei turned to his passion for computer science to help overcome a major research roadblock. His efforts have produced a new tool to quickly and accurately identify transcription factors—regulatory genes that work together to control a biological process or trait.

Wei, an assistant professor in the School of Forest Resources and Environmental Science, built a virtual map of the genes that have the greatest influence on a given biological process and broke that network down into its separate components. This enabled him to efficiently identify a cluster of transcription factors. "Once these transcription factors are identified," he explains, "scientists will know which genes to manipulate to get the results they want."

To test his algorithm, Wei identified twenty-four transcription factors in the human genome that maintain a stem cell in its ready-and-waiting state. The process took

Hairong Wei

him a day. It took biologists a decade and at least a few million dollars to identify twenty-two transcription factors, says Wei. Of those, Wei matched seventeen.

"We were surprised," he says. His group applied the technique to several data sets from *Arabidopsis* plants, poplar trees, and the Axolotle salamander. Based on existing research findings, their method identified transcription-factor clusters with a degree of accuracy ranging from 50 to 95 percent.

Brett Spigarelli

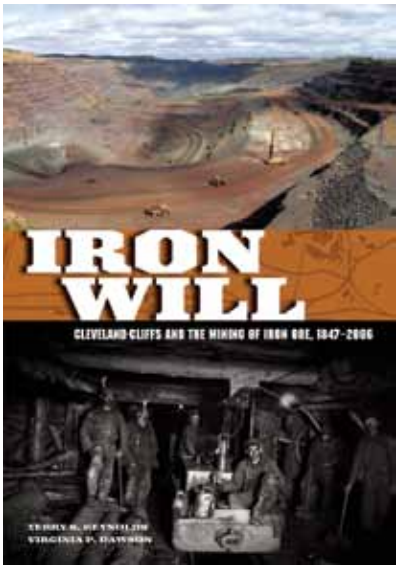
Carbon-hungry smokestack

Students at Michigan Tech have designed and built a smokestack that can capture carbon dioxide and turn it into a useful product.

Their eleven-foot bench-model smokestack gobbles up fully half of the CO_2 percolating through it. Their process not only captures carbon, it binds it in a solid form, making an undisclosed product that can be used as a construction material. The liquid itself can be recovered and used again. The group has applied for a patent and hopes to build a pilot plant in cooperation with an industry partner, Carbontec Energy Corporation.

Other scrubbers remove up to 90 percent of the carbon dioxide from a smokestack, but the liquid must be processed to strip away the carbon dioxide, which then must be stored. "This is a very expensive technique, which is probably why we do not see it commonly employed in industry," says PhD student Brett Spigarelli, a member of the research team.

The group is working to make the scrubber remove even more carbon dioxide. In the meantime, it offers businesses a significant benefit. Their goal is not only to capture the CO_2 at the lowest possible cost, but also to manufacture useful, marketable products.



Iron Will: The story of Cleveland-Cliffs

Upper Michigan's copper legacy has been well documented, the iron legacy less so. Now Terry Reynolds, a professor of social sciences at Michigan Tech, and Virginia Dawson, an independent researcher from Ohio, have published *Iron Will: Cleveland-Cliffs and the Mining of Iron Ore, 1847–2006.* The new book, published by Wayne State University Press, chronicles a company that was one of the region's earliest iron ore mining firms and is now the last one standing.

The business initially called the Cleveland Iron Mining Company became Cleveland-Cliffs in 1890, when it absorbed a long-time rival and became the most important producer on the Marquette iron range. It is now Cliffs Natural Resources.

The authors say the book's title, *Iron Will,* captures the company's "resilience in the face of panics, depressions, strikes, technical bottlenecks, and bankrupt partners."

Cliffs Natural Resources commissioned the history and gave the authors a free hand. Today, it is the country's leading producer of iron ore pellets. The authors call the company's survival over more than 160 years—a period marked by alternating prosperity and struggle—simply "remarkable."

2.2 billion candles

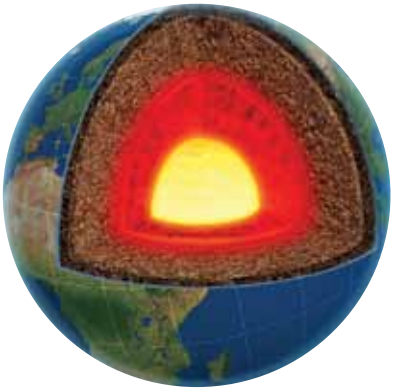
Work by a Michigan Tech geophysicist may have pushed the birthday of the Earth's inner core back over a billion years.

In the beginning, the Earth's core was made entirely of molten iron. Most theories suggest that the solid inner core formed about 1 billion years ago in the center of the still-liquid outer core. That would make the inner core a relative newcomer in the history of our 4.5-billion-year-old planet.

New research by Assistant Professor Aleksey Smirnov and colleagues at the University of Rochester and Yale suggests the inner core is much older. They came to their conclusion after tracking changes in the Earth's magnetic field in some of the planet's oldest rocks, including some found in the Keweenaw Peninsula.

"We looked at the changes in geomagnetic variation at a very, very long time-scale, and we could explain the variation only if the inner core existed 2.2 billion years ago," Smirnov said.

That's about 1.2 billion years older than most of the accepted models. His tentative explanation involves plate tectonics,



the process behind many earthquakes and volcanoes.

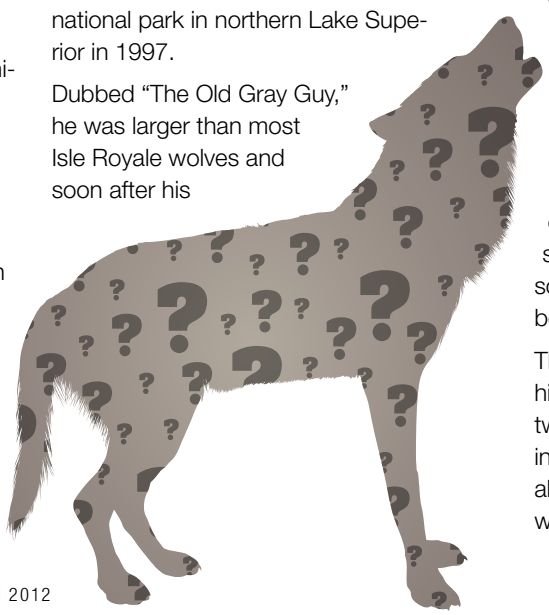
"When one plate goes under another plate, it goes deep in the mantle and reaches the core-mantle boundary," he said. That would cool the core, like adding an ice cube to a glass of soda pop. And by chilling the liquid iron, it could have formed the solid center.

It takes a couple hundred million years for a plate to go through the mantle. Plate tectonics probably started 2.5 billion years ago, if not earlier, so the timing fits with Smirnov's estimate of the inner core's formation.

DNA analysis reveals immigrant in wolves' gene pool

Wolves first traveled to Isle Royale over an ice bridge from Canada in the 1940s and have been isolated there ever since, or so the story went. Now, Michigan Tech researchers John A. Vucetich and Rolf O. Peterson have determined that a virile male wolf made it to the remote island national park in northern Lake Superior in 1997.

Dubbed "The Old Gray Guy," he was larger than most Isle Royale wolves and soon after his arrival became the alpha male of Middle Pack, one of the island's three packs. As he aged, his fur turned very light, a trait that had not been seen on Isle Royale but has since become common.



The immigrant wolf was discovered after Vucetich and Peterson collaborated with geneticists from Michigan Tech and Arizona State University to examine the DNA contained within wolf droppings they had been collecting for twelve years. The geneticists found a scat that carried several alleles—alternative forms of a gene—that had not previously been seen. Through field observations, Peterson and Vucetich confirmed that this scat belonged to The Old Gray Guy.

The Old Gray Guy died in 2006. But he left his mark, siring thirty-four offspring and twenty-two grand-offspring, "and counting," the scientists say. Today, 56 percent of all the genes now found in the Isle Royale wolf population trace back to him.

Building better bioenergy trees

Chandrashekhar Joshi's insights into how trees make cellulose earned him the 2011 Research Award.

by Jennifer Donovan

Cellulose is made up of chains of well-organized glucose molecules, and scientists would love to turn those glucose molecules into biofuel. But it is hard to break cellulose apart into glucose units, a first step in converting it into fuels like ethanol via fermentation. So if trees are to become the source of cellulosic biofuels for the future, someone needs to solve this cellulose breakdown problem.

Cellulose makes up about half the mass of wood cell walls, so why not develop and grow designer trees with cell walls that are easier to break down and turn into biofuel?

That's Chandrashekhar Joshi's goal. But the first step is to figure out how trees make cellulose in the first place. "If we discover how plants make it, we can later break it," says the professor of plant molecular genetics in Michigan Tech's School of Forest Resources and Environmental Science.

For his work on cellulose synthesis in bioenergy trees, Joshi was named winner of Michigan Tech's 2011 Research Award.

"We have been unraveling the process of cellulose synthesis in trees for over a decade now," Joshi said. "We hope that one day sustainable, renewable, and improved bioenergy and other useful products will result from our research."

Early in 2011, Joshi and colleagues published a groundbreaking paper in the British journal *Molecular Plant* that demonstrated for the first time the paramount role cellulose synthesis plays in the life of trees. Trees need cellulose to stand up and grow upward. The Joshi lab showed that suppressing just one gene for cellulose synthesis in aspen trees turns those trees into creepers or vines that cannot grow over a foot in height. The cellulose in the transgenic aspen trees is reduced by more than 75 percent. Yet they survive and continue to produce wood that is rich in lignin and xylan, polymers that hinder biofuel conversion and serve as alternative feedstock for biofuel.

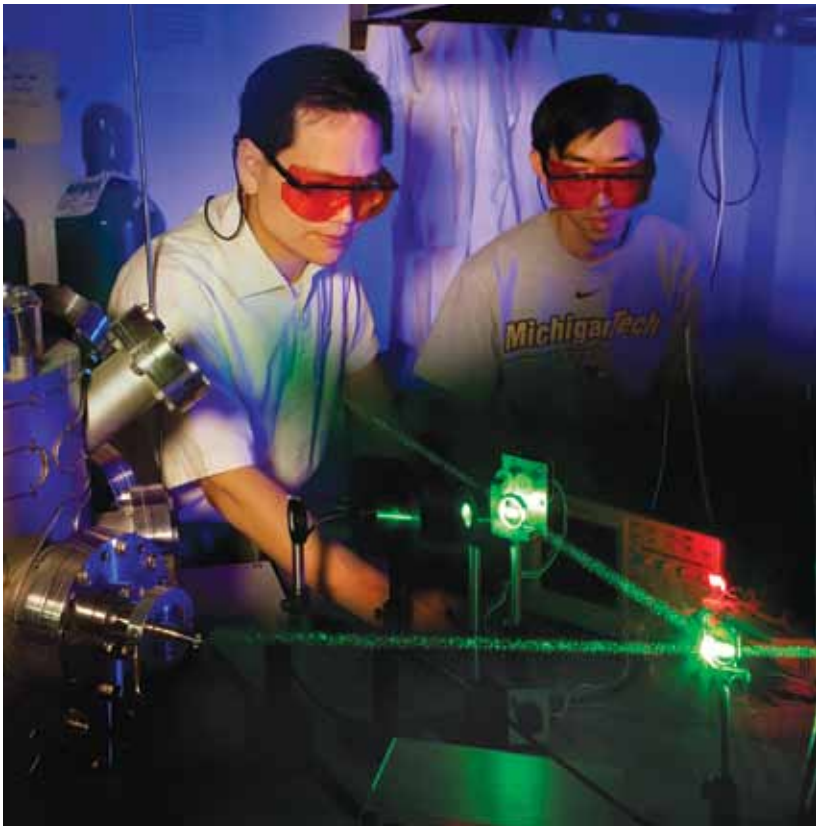
Among those recommending Joshi for the award was Stephen P. DiFazio, of West Virginia University. "His work is of fundamental importance in the burgeoning biofuels field, and his expertise is widely respected in the scientific community and beyond," DiFazio said.

Joshi has published 67 peer-reviewed papers, authored over 100 presentations, contributed to four patents, coedited two books on bioenergy crops, and received more than $6.5 million in research funding over the past fifteen years. "Michigan Tech is the place where dreams of building a better future really come true," he said. ■

For more information
www.mtu.edu/forest/about/faculty/joshi

Yap, Lee honored for nanotube discoveries

Their boron nitride nanotubes hold promise as super-protective coatings and semiconductors.



by Marcia Goodrich

For groundbreaking work in nanotechnology, Yoke Khin Yap and Chee Huei Lee have received Michigan Tech's Bhakta Rath Research Award.

The award, endowed by 1958 alumnus Bhakta Rath and his wife, Shushama Rath, recognizes a Michigan Tech doctoral student and advisor for "exceptional research of particular value that anticipates the future needs of the nation while supporting advances in emerging technology."

Yap, an associate professor of physics, and then-PhD student Lee (he graduated in 2010) invented a technique for synthesizing boron nitride nanotubes. Compared to their carbon-based cousins, boron nitride nanotubes have alluring qualities but, before Yap and Lee's pioneering work, had been notoriously difficult to grow.

The researchers created veritable nano-carpets of boron nitride nanotubes and discovered they possessed a number of interesting properties: They are perfect insulators, which means they could be doped to form designer semiconductors for use in electronics that operate at high temperatures. They are among the strongest materials known and can be dispersed in organic solvents, properties that could be useful in making high-strength composites and ceramics. Plus, they shed water like a duck's back. This quality, known as superhydrophobicity, holds at all pH levels, which means they could be used as protective coatings to shield against the strongest acids and bases.

Yap said Lee played an important role in their collaboration. "I enjoy working with Chee Huei, as he is willing to listen, think and work hard on an idea, and then he comes back to tell you much more than what you were expecting," said Yap.

Lee has authored or coauthored twelve peer-reviewed journal papers on their nanotube research, as well as three chapters and review articles and three papers in peer-reviewed proceedings. Their research was supported by the National Science Foundation and the Department of Energy's Office of Basic Energy Sciences. ■

For more information
www.phy.mtu.edu/yap/research.html

Three promising scholars receive CAREER Awards

by John Gagnon

Every year, the National Science Foundation bestows Faculty Early Career Development (CAREER) Awards on junior faculty who exemplify the role of teacher-scholars through outstanding research, excellent education, and the integration of the two. Three assistant professors at Michigan Tech earned CAREER Awards this year.

Forecasting flood risk

It is the nature of rivers to on occasion overflow their banks. Veronica Griffis wants to determine the future likelihood of a flood. People have been trying to do it for ages, with limited success.

"We need to develop new methods to predict the magnitude of flows we expect to see in the future, so we can design our infrastructure accordingly," she said.

Conventional procedures assume that the chances of a flood occurring in a given year are essentially unchanged over time. However, changes in the watershed from human activity or climate change complicate matters. Pavement, for example, translates to heavy runoff and higher flows in rivers. In contrast, forests and grasslands absorb water and decrease flows. The landscape, then, can be either a sluice or a sponge. Griffis, an assistant professor of civil and environmental engineering, pores over maps that identify land use and compares the watershed from year to year to see how it changes.

She also looks at other factors that affect flood magnitude: precipitation, temperature, and global climate patterns, examining data collected by the US Geological Survey and NOAA, as well as academic researchers. Her goal is to develop a statistical framework that accounts for variations in climate and land use and ultimately to project flood risk twenty to fifty years or more into the future.

She focuses on the northeastern quadrant of the US, extending as far west as Wisconsin and as far south as Virginia. Going back sixty-five years and more, she is studying 450 sites that are considered unimpaired by human activities and regulation, and an additional 300 sites that are deemed impaired.

Griffis has always been interested in the influence of humans on hydrology, whether surface or groundwater. She expects to find that the more complicated the influences, the more telltale the results, and the more certain the predictions.

All of the data will be used to inform the design of infrastructure, such as bridges, dams, and culverts. Without the proper model, "The structures that we build today are not going to be adequate in the future," she says. "This is rewarding work because it will ultimately make a difference."

Those who can, teach

It is said we should "gladly learn and gladly teach." Shari Stockero does both. "I'm not just doing my research," she says. "I'm also teaching my students to be better teachers."

Stockero, who holds a dual appointment in the Departments of Mathematical Sciences and Cognitive and Learning Sciences, combines her passions for mathematics and teaching to train novice math teachers. With students in Michigan Tech's teacher education program, she is videotaping public school teachers in the classroom and analyzing their instruction. Her aim is to identify those teachable moments that might help her students become better math teachers themselves. In particular, they catch instructors in the act of being "grounded in student thinking"—whether that be responding to a salient question or seizing an opportunity to make an important point.

"In our teacher education program, our students won't see every situation that will come up in the classroom, but hopefully this will help them recognize those key moments that they can later use," Stockero says. "I wish there was a magical way to get people to go out and be accomplished teachers right away, but it's a complicated learning process."

Eventually, Stockero will also use those videos to help public school teachers refine their talents. And, she will follow her student teachers into the classroom to assess how much they learned from their work in her project.

"It's exciting," she adds. "I push them. There's a lot to being an effective teacher. You not only have to know the math, you have to work with kids. You have to be able to figure out what they understand and don't understand and how it all fits together. There are so many pieces to the puzzle."

Omens of eruption

Greg Waite works in a world where the miniscule looms large.

Waite, an assistant professor of geological and mining engineering and sciences, monitors unusual movements of the earth associated with active volcanoes. These are not earth-shattering events where the ground heaves and cracks. Rather, they are centered in the conduit of a volcano and are what scientists refer to as volcanic earthquakes.

These tremors are not hazardous; the ones Waite measures cannot even be detected without sensitive instruments at close range. But these mini-movements can be harbingers of bigger eruptions to come. "They tell us about conditions in the conduit," Waite says.

Besides using seismographs, Waite uses ultraviolet imaging and low-frequency sound (infrasound) to record how much and how fast gases are released into the atmosphere, as well as the tilting caused by gas or magma pressing against the walls of the conduit. Ultimately, he aims to better predict a major eruption that might threaten humankind. "For the first time, we are quantifying the relationship between these small earthquakes and gas emissions," Waite says.

He is working on the Fuego (Fire) Volcano, in Guatemala, which has small eruptions every hour, spewing out magma and gas in stops and starts. "Gas gets blocked up, pressurizes, and inflates. The pressure reaches some threshold, and, boom! You have an explosion. What we're seeing is that volcanoes start to inflate maybe five to ten minutes before each explosion. There are lulls, but the eruptions are fairly dependable. So we're trying to use all these tools to study that phenomenon—what causes the explosion and how often these small earthquakes are associated with every explosion, even little puffs."

He wants to thoroughly understand Fuego and then develop a computer model he can apply to other volcanoes. "Maybe we'll be able to say, 'There's probably one coming.' The better we understand those wiggles in the seismograph, the better we can make those kinds of predictions." ■

Climate change and the weather underground

by Marcia Goodrich

Glaciers are melting and the Sahara is expanding. But what effect will climate change have on the world under our feet?

Carley Kratz, who is working on a doctorate in forest science, aims to find out. With her co-advisors, Andrew Burton and Erik Lilleskov, she is studying how added warmth affects the soil's tiniest creatures.

"My role is to look at how microorganisms are moving matter around in the soil, especially how they are cycling nutrients like carbon," said Kratz, who received a fellowship from the US Department of Energy Office of Science to pursue her research. To do that, she is analyzing all the DNA present in the soil using a new technology called pyrosequencing, which helps her identify the types of microorganisms and also gives information on how much carbon dioxide they may be producing.

The study started last fall at the University's Ford Center in Alberta, and Kratz is seeing some early results. "So far, it does seem like there is some change in metabolic function," she said. "Everything is respiring faster, working harder. Things are happening more quickly, which is kind of what you'd expect, considering basic chemistry: everything happens faster at higher temps."

She has seen a corresponding decrease in biomass below ground, which suggests that fungi have shifted into overdrive as they break down organic matter. To measure the action of fungi more precisely, Kratz uses hyphal ingrowth bags. "Some people call them little burritos," she notes. Filled with sand, they are made of a mesh that blocks roots and worms but allows in hyphae—miniscule fungal threads that can form symbiotic relationships with plant roots and greatly expand a plant's absorbing system.

"I measure their mass and also their respiration, the amount of carbon dioxide they give off," she says. "If more carbon dioxide is given off in warmer temps, it could mean that the warmth is accelerating the decay process"—and possibly loading the atmosphere with even more greenhouse gas.

But it's too early to reach any definitive conclusions, Kratz stresses. She is also working at the Harvard Forest, in Massachusetts, on two long-term studies of soil warming. "In Harvard, the biomass below ground is about the same as in the control plots, whereas here, we've seen a decrease," she said. That suggests that soil microorganisms may eventually return to equilibrium as the soil warms up, but whether that happens in Alberta remains to be seen.

Whatever the outcome, Kratz is very happy she chose Michigan Tech for graduate school. "The labs here are amazing; the amount of space and equipment I have for my research is wonderful," she says. "It's been really great." ■

A "package deal" for treating PKU

by Dana Yates

Eating a hot dog is a simple pleasure of childhood. But for kids with phenylketonuria (PKU), consuming this high-protein food can lead to seizures and a slowdown of motor skills and cognitive abilities. At Michigan Tech, though, biochemistry PhD candidate Kara Vogel is searching for a new way to manage PKU—one that she hopes will enable children to eat hot dogs without jeopardizing their health.

According to the American College of Medical Genetics, at least one in 25,000 babies born in the US has PKU. One of the most commonly inherited metabolic disorders, PKU is marked by a missing enzyme called phenylalanine hydroxylase (PAH). Without this enzyme, people are unable to process an amino acid called phenylalanine. Consequently, phenylalanine builds up in the body, crossing from the blood into the central nervous system and brain, and causing damage and developmental delays.

"You need some phenylalanine in your diet, but not a lot. It can be a difficult balance for someone with PKU to achieve," Vogel says. That's because a wide variety of foods contain phenylalanine, including meat, eggs, dairy products, pasta, bread, chocolate, and certain fruits and vegetables.

Babies with PKU must consume a phenylalanine-free formula, and children and adults should follow a low-phenylalanine diet to avoid health problems. But the restrictive, lifelong regimen isn't a perfect solution; phenylalanine levels can still remain elevated. Furthermore, while one drug has been approved to treat PKU, the medication only targets a less-common type of the disorder.

Not good enough, says Vogel. So, under the supervision of Michael Gibson, professor and chair of the Department of Biological Sciences, she is studying a novel treatment for PKU: amino acid transport inhibitors. These substances, when bundled with a deficiency of the enzyme PAH, have been shown to inhibit the movement of phenylalanine across the blood-brain barriers of laboratory mice. Now, Vogel is working to resolve an unintended consequence of this "drug packaging": a depletion of other important brain chemicals, including serotonin (the so-called "happy hormone" that influences mood).

Down the road, Vogel's research may lead to the development of a pill to manage PKU. Although the drug won't cure the condition, it could dramatically improve the quality of life of those who have the disorder. And that works for Vogel.

"My goal is to help alleviate suffering," she says. ■

Toward painless artificial legs

by Marcia Goodrich

Brandon Pereles has a knack for engineering and a heart for people. So it's no surprise that he has turned his talents toward those who have lost a leg.

In particular, he wants to help prevent the skin problems associated with using prosthetic legs. Unlike the sole of the foot, the skin on an amputee's stump is delicate and not designed to handle the stresses of walking. "If the force from the prosthesis isn't well distributed, you can get abrasions, sores, and cysts," says Pereles. Sometimes the pain can cause patients to quit walking all together.

Pereles's work is supported through a National Defense Science and Engineering Grant and additional funding from the US Department of Defense, which has a significant stake in the health of soldiers and veterans who have lost limbs in combat.

To address the problem, Pereles, a PhD candidate in biomedical engineering, is using sensing strips that could be embedded within the base of the sleeve at the top of the artificial leg. The strips would measure the force applied to the stump while the person walks and detect pressure imbalances early, so skin problems could be averted before they begin.

The sensing strips are made from Metglas, a thin, inexpensive alloy that, when excited by a magnetic coil, responds magnetically to varying amounts of force. "That makes it a wireless pressure sensor," Pereles says.

The entire system could be set up in a typical doctor's office. To measure forces on the stump, the patient would simply walk around briefly carrying a battery in a fanny pack. The magnetic coil would be held to the stump by a cuff, like a blood-pressure monitor. Results would be transmitted wirelessly to a computer. In addition to generating a color-coded map indicating pressure points, the system could also record the pressure on the stump quantitatively, in pounds per square inch or newtons.

The technology has potential for other uses as well. "We want to focus on biomedical engineering, but this could just as easily be put in concrete, in an airplane, anywhere you want to monitor force wirelessly," says Pereles.

He started doing research as a sophomore under the direction of Associate Professor Keat G. Ong, who is now his advisor.

"I realized I wanted to get into device development," Pereles says, so staying on as a graduate student was a natural choice. "I liked Dr. Ong, I liked the projects, and I like Michigan Tech," he says. "I've always liked building stuff and working with my hands, and I also want to help people. So this is a perfect fit." ■

Rachael Barlock's scale model of a stilling basin reduced scouring in the sandy "riverbed" below.

Tiny bubbles calm the waters

by Marcia Goodrich

Tiny bubbles in the wine may make you feel happy, but they're nowhere near as useful as the tiny bubbles Rachael Barlock puts in rushing water.

Barlock's bubbles can keep a raging torrent from eroding deep holes in a riverbed, a process called scouring. Her project is funded by the South Florida Water Management District, which wants to curb scouring downstream from its stilling basins. The purpose of a stilling basin is to still the water flowing into a river, often from a dam or other man-made structure. Usually, stilling basins do their job just fine. Sometimes, however, they are overwhelmed by the weather. "We're modeling for a hundred-year storm," Barlock says.

Barlock, a senior majoring in environmental engineering, got involved in the project through an undergraduate class taught by Brian Barkdoll, an associate professor in the Department of Civil and Environmental Engineering. "I was really interested in working with an actual client," she says.

Building on work started by graduate student Ted Champagne, she began testing different ways of using bubbles to combat scouring. In her lab, Barlock works with a one-thirtieth-scale model of an actual basin in Florida.

Most of the experiment's action takes place at the end of the stilling basin. There, Barlock places a long, hollow block of clear acrylic just a couple of inches high. Compressed air is forced through this block, called an end sill, and out an array of tiny holes punctured in its top. This forms a curtain of bubbles in the water as it pours into the sand-filled streambed below. The idea is to soften the impact of the water, similar to an aerator in a kitchen faucet.

Barlock tested two types of acrylic end sills with five different patterns of holes and found that one configuration seems to do a better job of minimizing the scour hole. Identifying the best configuration is important, because running an air compressor big enough to aerate all the water flowing in a big still basin is expensive. "I also found that just having an endsill in place helped reduce scour," she adds.

Barlock is planning to stay at Michigan Tech to pursue a master's degree in civil engineering with a concentration in water resources. Growing up in the tiny Upper Michigan town of Bergland, she had no idea she would have this heady opportunity. "In high school, I was good in science and math, and my dad said I should be an engineer, but I didn't even know what engineers did or what a master's degree was when I came here," she says. "I'm so excited to be doing this." ■

Fantastic mathematics

by Marcia Goodrich

Kaylee Walsh loves all the branches of mathematics so much she can't pick just one. "I can't focus on one thing," she says. "For me, that's the beauty of math."

Thus, she is completing her bachelor's degree in mathematics with a concentration in general math, which, in a sense, is no concentration at all. But it does allow her to broadly indulge her joy in what Einstein called "the poetry of logical ideas." Most recently, however, she focused on linear algebra as part of a research project with Mark Gockenbach, chair of the Department of Mathematical Sciences.

Walsh is acutely aware that most people wouldn't have the vaguest understanding of what she does, and she takes pains to explain. "Linear algebra takes a system of equations and represents them as matrices or vectors," she says. "So instead of addressing one equation at a time, you can address them all collectively."

For the project, she and Gockenbach tried to develop a better way to de-blur images. To do this, they used a tool of linear algebra called Tikhonov regularization, applying methods recently developed by other researchers. "For example, if you take an MRI, sometimes you get a blurry image because there's noise in your data," Walsh says. It's quite likely that you won't ever be able to extract the perfect image from the noise, but using Tikhonov regularization narrows down the range of possibilities, so you can get a better result.

The project began last summer and was grueling, building matrices and proving they would work. "In math textbooks, you do proofs all the time, and it's no big deal," she says. "It was neat to have to do my own, to struggle the way the early mathematicians struggled. A lot of it was over my head, but some days, I just took it on faith."

The struggle is paying off. The regularization method isn't perfect yet—sometimes it overcorrected for noise, and sometimes it undercorrected—but Walsh and Gockenbach have made progress. They have coauthored a paper, and Gockenbach expects to build on their findings, probably with a graduate student.

It won't be Walsh, at least for now. She has accepted a job offer from Gentex Corporation, in Zeeland, Michigan. "But it was so neat to go through this process, to find out what research is really like," she says.

And besides, she adds, it was fun: "I love linear algebra." ■

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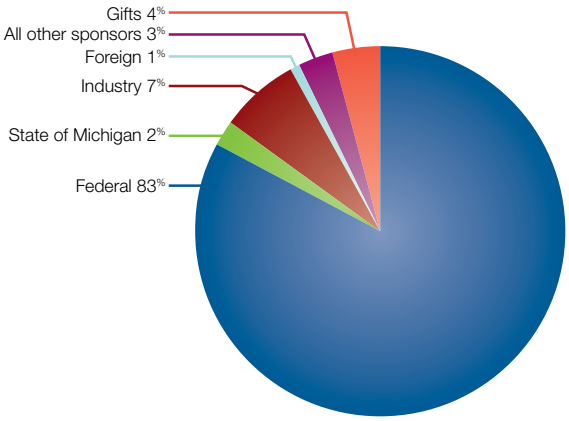
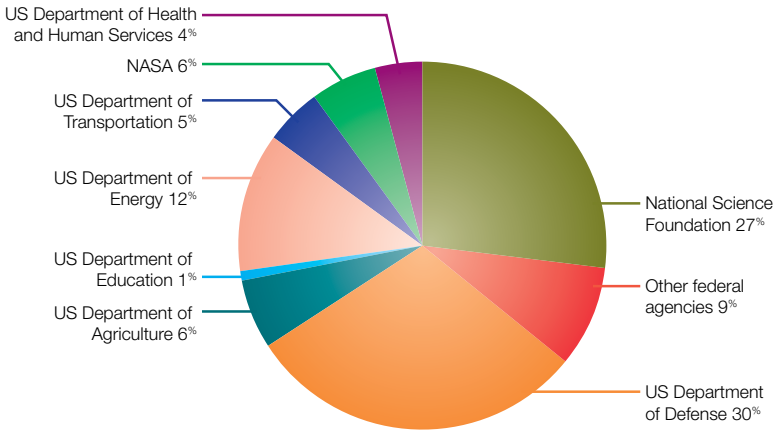
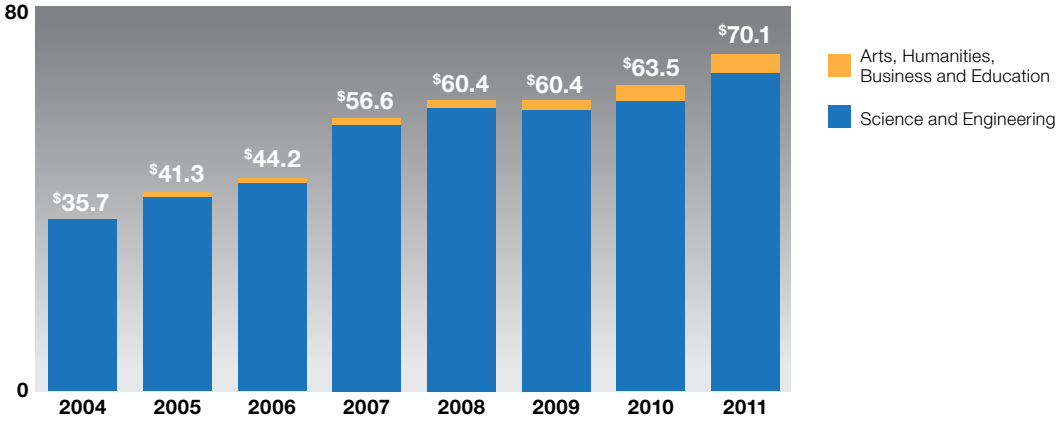
Fiscal year 2011



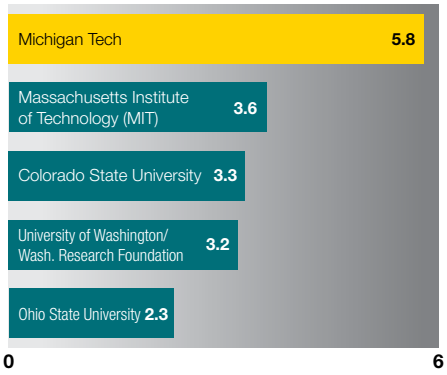
Federal awards
Fiscal year 2011



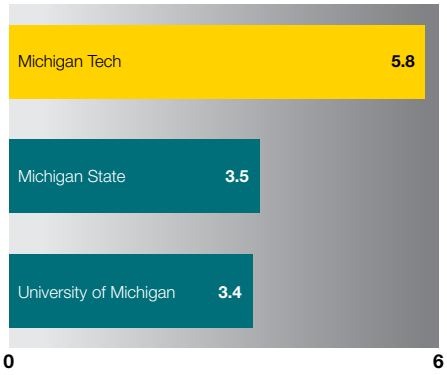
Research expenditures
(in millions of dollars)



2009 invention disclosures per $10 million of research expenditures
(compared to benchmark universities)



2009 invention disclosures per $10 million of research expenditures
(compared to Michigan universities)



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