utility vehicle, a well-used John Deere eGator (pictured on page 9) whose batteries had finally died, to run on a hydrogen fuel cell.

With zero greenhouse gas emissions, fuel cells offer an intriguing alternative to internal combustion engines. But that doesn't make them sustainable, says Keith. Currently, you can't do much with the hundreds of bipolar plates in a fuel cell stack once they fail other than put them in a landfill. Keith and his colleague Julia King, a professor of chemical engineering, are trying to develop better bipolar plates that can be recycled.

"We're using a thermoplastic polymer, with multiple carbon fillers, that can be remelted," Keith says. By mixing carbon black, synthetic graphite, and carbon fiber in the filler, they are also creating bipolar plates that are better at cooling the cell and provide improved electrical conductivity.

MINI-ROBOT VEHICLES PROVIDE MORE ANSWERS (AND QUESTIONS)

Fuel cells aren't limited to passenger vehicles. Supported by the Army Research Lab, Jay Meldrum, director of the Keweenaw Research Center, built a small, unmanned vehicle ("Little Brother") for them and powered it with hydrogen.

Meldrum is now working on a second project for the Army Research Lab, a 5,000-pound hybrid vehicle ("Big Brother") powered by diesel and hydrogen fuel cells. For this, he is tricking out a Bobcat loader of the type often seen at construction sites, but powered by an off-the-shelf fuel cell engine.

Working with them firsthand, Meldrum can count off the problems with fuel cells. Pound for pound, they don't pack the power of petroleum or even batteries. They don't work well in cold weather because the watery exhaust freezes, along with the engine. "And how do you refuel with hydrogen?"

But even though the technology has a ways to go, there are niches where fuel cells can shine even now. "The fact that they don't emit any toxic gases is a very good thing, and it makes them especially useful for inside work, as in warehouses," Meldrum says.

TOO EXPENSIVE TO SAVE THE WORLD?

The value of fuel cells, both as an alternative to petroleum and as an antidote to global warming, depends on your assumptions, says Allen.

Assume, for instance, that you are producing hydrogen with electricity from a coal-fired power plant. Under that scenario, fuel cell technology simply pushes the emissions up the energy chain. Then your fuel cell-powered vehicle becomes a de facto producer of greenhouse gases, Allen admits.

"But if you are using wind, solar, or nuclear power, then making hydrogen is very clean," he says. "There's no carbon monoxide, no carbon dioxide, and no soot."

Then there's the matter of sticker shock. Fuel cell vehicles are probably not yet gracing the lots at your local dealership, but once they get there, prepare to open wide your wallet. Honda has announced that it will lease a limited number of its fuel cell sedans in Los Angeles for monthly payments of $600.

Assume that the value of fuel cell vehicles can only be calculated in the cost of driving one, and they don't stack up, even in an era of three-dollar-a-gallon gas. Plus, there is the matter of hydrogen stations (what hydrogen stations?).

Heavy considerations, but broaden your economic assumptions, and the penalties paid for not moving to fuel cell vehicles could be much weightier, says Allen. The bottom line of climate change, from record droughts to flooded coastlines, could make hydrogen seem like the bargain of the century. ■

Little Brother (left) and Big Brother (right) unmanned vehicles, operated by fuels cells, are being designed, built, and tested at the Keweenaw Research Center.

WOLVES, MOOSE, AND MICHIGAN TECH

PAST, PRESENT, AND FUTURE

by Jennifer Donovan

The ranks of the wolves and moose of Isle Royale may be thinning, but as the study enters its fiftieth year, the predator-prey research is going strong.

Fifty Years of Isle Royale Wolf-Moose Research

1960 **1970** **1980** **1990** **2000**

1958 Durward Allen, Purdue University, begins bold "ten-year" research project, focusing on wolves and moose but including many other species in what we recognize today as an ecosystem approach.

1969 Severe winters usher in a decade of moose decline and wolf increase.

1972 Beaver population reaches peak, then declines because of intensive wolf predation coupled with an aging forest that provides less beaver food.

1974 The study moves to Michigan Tech's Rolf Peterson after Allen retires.

1975 Wolf population reaches the highest density known at that time anywhere in the world.

1980 Canine parvovirus arrives at Isle Royale when an infected dog visits the island briefly. Wolf population crashes as all pups present die, along with many adults.

1981 Assistant secretary of the interior cancels the study but changes his mind due to public pressure.

1983 Wolves in danger of extinction, leading to live-trapping and radio-collaring effort.

1988 Robert Bateman donates $50,000 from sales of wolf painting (on the cover of the *Research* magazine, right) to the study, initiating an endowment fund drive.

1989 Prompted by warm springtime weather, there is continent-wide mortality of moose from winter ticks.

1991 Strongest North Atlantic Oscillation of the 20th century results in severe winter and major moose die-off.

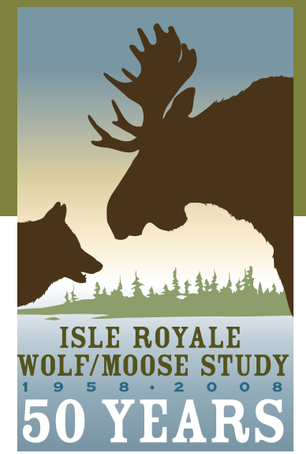
1995–1996 Major El Niño event ushers in new era of above-normal temperatures; moose begin sustained decline.

1998 John Vucetich joins the research as a coprincipal investigator.

2001 Warm weather the previous autumn leads to another continent-wide mortality event for moose from winter ticks.

2002 Moose reach the lowest population level in the fifty-year history of the project.

2007



Previous page: Wildlife ecologists Rolf Peterson and John Vucetich keep an eye on the wolf-moose relationship. Above: students analyze moose tracks on Isle Royale.

Wildlife ecologists Rolf Peterson and John Vucetich, from Michigan Tech's School of Forest Resources and Environmental Science, and graduate student, Joseph Bump, have compiled data for four new research studies and are preparing papers for scientific journals during the Isle Royale wolf-moose study's golden anniversary year.

The studies examine

- how arthritis in moose is linked to prenatal nutrition,
- how wolves affect the evolution of the size of moose,
- how wolves cause plants to grow bigger, and
- how moose teeth reveal the effectiveness of legislation designed to lower mercury levels.

Moose get the same kind of arthritis that affects humans as they age, and it is common in the moose of Isle Royale. Peterson has been examining moose bones found on the island over the past thirty years. He found that evidence of the incidence of arthritis follows clear cycles, rising or dropping dramatically depending on the size of the herd and the availability of nutritious food.

"When the population is large, nutrition is poorer," the researcher explains.

After decades of research, Peterson also has been able to link arthritis in aging moose to poor nutrition: both prenatal and immediately after birth. He can determine the age of an arthritic moose bone and then, knowing that the herd was large and the winter harsh in any given year, he can compare nutrition and arthritis rates.

Vucetich has been collecting evidence that predators affect the body size of their prey. Wolves favor smaller moose, he explains, so the moose that survive to reproduce tend to be larger animals. Vucetich has compiled what is likely the first documented evidence of this phenomenon in the wild.

Bump's research examines the interconnection between wolves, moose, and the plants that grow on Isle Royale. By hunting moose, whose carcasses are tremendous sources of nitrogen and phosphorus, wolves alter the amounts and distribution of those chemicals in the soil. When the ground is rich in nitrogen and phosphorus, plants grow bigger and are more nutritious, making them more attractive to moose.

In other research, Peterson and Vucetich have been able to demonstrate the effectiveness of the Clean Air and Water Acts of 1970 in lowering the levels of mercury in the air and water. Mercury gets deposited from the air on plants, Peterson explains. Plant-eating animals such as moose eat the mercury-laden vegetation, and, as their mercury levels rise, the chemical is deposited permanently in their teeth.

Vucetich and Peterson have been looking at mercury concentrations in the teeth of moose calves during their first year of life. "We study calves during their first year, because then we knew that any mercury found was deposited that year," the scientist explains. Canadian and Norwegian colleagues Peter Outridge, Rune Eide, and Rolf Isrenn contributed critical lab work.

Soon after the Clean Air and Water Acts were passed, the mercury levels had dropped by two-thirds, Peterson reports. Other researchers have found similar

John Vucetich tracks a moose that is infested with ticks.

effects in small studies in limited locales, but the Isle Royale study is the first one that spans an entire ecosystem.

Scientists have been studying the interactions of wolves and moose at Isle Royale National Park for half a century. In the late 1940s, a pack of wolves made the trek across fifteen to twenty miles of frozen waters of Lake Superior from Canada to Isle Royale. There they found a wilderness island safe from hunters and traffic and home to an abundant moose population. The wolves settled in to a self-contained ecosystem where they were virtually the only predators and the moose were their primary prey.

Conditions on the island made an ideal laboratory for scientific study of the predator-prey relationship free from outside influences. In 1958, biologist Durward Allen launched the Isle Royale wolf-moose study, chronicling population fluctuations of both kinds of animals and observing wolf-moose interaction and environmental changes to help explain these fluctuations.

The study continues today under the leadership of Peterson and Vucetich. They do aerial and ground observations in summer and winter, collect moose and wolf bones to analyze, and study vegetation, climate, air and water contaminants, and other environmental factors.

"Although wolves and moose are in the spotlight, this study has implications for understanding the broader components of an ecosystem," says Peterson. The primary lesson learned from this long-running study is that wildlife systems are complex, unpredictable, and dynamic by nature, and they are influenced by a large number of environmental factors, added Vucetich. "The data collected in the Isle Royale study provide a historical perspective that is very different from isolated snapshots of five- or ten-year periods," he explains. ■

For more information on wolf-moose research:

wolfmoose.mtu.edu

NSF CAREER AWARD RECIPIENTS

IN THEIR OWN WORDS

Three Michigan Tech faculty members were honored in 2007 with National Science Foundation CAREER Awards. According to NSF, it is their "most prestigious award" to support "those teacher-scholars who most effectively integrate research and education within the context of the mission of their organization."

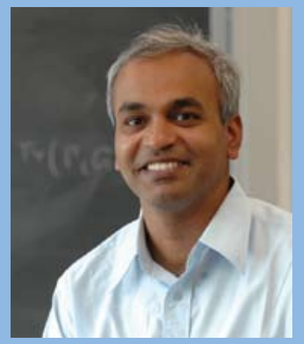
We thought we would let them discuss the award, and their teaching and research, in their own words.

Chunxiao Chigan

Assistant Professor, Electrical and Computer Engineering

On her research: "My CAREER award is for research on communications for vehicular ad hoc networks (VANETs). My development of VANETs will enhance traffic safety and traffic operation by addressing several challenges in access technology, dynamic power control, robust multi-hop communication, and the balance of security and privacy provisioning."

On the award: "To me, receiving an NSF CAREER award means a high academic recognition of our research and a strong affirmation of the potential technical and social impact of our research thrust. It further strengthens my lifetime commitment to strive to be an excellent researcher, teacher, mentor, and scholar."



Ranjit Pati

Assistant Professor, Physics

On students' involvement and outreach: "The NSF award supports two graduate students and several undergraduate students. Furthermore, it provides us the opportunity for outreach. Currently we are developing a layperson's version of molecular nanotechnology—an animated presentation for high school students."

On the award: "This is one of the most important achievements in my career thus far. Considering the level of competition each year at NSF, I am really honored to receive this award. One of the major objectives of this research is to design a single molecular transistor, which would sustain computing power growth beyond the year 2020. I am glad that the support from NSF will help us continue working towards this goal."

Zhenlin Wang

Assistant Professor, Computer Science

On his teaching: "We want to give students the freedom to be creative. Always, in the first class, I tell my students that, if my office door is open, you are welcome to stop by to talk about this class, talk about research, talk about your career."

On his research: "The modern compiler and computer architecture design largely relies on program locality, a property that makes memory systems work. My research will bring a new view to this and open a path for new compiler and architectural schemes for program optimization."

On the award: "The NSF CAREER award means acknowledgment from the academic society, encouragement from my colleagues, and my continued commitment to excellence in research and teaching."