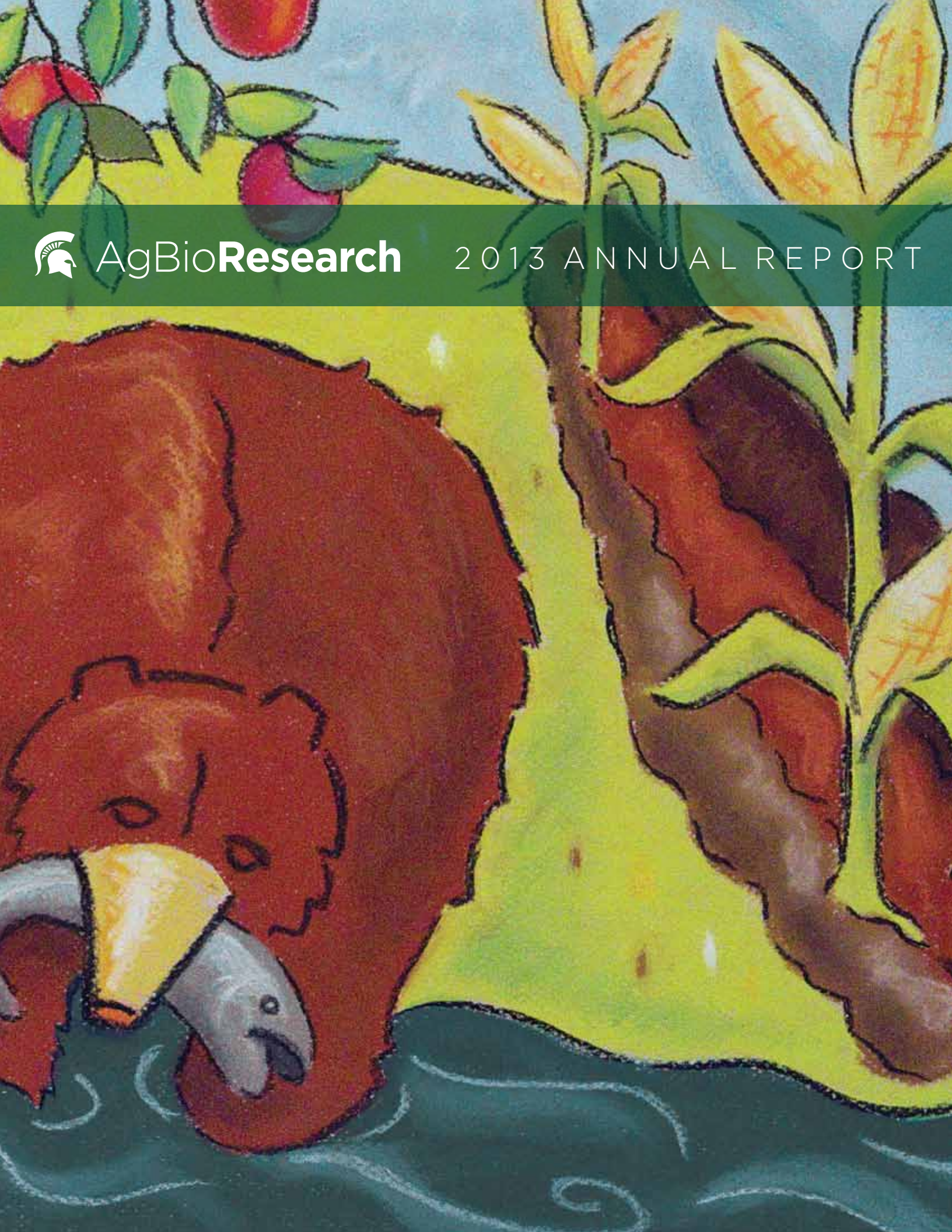

AgBioResearch

2013 ANNUAL REPORT

MICHIGAN STATE UNIVERSITY

AgBioResearch

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2013 ANNUAL REPORT

MANAGING EDITOR'S NOTE: As we interviewed the scientists involved in the research projects presented in this report, they provided us with lengthy lists of colleagues, students, organizations and funders integral to their efforts. Including all of this information would easily double the length of the report, so we opted to limit project narratives to key research elements and the importance of the work in its respective field. We do, however, want to convey the interviewees' acknowledgments of the individuals and organizations with which they collaborate and their gratitude for the support they receive in doing their work.

PAST YEAR HAS BEEN A GAME CHANGER IN MANY REGARDS

Doug Buhler
MSU AgBioResearch Director
CANR Senior Associate Dean of Research

In early 2013, I returned to work with Michigan State University (MSU) AgBioResearch after serving two years as interim dean of the College of Agriculture and Natural Resources (CANR). My stint at the helm of the college reaffirmed my belief that research is my true calling. Having started my career as a researcher, I discovered that being part of the search for scientific solutions in light of sometimes steep odds continues to be my passion.

Now, as director of MSU AgBioResearch and CANR senior associate dean of research, I am honored to be back working with some of the brightest researchers anywhere in the world. It's rewarding to see how their advancements in the areas of food production, safety and security, environmental protection and alternative energy continue to enhance lives here in Michigan and around the world.

Though my interest in research has never waned, I have taken note of some recent challenges that are changing the scientific landscape. Events of the past year, such as the Farm Bill impasse, the government shutdown and the sequestration, have cast a shadow on the financial security of many research projects, even those with prior commitments to funding.

Fortunately, scientists are used to being resourceful and rising to new challenges. We're already looking at alternative funding sources to continue the projects that mean so much to all of us. This new approach is also necessary for MSU AgBioResearch to maintain its on-campus infrastructure, as well as our 13 outlying research facilities throughout Michigan.

As some of you already know, MSU AgBioResearch originated in 1888 as the Michigan Agricultural Experiment Station. Our primary focus — as charged in the 1887 Hatch Act — was to conduct research and development projects on behalf of farmers. In 1925, the Purnell Act added agricultural economics, rural sociology and home economics to the mission.

Though the vision and scope have broadened to include scientists in six other colleges beyond CANR, I'd like to take this opportunity to reaffirm the MSU AgBioResearch commitment to its core programs in agriculture and natural resources. Together we have weathered some tough times over the recent years, and I believe it has helped strengthen our ingenuity resulting in stronger relationships with growers, producers and other stakeholders throughout this fine state.

As we move forward, we will need to make wise investment decisions. We have had to cut many things to balance our budgets in recent years. Important positions have remained unfilled, maintenance delayed, and equipment and operating budgets drastically reduced. In the coming years, we will need to balance our desire to hire new people with the need to support critical research infrastructure. Our researchers depend on high quality facilities and equipment, both on- and off-campus, to conduct high priority research and to be competitive for external funding. In particular, MSU AgBioResearch is striving to rebuild the financial resources to support our 13 outlying research centers across the state. We're proud to be working with industry partners to find new ways to make this happen.

This new financial landscape will require that we continue to step up our game in pursuit of new ways to deliver results that not only benefit the state's economy, but also enhance lives around the world. It is a critical step in what is sure to be a game changer for the entire industry.

Thanks for your continued support and the valued partnerships we have formed and will continue to build in the future.

Doug Buhler
MSU AgBioResearch Director

NEW MSU AgBioResearch FACULTY

Ortega

David Ortega, assistant professor in the Department of Agricultural, Food and Resource Economics, became affiliated with MSU AgBioResearch in July. His research focuses on applying his knowledge of Chinese agricultural economics to American and global agribusiness issues, and supporting domestic producers and agribusinesses in topics ranging from production-oriented decisions to the way the public perceives agricultural practices. He is also interested in consumer and producer behavior, the economics of food safety and quality, agribusiness management, and food safety in developing and emerging countries.

Ortega has been a member of the MSU research faculty since January 2013. Before coming to MSU, he was awarded research grants from the National Science Foundation, the U.S. Department of Agriculture, the Indiana-Illinois Sea Grant program, the Purdue Research Foundation and the University of International Business in China.

He received his doctorate and his master's degree in agricultural economics from Purdue University in 2012 and 2009, respectively, and his bachelor's degree in food and resource economics from the University of Florida in 2006.

Latham

Keith Latham, professor in the Department of Animal Science, became affiliated with Michigan State University and MSU AgBioResearch in August. His research focuses on understanding the early development of mammal embryos on a molecular level and how disruptions in that process can lead to disease later in life. His studies encompass genetics, cell biology, cell physiology and gene network analysis.

Before coming to MSU, Latham served as the associate chair of the Department of Biochemistry at the Temple University School of Medicine. For over 20 years, his lab pioneered methods for detailed molecular studies of embryos, stem cells and oocytes, an immature form of eggs in mammals.

Latham received his doctorate in biology from the University of Virginia in 1988 and his bachelor's degree, also in biology, from the University of Kentucky in 1982.

Richardson

Robert Richardson, associate professor in the Department of Community Sustainability, became affiliated with MSU AgBioResearch in August. His research focuses on sustainable development and the role of ecosystem services in supporting the welfare, livelihoods and food security of households and communities. He is also interested in the concept of social-ecological resilience — the capacity of communities to adapt to environmental and social change. His work has included assessments of the role of natural resources in poverty alleviation and food security, regional vulnerability to climate change and trade-offs in decision making about environmental management.

Robertson has been a member of the research faculty at MSU since 2007. Before coming to MSU, he served as associate director of the Institute of Sustainable Solutions at Portland State University and assistant professor of economics at Galen University in Belize. Robertson received his doctorate in agricultural and resource economics from Colorado State University, his M.B.A. in finance from New York University and his bachelor's degree in management from Tulane University in 2002, 1995 and 1989, respectively.

FINDING EGGS-ACTLY

the right solution for hen housing

It's not the "which came first — the chicken or the egg" controversy but rather a debate over housing for laying hens that has spurred a $6 million commercial-scale study that could affect Michigan's annual $229 million egg industry.

RIGHT: Janice Siegford collects data on hens in an enriched housing system at the poultry teaching and research facility on campus. *Photos: Jane L. DePriest.*

The Coalition for Sustainable Egg Supply is studying housing alternatives for egg-laying hens in the United States.

The Coalition for Sustainable Egg Supply is studying housing alternatives for egg-laying hens in the United States. The project involves researchers from five universities and representatives from food manufacturers, restaurants, food service companies and egg suppliers. The research aspect is being led by scientists at Michigan State University and the University of California, Davis.

"The goal is to keep egg laying a sustainable and viable industry in Michigan and in North America," said **Janice Siegford**, an MSU AgBioResearch animal scientist who is part of the coalition.

The activities were prompted in part because the European Union passed a law in 2012 that requires all commercial eggs to be produced in free-range barns or enriched cages, thus essentially banning conventional housing for hens.

Several U.S. states have already passed legislation to change hen housing. The Michigan Animal Industry Act, passed in 2009, gives producers 10 years to adopt the new standards. The law doesn't ban conventional housing, but says hens need to be able to stretch their wings without coming into contact with the cage, freely move around and lie down.

Currently, three types of hen housing systems are in use:

- Conventional cage housing has small cages housing four to nine hens. There may be thousands of cages per house, often housing 200,000 hens in each building.
- Enriched colony systems house 60 to 250 hens in more open cages that are larger and equipped with perches, nesting areas, and material to facilitate foraging and dust bathing. These systems can have about 50,000 hens in each building.
- Cage-free aviary systems allow hens to roam throughout a defined section of a building with perches, nesting areas and dust-bathing material. There are about 50,000 hens total per building.

"The conventional system is efficient and good for controlling disease and for environmental containment because manure is taken away constantly on a conveyer belt," explained Siegford, an assistant professor in the Department of Animal Science. "However, the hens are confined to a very small space. They don't have room to do chicken-type things – scratching the grass, pecking at bugs, dust bathing or perching.

"In the alternative housing systems, hens have opportunities to perform a wider range of behaviors, but some of these behaviors, such as pecking the feathers of other hens, may cause problems. At the moment, all of the systems have trade-offs, with strengths and weaknesses in different areas."

The goal of the coalition project is to collect scientific data to aid producers in making decisions about hen housing. The project is focused on five areas: economics, environment, worker health and safety, hen health and well-being, and food quality and safety.

Siegford's research, in collaboration with former MSU AgBioResearch scientist Michael Orth, now with Texas Tech University; MSU Extension specialist Darrin Karcher; and MSU animal science research associate Dana Campbell looked at hen health and behavior in the cage-free aviary systems. For this aspect of the project, researchers studied two large flocks of hens over two years at a commercial egg-laying operation.

Preliminary findings show that workers in the cage-free aviary houses were exposed to higher levels of dust and bacteria than those working in the conventional cage or enriched colony housing. This increased exposure is due in part to the effects of litter that accumulates on the floor in aviary housing. Egg quality was the same in all housing systems.

The next steps include assembling guidelines describing the positives and negatives of what researchers observed, as well as additional computer tools to help producers decide which housing system works best in their operations.

Siegford considers the preliminary data a significant milestone in understanding the impacts and trade-offs associated with each system. She hopes to conduct further studies looking at individual use of space in the aviary housing system with emphasis on animal welfare.

"We need more research to see scientifically how hens do in these systems because not all hens use the systems the same way," Siegford said. "But the preliminary findings combined with future data will greatly increase our scientific knowledge about sustainable egg production. That's something we can use to inform egg producers and people making purchasing decisions."

THE HUNT IS ON:

New funding spurs research on toxic chemicals

There are more than 1,200 hazardous waste sites in the United States. Sixty-seven of them are located in Michigan. They have commonly become known as Superfund sites after the program of the same name established by the U.S. Environmental Protection Agency to clean up contamination at these locations.

RIGHT: Krista Greenwood, a former student who now works for Dow Chemical, pulls cell stocks out of liquid nitrogen as part of an experiment in John LaPres' lab. *Photo: Kurt Stepnitz, MSU CABS.*

OPPOSITE: Although they work on separate projects for the Superfund Center, Tim Zacharewski (left) and John LaPres often confer on what works well in their labs.

The multidisciplinary team of toxicologists, microbiologists, statisticians and engineers is part of the MSU Superfund Center . . .

Now MSU scientists are using $14.1 million in funding from the National Institute of Environmental Health Sciences (NIEHS) to continue research on understanding the health risks from chemicals — primarily dioxins — commonly found at the sites. Research also focuses on remediation technologies to eliminate the potential for exposure to chemicals at the sites.

The multidisciplinary team of toxicologists, microbiologists, statisticians and engineers is part of the MSU Superfund Center, which has received funding from NIEHS since 1988 for various projects related to the Superfund program. MSU AgBioResearch toxicologists **John LaPres** and **Timothy Zacharewski** head two complementary Superfund projects.

"We want to understand why chemicals — most notably, TCDD (tetrachorodibenzo-p-dioxin) — are toxic and what are the human health risks associated with exposure to these chemicals," said LaPres, an associate professor of biochemistry and molecular biology.

His project involves the toxicological principle of dose response — the relationship between a toxic reaction (the response) and the amount of poison one receives or is exposed to (the dose). There are two important assumptions: there is almost always a dose below which no response occurs or can be measured; and once a maximum response is obtained, any further dose will not result in an increased effect.

"Knowing the dose-response relationship for TCDD is a necessary part of understanding the cause-and-effect relationship between chemical exposure and illness," LaPres explained. "This has huge implications for risk assessment and how we manage Superfund sites."

LaPres and researchers in his lab are attacking this very complex toxicological problem by using a panel of 36 strains of mice to model human populations.

"In layman's terms, we are trying to use different mouse strains to model human genetic diversity," LaPres explained. "We hope the results will give risk assessors an accurate way of calculating the risk of exposure for people who live or work near Superfund sites and ultimately show ways to minimize that risk."

The work is time-consuming. In fact, LaPres expects that it will be two years before data from the mouse experiments will be available. In the meantime, he and other researchers in his lab are working to find answers to some of the more subtle questions surrounding TCDD.

"We want to understand how TCDD works and its effect on cells and tissues," he said.

Zacharewski's research focuses on the effects of exposure to dioxins, especially the accumulation of fat in the liver.

"Fat accumulation in the liver by itself is not so much of a concern because it is a reversible process," explained Zacharewski, a professor of biochemistry and molecular biology. "However, the chronic accumulation of fat in the liver can progress into more complex diseases such as nonalcoholic fatty liver disease and metabolic syndrome, which have been associated with diseases such as diabetes, obesity, cardiovascular disease and liver cancer."

He is using mouse models and human liver cells to look for changes that would be consistent with fat accumulation in the liver.

"So far, we have found that dioxins work through a specific protein called the aryl hydrocarbon receptor to increase liver fat accumulation using fat from the food we eat. We believe that's what is creating the problem," said Zacharewski, who also is trying to discover whether the response in mice is relevant to humans and whether it can be a contributing factor in the increased incidences of liver cancer, diabetes and cardiovascular disease.

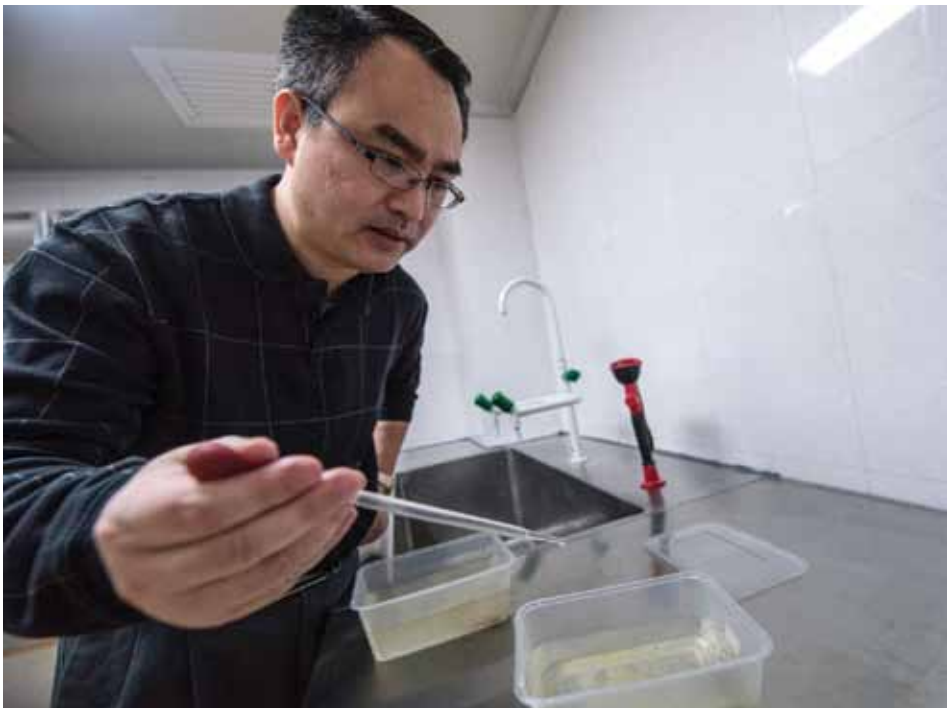
In addition, he wants to determine whether there are enough dioxins and other chemical compounds in the environment, not necessarily in the hazardous waste sites, to cause this effect in humans.

Zacharewski points out that the work on all of the MSU Superfund projects is collaborative, involving many investigators across campus working together to find answers.

"We also are taking advantage of the resources and infrastructure unique to MSU, especially the high performance computers at the Institute of Cyber-Enabled Research and emerging technologies available in the Research Technology Support Facility," he said.

OPENING NEW DOORS

to control deadly tropical diseases



ABOVE: Zhiyong Xi transfers mosquito larvae with a pipette at a lab at the Sun Yat-sen University-Michigan State University Joint Center for Vector Control for Tropical Diseases, which Xi helped establish to further research in eradicating malaria and dengue fever. *Photos: Kurt Stepnitz, MSU CABS.*

Malaria and dengue fever are mosquito-borne infectious diseases that affect millions of people worldwide and cause tens of thousands of deaths each year. Malaria has been eliminated in the United States; cases of dengue fever are rare, but the disease recently started to reemerge in Florida. These tropical diseases are major public health concerns in Africa, South America and Asia.

MSU AgBioResearch microbiologist **Zhiyong Xi** may have the answer to controlling or completely eliminating these diseases. His research with a strain of *Wolbachia*, an intracellular bacterium, has shown a way to stop both malaria and dengue virus from replicating in mosquitoes.

Researchers around the world are excited about the results of Xi's research, which has received considerable media attention.

"Researchers in labs around the world have been working on *Wolbachia*-based control strategies for more than 20 years," said Xi, an assistant professor of microbiology and molecular genetics. He began working with *Wolbachia* as part of his Ph.D. research at the University of Kentucky; later at Johns Hopkins University, his postdoctoral research focused on dengue and malaria in mosquitoes.

"It is difficult to put *Wolbachia* into the mosquito species that transmits malaria. Although the initial idea was to target for malaria control, we switched to using similar concepts to control dengue fever because the system to block that disease is easier," Xi explained.

Each disease has a particular mosquito species as vector (vectors are organisms that carry and transmit infectious pathogens into another living organism) — dengue is transmitted by *Aedes* mosquitoes and malaria by *Anopheles* mosquitoes. For dengue fever, Xi and his colleagues have been able to successfully maintain the bacterium — passed from mother to offspring — in *Aedes aegypti* mosquitoes for almost eight years. Furthermore, male mosquitoes infected with *Wolbachia* can cause uninfected females not to produce offspring, which maximizes the number of *Wolbachia*-infected individuals in the next generation.

Upon success of his research with dengue fever, Xi turned his attention to malaria.

"The research with dengue fever and the mosquito species that transmits it gave us a lot of knowledge and we learned new things," he explained. In particular, he and his research team perfected the technical skills needed to inject a mosquito egg with the bacterium.

His latest research, reported in the May 2013 issue of *Science*, shows that a stable *Wolbachia* infection can interrupt the transmission of malaria from mosquitoes to humans. Xi's lab was the first to succeed at this.

"From that first step, there is a possibility to use this to control malaria. The door is open," said Xi, who worked with a mosquito species called *Anopheles stephensi*, the key malaria vector in south Asia and the Middle East. He said the same technique may also work on other malaria-carrying mosquito species, such as *Anopheles gambiae*, which predominates in Africa.

The biggest challenge is getting the bacteria to form a symbiotic relationship with the mosquito.

"We want the two organisms to stably stay together," Xi explained. "This is where many other labs have failed. We want to force the bacteria to form a symbiosis with the mosquito vector, making the bacteria stay there forever so that the females will always produce offspring carrying this bacterium. One single female can produce hundreds of mosquitoes that carry the bacterium, and eventually you'll have millions of mosquitoes carrying it."

Several years ago, Xi developed a partnership with Sun Yat-sen University in Guangzhou, China, where he received his master's degree. He is now the director of the Sun Yat-sen University-Michigan State University Joint Center of Vector Control for Tropical Diseases.

With the help of researchers at the Chinese university, Xi hopes to conduct field trials, but he needs government approval and community support to test the concept. Xi's research with mosquitoes falls into a category of microbial insecticide that requires biosafety concerns to be addressed. The message that Xi hopes to convey is that *Wolbachia* is a bacterium that cannot infect humans or animals.

"This two-step process of getting regulatory approval from the government along with community support is very important to the success of this phase of the project," he said. "We will not release *wolbachia*-infected mosquitoes without both."

Researchers around the world are excited about the results of Xi's research, which has received considerable media attention. Although there is still much to be done to be able to eradicate these devastating diseases, Xi is enthused about the possibilities.

EMERGING MARKETS:

Finding new ways to get local products to consumers

ABOVE: Mike Hamm stands by produce at a local food hub, an increasingly popular way to make produce and meat raised nearby more readily accessible to people of all income levels as well as larger-scale institutions such as hospitals and school cafeterias. *Photos: MSU Center for Regional Food Systems.*

Michiganders consume 12 billion to 15 billion pounds of food a year.* The goal of the MSU Center for Regional Food Systems (CRFS) is to see how much of that food can be sourced, processed and delivered within Michigan in profitable ways while preserving natural resources.

"Michigan is in the middle of the Midwest with the second most diverse agriculture in the country," said **Michael W. Hamm**, MSU AgBioResearch scientist and CRFS director. "CRFS is focusing on all the things that can be done to build sustainable, local food systems."

Hamm believes that regional food systems should be part of a household food supply.

CRFS research, education and outreach on helping Michigan build better regional food systems officially began in February 2012. Hamm began similar work in 2003 when he arrived at MSU as the C.S. Mott professor of sustainable agriculture.

A major CRFS project, carried out with assistance from the Michigan Department of Agriculture and Rural Development (MDARD) and Morse Marketing Connections, is the development of the Michigan Food Hub Learning and Innovation Network. Food hubs are centrally located facilities with a business management structure to facilitate the aggregation and distribution of food products from small and midscale farmers in a particular region.

After farmers deliver their products, the food hub stores, processes, packages and markets the food to wholesale buyers such as restaurants, hotels and universities. Food hubs differ from other distribution systems because they work specifically with small and midsized farmers to provide local and regional foods. The sales benefit the local economy, community well-being and the environment by decreasing transportation distances.

Michigan, with a $91 million agriculture industry, has become a national leader in the development of food hubs. To support the statewide endeavor, MDARD provided approximately $900,000 in grants in 2012 to food hub projects in Detroit, Ann Arbor, Lansing, Traverse City and the Upper Peninsula. The CRFS has ongoing projects to help develop these locales and establish new hubs in Michigan.

CRFS also recently completed the 2013 National Food Hub Survey in collaboration with the Wallace Center at Winrock International. The survey shows that food hubs throughout the United States continue to develop as financially viable businesses providing locally produced food to wholesale customers.

"Surveys such as this one provide much needed data for those looking to fund, evaluate and further investigate the role of food hubs in regional food systems," Hamm said. The survey also provides a way to track changes in food hub development over the next decade. The center assumed national responsibility to conduct the survey every two years for the U.S. Department of Agriculture.

The survey revealed that more than 65 percent of U.S. food hubs operated independently without external funding sources and contributed significantly to the growth of local economies. Many hubs operate in rural or urban areas that have limited access to food items such as fresh fruits and vegetables.

Another focus of CRFS is the development of a statewide farm-to-school network that helps link schools with local growers, producers and processors with the goal of schools sourcing about 20 percent of their food products from Michigan. One project is a funding program with K-12 food service directors to help them get started buying Michigan agricultural products.

CRFS also brings together researchers, producers and marketers associated with the meat industry to look at how regional markets for Michigan meat products can be developed.

"Right now, Michigan meat products almost never go to Michigan markets," Hamm said. "This work group is attempting to find out if there is a way to create value-added products within a regional supply chain."

With an eye to the future, the center is working with agricultural economists to examine the impact of Michigan food on the state and develop tools to help regional governments evaluate the effect of local food on the local economy.

"There is a lot of research out there that overestimates the impact. We want to get more robust numbers that are more within the realm of reality," said Hamm, who envisions a process that can help communities understand what data they need to collect and then develop a process to use that data in an analytical framework.

Hamm believes that regional food systems should be part of a household food supply.

"Our food supply should include national and global trade but balance that with regional sources and markets," Hamm explained. "From our analysis, part of the key to food security is that balance between regional, national and global."

*M.W. Hamm (2010), *The Food System: A Potential Future.* Available at www.glynwood.org/files/2010/11/The-Food-System-A-Potential-Future.pdf.

NAVIGATING A NEW ERA:

Specialized models help researchers process 'Big Data'

ABOVE: Andrew Finley (second row, second from left), will lead a series of graduate student workshops in Boulder, Colo. each summer to facilitate learning, connect graduate students from diverse disciplines and help next-generation researchers navigate enormous ecological computing environments. *Photo: Courtesy of Andrew Finley. Opposite page: Merritt Turetsky.*

The United States Environmental Protection Agency (EPA) estimates that forests occupy approximately 751 million acres of land in the United States. Forests provide many benefits and services to society. In Michigan, they play an important role in the state's economy as a source of both employment and recreation. The EPA, however, is concerned that climate change will affect forest growth and productivity by altering the frequency and intensity of forest disturbances such as insect outbreaks, invasive species migration, wildfires and storms.

Wanting to understand more about the effects of climate and other ecological changes, the National Science Foundation (NSF) launched the National Ecological Observatory Network

NEON will collect approximately 600 billion raw ecological measurements per year for 30 years from 106 locations . . .

(NEON), a $434 million initiative that will create an open-access infrastructure that can be used to map, explore and predict changes in the nation's ecosystem.

Michigan State University (MSU) AgBioResearch statistician **Andrew O. Finley** is collaborating with NEON scientists to develop important statistical models, overcome technology challenges and educate future researchers who will use the observatory's data to manage the nation's natural resources.

NEON will collect approximately 600 billion raw ecological measurements per year for 30 years from 106 locations throughout the United States. These measurements, once refined into accessible "data products," will enable the understanding and forecasting of climate, land-use and invasive species change.

Ecological projections are typically based on data collected from microsystems, reflect a specific methodology, and are not generalizable to larger scales or systems. However, NEON's data products — defined as cataloged groups of synthesized information — will provide necessary data so researchers can explore pressing environmental questions at appropriate space and time resolutions at continental scales.

"NEON recognizes that its data products must be statistically robust," said Finley, MSU associate professor in the departments of Forestry and Geography. "Here, the central challenge is in specifying valid statistical models for creating data products from the high-dimensional spatial and temporal data collected from environmental sensors. Without the use of appropriate modeling techniques, the resulting spatial data products will amount to pretty maps that should not be used to inform policy or subsequent modeling efforts."

Time and space are two important factors in statistical projections. To make valid, large-scale predictions, researchers must employ models that acknowledge the uncertainty that the two factors create. Finley will work to supply such models.

"In the summer of 2012, I was a visiting scientist in the NEON Data Products group," said Finley, who is also an MSU adjunct professor in the Department of Statistics and Probability. "During that time, I was able to identify key modeling challenges in NEON's progression from raw data to data products. My research focuses on creating modeling frameworks and open-source software that address those challenges; it also has a huge education effort designed to draw together students and experts from multiple disciplines and institutions."

Finley explained that an understanding of the theories, methodologies and tools needed to employ advanced instruments and statistical models isn't usually included in ecology or natural resource education. His project also focuses on creating transdisciplinary educational opportunities for students in those fields.

Specifically, he plans to enrich science education in 23 southwestern Michigan K-12 schools by collaborating with the MSU Kellogg Biological Station; develop cross-college curricula for undergraduate and graduate students; and explore contemporary topics with graduate students and early-career scientists in advanced courses, workshops and symposia.

He is especially excited about the series of graduate student workshops he will lead in Boulder, Colo., each summer for the next four years. NEON and the National Center for Atmospheric Research (NCAR) will host the workshops.

"The idea is to get graduate students from diverse disciplines together to explore their research challenges and teach them new modeling and computing techniques," he said. He explained that successful navigation of the "Big Data" era requires next-generation researchers to have statistical and software tools that helps them develop valid answers to pressing questions.

"I'm excited to help projects like NEON succeed — there's substantial value in these kinds of initiatives," he concluded. "NEON's plans to develop and distribute these data will ultimately help forest scientists, like myself, manage and sustain forest systems capable of persisting in changing environments and continuing to meet society's demand for ecosystem services."

BEARING WITNESS:

Developing enriched models to monitor Michigan black bear populations

The Michigan Department of Natural Resources (MDNR) is charged with managing the state's American black bears, which primarily inhabit the northern two-thirds of the state. In 2008, the MDNR estimated that 18,000 bears lived in Michigan. Since then, the agency has grappled with indices, estimators and costly survey methods that provide conflicting projections of how the population has changed over time.

RIGHT AND OPPOSITE: The Michigan Department of Natural Resources Wildlife Division examines a wintering bear in Michigan's northeast Lower Peninsula. The bear — a 166-pound, 16-year-old female — was located in 2008 and outfitted with a radio collar so biologists could document her reproductive success, habitat usage and travel patterns. Biologists sedated, examined, weighed and then returned the bear to her den. *Photos: David Kenyon, MDNR.*

The current survey method requires significant field effort to distribute and monitor baits.

A Michigan State University (MSU) graduate student and two MSU AgBioResearch scientists are developing a reliable, cost-efficient method to monitor bear population dynamics and help the MDNR assess hunting license quotas, a key component of black bear management.

"Each year, the MDNR recommends how many licenses should be sold," said **Sarah Mayhew**, MSU Ph.D. student and MDNR research biologist. "The quotas are based on our understanding of bear population size, what direction we want that population to move in and how successful we think hunters will be."

Licenses are awarded through a lottery system across 10 bear management units in the state. In 2013, there were 7,906 available licenses and 32,024 applicants who hoped to hunt in one of those units. Mayhew explained that the quotas, when paired with research and education activities, help balance bear ecological systems, foster recreational opportunities and encourage peaceful cohabitation between bears and people.

Scott Winterstein, MSU professor of fisheries and wildlife, described the current population estimation techniques as time-consuming and costly. They employ capture-mark-recapture (CMR) field methods that provide researchers with necessary population estimates but require MDNR staff members to create the opportunity for every bear in the population to encounter a survey bait.

There are two black bear populations in Michigan: one in the Upper Peninsula and a second in the Lower Peninsula, north of a line between Muskegon and Bay City. The survey method requires significant field effort to distribute and monitor baits placed throughout the two regions, and translates into large investments of time and estimates of $50,000 to $75,000 each year they are run, Mayhew said.

After hypothesizing that she could apply less costly, more precise methodologies used by fisheries biologists to estimate bear populations, Mayhew contacted **James Bence**, MSU professor of fisheries and wildlife.

"I use statistical catch-at-age (CAA) models to estimate [fish] mortality rates and the rates of recruitment or entry of new, young individuals into a population, and to determine what fraction of death is due to harvesting," Bence said. "The models can then be used as a basis for rational management."

Mayhew explained that the CAA models use data sets and auxiliary information that are not associated with the CMR method and are already collected annually by the MDNR. Use of the CAA model could enable the MDNR to conduct CMR surveys less frequently.

"I expect the minimum outcome of the project to be a model that projects bear abundance every year, filling in the gaps of the CMR method and showing that we may be able to use [CMR] less often," Bence explained.

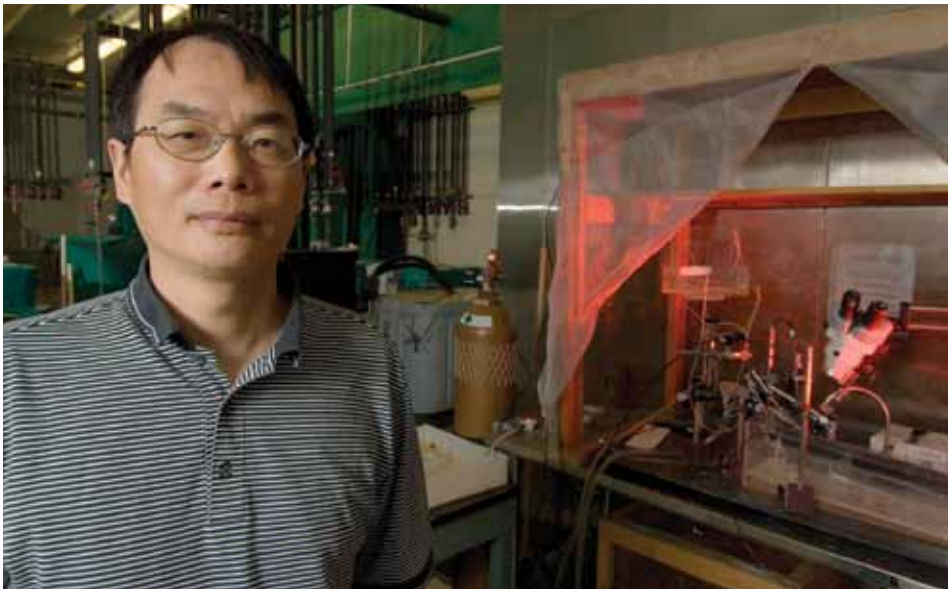
He does not believe that the CAA model will completely replace the CMR surveys but that the two could be used together. The CMR surveys effectively estimate the absolute number of organisms; the CAA model is effective at identifying the processes that cause changes in numbers of animals. Combined, they help paint a clearer picture without physically measuring the population every other year, Bence said.

"We are also hopeful that the CAA model will produce detailed estimates of how mortality varies among ages with the amount of hunting effort between bear sexes, allowing for better projections of what the bear population would do in the future, given different management actions," Bence said.

Winterstein concluded, stressing the importance of efficiency: "It's a good, fortuitous thing that we have access to these kinds of methodologies. State agencies are budget- and personnel-driven, so if it turns out we can use the CAA methodology to cut costs and save time, it'd be good news for the MDNR."

KNOW YOUR ENEMY:

Deciphered sea lamprey genome holds key for new management tactics



ABOVE AND OPPOSITE: The sea lamprey has no natural predators in the Great Lakes. Without management by the Great Lakes Fishery Commission, the sea lamprey would wreak untold havoc on the lake system's ecology. Weiming Li has unlocked the sea lamprey genome, which will help scientists to understand vertebrate evolution and develop more precise management tactics to control the invasive species. *Photos: MSU CABS.*

The sea lamprey is one of the oldest and most ecologically dangerous invasive species in the Great Lakes. Discovered in Lake Ontario in 1835, it has since spread through all five lakes in the world's largest freshwater system. A parasite, the sea lamprey latches onto fish with a concentric array of razor-sharp teeth and feeds on bodily fluids until the host dies. With no natural predators in the Great Lakes, sea lamprey have contributed to the unbalancing of the lake ecosystems, playing a significant role in the devastation of lake trout in Lake Superior and drastic population reductions in many important native predator and game fish.

Although sea lamprey numbers have significantly decreased thanks to management efforts by the international Great Lakes Fishery Commission — numbers are down to 10 percent of their premanagement levels — they remain a problem for ecosystems throughout the basin.

Developing tactics to combat the invasive species is paramount to the health of the lakes.

Recent landmark findings by Michigan State University (MSU) AgBioResearch scientist **Weiming Li's** laboratory have yielded hope for both new sea lamprey management techniques and insights into vertebrate evolution. In a paper published in 2013, Li's team of more than 60 researchers from 10 laboratories across the United States and Europe described the entire genome of the sea lamprey. This project, initiated by the National Institutes of Health, provides an unprecedented understanding of the species.

"Because of the profound impact that the sea lamprey has on our ecosystems, understanding its genome will be beneficial to both the Great Lakes ecosystem and the field of biology as a whole," said Li, a professor of fisheries and wildlife.

Unlike the genomes of many species, the sea lamprey genome is full of repetitive sequences that make it difficult to assemble in its entirety. Furthermore, high genetic variation between individual sea lamprey specimens renders it that much more difficult to find the commonalities throughout the species. The work of Li's team paid off, however, in a treasure trove of genetic information useful to researchers across the entire spectrum of biology.

The discovery provides great insight into the evolution of all vertebrate species. The sea lamprey diverged very early from the main stream of vertebrate species evolution and as a result has retained a number of primitive physiological characteristics not found in species that developed later, such as the lack of a jaw and nerves that are exposed rather than bundled together in a tissue sheath.

"Since it has vertebrae but not many of these other features common to vertebrate species, it is considered a very primitive animal," Li said. "Unlocking its genome helps us to understand what our own genome may have looked like millions of years ago."

The sea lamprey genome is also expected to be a crucial tool in developing better and more environmentally sound techniques for managing the species in the Great Lakes. Early management practices employed large quantities of lampricides, poisons designed to kill sea lamprey larvae before they could develop into parasitic adults. However, other Great Lakes species, such as sturgeon, proved to be susceptible to lampricides as well. Li's findings should lead the way to more finely tuned options with fewer environmental costs.

"The Great Lakes Fishery Commission is organizing a workshop on the future of the pesticides selectively targeting lamprey. Part of the reason this is possible is because of the availability of the lamprey genome," Li said. "It allows us to develop more environmentally friendly pesticides for dealing with them."

Developing tactics to combat the invasive species is paramount to the health of the lakes, he said.

"I imagine the fisheries of the Great Lakes would be decimated without these management programs," he said. "The sea lamprey remains a threat to the fish community in the Great Lakes ecosystem, and the knowledge generated by our lab helps in developing additional methods of controlling it. If you want to defeat your enemy, you need to know it very well."

The results of this work have the potential to go beyond evolutionary biology and environmental management.

"We've been able to develop biomedical research projects based on the lamprey genome," Li said. "For example, in humans, if the spinal cord is severed, the damage is usually irreversible, but the sea lamprey can regrow it. If we can determine why, it could lead to a technology that can help improve medical care for injured people."

In decoding the sea lamprey genome, Li and his team have provided the scientific community with an invaluable resource that has many applications.

"The lamprey genome is a resource that I hope will be used often by as many researchers as possible," Li said. "It's already accelerated many other research projects, and I hope it will continue to do so."

NO LAUGHING MATTER:

Managing nitrous oxide through carbon markets

Nitrous oxide is one of the top three greenhouse gases, according to the U.S. Environmental Protection Agency. Though it's less prevalent than other gases such as carbon dioxide, nitrous oxide — commonly known as laughing gas — is 300 times more effective than carbon dioxide at capturing heat and keeping it in the atmosphere.

RIGHT: Phil Robertson has devised a new protocol that will allow farmers to exchange their nitrous oxide emission reductions for profit on the carbon market. Nitrous oxide is a greenhouse gas 300 times more potent than carbon dioxide that can be released into the atmosphere through over-fertilizing. *Photos: Kurt Stepnitz, MSU CABS.*

This nitrous oxide enters the atmosphere as a greenhouse gas and can remain there for up to 120 years.

Half of greenhouse gas emissions are estimated to come from agriculture. To reduce these emissions, Michigan State University (MSU) AgBioResearch scientist **Phil Robertson** has helped develop an incentive for farmers to limit nitrous oxide output.

Nitrogen, in the form of fertilizer, is added to the soil to improve crop yields. Some farmers, however, apply more fertilizer to fields than plants require, he said. Microbes in the soil convert this nitrogen surplus into nitrous oxide.

"We previously assumed that a constant proportion of fertilizer nitrogen — about 1 percent — becomes nitrous oxide. That relationship isn't as straightforward as we thought," Robertson, MSU university distinguished professor of plant, soil and microbial sciences, explained. "What we've discovered is that the proportion is much higher when you apply more fertilizer than the crop needs because all of the excess becomes available to the microbes. In the absence of competition with plants, they are flooded with this resource."

This nitrous oxide enters the atmosphere as a greenhouse gas and can remain there for up to 120 years.

"We've been putting nitrous oxide into context with the other greenhouse gases emitted by field crops, and the size of its effect is quite surprising to people," Robertson said.

To reduce the release of other greenhouse gases, particularly carbon dioxide, some industries have voluntarily developed carbon offsets to limit the amount of gas that individual facilities or companies emit. As a consequence, a carbon market has emerged, in which these companies buy credits from industries able to decrease carbon emissions, and thereby meet voluntary reduction targets.

Farmers have, in previous years, been able to become involved in this type of trading, largely reserved for industries such as energy and manufacturing, through no-tillage practices. Not disturbing the soil prevents buried organic material from being exposed to the air, which accelerates soil decay and release of carbon dioxide.

"Through no-till farming, farmers can reduce the amount of carbon that leaves their soil," Robertson explained. "They could then theoretically sell that carbon savings to industry in the form of a carbon credit, although no present carbon markets allow credits for no-till farming."

Robertson and his colleagues have developed a way for farmers to be credited for more precise fertilizer use, which results in lower nitrous oxide emissions.

"We've devised a way that better nitrogen management can be rewarded," he said. "The idea is that if we can pay farmers to fertilize more carefully, it will keep excess nitrogen from being converted into nitrous oxide and released into the atmosphere. Prior to this, there was little incentive to reduce fertilization beyond it being the environmentally right thing to do."

Not only will this help farmers make money, it will help save money as well. By using less fertilizer on their land, they will reduce costs and maximize profits from participating in the carbon market.

The protocol essentially acts as a currency exchange for greenhouse gas offsets. Through it, farmers are able to convert nitrogen savings into carbon offsets and sell them on the carbon market. Similar approaches were previously developed for other greenhouse gases, such as methane.

"The nitrous oxide units they save can be sold as carbon credit equivalents simply by multiplying that amount by 300, the magnitude by which nitrous oxide is more potent than CO_2," Robertson said.

Greenhouse gas emissions restrictions and participation in the carbon market are currently voluntary in most of the United States, but many believe that national regulation is inevitable. This underlies interest in this work, primarily funded by the Electrical Power Research Institute.

"It will be to the advantage of the electric power industry to have as many sources of carbon credits on the market as possible," Robertson said. "This is a way of getting farmers in on the act, to give them another source of revenue and at the same time help address one of the more important environmental problems we face."

This forward-thinking approach helps emphasize a new agricultural contribution to society.

"A positive way of looking at agriculture is that it can now help solve the climate stabilization problem by reducing its nitrogen footprint," he said.

A DIFFERENT KIND OF OIL:

Studying *Nannochloropsis* as a biofuel source

ABOVE: Christoph Benning is studying marine alga *Nannochloropsis oceanica* as a source of biofuel. Drawn to the simplicity of its genetic structure and rapid high-energy lipid production, Benning's lab sequenced the alga's genome and aims to use that information to discover how it is able to produce large quantities of oil. Ultimately, he hopes to apply that knowledge to improve the oil production of other biofuel crops. *Photo: Kurt Stepnitz, MSU CABS.*

The search for sustainable sources of clean biofuels has led researchers to examine a wide array of organisms from across the entire biological spectrum. Corn, soybeans, a range of grasses and trees grown solely as energy crops, and even animal fat have all been studied. Recently, this search has taken scientists into the depths of the ocean, where oil-producing algae have offered new possibilities. Algae have become an attractive fuel source because they produce little in the way of greenhouse

The benefits of unlocking *N. oceanica* are far-reaching and varied . . .

gases, require less land than other biofuel crops and do not compete with food production, which has been a challenge to using crops such as corn. In 2008, the U.S. Department of Energy estimated that replacing all petroleum fuel in the country with algae-based fuel would require only 15,000 square miles, or approximately 0.42 percent of the land area of the United States.

One alga genus that holds promise is *Nannochloropsis*. Various species of *Nannochloropsis* are currently used as energy-rich food sources for fish larvae. Their ability to generate high quantities of lipids (naturally occurring fats), and other molecules used for energy storage, coupled with rapid growth rate, make them ideal biofuel candidates. One particular species, *Nannochloropsis oceanica (N. oceanica)*, is being studied as an example of algae's biofuel potential.

"I was consulting for an algae biofuels firm for around three years, and in that time I could see the biotechnical application of this species," said **Christoph Benning**, Michigan State University (MSU) AgBioResearch scientist. "Seeing its potential made me think it was a good organism to study in an academic environment."

Benning, an MSU professor of biochemistry and molecular biology, and his lab have been studying the genome of *N. oceanica* to assess its biofuel potential and, specifically, to compare it to the capabilities of yeast. (Yeast microbes consume sugars in plants and convert them into ethanol, which can then be used as fuel.)

"There were early indications that this alga species could be engineered in similar ways as yeast," Benning said. "We were looking for an organism that was capable of photosynthesis and had the same toolbox as yeast. *Nannochloropsis* gave us a promising candidate. We sequenced its genome and determined that new genes can be easily introduced into it."

The organism's great potential for the biofuel industry is only part of the story — Benning's research is also helping prepare a new generation of scientists.

"This is like working on a real crop," he said. "It's important both to academic researchers and to companies, so it's like killing two birds with one stone. We're training our students for the emerging bioeconomy, giving them the skills the industry is looking for."

N. oceanica presented Benning's lab with an ideal candidate for genetic analysis. With approximately 12,000 genes, its compact genome is smaller than that of other algae, which makes it easier to study. This genetic simplicity also renders it more malleable, a characteristic that Benning hopes to take advantage of as he aims to increase its already high oil production.

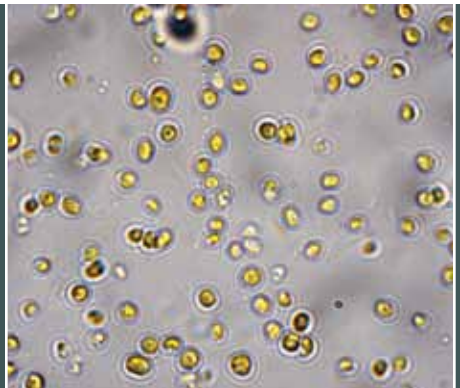
"In the long run, we are going to attempt to perform synthetic biology on this organism — meaning we are going to try to exchange entire gene pathways and reengineer the entire organism," he said. "Less complex is better for that kind of work."

The benefits of unlocking *N. oceanica* are far-reaching and varied — it offers advancements not only for algal biofuels but also for agricultural biofuels and medicine.

"We feel that this organism is highly geared toward making lots of high-energy compounds," Benning explained. "This species makes huge lipid droplets — that is, huge quantities of healthy fish-type oil. We want to find out how it does it so that we can transfer those genes to other plants. It would be very useful to be able to apply this to grasses, for example, to increase the energy density of those crops.

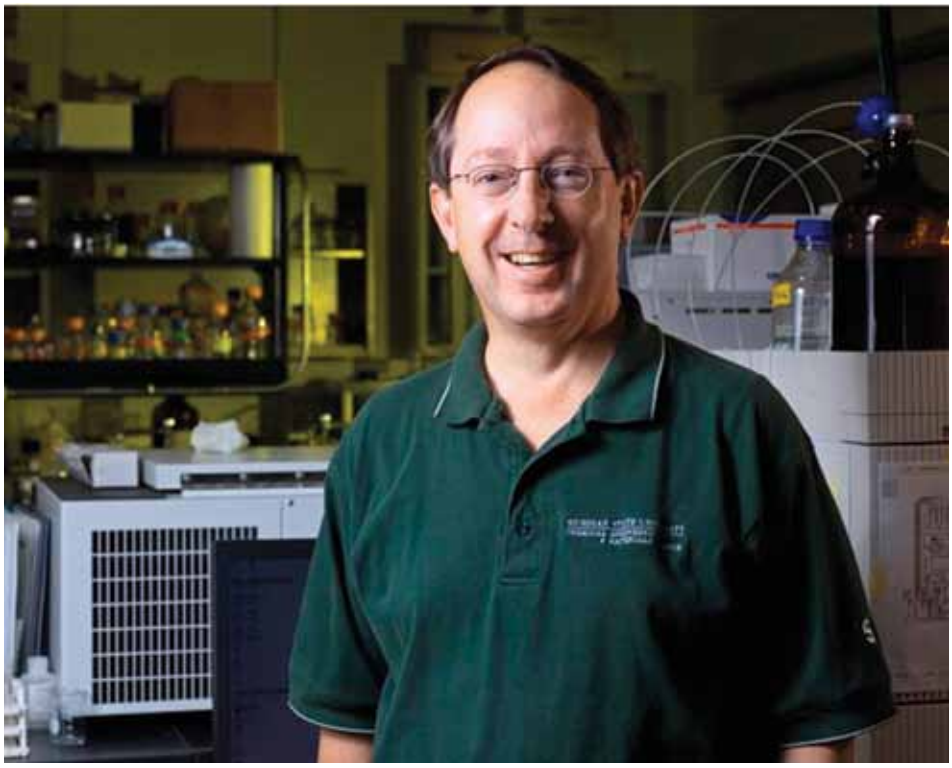
"We're exploring its potential for producing drugs as well. Using synthetic biology, we're collaborating with four European labs to reassemble *Nannochloropsis oceanica*'s pathways and develop a cancer treatment drug. That's the dream of the future — to be able to make not only bulk, high-energy biofuels but also high-value medicines."

This dream is already one step closer to reality. Benning has produced a draft of *N. oceanica*'s genome and is now refining it to proceed in unlocking the true potential of an organism once considered merely fish food.



GREEN ALCHEMY:

Turning agricultural residues into feed and fuel



ABOVE: Bruce Dale has spent the last 30 years developing technology to turn agricultural plant waste into valuable sources of biofuel and animal feed. The technology, Ammonia Fiber Expansion (AFEX™), processes plant matter high in cellulose into compact pellets that can be easily stored, transported and digested. *Photo: Kurt Stepnitz, MSU CABS.*

Worldwide, farms and other agricultural operations annually produce billions of tons of inedible plant matter — crop byproducts with high levels of difficult-to-digest cellulose. Regarded as having little economic or nutritional value, corn husks, wheat stems, soybean leaves, rice straw, sugarcane leaves and tops, and many other cellulosic materials are usually left on the ground after harvest. That is likely to change, however, thanks to recent technological advances by Michigan State University (MSU) and the Michigan Biotechnology Institute (MBI), a wholly owned subsidiary of the Michigan State University Foundation.

. . . cellulosic biomass is difficult to store and transport, and that has been a major obstacle in making it commercially viable.

For every year that cellulosic biomass is discarded, the pressure to produce new sustainable fuel sources increases. The rising cost of conventional fuels such as crude oil, coupled with the instability of fuel sources, has resulted in many proposed alternatives. To date, however, the only U.S. agricultural product to find widespread acceptance has been corn-derived ethanol. Corn's utility as a fuel source has been limited by its importance as a source of both food and livestock feed. The technologies being pioneered by MSU and MBI stand to help alleviate this pressure by turning discarded plant material into new sources for both biofuels and animal feed.

MSU AgBioResearch scientist **Bruce Dale** has devoted much of the past 30 years to developing a process to turn cellulosic biomass into an economical source of biofuel and animal feedstock. A process invented by Dale and scaled up for commercial use by MBI, Ammonia Fiber Expansion (AFEX™), allows for the conversion of cellulose-rich plant matter into animal feed and biofuels such as ethanol.

"It's been a major focus of my career," said the MSU university distinguished professor of chemical engineering. "I invented AFEX over 30 years ago. However, it's one thing to carry out a process in a lab and quite another to do it economically on a very large scale."

Bulky, unwieldy and quick to decompose in its raw form, cellulosic biomass is difficult to store and transport, and that has been a major obstacle in making it commercially viable. Dale's AFEX treatment helps resolve this issue by making it much easier to turn the treated material into pellets.

"During AFEX, ammonia penetrates the plant material and dissolves some of the linkages between structures in the plant cell wall," Dale explained. "The ammonia is hot and under a lot of pressure during this process. When you release that pressure, the mixture of ammonia and dissolved cell wall materials migrates from the inside of the cell wall to the outside. The ammonia evaporates and leaves the rest behind, similar to what happens with paint when the carrier liquid evaporates and leaves the color behind. The cell wall now looks like Swiss cheese; the ammonia produced a lot of holes in it, which means there's a lot more surface area available to digest."

The AFEX process renders the biomass into a slightly sticky substance that can be easily compressed into pellets. Reducing the material to pellet form is an important key to making AFEX economical. The pellets are not only easier to transport and store, they are expected to be more digestible for animals as well.

"We don't know for sure how much more digestible the AFEX-treated pellets are than untreated material or how they compare to the digestibility of corn, so the very next step is to investigate that question," Dale said.

In September 2013, MBI began a 160-day feed trial to test the efficacy of the pellets for beef cattle feedstock. The pellets are produced by MBI's new Department of Energy-funded AFEX pilot plant near the MSU campus. If the trial shows promise, Dale and his lab have envisioned a network of regional biomass processing depots where farmers could bring crop residues such as corn stover or wheat straw.

"We're hoping to develop a series of depots, so that farmers could take their bales of straw and other material 5 or 10 miles down the road, where it could be AFEX-treated and converted to pellets," Dale said. "You eliminate a lot of the problems with transport and storage by bringing the facilities close to the source."

The pilot plant is capable of producing up to 1 ton of biomass pellets each day. The commercial-level facilities necessary in Dale's model would be able to produce 200 tons daily.

If AFEX is successfully commercialized, Dale said it will benefit many people. Farmers would gain an additional source of low-cost livestock feed, as well as a new source of revenue by selling their previously discarded crop residues. The energy industry stands to reap substantial benefits by having a new biofuel source.

"The energy industry can piggyback on what will be, by then, an already existing system for processing and storing the animal feed product," Dale said. "We must have long-term, sustainable replacements for oil used to produce liquid fuels. The only option for that at low cost and with a low carbon footprint is biofuels made from cellulosic biomass."

RESISTANCE IS NOT SO FUTILE:

Genetic technologies for combating the soybean aphid

A 2008 survey from the U.S. Department of Agriculture National Agricultural Statistics Service found that 89 percent of the 63.6 million acres of soybean fields in the United States had been exposed to the soybean aphid, a devastating insect pest. Originally from eastern Asia, the soybean aphid sucks sap from the soybean plant and secretes sticky sugars that promote black mold growth, which inhibits photosynthesis. Female soybean aphids are born already pregnant, producing new generations in as few as five days. Up to 15 generations of aphids can be found on a single untreated plant.

RIGHT: Dechun Wang has been developing aphid-resistant soybean plants since 2002. By combining traditional plant breeding techniques with modern genetic research, he has been able to produce and continually refine a soybean variety, dubbed SPARTA, which is in use by every major domestic soybean seed company.

OPPOSITE: The soybean aphid sucks the sap of the soybean plant and secretes sticky sugars that interfere with the plant's ability to photosynthesize. Coupled with its ability to reproduce in a mere five days, this invasive insect is a formidable opponent of U.S. soybean farmers. *Photos: Kurt Stepnitz, MSU CABS.*

The soybean aphid was first found in Wisconsin in 2000. From there, it rapidly expanded throughout the nation . . .

"Soybean aphids can reduce the crop yield by up to 50 percent," said **Dechun Wang**, Michigan State University (MSU) AgBioResearch scientist. "They also spread viral diseases."

Soybeans, which also originated in Asia, have been grown primarily as a source of animal feed and vegetable oil in the United States since 1904. Nearly a century after the plant's North American debut, however, its old nemesis followed. The soybean aphid was first found in Wisconsin in 2000. From there, it rapidly expanded throughout the nation before being put in check through the use of chemical pesticides.

Wang, an MSU associate professor of crop and soil sciences, has been developing an alternative means of defeating the soybean aphid. Rather than depending on toxins that also threaten beneficial insects present in soybean fields, Wang has been working since 2002 to breed soybeans resistant to the aphid. He used seven sources of resistance and evaluated more than 1,000 breeding lines for aphid resistance each year. His work continues to narrow down the genes and gene markers that make a plant aphid-resistant.

"Traditional soybean aphid management costs between $10 and $12 per acre in pesticide," Wang said. "This year some farmers sprayed over one-third of their land. Soybean aphid may not be a major issue every year, but it is always a concern."

Using traditional plant breeding practices, coupled with cutting-edge gene identification technology, Wang and his lab have been able to detect a set of genes native to the soybean plant that makes it resistant to the predations of soybean aphids.

"We're trying to find natural resistance to the insects," Wang explained. "We started by screening over 2,000 soybean germ plasms [collections of genetic resources for an organism] and identified four that were resistant to the aphid. We're transferring the aphid resistance from those to other plants by traditional breeding methods, not genetic transformation.

"Genetic transformation is not necessarily quicker, and there are a number of concerns that come with taking that approach. Not only would we have to go through a complex federal procedure to commercialize it, but soybeans are not as easy to genetically manipulate as other plants, such as tobacco."

Through these techniques, Wang's lab developed SPARTA, a set of soybean germ plasm bred to resist soybean aphids. SPARTA was introduced in 2007; new, more refined iterations have been produced almost every year since. By 2012, every major domestic soybean seed company was using Wang's germ plasm, as were several non-U.S. companies. His work is not done yet, however.

"We continue identifying new DNA markers that are helping narrow down the exact genes that determine aphid resistance," Wang said. "We have rough map locations of the aphid resistance genes and are now focused on fine mapping to get closer to the genes we want. We're hoping to get to the actual resistant gene and identify the mutation. It takes a lot of effort, and it's the main project of my students."

The benefits do not stop with protecting soybean crops from their aphid enemy. The research is also helpful to plant breeders as Wang identifies and helps develop and propagate resistant soybean strains. The widespread use of SPARTA also reduces the amount of insecticide sprayed on fields, prevents deaths of benign insects, limits the volume of chemicals released into the environment and lowers the financial burden on soybean farmers. It also saves time because farmers do not have to continually scout fields for aphids. Though SPARTA is already widely marketed, Wang hopes to see its use increase.

"As long as it can get commercialized and out to farms, I'll be happy," he said. "Our work helps farmers and everyone who depends on a strong soybean harvest. That's why we do this."

PERFORMANCE-ENHANCING ADJUVANTS:

Using high-fructose corn syrup to increase herbicide activity

ABOVE: Donald Penner has been researching high fructose corn syrup-based adjuvants for herbicides since 1980. His adjuvants are broadly-applicable across a range of plants and herbicide types, and rank as one of MSU's most valuable patents.

OPPOSITE: In addition, Penner's technology has helped to increase the market demand for and the value of corn. *Photo: James Dau.*

Since the dawn of chemical herbicides to help farmers protect their fields and eliminate weeds, the quest to improve them has never ceased. Few have done more to further that goal than Michigan State University (MSU) AgBioResearch scientist **Donald Penner**. His work with herbicide adjuvants — chemicals added to herbicides to increase their effectiveness — has spanned the past three decades, advancing pesticide technology and producing one of the most valuable patents in MSU's history. Today, Penner continues to expand on that technology, hoping to extend his patent and its many benefits into the future.

Last year alone, adjuvants based on (Penner's) research were applied to tens of millions of acres . . .

Penner, a professor in the MSU Department of Plant, Soil and Microbial Sciences, began working on herbicide adjuvants in 1980, testing a multitude of materials. During this time, high-fructose corn syrup became readily available, and its price significantly dropped because of technological advances in the production process.

"I recalled some research done in the late '60s that applied sugar water to plant leaves," he said. "The experiment worked, and the plants sucked up the sugar water. That got me thinking about the possibilities of this other new sweetener, high-fructose corn syrup, and what we could do with that with a herbicide."

Through his early experiments, Penner found that high-fructose corn syrup increased the activity of herbicides when it was applied to the foliage of a range of plants. He took his findings to the MSU Innovation Center, where his discovery was patented and licensed. Since then, Penner's patented technology has become a staple of weed control programs in agriculture. Today, he experiments primarily with giant foxtail, velvetleaf and common lamb's quarters, weeds that are particularly prevalent and costly to farmers, to further refine the effectiveness and applications of the technology.

"The adjuvant I've developed increases the absorption of herbicide in plants, increasing the herbicide's activity," said Penner, who received the 2013 MSU Technology Transfer Award for his adjuvant research. "It works for a number of types of herbicides and many different plants. It's broadly applicable — that's what makes it so valuable."

The MSU Technology Transfer Award is given to researchers or research groups who have achieved long-term success in the development, licensing and commercialization of intellectual property at MSU.

"Patents like this are not produced overnight," Penner said. "I've been able to develop such a successful technology only by working hard at it for many years."

Penner's pioneering work with adjuvants has helped growers in two ways. First, it increased the market for corn by developing more uses for high-fructose corn syrup.

"Secondly, from an environmental perspective, increasing herbicide effectiveness means you don't need to use nearly as much of it to get the desired outcome," Penner said. "It limits the amount of chemicals introduced into the environment and would, ideally, help farmers save money by allowing them to purchase less herbicide to get the same result. They're able to do a lot more with less."

These results — increasing the utility of a domestic crop, limiting the amount of herbicide in agricultural products and reducing weed populations — have combined to make Penner's patent extremely valuable. Last year alone, adjuvants based on his research were applied to tens of millions of acres and generated more than $800,000 in royalties.

"Penner's work is one of the highest earning active patent packages for MSU," said Amber Shinn, marketing director for the MSU Innovation Center. The MSU Innovation Center handles the school's intellectual property, annually launching more than 120 discoveries into patented products and start-up businesses.

Developing a royalty-producing patent was a goal for Penner, with every other research achievement in the project a stepping stone to that final result.

"Ultimately, the royalties this patent has brought in help support MSU and its people," Penner said. "It supports future research and the efforts of MSU technology development for the agriculture industry."

Penner is working on ways to extend the patent which expires in 2017.

"The goal now is to improve and find new uses for the technology," he said. "What we're trying to do is anticipate the problems and challenges farmers will face in the future because of new technologies and circumstances. My research has changed very much since I began here at MSU, and it's still changing in order to help improve the practice of agriculture."

IMPROVING VALIDATION METHODS

to ensure safety of low-moisture foods

ABOVE: (From left) Bradley Marks and lab manager Michael James prepare almond samples before testing a pathogen heat treatment. Their work will help low-moisture food processors contend with pathogens such as *Salmonella*, which can thrive in this type of food. *Photos: Kurt Stepnitz, MSU CABS.*

In 2009, the Centers for Disease Control and Prevention (CDC) reported a *Salmonella* outbreak in peanut products that spanned 46 states, caused 714 people to become ill, contributed to approximately nine deaths and resulted in one of the largest food recalls in U.S. history. More than 3,900 products were pulled from the nation's shelves, and peanut producers estimated a loss of $1 billion* in production and sales.

Salmonella outbreaks in low-moisture foods — such as tree nuts, soy, wheat flour, black pepper and dry hydrolyzed vegetable protein — are an emerging issue prompting ingredient manufacturers to develop processes that reduce the risk of *Salmonella* contamination.

Marks puts low-moisture foods into three categories: big particles, powders and pastes.

Michigan State University (MSU) AgBioResearch biosystems engineer **Bradley Marks** is collaborating with the U.S. Food and Drug Administration (FDA), Washington State University and several industry groups to ensure the effectiveness of pasteurization processes used on low-moisture foods.

"*Salmonella* has been appearing in unexpected places over the past five years," said Marks, MSU professor of biosystems engineering. "We're most often concerned about the bacteria being in foods such as raw meat or poultry, but it turns out that *Salmonella* is very adept at surviving in dry foods. It will not grow in them, but it becomes much more difficult to kill. The time-temperature combination necessary to kill the bacteria can be nearly 100 times greater in low-moisture foods than in high-moisture foods."

Marks' past work to improve how processors predict the inactivation of pathogenic bacteria in high-moisture foods appealed to California's almond industry leaders, who approached Marks to help them prevent future almond-derived *Salmonella* outbreaks.

"Our initial almond projects looked at the temperature and humidity conditions needed to inactivate *Salmonella*," he explained. "The almond industry also engaged with several other private labs and universities to run related projects. Our collective work enabled them to develop protocols and requirements for validating almond pasteurization."

He explained that a processor must go beyond adopting practices that reduce the risk of *Salmonella* contamination — it must also prove that the process actually accomplishes this goal.

"Even the best hygiene practices cannot sufficiently ensure the safety of dry foods, so processing interventions are needed to reduce the risk of *Salmonella* in final products," Marks explained. "We know that in most cases, as a product becomes drier, *Salmonella* bacteria become harder to kill. But we don't know how the relationships between bacterial resistance and moisture content, fat content, structure, humidity or temperature affect the validity of the treatment process.

"A big part of our research is to develop the equations that describe these relationships so a processor can say, for example, 'I know the temperature and moisture content of my product, and I know how much humidity is in the air during the process; I can use those measurements to calculate the sufficiency of a treatment,'" he said.

Many low-moisture foods are physically modified and used as ingredients. Marks explained that it's nearly impossible to run tests with every low-moisture food in its various states, so it's imperative to identify the characteristics that could have the greatest effect on the validity of a process.

"We want to generate tools and models that can be generalized and applied to a range of products," he said. "If someone creates a new product or develops a new process and wants the FDA to approve it, we need to know whether the product and process is so unique that it doesn't fit into one of the categories of products and processes that have already been validated. This understanding enables processors to utilize appropriate and reliable tools for ensuring the safety of that product."

Marks puts low-moisture foods into three categories: big particles, powders and pastes. In each, *Salmonella* behaves differently and must be treated differently.

"We won't develop tools, tests and processes for every kind of particle, powder and paste in the world," he said. "Instead, we are using representative products from each category — such as one that's high in protein, one high in fat and another high in carbohydrates — to determine the key differences affecting *Salmonella* resistance to inactivation. Then we can start to supply the industry with information that says, if they run 'X' process they will be OK, even though their product is slightly different from other products treated with the same process.

"There are a lot of low-moisture food sectors in Michigan, from flour mills to soy processors to cereal end-products," Marks concluded. "Although we came into this from the almond angle, we're still looking at a problem that directly relates to companies operating in Michigan. This research is focused on the end point: delivering information, training and tools that leaders need to solve the problem — or avoid it entirely."

*Georgia Peanut Commission

DISCOVERY OF NEW GENETIC PATHWAY
aids in success of apple industry

Rebounding from one of the worst growing seasons in more than 50 years, Michigan apple producers were expected to harvest a record-setting 30 million bushels in 2013. It's an estimated yield nearly 10 times greater than the 2.7-million bushel harvest of 2012.

RIGHT: Randy Beaudry (right), works with apple growers like Adam Dietrich (left), to manage 2013's record apple crop. His efforts to preserve the post-harvest quality of fruits and vegetables have been essential to Michigan's agriculture industry. *Photos: Kurt Stepnitz, MSU CABS.*

For more than half a century, MSU researchers have refined the controlled-atmosphere (CA) process of apple storage.

Though the bumper crop was a relief to growers and a boost to the state's economy, storing the crop in a manner that does not compromise the apples' firmness, flavor or aroma requires a great deal of science. That research helps to ensure quality fruit year round and prevents the market from being flooded.

Michigan State University (MSU) AgBioResearch horticulturist **Randy Beaudry** has discovered a genetic pathway that plays an important role in producing apple aroma profiles, a key quality that helps Michigan apples remain competitive in national and international markets.

"One of the most important characteristics of the food we eat is its flavor, which is composed of taste and aroma," said Beaudry, MSU professor of horticulture. "In addition to the research I do to preserve the postharvest quality of fruits and vegetables, I also work on the chemistry and biochemistry of food quality."

For more than half a century, MSU researchers have refined the controlled-atmosphere (CA) process of apple storage. Beaudry has been at the forefront, working to perfect the technique. The storage method suspends the ripening process by regulating the amount of oxygen, carbon dioxide and nitrogen. The temperature and humidity of the storage areas are also controlled.

The storage technique also suspends the fruit's ability to synthesize esters, fragrant organic compounds that contribute to the apple's unique aroma. Beaudry explained that, though CA storage is very effective at helping the fruit remain firm, this secondary, unintended consequence can diminish aroma quality over time.

"The apples don't taste bad, but they can lack the rich flavor of fully developed apples," explained Beaudry, who is also a MSU Extension specialist. "Fruits change their aroma profiles in well-prescribed proportions, but a large number of things that humans do to fruits also alter them. Some of my early work documented the effect of CA and other storage treatments on aroma, and we found it takes time for apples to recover their ability to produce aroma compounds once they're removed from storage."

Beaudry's goal is to provide consumers with fruit that is firm and full-flavored.

"It would be wonderful to specifically trigger aroma formation without triggering softening," he explained. "This isn't the No. 1 priority of the apple industry, but in terms of its long-term vision, my research in this area will have some value."

Desiring a better understanding of how apples synthesize their aroma-producing esters, Beaudry began to search for genes that were expressed at the same time that apples synthesize ester compounds. Of the 10,000 genes he observed, one possessed characteristics implicated in ester biosynthesis.

"As we looked more into this oddball gene, we realized that its annotation, which is based on previous research, indicated that it would make apples smell like bananas — but it doesn't," he explained. "It turned out that the gene was, in part, annotated incorrectly and was actually part of a more substantial gene family."

Further exploration of this gene — along with a series of experiments that involved dissecting bacterial pathways, studying stable isotopes, isolating genomic DNA, expressing the gene in a bacterial system and determining the function of certain proteins — led to the identification of a previously undiscovered plant pathway: the citramalate pathway, which contributes to the formation of branched-chain acids and branched-chain esters.

"We were looking at something others probably would have told us was not a fertile area of investigation, but we were able to discover an entirely new biology in the specialized tissue of an apple fruit," he said. "We identified a new pathway that, for some apple fruits, is relatively important.

"Even scientists who spend a lot of time on applied research have to stay current in their science," Beaudry concluded. "If we don't, we fall behind. You have to have applied science to recognize the problems for what they are and, when possible, take them to the fundamental level and try to build some new science. The apple industry is happy with the storage problems I am addressing, but they also know that flavor is important for the resale value of apples — especially apples that have been stored for a long period. With that in mind, the discovery of this pathway certainly fits into the long-term objectives of that group."

MANAGING WILDLIFE DISEASES
with insight on bioeconomics

ABOVE: Richard Horan and Christopher Wolf are taking a bioeconomics approach to assessing the long-term ecological and economic effects of various wildlife disease-management decisions. *Photo: G.L. Kohuth, MSU CABS. Opposite page: David Kenyon, MDNR.*

Since 1975, the Michigan Department of Natural Resources (MDNR) has worked to eliminate bovine tuberculosis (bTB) from free-ranging white-tailed deer populations. This disease, caused by *Mycobacterium bovis*, can spread from infected deer to humans and other animal species, especially cattle.

Because bTB can affect Michigan livestock industries as well as deer management decisions, baiting guidelines and livestock trade flows, the MDNR and the Michigan Department of Agriculture and Rural Development (MDARD) have taken great measures to reduce disease prevalence in endemic areas of the state. Collectively, the two agencies have invested more than $86 million in surveillance, control and testing activities to reach and maintain a relatively consistent level of success for more than a decade.

When diseases spread from wildlife to domesticated livestock, producers often incur significant economic damage . . .

Michigan State University (MSU) AgBioResearch economists **Richard Horan** and **Christopher Wolf**, MSU professors of agriculture, food and resource economics, are developing a bioeconomics decision theory to help wildlife and livestock managers better understand the economic and epidemiologic trade-offs of disease management actions, equipping them to identify actions with the greatest economic welfare.

"My initial interest in this area was sparked because of the predominance of white-tailed deer hunting in Michigan and the prevalence of bTB; I wanted to understand how to manage this valuable wildlife species while taking disease impacts and hunter benefits into account," explained Horan. "Though we've done some numerical work with bTB in deer, this theory will be applicable to disease management across many wildlife species."

Horan takes a bioeconomics approach to disease management — which combines economic, ecological and epidemiological models — to better understand disease proliferation, the costs and benefits of various management actions, and how people respond to risk.

Horan explained that traditional disease management is rooted primarily in epidemiology and is based on metrics that do not acknowledge the impact of human/ecological interactions on disease dynamics. One such metric, the basic reproduction ratio (R0), is used as a fixed value to predict how quickly a disease will spread and to calculate population thresholds – the percentage of a population that must be targeted to effectively stop or diminish the spread of disease.

Horan contends that these thresholds should not be treated as fixed values because human behavior can change them. For example, feeding and baiting sites promote transmission of bTB by bringing deer into close proximity with one another. If wildlife managers reduce the number of feeding sites and thereby reduce the rate at which disease is transmitted, then the number (threshold) of deer that must be culled to stop or slow the spread of disease changes.

Economic variables can also change thresholds, as well as how managers might choose to respond to them.

"We've found that getting rid of a disease is not always cost-effective," Horan said. "Because the costs can be so high and the benefits marginal, managers may decide it's best to allow the disease to remain in the population at a low level and invest in control measures."

When diseases spread from wildlife to domesticated livestock, producers often incur significant economic damage from lost productivity, imposed herd depletions and trade bans. Part of Horan and Wolf's research explores the economic effect of disease management on trade. One finding is that the relative level of infection is a key driver of trade incentives.

"If a cattle breeder has a low level of infection in his herd and the owner of a feedlot has a higher level of infection in his herd, the feedlot owner may have more incentives to trade — to sell off more of his animals and purchase others from other breeders," Horan explained. "Taking a group of animals with a high-prevalence disease rate and replacing them with animals from a low-prevalence source reduces risk and is a means of managing disease."

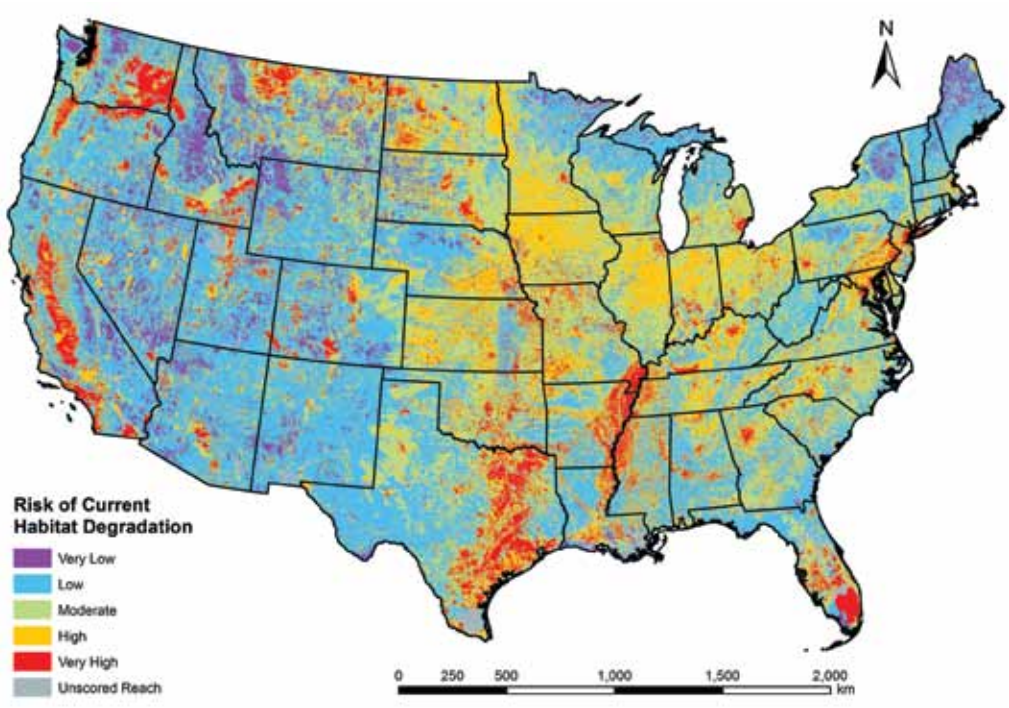
Horan noted that there are a number of regions in the country with livestock trade bans.

"If we can use trade patterns to predict which places are more likely to import infected animals, it may be possible to thwart the disease, and ultimately save money, by better targeting surveillance efforts to identify infected animals when they arrive," he said.

"Epidemiological systems and human systems are jointly determined," Horan concluded. "People respond to environmental risk and the environment responds to the actions taken by people. Decision models that utilize this theory will give livestock and wildlife managers a better understanding of how their choices may affect economic welfare, wildlife populations and disease rates."

A FISH-EYE VIEW:

Assessing fish habitat conditions in U.S. rivers



ABOVE: The results of a nationwide assessment of human effects on fish habit in the rivers of the United States initially issued in 2010. Dana Infante is one of the principal investigators on the ongoing project which is next scheduled to be completed and released in 2015.

About one out of every four streams in the lower 48 states is at high or very high risk of current habitat degradation. This finding is from a report titled "Through a fish's eye: The status of fish habitats in the United States 2010," which summarizes the results of an unprecedented, nationwide assessment of human effects on fish habitat in the rivers and estuaries of the United States.

Dana Infante, associate professor in the MSU Department of Fisheries and Wildlife, is one of the principal investigators on the assessment project, which is scheduled to be completed every five years. (The next report is due in 2015.) The objective is to estimate the risk of disturbance to fish habitats in the nation's rivers on the basis of information about human activities occurring in the watersheds and the local areas affecting each aquatic habitat.

In general, Infante said the health of rivers has improved since the 1970s adoption of the Clean Water Act . . .

"If you think about the Red Cedar River on Farm Lane [on the MSU campus], what happens there — the condition of habitats you find, the kinds of fish you find — depends in part on what is happening upstream throughout the entire watershed," she said. "There are forests, agriculture, homes, roads, and together all of those factors interact to influence what's happening downstream. Understanding rivers in this way is a landscape approach, and it's one that researchers take when conducting large-scale analyses such as the national assessment."

The project was initiated in 2004 when leaders and decision makers charged with fisheries management and conservation announced that there were challenges facing the nation's freshwater fisheries. They started an endeavor called the National Fish Habitat Partnership (NFHP) in an effort to provide information and resources that would enable volunteers to go to the degraded places and conduct work to improve them. So far, NFHP has helped organize 17 partnerships nationally. Improvements can include activities such as removing a dam or adding structure to a stream to provide protection for the fish.

"My work is a small component of NFHP proper, and it's intended to provide that overall picture of conditions that can help manage an outcome of this work," she said. "This has a lot of reach in Michigan because data that have gone into this project represent perhaps the largest and most consistent collection of landscape-scale and freshwater fisheries-based data in the country, and we've shared key datasets and results from this effort with the state of Michigan."

Infante said it's been a rewarding experience, especially working alongside such diverse organizations as the U.S. Fish and Wildlife Service, the U.S. Geological Survey, The Nature Conservancy, the World Wildlife Fund, Trout Unlimited and the U.S. Forest Service, to name a few. And the results have helped guide on-the-ground renovations to improve fish habitats and the environment in general.

"Because of that landscape approach — the theory that fish at any given point are being affected by factors occurring upstream — fish may be an overall good indicator of environmental health," she said. "We know that if we have limitations in a certain place along a river, there may be something occurring upstream with the potential to affect forests, animals and possibly people."

Since the data compiled for this project were made available online (fishhabitat.org), there have been hundreds of downloads. Infante said that her lab created some of the datasets and helped pull the others datasets into usable formats for river analyses. Her lab also wrote the specialized computer coding that facilitated the work.

"It's one thing to provide scientific input and results, but if a manager has no capacity to implement the kinds of solutions suggested by your science, that's not going to be useful," she said. "They're not going to find a map like this of any value unless we can help them strategize about how these colors on the map can be translated into actions that they can take."

But Infante admits that general acceptance of assessing habitat conditions through landscape data has required some convincing.

"Historically, people had no idea how to even guess what might be happening in a river unless they travelled and studied that particular place," she said. "Now, with these map-based approaches, you can get an idea of the condition of a system without going there. With over 2.6 million unique river reaches in the U.S., agencies just don't have the capacity to assess each reach on site. Estimating habitat condition from landscape data provides an opportunity to better manage rivers than we've had in the past. We can be a little smarter about how we do things. We can use funds more efficiently and target areas for management actions that the science suggests would be most appropriate."

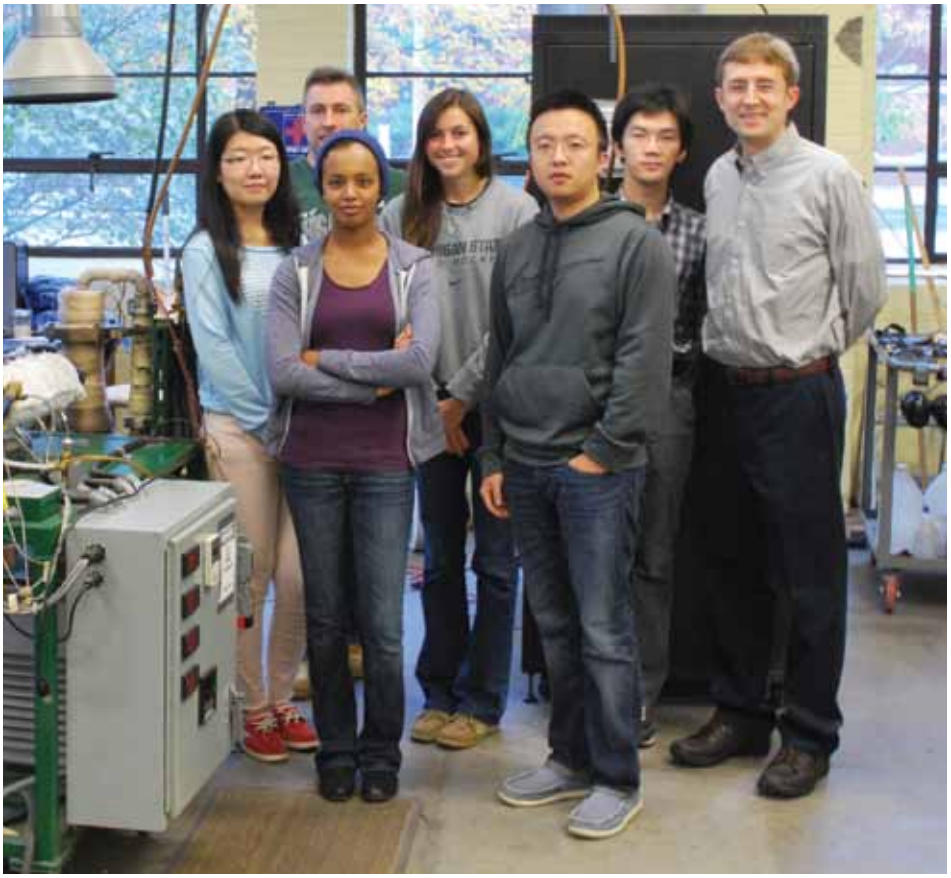
In general, Infante said the health of rivers has improved since the 1970s adoption of the Clean Water Act, which reduced impacts from point-source pollutants to rivers.

"What's more difficult to characterize are effects from non-point-source pollutants, such as human land uses," she said. "We still don't fully understand those, but with the landscape approach, current research is answering how those effects vary regionally and which fishes may be most responsive."

A VIABLE ALTERNATIVE TO COAL:

Converting woody biomass into renewable energy

Michigan State University's 5,200-acre campus is primarily powered by the T.B. Simon Power Plant, which burns coal, natural gas and biomass to produce steam that is used for heat and electricity. Coal has been the plant's fuel source since it's inception, but research within the past two decades has shown the harmful byproducts of this energy source. As a result, the university has begun to increase the use of natural gas and biofuel at the plant, and has installed equipment to reduce emissions.



RIGHT: Christopher Saffron (far right), with MSU Biosystems and Agricultural Engineering students (front, from left) Yunhua Ding, Mahlet Garedew, Li Chai and (back, from left) John Budaj, Kristen Henn and Zhongyu Zhang. The students have been working on a design project to explore efficient ways of converting woody biomass into viable coal alternatives.

OPPOSITE: Woody biomass chips on the left with torrefied wood chips on the right. The torrefied chips are ground and then converted into dense forms that are easily transported.
Photos: Holly Whetstone.

Saffron notes that having biomass cultivation near torrefaction facilities would also offer an economical advantage.

The Energy Transition Plan adopted by the MSU Board of Trustees in 2012 aims for the university to eventually be 100 percent reliant on renewable energy sources. The plan outlines a requirement of 15 percent campus renewable energy by the year 2015 and 40 percent by 2030. To help meet these goals, a group of MSU researchers and students are collaborating to explore efficient ways of converting woody biomass into viable coal alternatives.

Christopher Saffron, assistant professor in the departments of Biosystems and Agricultural Engineering and Forestry, is leading the project aimed at transforming bulky woody biomass into dense, compact forms that have low ash content to minimize the risk of fire, can be easily transported, are water-repellent and can be stored outdoors for extended periods of time.

"It's a replacement for coal," Saffron explained. "Although it's completely derived from biomass, it burns like coal. It is brittle like coal. It behaves like coal, so it's a drop-in coal substitute that we're attempting to make."

The first step in converting the biomass into a renewable energy source is putting the wood chips through a process known as torrefaction. This process, which Saffron calls a "mild pyrolysis," takes place in a torrefaction reactor, which heats the biomass in an oxygen-free environment to temperatures between 250 and 350 degrees Celsius for up to 40 minutes at a time.

Saffron is overseeing a team of undergraduate students who are designing a densification system to transform the torrified biomass chips into a more compact, denser form that can be economically transported. Following the torrefaction process, Saffron said the brittle, lightweight chips are ground into a fine powder.

"Then we must densify the ground torrefied biomass to a level where it's affordable to transport," he said. "It's important that transportation vessels be load-limited and not volume-limited to reduce hauling costs. Volume-limited transport results in hauling light loads, which will require many trips. We aim to avoid this expense by densifying biomass into briquettes, pellets or pucks, which reduces the number of trips between the regional torrefaction facility and the power plant."

Saffron notes that having biomass cultivation near torrefaction facilities would also offer an economical advantage. In fact, some of the woody biomass he plans to eventually burn at the university power plant has been planted on the southern part of the campus. Fellow MSU AgBioResearch scientist **Raymond Miller** is in charge of the hybrid poplar plantings, which are expected to total 60 acres.

"This collaboration really underpins the conversation. Those trees can be harvested every 6 to 9 years, and they grow on land not used as agriculture to avoid the food versus fuel debate," Saffron said. "In addition, there are a lot of landowners no longer supplying material to the paper industry because of its decline in the Upper Peninsula. Something like this could come along and give them another product to produce and help stimulate the economy."

Saffron said his lab is examining the use of small, pellet-shaped forms of the torrefied material as well as larger sizes in the shapes of briquettes and hockey pucks.

"There are a lot of groups looking at torrefied material," he said. "The new piece is going to be the operating conditions required for the densification system to generate stable pellets, briquettes or pucks. That may involve a number of things from different temperatures during the densification process to binding agents that can hold the pellet together. Making the final material stable is really the new part of the equation, and that's where our research program is headed."

Saffron said he is confident that this technology can compete with other alternative energy sources, especially given Michigan's increasing inventory of biomass.

"It's very difficult to compete with fossil sources of energy because of the costs," he said. "Coal is probably about half the price of torrefied biomass, and natural gas is even less expensive nowadays. However, with the new mandate in Michigan, we no longer have to compete head-to-head with coal. We compete with other alternative sources of energy — wind and solar — and we think we can be competitive with those, especially when you put them on equal footing."

A pilot burn of the torrefied biomass is expected to take place at the T.B. Simon Power Plant this spring.

BEEFING UP THE NUMBERS:

Looking at ways to assist local food systems

ABOVE: Jason Rowntree is looking at ways to increase locally sourced foods with particular emphasis on beef selection. He said a handful of corporations control about 90 percent of global meat distribution. He has developed local food system models at the MSU Lake City Research Center and plans to expand those endeavors to the Upper Peninsula in 2014. *Photos: Kurt Stepnitz, MSU CABS.*

Locally produced foods are a small but growing facet of U.S. agricultural sales. The U.S. Department of Agriculture (USDA) estimates that the farm-level value of local food sales totaled $4.8 billion in 2008, less than 2 percent of the U.S. market for agricultural products. An estimated 107,000 farms are engaged in local food systems, or about 5 percent of all U.S. farms.*

Rowntree is looking at ways to improve the economics of small and medium-sized beef producers in the upper Great Lakes region.

Jason Rowntree, Michigan State University (MSU) assistant professor of beef cattle and forage utilization, is looking at ways to beef up those numbers — literally. He says that, although consumers are increasingly demanding locally sourced food products, they have little choice at the supermarket, especially in protein selection. In fact, he said, a mere handful of corporations control about 90 percent of global meat distribution.

"I'm not saying that we shouldn't have multinational companies. In fact, I have many friends employed by those types of facilities," he said. "My point is — should we, as a community or even as a nation, completely rely on those companies to provide that food? I think what we need is a dichotomy of food production systems that will help add resiliency to our local communities."

Rowntree is looking at ways to improve the economics of small and medium-sized beef producers in the upper Great Lakes region. He has developed a local food system model in the Lake City area that includes 20 local cattle producers who will each provide 10 steers as part of the project. Three of the participating producers are working to convert more than 1,000 acres to a pasture-based model, and two obtained Michigan Department of Agriculture and Rural Development (MDARD) grants to develop on-site packing and processing facilities.

As part of the local food system model, Rowntree has also partnered with a local family-owned grocery store where some of the cattle will be sold. He calls it a "pasture-to-plate" concept with substantial potential to benefit the local economy. Rowntree cites a University of Kentucky study that reveals that every $1 spent on beef cattle production returns $3.50 to the local community. Using that multiplier, Rowntree's 200-steer project could equate to as much as $500,000 to the surrounding area.

The absence of in-state processing facilities forces Michigan producers to ship cattle out-of-state — some 500 to 1,000 miles in one direction, Rowntree said.

"The bottom line is that the longer we keep beef cattle in Michigan, the more value it gives to our local economy, regardless if they are grass-fed or grain-fed," he said. "Local packing and processing is the lifeblood of our communities, and if we don't have them, we're completely dependent on someone else to feed us."

And it's not only consumers who are gaining interest in locally sourced meat. According to a survey of 1,800 professional chefs conducted by the National Restaurant Association, locally sourced meat and seafood was the No. 1 food trend in 2012.

"I'm not trying to pit big business against small business, organic production versus conventional production — that's not the point," he said. "The main thing is that there are always challenges in life that put pressure on our food production, whether it's devastating weather events, energy prices or climate change. When any of those events occur, it immediately puts stress on where our food comes from."

Rowntree has made it his life's work to simplify regional food distribution systems. He emphasizes the importance of finding ways to more adeptly link local producers with local consumers to lower input costs while adding value to the system.

With local food celebrations such as Beefstock and Pigstock now under way in Traverse City, Rowntree believes he is in the right place at the right time. (A vast majority of his research is being conducted at the Lake City Research Center in Lake City, just south of Traverse City. He plans eventually to expand the studies to the Upper Peninsula Research and Extension Center in Chatham.) He realizes, however, that there are obstacles ahead.

"The main challenge to a local food system is that a huge integrated packer can process the animal, pack it and ship it to whomever for a fraction of the cost compared to a medium-sized competitor," he said.

Rowntree remains committed to lessening society's reliance on the global food highway.

"If there are high fuel costs and trucking becomes too costly, the cost of food will subsequently rise," he said. "We need to have other strategies that can help supply food to consumers."

His three-year study is funded by the USDA Sustainable Agriculture Research and Education Program and is expected to conclude in 201

**The Role of Local Food Systems in U.S. Farm Policy*; USDA, January 2012.

MSU AGBIORESEARCH CENTERS

1 Clarksville Research Center
9302 Portland Road
Clarksville, MI 48815
Phone: 616-693-2193
Farm Manager: Jerry Skeltis

2 Dunbar Forest
12839 S. Scenic Drive
Rt. 1, Box 179
Sault Ste. Marie, MI 49783
Phone: 906-632-3932
Non-Resident Forester: Ray Miller

3 Fred Russ Forest
20673 Marcellus Highway
Decatur, MI 49045
Phone: 269-731-4597
Non-Resident Forester: Greg Kowalewski

4 Lake City Research Center
5401 W. Jennings Road
Lake City, MI 49651
Phone: 231-839-4608
Farm Manager: Doug Carmichael

5 Montcalm Research Center
4629 W. McBrides Road
Lakeview, MI 48850
Phone: 989-365-3473
Farm Manager: Bruce Sackett

6 MSU Forest Biomass Innovation Center
6005 J Road
Escanaba, MI 49829
Phone: 906-786-1575
Farm Manager: Ray Miller

7 Northwest Michigan Horticultural Research Center
6686 S. Center Highway
Traverse City, MI 49684
Phone: 231-946-1510
Farm Manager: Bill Klein

8 Saginaw Valley Research and Extension Center
3775 S. Reese Road
Frankenmuth, MI 48734
Phone: 989-652-8014
Farm Manager: Paul Horny

9 Southwest Michigan Research and Extension Center
1791 Hillandale Road
Benton Harbor, MI 49022
Phone: 269-944-1477
Farm Manager: Dave Francis

10 Trevor Nichols Research Center
6237 124th Avenue
Fennville, MI 49408
Phone: 269-561-5040
Farm Manager: Jason Seward

11 Upper Peninsula Research and Extension Center
P.O. Box 168
E3774 University Drive
Chatham, MI 49816
Phone: 906-439-5114
Farm Manager: Paul Naasz
Center Coordinator: Ashley McFarland

12 W.K. Kellogg Biological Station
3700 E. Gull Lake Drive
Hickory Corners, MI 49060
Phone: 269-671-5117
Assistant Director/Facilities and Operations: Phil Barry

13 W.K. Kellogg Experimental Forest
7060 N. 42nd Street
Augusta, MI 49012
Phone: 269-731-4597
Resident Forester: Greg Kowalewski

☆ South Campus Field Research Facilities
246 Spartan Way
Michigan State University
East Lansing, MI 48824-3005
Phone: 517-355-3272
Director: Charles J. Reid

American Association of Bovine Practitioners

Grooms

Michigan State University (MSU) large animal veterinarian **Dan Grooms** was elected 50th president of the American Association of Bovine Practitioners, the largest organization of cattle veterinarians in the world. Grooms will provide leadership and direction for the organization, which represents the interests of veterinarians specializing in cattle throughout North America, as well as parts of Europe and South America. In addition to providing educational opportunities to its 6,000 members, the group also informs on topics such as animal welfare, food safety and prudent pharmaceuticals usage.

American Society for Horticultural Science

Grumet

MSU Department of Horticulture professor **Rebecca Grumet** was named a fellow of the American Society for Horticultural Science, the world's premier professional society for horticultural science. The ASHA, founded in 1903, is a network of national and international scientists whose research keeps fruit, nut, vegetable, turf and ornamental crop producers competitive as they raise sustainable crops. Grumet is internationally recognized for her use of molecular techniques to address challenges in the field. Her research has significantly improved world knowledge of *Cucumis* (cucumber and melon) floral and fruit development and disease resistance.

Baker

American Veterinary Medical Association Council on Research

MSU AgBioResearch associate director **John Baker** was appointed to a three-year term on the American Veterinary Medical Association (AVMA) Council on Research. The council advises the AVMA executive board on scientific research and discovery with impacts on the veterinary profession to sustain and advance the scientific bases of veterinary medicine. Baker also served on the council from 2003 to2009. Before being named associate director of MSU AgBioResearch in 2006, Baker was College of Veterinary Medicine (CVM) associate dean for research and graduate studies, director of the University Research Containment Facility and CVM Vivarium, and a professor of large animal clinical sciences.

University Distinguished Professors

Four Michigan State University (MSU) AgBioResearch scientists were among nine faculty members named university distinguished professors in recognition of their achievements in the classroom, the laboratory and the community:

Dale

Bruce Dale is a pioneer in cellulosic ethanol and has spent his career in developing sustainable biofuels. As a leader in the U.S. Department of Energy's Great Lakes Bioenergy Research Center activities at MSU, Dale devotes much of his research to the commercialization of cellulosic ethanol. He was also the top-ranked academic by *Biofuels Digest* 2012-2013 list of the Top 100 people in Bioenergy.

DellaPenna

Dean DellaPenna is regarded as one of the world's foremost experts on the biosynthesis of nutritionally important micronutrients in plants. His pioneering research on carotenoids and vitamin E biosynthesis in plants employs the tools of biochemistry, genetics and genomics to uncover the enzymes that plants use to make these key molecules.

He

Sheng Yang He, an internationally recognized leader in research on plant-pathogen interactions, has made numerous groundbreaking contributions to the understanding of the molecular mechanisms by which bacterial pathogens infect plants and by which plants resist pathogens.

Kelly

James Kelly is an internationally recognized geneticist and bean breeder. He has been at the forefront of MSU bean breeding research for more than 30 years. Over the years, his work has led to the development of new high-yielding, upright, disease-resistant bean varieties in a wide range of market types with the superior culinary quality demanded by the canning and export industries.

The title of university distinguished professor is among the highest honors bestowed on faculty members by the university. Those selected for the title have been recognized nationally and internationally for the importance of their teaching, research and outreach achievements.

U.S. Department of Energy and U.S. Department of Agriculture Biomass Research and Development Technical Advisory Committee

R. Miller

Raymond O. Miller, director of the MSU AgBioResearch Forest Biomass Innovation Center in Escanaba and adjunct professor in the MSU Department of Forestry, was appointed to the U.S. Department of Energy and U.S. Department of Agriculture Biomass Research and Development Technical Advisory Committee. The group advises the secretaries of energy and agriculture on the allocation of resources for the commercialization of bioenergy systems to meet the goals of the Renewable Fuel Standard for transportation fuels. This is a particularly challenging responsibility because of reduced and uncertain funding for bioenergy programs, Miller said.

MSU Distinguished Faculty Awards

Three MSU AgBioResearch faculty members received Distinguished Faculty Awards at the 2013 MSU Awards Convocation for their outstanding contributions to education and research:

Landis

Douglas A. Landis, also named interim chairperson of the Department of Entomology in 2013, is passionate about education and how to work with, rather than against, nature. His research focuses on the interactions of insects with landscape structure and the application of that knowledge to ecology-based pest management and weed control. Landis has helped to garner more than $28 million in grant funding, with nearly $7 million assigned to him.

D. Miller

Dennis J. Miller, professor of chemical engineering, exemplifies the ideal of blending research, teaching and service in the university environment. Recognized as a leading expert on catalysis, reaction engineering, biofuels and reactive distillation, Miller has achieved impressive and critical accomplishments in the field of green chemistry and catalysis, and exhibited pioneering leadership in the use of renewable biomass feedstocks to make chemicals and fuels traditionally obtained from petroleum.

Osteryoung

Katherine W. Osteryoung, professor of plant biology, is a pioneer in the field of chloroplast division and biology in plants. Chloroplasts carry out photosynthesis and produce many compounds critical for plant growth and development, including membrane lipids, amino acids and growth regulators. Osteryoung's discovery of the first chloroplast division gene is considered to be the definitive evidence supporting the hypothesis that photosynthetic bacteria were the evolutionary ancestors of chloroplasts. This discovery launched an entirely new field of research on the molecular analysis of chloroplast division in plants and algae. She has been honored as a fellow of the American Association for the Advancement of Sciences and a fellow of the American Society of Plant Biologists.

MSU AgBioResearch 2013 PUBLICATIONS

Futures Magazine

Published twice annually, *Futures* is a free, reader-friendly publication that provides a thematic, in-depth look at research that is applying science in practical, real-world ways that boost Michigan's economy, sustain the state's natural resources and enhance people's quality of life.

To subscribe, visit agbioresearch.msu.edu

Spring/Summer 2013

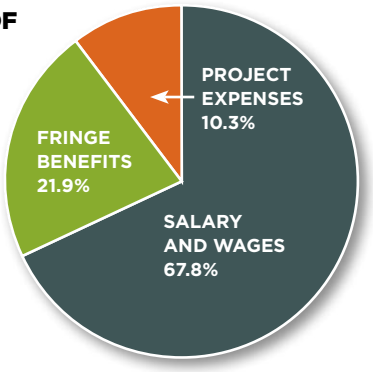
Perennial Powerhouse: Plant Research Fuels New Frontiers

Michigan State University is a mecca for green thumbs who have devoted their lives to studying plants for various reasons — to help feed the world, in pursuit of a medical cure or to improve the environment. This issue celebrates the vast contributions MSU researchers, both past and present, have had on the world of plant science.

Fall/Winter 2013 • *MSU AgBioResearch in a Snapshot; from local to global*

Originally founded in 1888 as the Michigan Agricultural Experiment Station, MSU AgBioResearch was initially charged with helping farmers improve production techniques and yields. Throughout its rich history, the organization has expanded the breadth and depth of its research. This issue takes a look at the diverse types of endeavors being conducted with valuable impacts both near and far.

DISTRIBUTION OF APPROPRIATED FUNDS



INCOME:

Federal Appropriation	
Hatch	$ 4,748,190
McIntire-Stennis	$ 290,078
Hatch RRF	$ 1,181,347
Hatch Animal and Disease, Section 1433	$ 101,184
Total Federal Appropriations	$ 6,320,799
State Appropriations	$ 29,107,871
Total Appropriations	$ 35,428,670
Grant – Federal, State and Private*	$ 56,195,851
TOTAL INCOME	$ 91,624,521

EXPENSES:

Salaries	$ 24,030,078
Fringe Benefits	$ 7,747,825
Project Expenses	$ 3,650,767
Grants – Federal, State and Private*	$ 56,195,851
TOTAL EXPENSES	$ 91,624,521

PERSONNEL:

(Full-time equivalents funded from appropriated funds)

Research Staff	
Professors	66.84
Associate Professors	28.48
Assistant Professors	19.86
Research Associates and Specialists	7.10
TOTAL RESEARCH STAFF**	122.28
Support Staff	
Administrative Professionals	47.13
Supervisors	23.59
Clerical	17.14
Technicians	3.93
TOTAL SUPPORT STAFF	91.79

**Grants are reported using most recent three-year average*

***Does not include department chairpersons and unit administrators*

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As of 1-1-2014

Douglas Buhler, Director
CANR Senior Associate Dean for Research

John Baker
Associate Director

Carolyn Adams
Research Support Coordinator

Natasha Berryman
Communications Manager

Lori Bramble
Research Support Coordinator

James Dau
Communications Coordinator

Jackie DeSander
Administrative Assistant

Tonia DuMont
Executive Staff Assistant

Linda Haubert
Projects Administrator

William Humphrey
Research Support Coordinator

Beverly Riedinger
Business and Finance Manager

Holly Whetstone
Senior Communications Manager

AgBioResearch Affiliated Deans

As of 1-1-2014

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College of Agriculture and Natural Resources

Karen Wurst — Dean;
College of Arts & Letters

Pam Whitten — Dean;
College of Communication Arts & Sciences

Leo Kempel — Acting Dean;
College of Engineering

R. James Kirkpatrick — Dean;
College of Natural Science

Marietta Baba — Dean;
College of Social Science

Christopher Brown — Dean;
College of Veterinary Medicine

AgBioResearch Unit Administrators

(UNITS RECEIVING FUNDING)

As of 1-1-2014

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Advertising, Public Relations and Retailing

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Agricultural, Food and Resource Economics

Janice Swanson, Chairperson
Animal Science

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Ajit Srivastava, Chairperson
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Rena Harold, Interim Director
School of Social Work

Raymond Jussaume, Chairperson
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MISSION STATEMENT:

The mission of MSU AgBioResearch is to engage in innovative, leading-edge research that combines scientific expertise with practical experience to generate economic prosperity, sustain natural resources, and enhance the quality of life in Michigan, the nation and the world.

The mission, supported by more than 300 scientists working in agriculture, natural resources, engineering, social and natural sciences, human ecology and veterinary medicine, has enabled MSU AgBioResearch to be one of the most successful organizations of its kind in the country. This success is due to the efforts of outstanding researchers; close partnerships and collaborations with MSU Extension, seven MSU colleges, federal and state agencies, commodity groups and other key stakeholders; and exceptional legislative support.

MSU AgBioResearch is an equal opportunity employer and complies with Title VI of the Civil Rights Act of 1964 and Title IX of the Education Amendments of 1972.