futures

MICHIGAN AGRICULTURAL EXPERIMENT STATION

FALL 2007
VOL. 25 NO. 3

EMERGING ISSUES

looking into futures

Emerging Issues

In a typical issue of *Futures*, you'll read stories about a variety of research projects grouped around a major area of focus of the Michigan Agricultural Experiment Station. In this special Emerging Issues edition of *Futures*, we give you stories grouped around two very different but very important topics: pollinators and agrifood nanotechnology. Both made headlines in 2007, and both need more study to address concerns surrounding them. MAES scientists have been among the first to step in to fill these research voids.

At the end of 2006, beekeepers around the country began to sound the alarm. Honeybees were disappearing. The bees were presumed dead, but there were no insect corpses to examine — the bees were just gone. With this coming on the heels of deadly Varroa mite infestations that had wiped out large numbers of honeybees, it's not surprising beekeepers were panicky.

Dwindling honeybee numbers sparked concern about pollinators in general. About 80 percent of the world's crops need pollination to reproduce — one out of every three bites of food you eat depends on pollination. In Michigan, about $455 million worth of crops depend on pollinators, primarily honeybees. To raise awareness and encourage more research on pollinators, June 24-30 was declared National Pollinator Week by the U.S. Senate and Pollinator Week in Michigan by Gov. Granholm.

MAES scientists are studying pollinators from a number of angles, from identifying native plants that will attract pollinators and other beneficial insects to surveying Michigan's native bee populations to helping write a national report on the status of pollinators in North America.

In another, tremendously smaller arena, MAES scientists are studying the social and ethical dimensions of agrifood nanotechnology, using agricultural biotechnology as a model to begin the discussion. Nanotechnology — working with materials that are one-billionth of a meter in size — has the potential to revolutionize all facets of agriculture, from farm fields to grocery store shelves. Nanomaterials exhibit entirely different traits than conventionally sized materials – the electrical, chemical, mechanical and optical properties of materials are all different at the nanoscale. Because common reactions are altered, established safety rules and regulations may not apply to nanomaterials. MAES scientists in the MSU Institute for Food and Agricultural Standards are helping to open up the dialogue on nanotechnology standards so that all stakeholders have a voice in the discussion.

We hope you enjoy this issue of *Futures* on emerging issues and that it helps you understand a little more about the Michigan Agricultural Experiment Station and the research it funds. If you have comments about this issue or would like to subscribe (it's free!), send a note to *Futures* Editor, 109 Agriculture Hall, Michigan State University, East Lansing, MI 48824-1039, or send an e-mail to depolo@msu.edu. You can also call 517-355-0123.

For the latest information about MAES research and events, I invite you to subscribe to the free MAES e-mail newsletter. Sign up by visiting the MAES Web site at www.maes.msu.edu/news.htm. You also can view this and past issues of *Futures* on the Web site by clicking on the "research publications" tab.

::: Jamie DePolo

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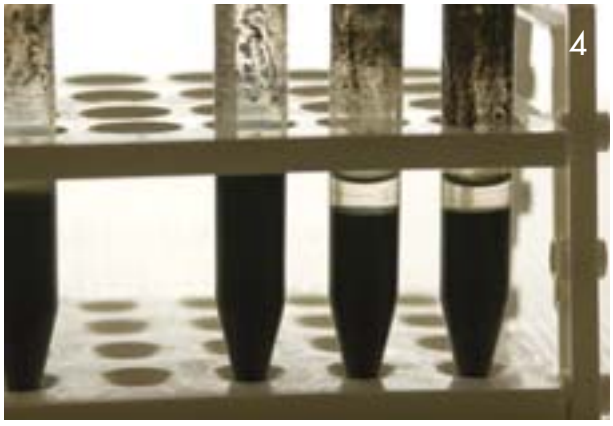

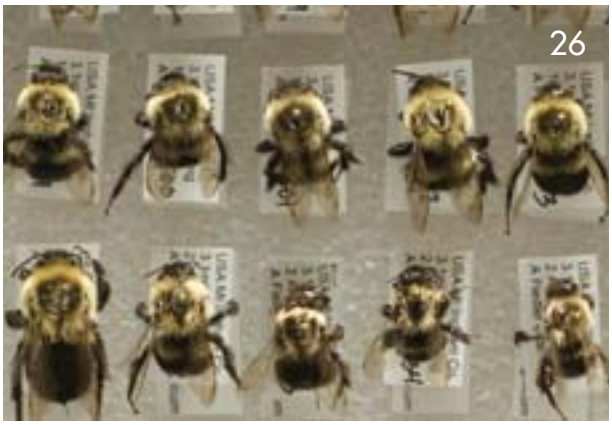

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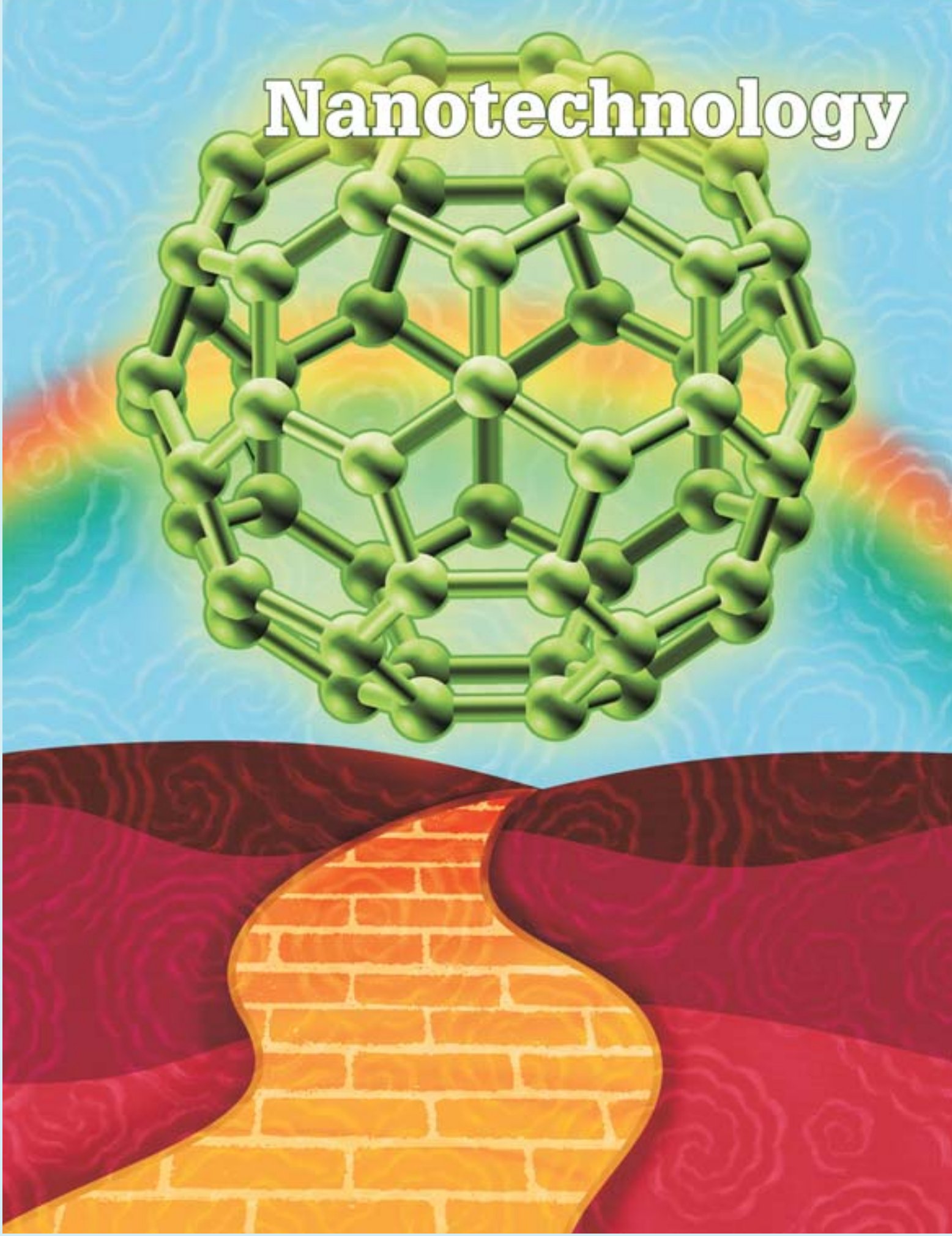
Nanotechnology



and the Agrifood Sector:

Welcome to Munchkinland!

"Toto, I've a feeling we're not in Kansas anymore…"

—Dorothy Gale, The Wizard of Oz

Despite assembling an unprecedented cast of 124 little people and featuring special effects never seen before, the 1939 production of the Wizard of Oz has met its match in the magic and novelty of nanotechnology — the science of the very, very small.

Given that the Wizard of Oz was touted as "the greatest magic film ever made," it's not much of a stretch to imagine Dorothy's ruby slippers containing tiny nanopigments to give them their brilliant, eye-catching color. Or that the glowing iridescence of the Emerald City was the result of metallic nanoparticles sensitive to light. Recent advances in the technology of "nano" have, indeed, landed us somewhere over the rainbow and far beyond what could be imagined in the "merry old land of Oz."

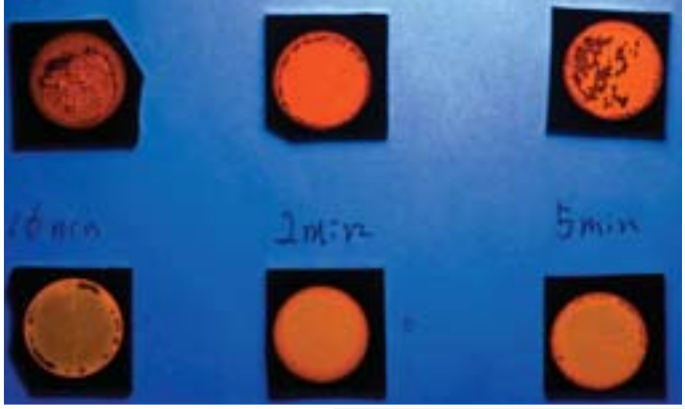
MAES researcher Larry Busch heads the Institute for Food and Agricultural Standards. Busch has been studying nanotechnology standards for more than a decade and says basic research on the health, safety and environmental impact of emerging nanotechnologies is necessary before standards can be set.

There's No Place Like "Nano"

So what is nanotechnology, anyway? "Nano" — short for nanometer — comes from the Greek word "nanos," meaning "dwarf." A nanometer is one-billionth of a meter. That's like comparing the size of a marble to the size of Earth. Things at the nanoscale level are so small that they can be seen only with devices such as the super magnifying scanning tunnel microscope and the atomic force microscope, tools that were developed and first used in the mid-1980s. Nanomaterials exhibit entirely different properties than conventional materials. Some nanomaterials possess superior electrical, chemical, mechanical and optical properties. Work with these properties forms the basis of new technologies.

"In a nutshell, 'nano' is the new 'micro'," said MAES researcher Larry Busch, professor of sociology and director of the Institute for Food and Agricultural Standards (IFAS). "From the 1960s until about 20 years ago, microtechnology was the big thing — witness Silicon Valley and the electronics industry, the rise of computer software and the Internet. Now that we have tools that allow us to actually see and move individual atoms, we'll be able to take the advances of microtechnology to a new level."

Nanotechnology has the potential to revolutionize methods of manufacture and distribution in all sectors of the U.S. economy. Agriculture — among the oldest and most established sectors — will be no exception. From fields to grocery store shelves and from consumption to disposal, nanotechnology is transforming the way food is produced, packaged and distributed.



Far left: **MAES scientist Evangelyn Alocilja uses nanomaterials to develop new types of biosensors to detect pathogens in food, water and animals. She recently developed a biosensor to detect *Bacillus* species and bovine viral diarrhea virus.** ***Left:*** **Porphyrin solution.** ***Above:*** **Nanoporous silicon chip sensors have photo-luminescent properties.**

"The technology piece is the new thing," said MAES researcher Evangelyn Alocilja, biosystems and agricultural engineering scientist, who is currently working on understanding and developing nanoscale devices and systems for use in agricultural, food and biological systems. "You are using tools from science, physics, chemistry and engineering related to the understanding and control of matter to develop very small structures; usually things from 1 to 100 nanometers in size."

When you attempt to manipulate and control matter at this scale, the properties of matter differ in fundamental and valuable ways, she pointed out.

"Nanoscale materials are very different from their larger counterparts," Alocilja said. "For example, the smaller the particles get, the greater the changes in the particles' chemical, electronic, magnetic and mechanical properties. Nanoparticles also have an increased surface area, which offers more space for interaction with other substances."

Experts use the analogy of brewing coffee to explain the difference that increased surface area can make. Picture a coffeemaker. If you use whole coffee beans, you get a very weak cup of coffee. But if you grind the beans first, you increase their surface area and, as a result, get a darker, stronger brew.

"The nano field looks to take advantage of these special properties through the creation of improved materials, devices and systems," Alocilja said.

Follow the "Nano" Brick Road

MAES scientists are working on a variety of fronts in agricultural and food (agrifood) production nanotechnology. Research is under way on biosensors and radio frequency identification tags to identify, trace and monitor food products from farm to fork. In addition, a wide range of other technologies are under development, including agrichemicals that release only when they're in contact with crop plants, spoilage indicators on food products, and "smart" packaging that interacts with contents to reveal information on product spoilage, safety and nutritional content.

"It's not just food — everything from food processing equipment to packaging and distribution systems is being affected by nanotechnology," said John Stone, research scientist at IFAS. "Applications are found throughout the food supply chain."

Susan Selke, professor and acting director of the School of Packaging, points out that nanotechnology plays an important role in the packaging of agrifood products.

"Lots of the nanotechnology applications in packaging are related to creating barriers or sensors," Selke said. "Pop-Tarts packaging is a good example of the advances made with this technology."

When Kellogg introduced Pop-Tarts in 1964, they came in a paper wrapper with an aluminum foil interior to prevent oxidation, which can render products rancid and stale. As technologies evolved, this packaging was enhanced to reduce the amount and cost of the packaging while maintaining product quality. Today, Pop-Tarts come wrapped in a metalized film package that has a nanoscale layer of aluminum that effectively keeps oxygen and water vapor out.

Nanotechnology also can help in selecting ripe produce. Special sensors with nanotech components capable of detecting the ripeness and freshness of packaged produce are used in stores today. The sensors work by measuring the concentrations of specific substances within a package.

"For example," Selke said, "at Meijer supermarkets, some packages of pears contain sensors — small, round labels that change color as the pears get riper. That lets both stockers and buyers know just how ripe the produce is."

There are also nanotech time and temperature indicators on distribution packaging and pallets that can determine if something happens to a product during the shipping cycle. Other potential benefits of applied nanotechnology include the ability to detect a product contamination problem before it hits the shelves, helping to avoid safety and health hazards and massive recalls; inventory control; and "just-in-time" ordering.

Radio frequency identification (RFID) — an automatic identification method that relies on storing and remotely retrieving data using tiny devices called RFID tags or transponders — is another technology increasingly being used in the agrifood industry. These devices range in size from smaller than a dime to half the size of a grain of sand.

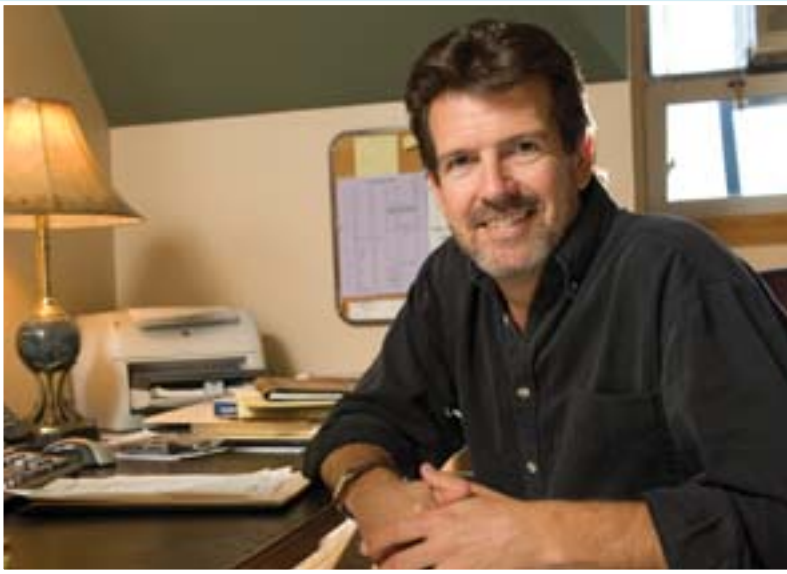
"An RFID tag is an object that can be stuck on or incorporated into a product for the purpose of identification using radio waves," said MAES packaging scientist Robb Clarke. "They 'listen' for a radio query and respond by transmitting their own unique identification code."

A major focus in RFID use is supply chain management — improving the efficiency of inventory tracking and management from warehouse to consumer. RFID tags are commonly used in case, pallet and shipping container tracking and truck and trailer tracking in shipping yards. In comparison to traditional technologies, RFID technology has the potential to prevent or reduce the sources of errors, reduce labor costs, simplify business transactions and reduce inventory inaccuracies.

Clarke and a team of graduate and undergraduate students and other MSU scientists are doing real-world research and testing related to automatic identification and sensor network technologies with a focus on RFIDs. An off-campus research and testing facility in Lansing will provide the necessary space and research capabilities to examine and solve automatic identification issues with industry and partnering stakeholders.

"This is a great example of a dynamic, industry-university partnership focused on developing technologies that will enhance and improve business practices not only in Michigan but across the U.S. and internationally," Clarke said. "Such a focus will help develop standards for data collection and communication and will help us define applications best suited for homeland security and safety of agricultural packaging and shipments."

Another area where MAES scientists are using nanotechnol-



Right: **John Stone, research scientist in the Institute for Food and Agricultural Standards, has helped coordinate three agrifood nanotechnology conferences and compiled a variety of educational resources to inform discussion, research and standards-setting activities related to the field.** ***Below:*** **Susan Selke, acting director of the School of Packaging, studies the role of nanotechnology in packaging. Pop-Tarts** ***(below right)*** **come in a package with a nanoscale layer of aluminum to keep out water vapor and oxygen so that the pastries stay fresh longer.**

ogy is in the development of devices that can detect pathogens in food animal production systems. Recent bioterrorism events in the United States and outbreaks of foreign animal diseases in Europe (foot-and-mouth disease and swine vesicular disease) have heightened awareness of the need to develop strategies to protect the nation's livestock from environmental threats and disease. Infectious diseases prevalent in the livestock industry continue to cost producers millions of dollars. Innovative ways to control these pathogens are needed.

"Regardless of their nature and source, one of the keys to pathogen control is rapid detection so that appropriate practices and responses can be implemented in a timely manner,"

MAES packaging researcher Robb Clarke is studying how radio frequency identification (RFID) tags can be used to improve the efficiency of inventory tracking and management from warehouse to consumer. Clark is working with industry partners at a testing facility in Lansing to simulate real-world situations.

Alocilja said. "Electronic biosensors have shown promise as a rapid, cost-effective and sensitive detection tool."

Alocilja recently developed a biosensor capable of detecting a virus in blood and, in collaboration with MAES large animal clinical scientist Daniel Grooms, is conducting further tests in nasal swabs and skin samples collected from cattle that are carriers of a disease known as bovine viral diarrhea (BVD). The BVD virus is one of the most important viral pathogens of cattle worldwide.

"This type of work has been done at the micro level but not at the nano level before," she said. "Moving to the nanoscale level is like going from a one-lane road to a 10-lane highway."

Using a variety of very, very small structures — nanowires, nanotubes, nanomagnets and nanopores — Alocilja was able to develop a system that can be used as a diagnostic tool to detect cattle infected with the virus so they can be separated from the rest of the herd, greatly reducing the exposure risk and potential spread of this infectious disease.

"Now that we have BVD as a model, we are looking at adaptations that might be useful in detecting other pathogens important to the livestock industry, such as avian influenza virus and *Mycobacterium avium* subspecies paratuberculosis," Alocilja said.

Mycobacterium avium subspecies paratuberculosis (MAP), known as paratuberculosis, causes Johne's (pronounced "YO-nees") disease in cattle. A chronic intestinal infection, Johne's causes diarrhea, weight loss, decreased milk production and death.

Related research includes the development and refinement of a biosensor that can be used onsite to detect and verify pathogens in farm, food and environmental samples before microbial contaminants are passed up the food chain. The biosensor may also be used for point-of-care diagnostics during food poisoning outbreaks and as an added tool for food protection and defense measures.

"We are also currently developing various biosensor designs using nanowires, electrically active nanomagnetic particles and biobarcoded nanogold particles that will quickly detect high priority select agents of concern to homeland security," Alocilja said.

Lions and Tigers and Bears, Oh, My!

Though the application of nanotechnology has the potential to revolutionize the agrifood industry, it also brings its own set of environmental, social and ethical challenges and concerns — particularly related to the issues of data generation, control and privacy.

Many companies store sensitive shipping and distribution information on chips. But the chips can be scanned and the information then loaded onto computers and rendered insecure. And small environmental testing devices containing nanocomponents could offer ordinary citizens the ability to monitor chemicals being emitted from a nearby factory and distinguish them from those being used on a local farm. Such developments likely would change the power relationships in food and environmental politics.

"We need to ensure that data collection is fair, transparent and subject to law if we're going to build consumer confidence and take advantage of the benefits of this new technology while safeguarding individual privacy and proprietary information," Stone said.

Stone and others suggest that a model for public collaboration with government and industry is essential to lay the groundwork for more socially responsive agrifood nanotechnology.

"As we travel down the nanotechnology road, there is a critical need to look at the risks and ethics associated with its application in the agrifood sector," said MAES scientist Paul

NANOTECHNOLOGY
Sizing Things Up

- A human hair is about 80,0000 nanometers wide.
- An adult pinky fingernail is about 10 million nanometers across.
- A nanometer is one-tenth the thickness of the tinted coating on a pair of sunglasses.
- The head of a pin is 1 million nanometers wide.
- A dollar bill is 100,000 nanometers thick.
- An ant is 5 million nanometers long.
- Comparing 1 nanometer to an inch is comparable to 1 inch to 400 miles.
- Shaquille O'Neal is 2.160 billion nanometers tall.

Nano comparisons excerpted from June 2006 issue of National Geographic Magazine, "Nano's Big Future," pp. 98–119.

Thompson, who holds the W.K. Kellogg Chair in Agricultural, Food and Community Ethics at MSU. "Because the development of this technology is still in its early stages, we are in a unique position to identify and address its implications before we get too far down the road."

Lessons learned from earlier technologies – most recently agricultural biotechnology – are informing the development of nanotechnology.

"One of the biggest lessons to be drawn from the ag biotech experience was the perceived failure to engage diverse stakeholders and other potentially affected groups in a dialogue as standards were being set," Stone said. "Dialogue and debate among all actors in the supply chain about the issues confronting agrifood nanotechnology and its use – both positive and negative – should precede the development of standards to better identify the social landscape and consequences of standards decisions."

Thanks to the lessons drawn from the controversy surrounding genetically engineered food, Stone believes that there is a unique opportunity to better understand what is coming, think through the potential impacts and develop a roadmap to inform the standards-setting process of agencies and organizations dealing with emerging nanotechnologies and their potential applications.

"The introduction of any new technology offers challenges across numerous sectors," said Busch, who was heavily involved in agrifood biotechnology and has been looking at the standards side of nanotechnology for the past decade. "There is a treasure trove of questions related to the establishment of regulatory standards and laws for this new technology, such as 'How do we name it?' 'How do we regulate it?' 'How do we know what we're talking about?'"

Busch added that basic research is needed to determine the health, safety and environmental impact of emerging nanotechnologies.

"Without such data, it is difficult to move the standards-setting process forward," he said.

At the end of the day, Thompson contends that inclusiveness and transparency in developing policies and standards for agrifood nanotechnology will largely determine consumer acceptance of this new technology and its applications.

"Consumer confidence in the ability of the regulatory system to ensure food safety and protect the environment is critical to the success or failure of agrifood nanotechnology," he said. "A new technology is going to be profitable only if people trust it and see the benefit in it."

Somewhere Over the Rainbow

So what might an agrifood nanofuture include? Ice cream modified to reduce the amount of fats and sugars absorbed by the body. "Smart" foods that can sense an individual's food allergies and block the offending ingredients. Intelligent packaging that extends food's shelf life by detecting spoilage and releasing antimicrobials. Plant seeds that produce various properties in one crop, including color, size and yield. Remote nanosensors that monitor pH levels, nutrients, pests and diseases, all of which will reduce on-farm labor.

Some might posit that at only 20 years out, nanotechnology is more of a vision or a promise than a reality, but researchers are making great advances in its application.

"What seems like science fiction now will most likely become commonplace in the not too distant future," Selke said. "For example, it's conceivable that we'll be able to go to the grocery store, fill our carts and then simply walk through a scanner that reads what's in your cart, totals it, charges or debits your account, and off you go."

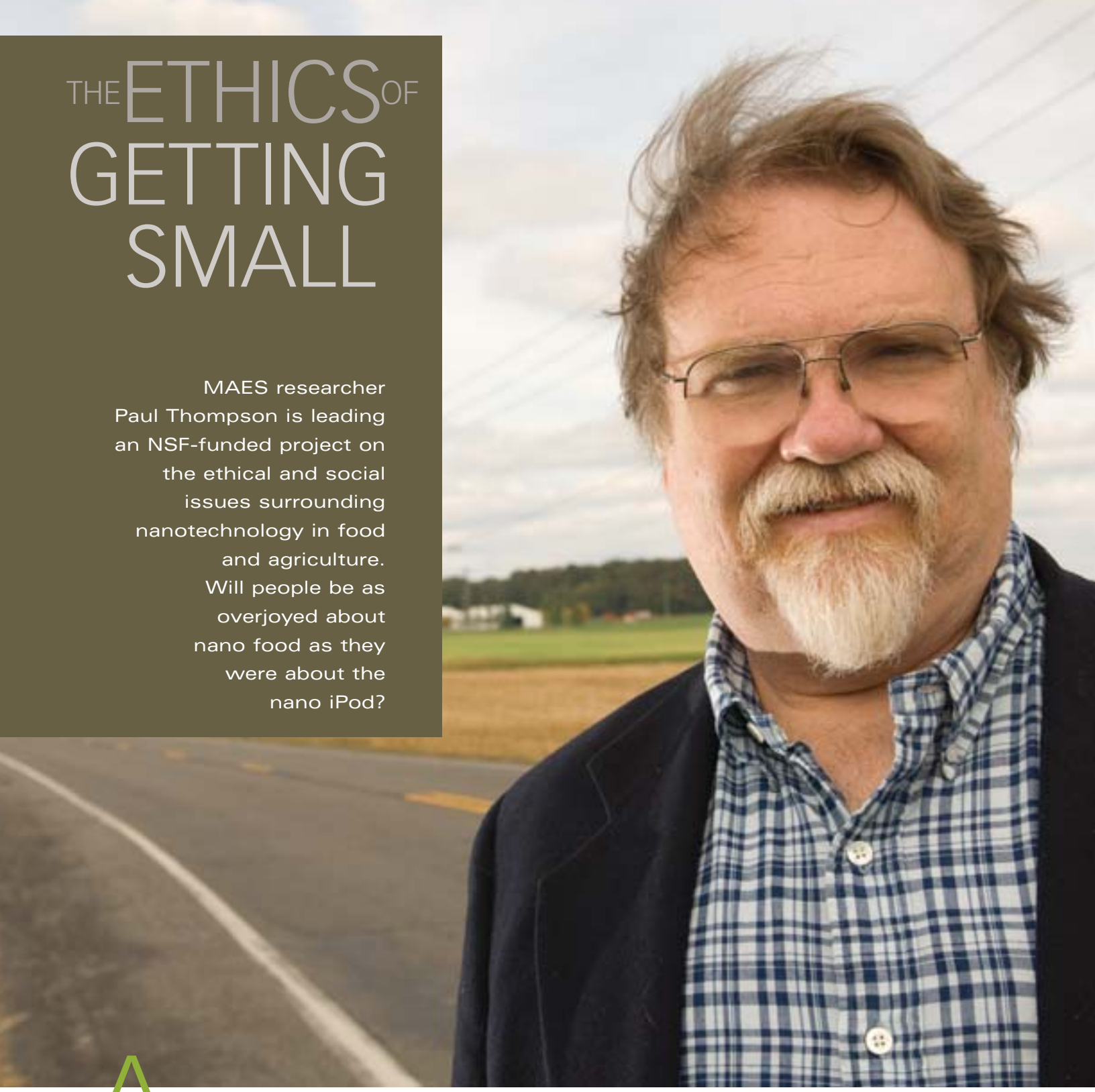
"It's exciting to be doing research using this new, cutting-edge technology," Alocilja said. "There are so many things we didn't know before because the physics at the nano level are so different. Because nanotechnology cuts across so many disciplines in its application, it gives us the ability to come up with unexpected complementarities that have never been thought of before."

Regardless of where the next 15 to 20 years take us, it's a fair bet that if the Lollipop Guild had had access to the technology available today, it would have produced nutritionally enhanced lollipops containing nanocapsules that would allow Oz residents to choose the flavor of their lollipops according to personal preference. Of course, the lollipops would be produced according to the standards wisely set forth by the Nanotech Advisory Council and the great and powerful Wizard of Oz!

::: Val Osowski

THE ETHICS OF GETTING SMALL

MAES researcher Paul Thompson is leading an NSF-funded project on the ethical and social issues surrounding nanotechnology in food and agriculture. Will people be as overjoyed about nano food as they were about the nano iPod?



As a graduate student in the '70s, Paul Thompson was drawn to the study of technology and risk. His dissertation was a risk analysis of nuclear power, research that was both topical and practical as nuclear plants sprouted across the country and Three Mile Island melted down in Pennsylvania. After receiving his doctorate, Thompson went to Texas A&M for a 1-year position in environmental philosophy and was introduced to the dean of the College of Agriculture and Life Sciences, who wanted to start a program on ethics in agriculture.

"HOW PEOPLE LEARN ABOUT NANOTECHNOLOGIES, FROM WHOM AND WITH WHAT MESSAGE WILL BE CRITICAL TO PUBLIC PERCEPTIONS IN THE FUTURE."

"I thought it was a good way to merge my interest in the environment and risk," he said.

Thompson wrote his first paper on biotechnology in 1986, using the relatively new science as a way to illustrate the intersections of the environment, risk and ethics.

Today, Thompson holds the W.K. Kellogg Chair in Agricultural, Food and Community Ethics at MSU and is the principal investigator of a $1.7 million 4-year National Science Foundation (NSF) grant to study the social and ethical dimensions of agrifood nanotechnology, using agricultural biotechnology as a touchstone to begin the discussion. The agrifood nanotechnology project, as the research is called, is being conducted through the Department of Community, Agriculture, Recreation and Resource Studies (CARRS) and the Institute for Food and Agricultural Standards (IFAS) and takes advantage of MSU's national reputation for social science research on technology. Other MSU scientists participating in the research are Lawrence Busch, university distinguished professor, MAES sociologist and IFAS director; John Lloyd, university distinguished professor of mechanical engineering; Susan Selke, professor and acting director of the School of Packaging; John V. Stone, applied anthropologist and IFAS faculty research associate; Ken David, associate professor of anthropology; Tom Dietz, director of the Environmental Science and Policy Program and assistant vice president for environmental research; Les Bourquin, MAES food science and human nutrition researcher; and Deepa Thiagarajan, visiting assistant professor of social science and community, agriculture, recreation and resource studies. Brady Deaton, assistant professor of agricultural economics at the University of Guelph and former doctoral student at MSU, is also working on the project.

"This project fits in very well with the IFAS mission," Busch said. "Part of what we're looking at is what agrifood nanotechnology means and how it should be regulated, as well as the standards that need to be developed and who participates in the decision-making process."

"Everyone in the world has an interest in food," Thompson said, "which is why I think agricultural biotechnology became and still remains an issue for so many people. Biotechnology brought together a lot of concerns that are unique to that technology and food. In this project, we're looking back at biotechnology and analyzing whether there are any analogies with agrifood nanotechnology. What we're finding is that the biotechnology concerns may not be tied to all new technologies in the food sector, including nanotechnology."

Lessons from Biotechnology

Agricultural biotechnology is a collection of scientific techniques, including genetic engineering, that are used to improve plants, animals and microorganisms. In traditional plant breeding, a scientist crosses the initial plant with another variety that has a desirable trait, such as disease resistance. But the scientist doesn't know which genes from each parent plant are in the new offspring plants — all the genetic information gets mixed up at pollination, and the breeder has no control over which genes from each parent make up the offspring. One of the parent plants also may have an undesirable trait, such as lower yield, that the offspring may have inherited. The breeder has to study the offspring plants and determine which characteristics they have. If the offspring are only a little more disease-resistant or have a lower yield, then the breeder has to make backcrosses (crossing an offspring plant with a parent plant) to strengthen the desirable trait and get rid of the undesirable trait. It takes many, many backcrosses and 15 to 20 years to create a new plant variety.

Biotechnology eliminates much of this breeding uncertainty. It allows a scientist to take the one gene or group of genes responsible for the desirable trait and insert only that one gene or group of genes into the offspring.

The first food products of biotechnology — an enzyme used in cheese production and a yeast used for baking — appeared on the market in 1990. In 2001, the acreage planted in biotechnology crops (also known as GMOs — genetically modified organisms — transgenic crops or bioengineered crops) was more than 40 times larger than it was in 1996. About 5.5 million farmers grew 130 million acres of biotech crops in about 15 countries, with the United States, Canada and Argentina leading the way.

The concerns around biotechnology include the emergence of uncontrollable "superweeds," genetic pollution — the idea that biotech crop genes can move into other plants — and horizontal transfer — that biotech crop genes will move into people or bacteria. People are also concerned that biotechnology will affect the biodiversity of plants or that formerly benign plants will cause allergic reactions in consumers. What happens if a peanut gene is inserted into a cucumber, for example? Would someone with peanut allergies now be allergic to these transgenic cucumbers?

"I think nanotechnology can learn from biotechnology," Thompson said, "but it's certainly not the same thing. Scientists are looking for a magic bullet to dodge — 'If we can

"WE CAN TALK TO PEOPLE ABOUT WHAT'S AT STAKE AND WHO WANTS TO BE INVOLVED BEFORE THE DECISIONS ARE MADE. PEOPLE NEVER FELT LIKE THEY WERE ASKED THOSE QUESTIONS WITH AGRICULTURAL BIOTECHNOLOGY."

just answer this specific concern, the technology will be accepted.' But the overriding lesson from biotechnology is that there isn't just one issue in accepting new technology. There is no magic bullet."

Size Does Matter

Biotechnology is essentially a molecular approach to biology. Nanotechnology, on the other hand, is defined completely by the size of the particles involved — specifically, particles smaller than 1 billionth of a meter. Biology, food chemistry, engineering — all these sciences can be nanotechnology if the bits are small enough.

"It seems silly to define technology as a measure, but that's really what we're doing right now," Busch said.

"People are making different choices about when to use the word 'nanotechnology,'" Thompson explained. "Some packaging research using nanotechnology was under way long before the term started to be used, so it's not defined as nanotechnology. People want to clearly explain the research. Sometimes using the term 'nanotechnology' helps, and sometimes it doesn't add anything."

Thompson said that people were troubled by a perception of lack of choice regarding agricultural biotechnology — the average person had no say in the matter. Biotechnology was seen as pervasive. Experts had figured out what certain people wanted — corn that could withstand applications of a specific herbicide — and then offered them only that. People who didn't want GMO corn didn't feel they had any options — all the decisions had been made before they even sat down at the table. When the critics voiced their opinions, they felt they were not taken seriously. So the critics became angry and vocal.

"With our agrifood nanotechnology project, we're working on nanotechnology at the very beginning of the science," Busch said. "We can talk to people about what's at stake and who wants to be involved before the decisions are made. People never felt like they were asked those questions with agricultural biotechnology."

To facilitate participation in nanotechnology issues and decisions, the scientists are using part of the NSF grant to hold a series of international agrifood nanotechnology conferences, as well as a brown bag seminar series on campus.

The first conference, "What Can Nano Learn from Bio? Lessons from the Debate over Agrifood Biotechnology and GMOs," took place in 2005 and featured attorneys, policy researchers, anthropologists, sociologists, political scientists, engineers, consumer advocates, industry representatives, philosophers and economists discussing the missteps and successes of biotechnology and how agrifood nanotechnology could use this history as a roadmap of what should and shouldn't be done. The second conference, "An Issues Landscape for Nanotechnology Standards," was held in 2006 and examined issues related to developing standards for nanotechnology, including product standards, regulations and connectivity between products. The third conference, "What Is Agrifood Nanotechnology?" took place in April 2007 and used the conclusions of the first two conferences to look at issues relating to potential agrifood nanotechnology applications, governance of those potential applications, and public participation in the application and governance processes.

Susan Selke, acting director of the School of Packaging, is a member of the research group studying the social and ethical dimensions of agrifood nanotechnology. She says that new regulatory approaches may be needed for nano-sized compounds.

"We're convening these events to bring in a broad cross-section of stakeholders," explained John Stone, who helps develop graduate courses for the IFAS in addition to his research. "One message that came through loud and clear during our first conference was that broad stakeholder participation was largely absent or after-the-fact at best during agricultural biotechnology R&D phases. So our intent in holding this

Institute for Food and Agricultural Standards

Since its inception in 1998, the Michigan State University Institute for Food and Agricultural Standards (IFAS) has played a lead role in raising fundamental issues in equity, fairness and transparency of food and agricultural standards at the local, national and international levels.

The IFAS is an interdisciplinary teaching, research and policy analysis organization that focuses on the social, economic, political and ethical aspects of grades and standards creation, enforcement and review. It is part of a small but growing international network of scholars and practitioners concerned with these issues.

"We are surrounded by standards," said MAES scientist Larry Busch, university distinguished professor of sociology and IFAS director. "They define the criteria by which products, processes and producers in our society are judged so that 'common goods' such as food safety, environmental protection, worker health and safety, and food quality can be maintained and enforced. Without standards, our contemporary world simply could not exist."

Though standards shape our lives, they are largely invisible and anonymous, Busch pointed out.

"Standards are analogous to social habits," he said. "Individual habits allow you to routinize certain behaviors and activities — such as shaking hands with your right hand instead of your left when you greet someone or leaving the appropriate tip when dining out — so you are free to think of something else. Standards, likewise, provide the means for handling a wide range of issues so you can get on to more important things."

In addition to supporting a number of research and outreach activities related to agrifood standards setting, the institute also offers an online proseminar course in food and agricultural standards taught by IFAS-affiliated instructors, free monthly agrifood nanotechnology brownbag seminars, a certificate program in food regulatory and quality standards, and MSU graduate specialization coursework in food and agricultural standards.

The IFAS also has a Web site (www.ifas.msu.edu) that serves as a "virtual institute" providing information and resources related to agrifood standards. The site includes links to key research activities, institute publications, academic institutions, domestic and international bodies involved in food and agricultural standards, and IFAS staff members, researchers, collaborators and affiliates.

As a national leader in the agricultural standards arena, IFAS is also serving as a catalyst and convener related to standards setting and stakeholder involvement in the new and growing field of agrifood nanotechnology.

"There is a critical need to identify the most likely applications of nanotechnology within the agrifood sector so that proactive strategies can be developed early on to address social and ethical issues and ensure that the technologies themselves are responsive to diverse interests and perceived needs," said MAES scientist Paul Thompson, who holds the W.K. Kellogg Chair in Agricultural, Food and Community Ethics at MSU and works closely with the IFAS.

To date, the IFAS has convened three agrifood nanotechnology conferences and is developing a variety of educational resources to inform discussion, research and standards-setting activities related to this new and novel field.

"As far as I know, there is currently no other entity like the IFAS," Busch said. "But given the continued importance of standards setting and the opportunities and challenges posed by the advent of nanotechnology, I believe that general studies of standards will grow considerably at lots of universities and campuses in the next 10 to 15 years."

The IFAS is funded by the National Science Foundation, the MAES and MSU.

::: Val Osowski

series of events was to provide venues so all stakeholder groups — NGOs [nongovernmental organizations], labor, regulatory agencies, industry, trade associations, standards-setting bodies, as well as numerous academic and technical disciplines both domestically and internationally — can come together to share their perspectives and, we hope, come to a better understanding of both the breadth and depth of one another's concerns."

Public Perception of Nano

According to a March 2007 survey done by the Project on Emerging Nanotechnologies (PEN), a partnership between the Woodrow Wilson International Center for Scholars and the Pew Charitable Trusts, public opinion of nanotechnology is up for grabs. To start, most people say they are unaware of what's going on in nano. When given some information, consumers appreciate that nano can keep food safer and create new treat-

"MOST NANOTECH PRODUCTS HAVE CONSUMER BENEFITS, BUT IT'S ULTIMATELY UP TO THE CONSUMERS TO DECIDE WHAT THEY WANT. ...[O]FFERING PEOPLE INFORMATION AND CHOICES CAN MAKE THEM MORE RECEPTIVE TO NEW TECHNOLOGY."

As director of the Institute for Food and Agricultural Standards, MAES scientist Larry Busch has made MSU a national leader in the agricultural standards area. He is also part of the team studying nanotechnology ethics and is working to facilitate public participation in nanotechnology decision making. Busch says the project fits in well with the institute's mission because part of the project is looking at how agrifood nanotechnology should be regulated.

ments for diseases, but they want to be assured that new products are safe.

"It seems that people's notion of nanotech is vague," Thompson said. "This could be due in part to the science's broad definition and to its uneven use. The NSF definition of nanotechnology encompasses many things and is very broad. The food industry seems to have made a decision not to use 'nanotechnology' when referring to some new developments that are taking place at that scale, while other industries have embraced the term. So in that sense, it can be hard to explain."

PEN scientists said that government, business and educational institutions need to take a more proactive role in engaging with and communicating to the public about nanotech.

"How people learn about nanotechnologies, from whom and with what message will be critical to public perceptions in the future," said Don Braman, PEN researcher and George Washington University professor.

Ensuring the safety of new agrifood nanotechnology products and processes — the public's No. 1 concern — will likely cause some changes at regulatory agencies.

"Agencies are used to dealing with compounds and materials in certain ways," explained packaging scientist Selke. "If agencies have determined that materials are safe based on the behavior of common sizes, this may not be meaningful when the particles are nano size — they may behave quite differently, and consequently, new regulatory approaches may be needed."

In her research on nanotech packaging materials, Selke said that any interactions with food were always stringently tested for, but overall, nanotech packaging was less likely to have hazards associated with it than some other types of nanotechnology.

"For example," she continued, "if a sunscreen uses nanotechnology to encapsulate zinc oxide into the formula, over time, can the nanoparticles of zinc oxide get into the body? If the nanoparticles are in the package rather than the product and encapsulated within the material, they're not moving too much. There's likely less risk, but it's still something to consider."

"There are no rules of thumb on which nanoparticles are toxic or not," Busch added. "And what happens when the particles degrade? Testing is an issue."

"Studies are beginning on the toxicity of nanoparticles — in particular, carbon nanotubes," Thompson said. "And there is talk about the need for a risk assessment on nanotechnology. I think nanotechnology scientists are highly aware of the need to be inclusive and thoughtful when discussing any risks associated with nanotechnology."

Across the Atlantic, where the general public has been much more opposed to agricultural biotechnology than the population in the United States, the European Union is making a concerted effort to involve people at the beginning of the nanotechnology process.

"The EU made a decision to fund and promote agrifood nanotechnology," Thompson said. "The community of researchers has worked to have social and ethical research integrated into the hard science of nanotechnology. There is a commitment to have scientists talking to the public and participating in workshops and being available to answer questions and explain. Along with some other researchers from this project, I'll be going to Europe to participate in some of these workshops."

"Most nanotech products have consumer benefits," Busch concluded, "but it's ultimately up to consumers to decide what they want. We learned from biotechnology that being inclusive and offering people information and choices can make them more receptive to new technology."

:::Jamie DePolo

the rules of attraction

About 80 percent of the world's crops need pollination to reproduce. As development and other stressors cause pollinator numbers to decline, two MAES scientists and their graduate students are working to make Michigan landscapes more appealing to the insects that carry out this vital work.

As you munch your lunch of peanut butter and jelly, or salad, or pasta with tomato sauce, thank the bees, birds, beetles, butterflies, mosquitoes and bats that made it all possible. Tomatoes, melons, blueberries, apples, peaches, squash, cucumbers — nearly 80 percent of the crops that provide food for the world need outside help transferring pollen from one flower to another so they can produce fruits, vegetables, nuts, seeds and fiber. Experts estimate that one out of every three bites of food we eat is made possible by pollinators.

Rufus Isaacs *(above)* and Doug Landis *(above right)*, MAES entomologists, have identified a number of native plants that attract beneficial insects to landscapes. Isaacs is especially interested in plants that can attract native bees to blueberry fields to help farmers pollinate their crop. Landis, pictured with a cup plant, one of the best plants for attracting both native bees and natural enemies, is starting field trials to see if fields bordered by the native plants have fewer pest insects as well as higher yields.

For thousands of years this work has gone on largely unnoticed by anyone outside of agriculture or beekeeping. Though other creatures contribute to pollination, honeybees carry the bulk of the work on their delicate wings. In the past few years, outbreaks of Varroa mites in honeybee colonies and the mysterious colony collapse disorder (see story on page 26) have decimated U.S. honeybee populations and sparked a growing wave of concern about the status of the world's pollinators.

"Pollinators play a critical role in helping produce the food we eat and in maintaining natural plant communities and healthy ecosystems," said Doug Landis, MAES entomologist. "As people began to notice the decline in honeybee populations, they've focused their attention on pollinators in general, which is a good thing."

Even Congress has taken note. The U.S. Senate designated June 24-30, 2007 as National Pollinator Week "to recognize the vital role of pollinators to ecosystem health and agriculture and the value of ongoing public-private partnership efforts to increase awareness and support for protecting pollinators." Gov. Granholm followed suit by proclaiming the same week Pollinator Week in Michigan. The U.S. Postal Service introduced a set of pollination stamps in June, featuring Morrison's bumblebees, a calliope hummingbird, a lesser long-nosed bat and a Southern dogface butterfly.

MAES scientists were concerned about pollinator decline long before the issue hit the headlines. Landis and Rufus Isaacs, MAES entomologist, began work in 2003 on ways to attract pollinators and other beneficial insects to landscapes using native plants. Together with graduate students Anna Fiedler and Julianna Tuell, the scientists studied 54 native plants and ranked them according to their come-hither power over the beneficial insects. Ultimately they recommended 26 native plants on the basis of their powers of attraction as well as their bloom times. The scientists wanted to recommend plants with a range of bloom times so growers and

gardeners could have the option of choosing plants that flower from May until October.

"Entomologists have long recognized natural enemies and pollinators as essential parts of every growing ecosystem," Landis said. "However, not all farms and landscapes contain the resources these beneficial insects require, including a constant supply of flowering plants providing ready access to pollen and nectar. Entomologists frequently recommend planting several easy-to-grow non-native plants to attract and feed natural enemies and pollinators. But non-native plants do not add to native biodiversity, and some can become invasive. We wanted to see if native plants worked as well as non-native plants and discovered that many were equally good and some quite a bit better."

The project started when Landis and Fiedler received a U.S. Department of Agriculture (USDA) special grant and money from Project GREEEN, Michigan's plant initiative, to evaluate native Michigan plants for their ability to attract natural enemies of insects that attack crop and landscape plants. Natural enemies help control pest insects without chemicals, an especially attractive option for certified organic growers or any farmer looking to implement integrated pest management strategies (IPM) and reduce chemical use. Natural enemies can be either predators — insects that eat the young and adult of the pest insects — or parasitoids — insects that use pest insects as a host for egg-laying; after the egg hatches, the young feeds and develops inside the host, killing it. The pest insects that the natural enemies prey on tend to be pests across a number of field crops, fruit and landscape plants, so the recommended native plants are suitable for farmers and homeowners alike.

A Small Step toward Restoring Native Prairie Plants

Part of Landis' research interest focuses on grasslands, one of the most endangered ecosystems in the world. Since the Europeans settled in North America, native grasslands have declined severely, primarily because the land was converted to agricultural use. In Michigan, experts estimate that about 2.5 million acres of native prairie (a type of grassland) existed before European settlement, mostly in the southern Lower Peninsula. Today it's estimated that fewer than 2,000 acres remain.

"We picked native prairie and savanna plants that used to be much more common in Michigan to test," Landis said. "We compared these native plants to the five most commonly recommended non-native plants, and we found that many native plants were either as good or better than the non-native plants. The non-native plants had a narrow range of bloom time, so they wouldn't be attractive to beneficial insects all season."

Landis and Isaacs also were aware that some of the native plants could be considered weeds.

"Pollinators play a critical role in helping produce the food we eat and in maintaining natural plant communities and healthy ecosystems."

The researchers then received a 3-year Sustainable Agriculture Research and Education grant to continue the work. Isaacs and Tuell were funded by an MSU sustainable agriculture special grant to join the project, bringing a new component that would assess the plants for their attractiveness to native bees.

"Many species of native bees that are important pollinators, such as bumblebees, require nectar and pollen throughout the entire season," Isaacs explained. "If an area doesn't have it or has it for only a month, the bees move elsewhere to find food. Evaluating these plants is a critical first stage in building a sustainable bee conservation strategy that can be employed by farmers."

The native plants were tested for "weediness" and aggressive ones were eliminated. The researchers also eliminated any plants that attracted pest insects.

The results of their work are available in two MSU Extension bulletins, a pocket flip book and a set of online tools available through the native plants Web site: www.native-plants.msu.edu.

Moving Forward with Field Trials

This year, the scientists received a National Research Initiative grant from the USDA to place the top-rated native plants in farm fields and examine whether more natural enemies and pollinators are attracted to crop fields bordered by the plants. They also will measure whether there are fewer pest insects and if yields increase.

"We're looking at three broad ecosystems," Landis said, "the Saginaw Valley, an area near the MSU campus and southwestern Michigan. We want to look at a range of landscapes. Our hypothesis is that landscapes with moderate resources for beneficial insects will benefit the most from the addition of native plants, but it's really a total unknown. I think we'll learn a lot."

The researchers will be looking at a number of variables to assess the effectiveness of the native plants, including location of the plants and the spatial scale that is best for the beneficial insects.

In western Michigan, Isaacs, Tuell and graduate student Nate Walton are working at four blueberry farms, putting strips of native plants alongside fields. They're comparing the abundance of native bees and natural enemies in the flowering native plant strips to areas without the flowering plants to measure the benefits the flowers provide.

"Blueberries are intensively managed, so we didn't want to put the native plants in the middle of the fields," Isaacs explained. "We'd be luring the bees in and then putting them at risk of being sprayed with insecticide."

Landis anticipates that beneficial insects that walk will do better in smaller areas; those that are strong fliers will probably prefer a large area.

Besides the direct benefits to agriculture, the scientists said the native plants provide other ecological and aesthetic benefits.

"These native plants can be used to buffer ditches and streams," Landis explained, "for which the National Resources Conservation Service offers a cost-sharing program. Right now people don't commonly think of using native plants for this, but there's no reason why they couldn't be used. The native plants could also be used along fencerows to reduce invasive species while attracting beneficial insects. The native plants contribute to biodiversity and also attract birds and wildlife."

Hospitality for Michigan Bees

Because honeybee populations are declining, Isaacs and Tuell are using more than native plants to attract a variety of bees to blueberry farmers' fields — they're placing nesting boxes in the fields for certain types of cavity-nesting bees and making sure that there are spaces of open soil near the native plants so that ground-nesting bees will have a desirable place to live.

"We're trying to create a haven for native bees in agricultural land, which is complicated," Isaacs explained. "We have to find suitable places close enough to the field so the farmer gets the benefits from the bees. Many times, the open spaces on farms are not near the crop fields."

Bees do almost all the pollination for blueberries, so blueberry growers need bees to ensure a good crop. Though most farmers depend heavily on honeybees, bumblebees are actually the ideal blueberry pollinator.

"The blueberry flower needs to be shaken for the pollen to come out," Isaacs explained. "Bumblebees have some unique behaviors that allow them to do this. They can decouple their wings from the flight muscle and then vibrate to shake the flower without their wings moving. The pollen falls all over their heads, and then they deposit some on the next flower while collecting most of the pollen to carry back to the nest."

Honeybees can't shake their tail feathers or flowers like this. But honeybees are more abundant, as well as movable. Many growers use rented hives to pollinate their crops, so one hive of honeybees may move from coast to coast during the growing season, working on various crops as they come into flower. In contrast, bumblebee colonies last for only a year. In late summer, the new young queens mate (the males then die), and then each hibernates in the soil over the winter. When a queen emerges in the spring, she builds a new nest and founds a colony with her offspring. Farmers who would like to use bumblebees for pollination can purchase a new colony every year to start the spring with an abundance of bumblebees.

"Because there are more honeybees than any other bee species and because they're so flexible, they've become the world's main pollinators by default," Isaacs explained. "But the honeybee is not native to this country, and it is not well-adapted to Michigan's cool spring weather. Honeybees won't fly if it's cloudy or rainy or cold, which can be a problem some springs. We've found almost 30 species of native bees, including bumblebees, in Michigan blueberry fields during bloom. These bees are adapted to our environment.

"A long-term goal of our research is to help blueberry growers make sure their crops get maximum pollination every year," he continued, "and this will depend on having a diversity of pollinators to get the pollen moved from flower to flower."

Blueberry flowers need a certain number of pollen grains to produce quality fruit with excellent crop yield. Native bees deliver more pollen to each flower and move from flower to flower faster than honeybees. But because there are so many more honeybees, they currently do most of the pollination work at blueberry farms. The logical question, then, is if there were more native bees, would their blueberry pollination increase?

To begin answering that question, as well as determine which bee species were most abundant in blueberries, Isaacs and Tuell began a population survey of native bees 4 years ago,

Left: **Even the government recognizes the power of pollinators. In 2007, the U.S. Postal Service introduced a set of pollinator stamps featuring bumblebees, a hummingbird, a bat and a butterfly.** ***Below:*** **Rufus Isaacs and graduate student Julianna Tuell collected and identified native bees in 15 farmers' blueberry fields around the state for the past 4 years — the first comprehensive survey of native bees in Michigan blueberries. More than 150 species of bees were identified.**

the first comprehensive survey of native bee populations in the state's blueberry crop. Working with 15 farmers, the scientists collected and identified bees each spring and summer. They found a huge diversity of bees — more than 150 species were identified.

"Many of those were single individuals, but that's still a very large number of species and speaks to the insect diversity in farm landscapes," Isaacs said.

The entomologists also were interested in how farming practices affected the native bees, so they collected insecticide spray records from the growers to see if there were any links between sprays and the number of species as well as actual numbers of bees in the landscape. Most insecticides are sprayed either before or after the blueberry bushes flower. Initial results show that intensively managed fields (fields that received more sprays) had fewer native bees.

"This suggests that what growers do to control pest insects before or after flowering can affect native bee numbers," Isaacs explained. "It also suggests that if growers use IPM strategies such as scouting and biological controls to manage insects with minimal insecticide use, native bee populations would be higher."

Isaacs and Tuell also examined how the blueberry fields were managed and the types of landscapes that were around the fields. Unmown ditches were linked to high native bee populations — even small unmowed strips helped boost bee populations. The landscape factor that had the most influence on native bee populations was having natural areas nearby. In other words, blueberry fields that were next to wild natural areas were more likely to have higher native bee populations than fields that were next to another blueberry field.

In May, the researchers published what they had learned in an MSU Extension bulletin, "Conserving Native Bees on Farmland."

"The bulletin is based on our work with Michigan blueberry farmers, but the fact sheet is relevant for growers and others in the eastern United States who want to attract more native bees to their land," Isaacs said. "Right now, honeybees are the only pollinators for many farmers, but the native bees are a good insurance policy to have. This guide gives growers some simple steps toward diversifying their pollinator force."

::: Jamie DePolo

"Those unconcerned about the natural world, and I hope their numbers are dwindling by persuasion, will do well to consider the consequences for humanity of the decline of pollinator complexes. Eighty percent of the species of our food plants worldwide, we are informed, depend on pollination by animals, almost all of which are insects. One of every three mouthfuls of food we eat, and of the beverages we drink, are delivered to us roundabout by a volant bestiary of pollinators. Humanity, for its own sake, must attend to the forgotten pollinators and their countless dependent plant species."

—Edward O. Wilson, Harvard University

excerpted from the foreword of The Forgotten Pollinators *by Stephen Buchmann and Gary Nabhan*

Taking Stock:

THE STATUS OF POLLINATORS IN NORTH AMERICA

Imagine life with no chocolate or honey, no bananas or blueberries, no dates, figs or almonds. Imagine no vanilla in your cookies, no cinnamon on your cinnamon roll and no steaming cup of coffee on a cold winter morning. These and the countless other foods, beverages and spices we enjoy and derive benefit from exist thanks to the relationship between pollinators — insects, birds, bats and other animals — and the plants with which they interact. A wide variety of fibers, fuels, oils and medicines are also the result of such plant-pollinator relationships.

Pollinators are not just vital contributors to our food supply and economy — they are critical to the sustainability of our ecosystems and the biodiversity of our planet. Animal-pollinated trees and plants provide food, nesting places and shelter for a wide variety of species and contribute to many ecosystem functions, including water filtration, flood and erosion control, and the revitalization of deforested areas. Studies indicate that pollinator-plant relationships encompass almost 400,000 species, and that about three-fourths of the more than 240,000 species of the world's flowering plants rely on pollinators for fertilization and reproduction.

The Buzz over Pollinators

The past quarter century has seen increased public awareness and concern by scientists, growers, beekeepers and wildlife enthusiasts that pesticides, pollutants, disease, habitat fragmentation, overhunting and other threats have significantly reduced pollinator numbers and their ability to function. Most recently, alarm over a significant and mysterious decline in the population of pollinating honeybees — known as colony collapse disorder (CCD) — has underscored the importance of pollinators and the need to become more vigilant and knowledgeable about their health and well-being.

Five major fruit crops are 100 percent reliant on insect pollination: almond, apple, avocado, blueberry and cranberry.

MAES agricultural economist Scott Swinton was the only economist on the national committee that assessed the status of pollinators in North America. He helped the group determine the value of pollinator services, taking into account other necessary inputs that also add value.

With documented cases in Michigan and 32 other states and no definitive answer yet as to its cause, CCD has affected an estimated 600,000 of the 2.4 million bee colonies in the United States since its discovery in late 2006.

Apprehension about a potential pollinator crisis prompted the North American Pollinator Protection Campaign to ask the National Research Council (NRC) to commission a study on the situation. In response, the NRC assembled a committee of 15 biologists and other scientists from across the United States, Canada and Mexico to assess the status of pollinators in North America and produce a report on its findings.

"The charge of the committee was to compile population and trend data for both managed [including honeybees, alfalfa leafcutting bees and bumblebees] and wild pollinators [butterflies, bats, hummingbirds, wild bumblebees, etc.] and then determine to what degree, if any, they are experiencing declines," said committee chairperson May Berenbaum, entomologist from the University of Illinois, Urbana-Champaign. "In places where decline could be established, the group was asked to identify its likely causes and consequences and to make recommendations on the steps needed to prevent, slow or reverse decline."

Scott Swinton, MAES agricultural economist, was selected to serve on the committee to help shape an understanding of the economic implications of pollination.

"The NRC decided that it was important to include an economist on the committee," he said. "In addition to exploring pollinator issues related to population trends, research, monitoring and conservation efforts, there are big questions about how to determine the value of pollination services, such as the value of having healthy honeybees and the value of having pollination that allows for the reproduction of natural species."

Swinton was absolutely key to the entire process, Berenbaum noted.

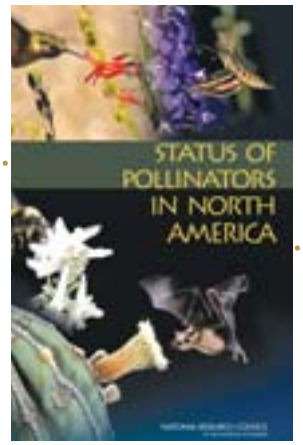
"Probably the first issue we had to tackle as a committee was to differentiate between decline and shortage — a critical distinction raised by Scott at the first meeting he attended," she said. "He really did hold our feet to the fire, as it were; he really made us appreciate the importance of economics."

Committee members spent 18 months examining and analyzing published literature, meeting with experts familiar with the lives of pollinators and interviewing people whose livelihoods depend on pollinator activities.

The committee's report, "Status of Pollinators in North America," offers a snapshot of pollinator status in the United States, Canada and Mexico, and a series of recommendations to best monitor and conserve pollinators.

Dollars and Cents: What's Pollination Worth?

An issue the committee wrestled with while compiling the report was how to determine the appropriate value of services provided by pollinators, particularly for agriculture.



"Pollination provides a wide range of services to a diversity of commodities," Swinton said. "For this reason, it is important to develop a reasonable way to assign value that gives pollination its due while, at the same time, takes into consideration other required inputs that add value as well."

According to the report, the annual value of honeybee pollination to U.S. agriculture has been variously estimated at $250 million, $1.6 billion to $5.7 billion, $9 billion, $14.6 billion and $18.9 billion. Because of his extensive background in applied economics, Swinton was able to explain why some numbers were bigger than others.

"Lots of numbers get thrown around for value; some of them are carefully developed and some of them aren't," Swinton said. "The biggest difference in the world of pollination is that some studies factor in only the direct value of pollination — the value of agricultural products that would not exist unless they had been pollinated — while others include indirect benefits of pollination in commercial worth."

The existence of an almond or a peach is a perfect example of a direct benefit of pollination, Swinton pointed out. If a flower wasn't pollinated, there would be no fruit. In other cases, pollination doesn't produce a commodity directly, but other benefits come about through food chain relationships.

For example, alfalfa seed, a bee-pollinated crop with an annual value of $109 million (direct effect) is used to produce hay (for livestock forage) that is valued at $4.6 billion per year (indirect effect).

"Pollination is not necessary to have alfalfa hay if you already have the plants," Swinton said. "But to get the plants, you have to have a pollinated seed. Because of this, some include this second-generation effect in their valuation numbers. We even found one study that included third-generation effects. A proportion of the value of all dairy product production in the United States was included because dairy cows eat alfalfa and alfalfa hay requires alfalfa seed that requires a pollinator."

So does everything in the world depend on pollination?

"The question to ask is whether it's appropriate to say that 100 percent of the value of a product such as almonds is due to pollinators," Swinton continued. "While pollination is absolutely required for agricultural products to be created, they also absolutely require land, equipment, labor and other important inputs. All of these approaches to valuation can be legitimate, but one has to be careful and not compare apples and oranges."

The Status Quo: There's A Great Deal We Don't Know

The report found that long-term population data for most North American pollinators are lacking and information about their basic ecology is incomplete, so accurate status assessments are difficult.

Still, the committee found sufficient evidence to determine the status of a range of pollinators and to gain an understanding of both the ecological and commercial value that pollinators provide.

Of the 15 recommendations offered by the committee, Swinton placed the need for improved data gathering, more research and staffing funding, and the establishment of citizen-scientist programs to help identify and monitor pollinators at the top of his list.

Since 1947, the U.S. Department of Agriculture (USDA) National Agricultural Statistics Service (NASS) has tracked honeybee colonies managed by beekeepers in the United States.

"This is a very remarkable and enduring set of agricultural production and marketing data," Swinton said. "Very few countries in the world even come close to having comparable information."

However, changes in the management and use of honeybees by beekeepers and more acreage going into production as a result of market demand for bee-pollinated food crops has greatly diminished the usefulness of traditional honeybee data collection methodologies.

"Until a few years ago, the primary focus of beekeepers was producing honey," said MAES entomologist Zachary Huang. "Bee rental for pollination activities was a secondary activity. Today, more than half of the nation's honeybees ride on trucks to California every February to pollinate the state's almond crop."

More than three-fourths of the planet's flowering plants rely on more than 200,000 species of animal pollinators to meet their reproductive needs.

Pollination services are currently estimated to be 60 to 100 times more valuable than the market price of honey, Huang noted.

For these and other reasons, improved information gathering for the beekeeping industry is critical to monitoring the status and well-being of North America's honeybee population, according to the report. Committee recommendations call for collecting annual data on bee abundance, recording pollination services, monitoring winter losses, and collecting commercial honeybee pollination data that include information on the crops pollinated and leasing fees from beekeepers and crop farmers.

COMMITTEE ON THE STATUS OF POLLINATORS IN NORTH AMERICA RECOMMENDATIONS

For managed pollinators:

- Improved information gathering for the beekeeping industry is critical, and the National Agricultural Statistics Service (NASS) should modify its data collection methodologies.
- The Animal and Plant Health Inspection Service (APHIS) should ensure that its regulations prohibit introduction of new pests and parasites along with imported bees, and Congress should expand the Honeybee Act of 1922 to include culturing of bumblebees and the fostering and breeding of other imported pollinator species.
- Through research at the Agricultural Research Service (ARS) and competitive grant programs, the USDA should expand its efforts to encourage innovative approaches to protecting honeybee health and improve genetic stocks of honeybees.
- The ARS should create research entomology positions in its fruit and vegetable laboratories in geographically diverse regions of the United States to develop new non-*Apis* [honeybee] pollinators and establish protocols for management, develop and implement bombiculture (raising honeybee colonies) disease management programs, address pathogen problems in culturing alfalfa leafcutter bees, conduct research on landscape and farm management related to pollinators, and provide guidance on pollinator-friendly management practices.
- Private-sector funding mechanisms for honeybee health and technology transfer from government research facilities should be created and enhanced to meet pollination needs.
- The USDA should establish discovery surveys for crop pollinators throughout the range of crops in North America to identify the contributions of wild species to agricultural pollination.

For wild pollinators:

- The ARS should expand basic research on the systematics of pollinators and on the development of rapid identification tools to address the taxonomic impediment to assessing pollinator status.
- APHIS should require that any commercially produced bumblebee colony shipped within the United States be certified as disease-free to prevent pathogen spillover to wild populations.
- The U.S. Geological Survey, the Fish and Wildlife Service and other agencies responsible for natural resource protection should establish discovery surveys for pollinators of rare, threatened and endangered plant species.

Seven of the nine crops that provide at least 50 percent of the vitamin C to the human diet depend partially or entirely on animal pollination: oranges, cabbages, green peppers, tomatoes, melons, tangerines and watermelon.

- The federal government should establish a network of long-term pollinator monitoring projects that use standardized protocols and joint data-gathering interpretation in collaboration with Mexico. A rapid, one-time assessment of the current status of wild pollinators in North America to establish a baseline for long-term monitoring is a laudable initial goal.
- The National Science Foundation and the USDA should recognize pollination as a cross-cutting theme in their competitive grant programs and work together to integrate research that ranges from the genomics of honeybees and the systematics of wild pollinators to the effects of global climate change on pollinator-plant interactions.
- Economic incentives for pollinator conservation should be expanded.
- As part of their outreach, federal granting agencies should make an effort to enhance pollinator awareness in the broader community through citizen-scientist monitoring programs, teacher education, and K-12 and general public education efforts that center on pollination.
- Professional societies should collaborate with landowners and the public to increase awareness of the importance of pollinators and to publicize simple activities the public can use to promote and sustain pollinator abundance and diversity.
- Congress should not consider any Endangered Species Act amendment that would create additional barriers to listing pollinator species as endangered.

"Based on the committee's recommendation, the USDA will begin to refine its data collection methodology starting with the 2007 agricultural census," Swinton said. "These changes will help beekeepers and growers to know what is going on numerically, particularly when it comes to assessing population numbers and colony health, and distinguishing between honey production activities and pollination service activities."

In addition, new management practices need to be explored to help increase the use of wild pollinator species for agriculture, the report noted. The committee called for the development of rapid response tools and the use of discovery surveys to identify the contributions of wild species to agricultural pollination and establish a baseline for future studies.

"The idea here is to get better information on native pollinators," Swinton said. "While we can do a better job of collecting information on honeybees and other managed pollinators, we already have pretty extensive historic data. With native pol-

linators, the knowledge gaps are massive, and until we know what's out there, we have no way of figuring out what needs to be done."

The committee also urged the USDA and other federal agencies to support research aimed at the sustainable management of pollinator populations.

Specific recommendations call for an expansion of the USDA's Agricultural Research Service (ARS) and competitive grant programs to encourage innovative approaches to protecting honeybee health and improving the genetic stocks of honeybees, and for the National Science Foundation and the USDA to work together to integrate research that ranges from the genomics of honeybees and the classification of wild pollinators to the effects of global climate change on pollinator-plant interactions.

As a result of the report, legislation has been introduced in Congress that would provide funding for pollinator research efforts and place a greater emphasis on pollinator conservation programs.

"Given the importance of maintaining pollinator populations and the urgency of potential pollination deficits in fruit, nut and vegetable crop acreage, more focused research into pollinators and pollination is needed," Swinton said. "This and future legislation will help ensure that adequate funding is available to address a range of pollinator challenges and conservation practices."

The committee found assessing pollinators' status to be difficult. Part of the problem is that few people are trained to recognize and properly classify pollinators, so there is almost no information on their abundance, habits or behaviors.

Partnering for Pollinators' Sake

One of the biggest challenges in monitoring pollinators is that there are very few taxonomists trained to recognize and properly classify these creatures.

"Most of us look and say, 'Oh, it's a bee,' but there are hundreds of species of bees, and it's difficult to recognize the differences," Swinton said. "Likewise, many species of butterflies, moths and beetles are pollinators. There are thousands of pollinating species out there, and we have almost no information about their abundance, behaviors or habitats."

The committee recommended a two-pronged approach: training more taxonomists as well as encouraging private citizens to participate in voluntary pollinator identification campaigns to address this issue.

"The idea here is to cultivate more experts who can begin to identify additional pollinator species and, simultaneously, engage the public in citizen science where people learn to identify certain species of pollinators and then report what they've seen and where through public databases," Swinton said. "There's a vast range of pollinators out there, and until we get more scientists and citizens involved in studying and monitoring them, we simply won't know what we have."

The process that the Audubon Society uses to conduct its bird counts is a model that Swinton believes can be used effectively for pollinator populations.

"There are thousands of birders around the nation who voluntarily submit data about bird sightings," he said. "Though the data may not be quite as reliable, the volume of data they are able to collect is amazing. We couldn't get that amount if only professional taxonomists were doing this. I believe there will be an explosion of this kind of work in the pollination world."

Pollen Nation: Food for Thought

To close the report's preface, committee chairperson Berenbaum wrote: "That the conclusions reached by the committee and presented in this report will inspire a rash of Hollywood disaster films is extremely unlikely — tidal waves, floods, fires and explosions remain inherently more cinematic than just about anything involving flowers, birds, bees and butterflies — but it is to be hoped that the recommendations will inspire discussion and action nonetheless."

Swinton holds the same hope and sees himself remaining active in pollinator discussions and research efforts.

"Participating on the committee really opened my eyes to some very interesting research issues related to pollinators," he said. "I haven't started a new research project in this area, but I am quite interested in thinking more rigorously about how we measure the value of an activity such as pollination."

The Status of Pollinators in North America report is available from the National Academies Press, 500 Fifth Street, NW, Washington, DC 20001; 800-624-6242; www.nap.edu.

::: Val Osowski

Globally, pollinators are fundamentally important for the production of roughly 30 percent of the human diet and most fibers (cotton and flax), edible oils, alcoholic beverages, nutraceuticals and medicines created from plants.

Scientists have an official name for the disappearing honeybees — colony collapse disorder.

But they don't know what's actually happening to the bees.

MAES entomologist Zach Huang has some ideas about the disease.

Going, Going, Gone

In late 2006, beekeepers across the country began to panic. Their honeybees were disappearing. Keepers would open a hive to check on the insects, and instead of the 40,000 bees they had seen just the week before, a scant 200 would be buzzing around the combs. And there were no dead bees in the hive. The bees were just…gone.

By January 2007, the entire agricultural and ecological community began to share the beekeepers' panic. Amid reports of unprecedented colony losses, bee populations were rapidly declining. Honeybees are the main pollinators for hundreds of crops — experts estimate that about one-third of the food eaten in the United States has been pollinated by the honeybee. Almonds, apples, blueberries, avocados, cherries, broccoli, pumpkins, sunflowers, and many other fruit, vegetable and nut crops are almost totally dependent on honeybee pollination. Scientists at Cornell University estimate the value of honeybees as commercial pollinators to be about $15 billion. In Michigan, about $455 million worth of crops depend on honeybees. Almond growers in California need about 1.5 million colonies to pollinate their trees during a 3-week window in late February and early March. If the bees keep disappearing, the crops eventually will, too. No other pollinator can take the place of the honeybee.

As more and more empty hives were found across the country (so far 35 states have confirmed incidents), scientists coined a new term, colony collapse disorder (CCD), to ensure that everyone was talking about the same thing. ▼

MAES entomologist Zach Huang inspects one of his hives on campus. So far, none of his bees have been afflicted with CCD. He wonders if CCD is caused by a combination of factors, which would make a definitive cause — and a cure — difficult to tease out.

"CCD is a very puzzling problem," said Zachary Huang, MAES entomologist. "So far, we've been able to rule out a number of causes. We know it's not genetic because it can't be linked to a specific queen breeder. We know it's not linked to genetically modified plants. We know it's not geographically clustered because it's been reported at locations across the country. We've ruled out radiation from cell phone towers, imadocloprid [a pesticide] and bee feeding. But we're not close to figuring out what *is* causing CCD."

In January 2007, the CCD Working Group was formed to identify the causes of the disease and develop strategies to prevent further bee casualties. Huang wasn't part of the initial working group, but he was invited to the first CCD conference in Washington, D.C., and has formed some theories about what's causing CCD. Huang also provides CCD information for Michigan beekeepers and farmers on his Web site, www.cyberbee.net.

According to Huang, CCD shows up most often in migratory colonies, though the disease is not limited to these traveling bees. Because there is such a demand for bees as pollinators, many beekeepers rent out their hives to farmers across the country. One hive could pollinate almonds in California, apples in Washington, cotton in Texas and oranges in Florida.

Reports of dead bees in Europe and China ignited fears that CCD had spread to those continents. But Huang said this turned out to be untrue. The Chinese and European bees were dying and had different symptoms than colonies with CCD.

"The latest paper on the subject postulates that CCD is caused by a pathogen," Huang said. "But because we don't have any corpses to study, it's hard to be definitive. The evidence is circumstantial."

Scientists recommend that beekeepers avoid using the old equipment that was in contact with colonies with CCD. When new colonies are introduced to the old equipment, they, too, develop CCD.

"Irradiating the equipment did seem to kill whatever is causing CCD," Huang said, "which suggests some sort of pathogen or parasite. But we don't know anything more than that."

For his part, Huang wonders if CCD is caused by a combination of factors, which would make a definitive cause difficult to tease out. On its own, each factor might be relatively benign, but when they're layered on top of one another, the result might be deadly. For example, if a hive is infested with Varroa mites, the colony is weakened — there are fewer bee offspring and more deformed bees. Varroa mites are parasites that inject an immunosuppressant into the bees while they suck the bees' blood. This could then make it difficult for the bees' immune systems to fight off other diseases. In addition, moving a hive every few weeks during pollination season

stresses the bees. While they're working as pollinators, the bees are also exposed to pesticides. In this stressed, immunosupressed, weakened state, the colony might be vulnerable to an opportunistic infection that wouldn't affect healthy bees or bees that hadn't been exposed to all these hazards.

In September, the CCD Working Group announced that a disease, Israeli acute paralysis virus, seemed to be strongly associated with beekeeping operations that had experienced big losses. The research found some evidence of the virus in some Australian bee samples, though Australia hasn't reported CCD levels comparable to those seen in the United States.

"CCD is a very puzzling problem. So far, we've been able to rule out a number of causes. But we're not close to figuring out what is causing CCD."

"This is a nice development," Huang said, "but the virus must be working together with some other factors because Canada has been importing bees from Australia, and those bees do not have CCD. Australia has the virus but not much CCD, probably because there are no mites to transmit the virus. So there's a link between the virus and CCD, but there's no proof of causation."

Intriguingly, this isn't the first time bees have disappeared. In his research, Huang found a paper from 1879 saying that honeybees seemed to have developed a "disappearing disease" that lasted for about 5 years. Other reports have described symptoms similar to those of CCD in the more recent past. Scientists are unsure if the conditions are all caused by the same factors. One thing everyone is sure of is the need for more research.

In March, a bill was introduced in Congress that would give the U.S. Department of Agriculture $50 million over 5 years to study colony collapse disorder. Legislators also are discussing a possible emergency appropriation and are considering adding research money for CCD to the farm bill. At the end of June, a group of senators upped the ante by introducing the Pollinator Protection Act, which would authorize $89 million in federal funding over 5 years for research on protecting bee and native pollinator populations.

"More work definitely needs to be done," Huang said. "If the funding is authorized, I hope to compete for some of these grants and help figure out this problem."

::: Jamie DePolo

Yulun Fu, an entomology graduate student working with Zach Huang, does maintenance on a hive at the MSU apiary. In Michigan, about $455 million worth of crops depend on honeybees.

Research *in the news*

Newly Identified Gene May Offer Clues to Infertility in Both Cows and Women

A newly identified gene that controls embryo development in cows may someday offer clues into the cause of infertility in women.

A team of researchers from Michigan State University led by George W. Smith, MAES animal scientist, has discovered that the new egg-specific gene, JY-1, is necessary for embryonic development in dairy cows. The research was reported in the Oct. 29 online issue of the Proceedings of the National Academy of Sciences.

Besides potentially offering the dairy industry more solutions for the infertility problem that costs it more than $1 billion per year, the new gene provides clues into the egg's role in embryo development and may ultimately provide new options for the more than 9.3 million women treated annually for fertility problems.

According to Smith, cows are a better model for human fertility research than the standard mouse model. Like women, cows usually release a single egg and give birth to one offspring at a time. Mice, in contrast, release multiple eggs and give birth to litters of pups.

"Our research focus is infertility in dairy cows," Smith said. "We want to understand the role of egg quality in infertility and create new solutions for dairy producers to manage their biggest problem. But there could certainly be human implications."

Smith and his team, which includes former graduate student Anilkumar Bettegowda and Jianbo Yao, a former fellow in the MSU Center for Animal Functional Genomics, as well as MAES animal scientists Paul Coussens and Jim Ireland and visiting professor Osman Patel, know the bovine chromosome where the JY-1 gene is located. A similar gene is located on the matching chromosome in humans but does not appear to be functional.

"There may be other related genes in humans that perform the same function as JY-1," Smith said. "We know this gene is necessary for cow embryos to develop, so it makes sense that humans have a related gene with a similar function."

Infertility and other reproductive problems are one of the dairy industry's biggest concerns. Pregnancy is a requirement for milk production, so if a cow can't get pregnant or can't maintain a pregnancy, a farmer suffers not only the loss of the milk but the loss of the animal and the cost of replacing her, plus higher veterinary and insemination costs.

"We now know the JY-1 gene is required for embryo development in dairy cows," Smith said. "Our next steps are to determine how the gene is regulated and how different levels of the protein affect fertility. There are still a lot of unknowns, but this is the first piece of the puzzle."

The research was supported by the Rackham Foundation, the MSU Office of the Vice President for Research and Graduate Studies, the MSU Center for Animal Functional Genomics and the Michigan Agricultural Experiment Station.

From Field to Fuel: MSU Research Drives Future Planting Decisions

Some call it corn, others call it maize, but at MSU, it's what is driving research to fuel the emerging bioeconomy.

Corn has been produced as food for thousands of years, but until recently, exploring its role in producing energy was a new frontier.

"With a growing demand for corn grain to supply the burgeoning ethanol market, the time had come to find an effective way to identify which hybrids would yield the highest amounts of ethanol," said Kurt Thelen, MAES crop and soil sciences researcher. "This type of work had never been done, so a lot of basic questions had to be answered."

Thelen's research will benefit growers seeking higher ethanol-yielding hybrids, the biorefineries set up to process corn into ethanol, and the end users who fill their vehicle or farm machinery tanks with ethanol-based fuel.

"The work we're doing is directly applicable to Michigan growers. It will not only benefit our state economically, but it will ultimately provide us with access to more sustainable and environmentally beneficial energy sources," he said. "As a state, Michigan is committed to becoming the leader in developing alternative energy sources, and research such as this helps to establish our position as a leader."

Thelen and his colleagues compared 286 hybrids under Michigan growing conditions to measure the differences in the amounts of starch-generated ethanol produced. They were surprised to find up to a 22 percent difference among hybrids.

"The variability between hybrids was surprising. We have confidence in our methods because our average ethanol yield matched up with the national average of 2.8 gallons of ethanol per bushel, but we were also surprised by the percentage differences in variability within individual fields and also across the state," he said.

The difference of a few percentage points can make a difference of thousands of dollars in return.

"For a plant producing 50 million gallons of ethanol per year, even a small increase of 4 percent in hybrid ethanol yield results in significant returns," Thelen said. "Fifty million gallons multiplied by 4 percent would result in 2 million additional gallons of ethanol per year, and at $2 per gallon for ethanol, this equals out to $4 million."

Thelen noted that researchers are only beginning to understand how crop genetics and landscape and environmental characteristics contribute to the variability of ethanol yield.

"With the 2006 crop we observed that the farther north we sampled in the state, the higher the ethanol yield. Additionally, we saw swings of 20 percent in the gallons of ethanol produced per bushel of corn depending upon where it was grown in the

same 120-acre field," he said. "Ongoing work will focus on identifying how field-level and latitudinal variability contribute to differences in ethanol yield."

The next logical step will be to apply the same types of experiments being used with corn to cellulosic sources of ethanol such as switchgrass and corn stover.

"Branching off into switchgrass and other crops to determine the role they can play in the ethanol industry will help minimize the potential ramifications of the food versus fuel debate," Thelen said. "We believe we can supply both markets."

Funding for this project was provided by Project GREEEN, the U.S. Department of Energy, Chrysler LLC and the Michigan Agricultural Experiment Station, with participatory support provided by the plant industry groups.

MSU Receives $3.5 Million Kellogg Grant to Develop Pasture-Based Animal Program

A "field-to-fork" approach to farming may ultimately offer consumers greater access to environmentally friendly food choices while enhancing the vitality of rural communities.

A 3-year $3.5 million development grant from the W.K. Kellogg Foundation will allow MSU to establish a pasture-based dairy facility at the W.K. Kellogg Biological Station (KBS) in Hickory Corners, Mich., and develop supply chains and markets for pasture-based dairy products. The dairy facility will be a focal point for research, education and outreach programs that provide farmers with information on dairy management options for moderate-sized to small operations that focus on sustainability from production through consumption.

The funds, granted through the foundation's food systems and rural development programming area, will be used to establish a pasture-based dairy facility and composting program at KBS that will be a key component of the MSU initiative in sustainable agriculture and food systems. The grant will provide partial funding to hire two new faculty members in animal grazing ecology and human ecology in rural development. The grant also will provide seed funding for research, outreach and education programs focused on ecological and environmental aspects of animal production, rural community development, and the processing, distribution and marketing of pasture-based dairy products.

"To ensure the vitality of rural communities, it is important that we create better market opportunities for small and mid-sized farms," said Mike Hamm, MAES scientist who holds the C.S. Mott Chair for Sustainable Food Systems. "These farms are the backbone of communities — as food providers, purchasers of local goods and services, employers, taxpayers and stewards of the landscape. Expanding production options that improve the viability of these farms will help strengthen healthy rural economies and communities."

The project team hopes to strengthen distribution networks and demand for locally grown animal products raised on pasture. Developing markets based on the place and method of production will help small and medium-scale farms in Michigan to maintain an added-value advantage for which consumers are willing to pay a premium.

"This program will provide a unique opportunity to evaluate how an animal production system operates in the context of other aspects of the landscape — agricultural, managed and natural," said Kay Gross, director of the Kellogg Biological Station. "KBS is well-suited for this type of work because of the strong programs in ecology and sustainable row-crop agriculture that we have here."

The conventional dairy operation currently operated at KBS will be converted to a pasture-based program over the next 2 years. A 120-cow milking herd will be maintained on an intensively managed rotational grazing system and on a replicated plot-based pasture system. A portion of the milk produced at KBS will be used for production of cheese at the MSU Dairy Plant.

"The development of a pasture-based dairy at KBS allows us to expand our portfolio of production alternatives for farmers and to develop new research and outreach programs that fit with interests and needs of diverse farm stakeholders," said Karen Plaut, chairperson of the MSU Department of Animal Science.

In addition to the development of a pasturing program at KBS, the initiative will support connections to farm-based and high school-based satellite sites across Michigan focusing on sustainable crop and animal production. Education and outreach programs will extend to MSU undergraduate and veterinary medicine curricula, as well as to primary and secondary school programs, farmers, consumers and public officials.

MAES Scientist Edits New Journal on Biofuels, Bioproducts and Biorefining

As societies around the globe look to reduce their dependence on petroleum-based fuels, plants and other biobased materials are being viewed as the raw materials for fuels, chemicals and other products. But making the change to products made from renewable resources will require new skills, knowledge and research.

"The movement toward a bioeconomy presents great opportunities for forward-thinking institutions to become catalysts for beneficial change and reap the related benefits," said Bruce Dale, MAES chemical engineering and materials science researcher and Office of Biobased Technologies associate director. "But given the breadth of the issues involved — agronomy, public policy, microbiology and chemical engineering, to name just a few — and the depth of expertise required along with that breadth, it may be difficult for many institutions to successfully navigate the bioeconomy transition."

To help a wide variety of institutions understand and better manage the bioeconomy transition, a new journal, Biofuels, Bioproducts & Biorefining (BioFPR), has been launched with Dale as editor.

"This is not another technical journal," Dale explained. "Many good technical journals already exist in related fields. BioFPR will provide reviews by recognized experts across the breadth of related issues, perspective pieces and many other services to help move the bioeconomy forward."

BioFPR bills itself as the definitive source of information on sustainable products, fuels and energy. Each issue will present a

mix of news, patent intelligence and feature articles, as well as peer-reviewed articles.

The journal is published by the Society of Chemical Industry (SCI) and John Wiley & Sons Ltd. BioFPR subscription information and selected free content are available online at http://www.biofpr.com/index.html.

Marrying Natural and Social Sciences for Mother Earth's Sake

No one says marriage is easy — but an international group of 16 natural scientists and social scientists, including three from Michigan State University, are saying that the wedding of natural sciences and social sciences is called for.

For the first time, a paper published in the Sept. 14 edition of the journal Science synthesizes complex characteristics when humans and natural systems couple up, using six case studies from around the world. To understand the complex world and to enable good science to transform to good policy, specialization must ease up, according to the paper "Complexity of Coupled Human and Natural Systems."

"In the past, natural scientists such as ecologists often excluded humans from considerations, while social scientists usually ignored the impact of natural systems on the humans, although humans and natural systems interact with each other as coupled systems," said Jianguo "Jack" Liu, lead author of the paper and Rachel Carson Chair in Ecological Sustainability at the MSU Center for Systems Integration and Sustainability. Liu is an MAES scientist. "As the world is becoming increasingly connected in various ways, there is an urgent need to integrate natural sciences and social sciences to understand global challenges and develop feasible policies for effective solutions to complex problems."

The case studies represent both urban and rural areas; both developed and developing countries; and various ecological, socioeconomic, political, cultural and geographic settings. They provide excellent information for comparing and contrasting complex aspects of systems on five continents — Africa, Asia, Europe, North America and South America.

All of the example systems are faced with pressing environmental and human challenges. In Kenya, forests give way to croplands, cropland soil degradation causes more poverty, and more poverty leads to more deforestation. In China, tourism, residents and pandas vie for real estate. In Washington state's Puget Sound, single-family housing crowds rich bird habitats; in Wisconsin's Northern Highland Lake District, recreation affects sensitive fish habitats. In tropical Altamira, Brazil, crop changes and recent deforestation take a toll. And in Vattenriket, Sweden, land use choices made several hundred years ago continue to have impact on a wetland of international importance.

The case studies look not only at landscape patterns, wildlife habitat and biodiversity but also at socioeconomics, policies, governance and social networks. They examine complex ecological and socioeconomic patterns and processes over time and across space. They analyze and look to understand why policy often didn't produce the expected outcome.

For example, in Wisconsin, where indigenous populations compete with recreation, smelt was introduced as a food source for game fish such as walleye. The plan backfired when the smelt gobbled the young walleye, decimating the population.

"Everyone wants to preserve parts of the past but not the same parts, so people have different visions of the future," said Steve Carpenter, a co-author of the paper and Stephen Alfred Forbes Professor of Zoology at the University of Wisconsin in Madison. "These differences drive the politics of change in the region. Our research uses the Northern Highland of Wisconsin to understand key aspects of change in a region where ecosystems and society are closely connected."

The study of the Wolong Nature Reserve in southwestern China, which is one of the largest homes to the endangered giant panda, found that policies to conserve panda habitat had unexpected effects on people and panda habitat. For example, a natural forest conservation program to prevent illegal forest harvesting spurred many new households to form by splitting existing households into smaller ones because the government's incentives were provided on a household basis. Generally speaking, more households demand more land for housing and more energy for heating and cooking, and smaller households are less efficient in resource use per person than larger households.

All the studies show that the path from cause to effect is often not a straight line and that, in some cases, effects take decades to emerge. Modern life has raised the stakes, Liu said. The global neighborhood is more crowded.

"Even 50 years ago, the world population was only 40 percent of today's population, humans used fewer resources and didn't have as much environmental impact as today," Liu said. "Now resources are getting more and more limited. The number of households is increasing much faster than population size, and the demands for resources and consumption are skyrocketing.

"A lot of things are getting closer to the threshold. If you have a little bit more, the whole system may collapse."

"Government agencies have recognized for a number of years the need for researchers who can cross the boundaries between the social and natural sciences because they have to confront real-world problems where the ecological and social systems interact," said Thomas Dietz, paper co-author and MSU assistant vice president for environmental research and director of the MSU Environmental Science and Policy Program. "Some approaches, like those we review in this study, are focused on local systems. Others, like many studies of climate change, compare nations or look at the global system. We need all these approaches."

"The future of a sustainable environment demands that scientists and policy-makers understand the coupling of human and natural systems," said William Taylor, another paper co-author and chairperson of the MSU Department of Fisheries and Wildlife. "Without such understanding and systems thinking, we are doomed to degrading environments, reduced biodiversity, social instability and an overall decline in the quality of life. I am optimistic that the approach of

coupling human and natural systems will provide the road map for enhancing our abilities to develop the needed governance systems to ensure a socially and ecologically sustainable future."

The research was funded by the National Science Foundation, the National Aeronautics and Space Administration, the National Institutes of Health, the National Natural Science Foundation of China, MSU (the Michigan Agricultural Experimental Station, the Rachel Carson Chair in Sustainability, the University Distinguished Professorship and the Environmental Research Initiative), the Swedish Research Council for the Environment, Agricultural Sciences and Spatial Planning, and the Swedish Foundation for Strategic Environmental Research.

Boone and Crockett Club to Establish Wildlife Conservation Endowed Professorship

A century after President Theodore Roosevelt visited Michigan Agricultural College, an exclusive organization that he founded will establish an endowment to cultivate future leaders in wildlife conservation and management.

The Boone and Crockett Club, established in 1887 to conserve North American wildlife and the fair chase ethic, has announced $1.4 million in gifts and pledges and $350,000 in planned gifts to create the Boone and Crockett Club Professorship in Wildlife Conservation at MSU. This represents half of the $3.5 million goal the club has set for the endowment.

According to Bill Demmer, Lansing businessman and Boone and Crockett Club vice president for conservation, the endowed chair will work to create both future leaders for state, tribal, national and global wildlife resource management agencies and a public more informed about wildlife conservation.

"We are delighted to partner with Michigan State University to establish this endowed professorship," Demmer said. "The individual selected will not only be a national and international leader in science-based wildlife management and conservation but will establish exemplary teaching, research and outreach programs that will develop tomorrow's visionaries and leaders."

The Boone and Crockett Club endowed chair will be housed in the Department of Fisheries and Wildlife and will collaborate with other units across campus; the Michigan Department of Natural Resources; other state, federal, tribal and international resource management agencies; and non-governmental wildlife conservation organizations in Michigan and across North America.

"This professorship will attract the best and brightest young minds to Michigan State University for both undergraduate and graduate study," said William Taylor, chairperson of the Department of Fisheries and Wildlife.

"The fact that the Boone and Crockett Club has selected MSU for this endowment is a wonderful tribute which underscores our strong tradition of forging partnerships with organizations with similar missions and values," Taylor continued. "The establishment of the Boone and Crockett Club Professorship in Wildlife Conservation at MSU demonstrates the essential nature of this great land-grant institution, innovatively bringing together citizens, policy-makers and the academic community to develop the public leadership which will serve to enhance the ecological, social and economic well-being of Michigan and North American wildlife resources in the years to come."

Plant Viruses from Past Provide Ecological Clues

Taking the medical history of a grassland may seem a bit esoteric — after all, how sick can grass be? However, scientists have discovered plant viruses from as early as 1917 containing information crucial not only for plant scientists but also for those working in ecology, human health and bioterrorism.

Carolyn Malmstrom, MAES plant biology scientist, isolated historical viral RNA sequences in native and invasive grasses revealing a complex picture of struggles of species, interactions with insects and implications for the ways viruses behave today. The findings were reported in the Oct. 16 edition of the Journal of Ecology.

"This work points out that the virus world does have an active, long-term role in nature, not just in agriculture," Malmstrom said. "We very much need to understand how viruses can move and influence our crops. If we care about our crops, we need to care about what's happening in nature."

When living in northern California, Malmstrom noticed that a walk through grasslands dominated by nonnative annual plants meant getting covered in aphids, an infestation that wasn't typically seen in perennial grasses indigenous to the area.

It made her wonder what the differences were — and what that meant to the overall health of those ecosystems.

Those questions ultimately led to viruses, which can be spread among plants by aphids the way that mosquitoes spread disease among humans. Malmstrom explained that little is known about viruses in nature — that's usually a discussion reserved for agricultural crops. But recent advances in molecular techniques have unveiled natural systems teeming with viruses and thus raised the question of what the impact of those viruses is.

"We've always assumed viruses largely are manifested in agricultural systems because the system is unbalanced due to human interaction," Malmstrom said. "But now we are understanding that viruses are more common in nature than people realize — and that there's a whole class of biological interactions going on out there that we know hardly anything about."

The paper deals with historical virus ecology — understanding how viruses affected grasslands years ago. The team examined dried California grasses in plant collections from the early 1900s. Unprotected, RNA typically degenerates quickly, but Malmstrom's group discovered that the old RNA in these descendents of common grain viruses had been protected by the viruses' exterior proteins and could still be recovered almost a century later.

"These are the oldest plant viruses anyone has gotten out of plant material in North America," Malmstrom said.

The work suggests that these barley and cereal yellow dwarf viruses may have helped invasive grasses take over California in the 18th and 19th centuries.

The history, Malmstrom said, is important in understanding how viruses spread and change. People have been bringing in new species of plants to the New World since Columbus arrived in the 15th century, and these invasions rocked the ecological world. In California, native perennial grasses gave way to new annual grasses, and aphid populations grew larger. Because aphids can carry viruses over long distances, increases

in their numbers can alter disease dynamics over a large area. In California, more native grasses likely got sick after Europeans arrived, just as Native Americans did.

"We are able to take modern and historical viruses and put them in a family tree so we can start investigating how far back different virus groups split from each other," Malmstrom said. "Our work suggests that some of the big branching of viruses happened during early global exploration by humans. We want to understand how human influence shapes how viruses evolve."

The work was funded by the National Science Foundation and also supported by the Michigan Agricultural Experiment Station.

Microbiology No Small Matter in Updated Reference Manual

A new, state-of-the-art reference manual for microbiologists has just been released, thanks to the efforts of MAES scientists C.A. Reddy, Tom Schmidt and John Breznak. The book, Methods for General and Molecular Microbiology (now in its third iteration), has long served as the first source for traditional microbiology techniques and commonly used modern molecular microbiological methods.

MSU microbiologists have edited and compiled the manual for 26 years.

"MSU has traditionally been strong in microbiology," said Reddy, who served as editor-in-chief for the 1,069-page third edition. "We have three members of the National Academy of Sciences in the department right now: James Tiedje, Richard Lenski and Michael Thomashow. That's quite an honor. And the microbial ecology group here is well-known throughout the world."

Reddy was tapped as editor-in-chief for his expertise in microbiological processes and his experience in editing various publications, Schmidt explained.

Though many other microbiology manuals are available, they largely address more contemporary methods. Many of the books on traditional methods are out of print and difficult to find.

"This book encompasses the new methods and includes the framework of the classical methods that people are still using every day," Schmidt said. "As far as we know, it's the only book of its kind. The biggest challenge was keeping it to one volume so it could be kept in the lab for easy reference."

The editing team, which also included MSU researcher Loren Snyder and scientists from the University of Guelph and Ohio State University, made the new edition more expansive by adding two entirely new sections on fungi and community and genomic analysis and compiling 47 chapters (there were 31 chapters in the previous edition).

Even though the book was overseen and produced by MSU faculty members, its authorship and use are international.

"There are contributors from across the United States and throughout the world, including Africa, Asia, Australia, Canada, Europe, Germany, India, Israel, Scotland and Switzerland," Schmidt said. "It's not a parochial view of the methods, and all the authors are authorities in their respective fields."

The Manual for General and Molecular Microbiology is available from the American Society for Microbiology (ASM), 1752 N. Street NW, Washington, DC 20036; 202-737-3600; www.asm.org.

New Faculty Members

The MAES is pleased to welcome the following four new faculty members with MAES appointments.

Andrew Finley, assistant professor of forest management and modeling, became affiliated with the MAES in August. His research areas include natural resource inventory, Bayesian and spatial statistics, and statistical computing. His research focuses on spatiotemporal modeling of important economic and ecological forest attributes, indices of biodiversity and ecological systems. A central theme in his research is the use of models to integrate information from various sources to improve inference and predictions.

Finley received a doctorate in natural resources science and management and a master's degree in statistics from the University of Minnesota in 2007, a master's degree in forestry from the University of Massachusetts in 2003, and a bachelor's degree in forestry from Pennsylvania State University in 2000.

Matthew Grieshop was named assistant professor of entomology in October. His research goals are to develop new pest management tactics and strategies that enhance ecological and economic sustainability within the philosophical framework of organic agricultural practices. More specifically, he's interested in how "weaknesses" in pest life history or behavior can be exploited for pest management as well as the refinement and extension of newly developed pest management in cooperation with organic producers.

Before coming to MSU, Grieshop served as a postdoctoral research assistant at Washington State University since 2005, studying how to improve mating disruption of tree fruit pests. He received his doctorate in entomology from Kansas State University in 2005, his master's degree in entomology from Montana State University in 1999 and his bachelor's degree in environmental studies from the University of California-Santa Cruz in 1995.

Jennifer Lau, assistant professor of plant biology, became affiliated with the MAES in August. Her research bridges community ecology and evolutionary biology to explore how plants interact with both the biotic and abiotic environments and how the plants respond to multiple selective pressures. She is particularly interested in studying the indirect effects that occur when changes in the biotic or abiotic environment change interactions between plant community members.

Based at the Kellogg Biological Station in Hickory Corners, Lau has been an MSU faculty member since June. She received her doctorate from the University of California-Davis in 2005.

Janet Lewis, assistant professor of crop and soil sciences, became affiliated with the MAES in October. Her research focuses on developing soft red and white winter wheat varieties for Michigan with improved yield, milling and baking qualities, and resistance to biotic and abiotic stresses. She's also working on identifying and understanding resistance to *Fusarium* head blight, also known as wheat scab, a problem fungal disease for Michigan growers that affects yield and quality. Scab is also a health concern for humans and animals because the fungus produces mycotoxins.

Before coming to MSU, Lewis spent a year as a postdoctoral fellow in a small grains genomics laboratory at the University of Minnesota and 2 years as a postdoctoral fellow at the International Maize and Wheat Improvement Center in Mexico. She received her doctorate in crop and soil sciences and plant breeding and genetics from MSU in 2004 and her bachelor's degree in botany from the University of Michigan in 1997.

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