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Published Since 1957

LOUISIANA Agriculture

Assuring Our Future Through Scientific Research and Education

Balancing the BENEFITS and CHALLENGES of Louisiana's insects

LSU AgCenter
Research · Extension · Teaching

Louisianians and Insects: A Long History of Benefits and Battles

Kyle Peveto

As long as Louisiana has been settled, its humans have had to learn to live with insects.

The written entomological history of this region's insects began almost three centuries ago, said Rogers Leonard, who recently retired as the AgCenter associate vice president and program leader of animal and plant sciences.

An entomologist, Leonard spoke about the history of entomology in Louisiana when he was the featured speaker at the LSU AgCenter Department of Entomology Jerry B. Graves Distinguished Seminar Series in November 2019.

Rogers Leonard, left, receives the Jerry B. Graves Distinguished Lectureship award from Jerry Graves, professor emeritus in the Department of Entomology, in November 2019, when Leonard gave a talk on the history of entomology in Louisiana. Graves was Leonard's major professor. Photo by Kyle Peveto

"I was once told that history can be a dangerous thing," Leonard said. "It represents the past and may be an indicator of things to come, not a guaranteed predictor of the future."

The entomology of Louisiana was first documented in 1758 by the naturalist Le Page du Pratz. He wrote about pests in and around New Orleans, including cockroaches, lice, grain weevils and flies.

During his presentation, Leonard noted the historical firsts in Louisiana. In 1804, eight years before Louisiana was admitted into the United States, honeybees were first recorded, Leonard said. The nation's first insecticide law was passed in Louisiana in the 1890s to control the purity of Paris green, a pigment that became an insecticide.

Early entomologists were often jacks-of-all-trades, Leonard said, studying insects along with art, medicine or other animals.

"They had little competition and were armed with the fact that a poorly educated public saw a clear need for pest management all across the board, urban as well as rural, to protect their food, homes and health," Leonard said.

The federal Hatch Act of 1887 created funding for more agricultural experiment stations, and the Smith-Lever Act of 1914 officially created state cooperative extension agencies to work with land-grant universities.

H.A. Morgan became the first entomologist working for the Louisiana Agricultural Experiment Station, which is part of the AgCenter, in 1889. The state of Louisiana hired its first state entomologist, C.O. Hopkins, in 1929.

Across the South, producers fought the boll weevil in their cotton fields with the pesticide DDT. In 1955, researchers documented that the pest had become resistant to DDT. Jim Brazzel, one of the researchers who wrote the 1959 paper that led to the program that officially eradicated the boll weevil, was a graduate of LSU, Leonard said.

Many entomologists in Louisiana have worked on the control of red imported fire ants, which have pestered homeowners and livestock producers for decades. The Louisiana Legislature put eradication of the red imported fire ant in the state budget, Leonard said, creating an initiative for areawide control in 2000.

Leonard encouraged his fellow scientists to consider this history as they face the challenges of the future.

"We must always look forward, but we have to understand our history in order to not repeat the mistakes of the past," he said.

Kyle Peveto is an assistant specialist with LSU AgCenter Communications.

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ON THE COVER: Beetles, which include weevils, are the most diverse order of life on the planet. The jewel beetle displays a striking diversity of both iridescent and pigmented coloration. The way beetles view color is one way they communicate, a process being studied by Nathan Lord, assistant professor in the LSU AgCenter Department of Entomology. Photo by Nathan Lord

AgCenter NEWS

4-H keeps students involved during pandemic

Second-grader Piper Jones, a member of 4-H Cloverbuds in Richland Parish, displays cupcakes in a virtual cooking contest.

Because connecting with friends and participating with peers in learning activities is important for youth even when shuttered at home during the COVID-19 pandemic, LSU AgCenter 4-H agents are recreating 4-H Club experiences virtually to supplement classroom learning at home.

Since most parish 4-H programs offer special awards for outstanding members based on participation in or completion of certain projects, many virtual events have been adapted to meet those criteria. Online pet shows, talent competitions, and photography and art contests are just a few. Even cooking contests have found a place online with weekly themed challenges emphasizing breakfast, lunch, dinner or snack recipes.

Richland Parish 4-H agent Joanna Strong first posted food safety tips and healthy recipes on Facebook, then encouraged 4-H Club members to prepare their favorite dish and submit a photo for the competition. **Karol Osborne**

AgCenter website helps fishing industry during pandemic

Lance Nacio makes a sale of fish to a consumer on April 9 in Lafayette. Nacio, a third-generation fisherman, from Montegut, said the direct sales are a boost for his struggling business. Photo by Bruce Schultz

Fisherman Lance Nacio, of Montegut, Louisiana, is trying to keep his struggling seafood business going, one sale at a time. With curtailed restaurant operations during the pandemic, he and other fishers have had difficulty selling their catch.

Nacio, a third-generation fisherman, set up a pop-up sale in the parking lot of Randol's Restaurant in Lafayette, which was promoted on the Louisiana Direct Seafood website and on Facebook.

Thomas Hymel, LSU AgCenter and Louisiana Sea Grant fisheries agent, said the direct sales facilitated by Louisiana Direct Seafood is allowing seafood businesses to continue cash flow, although it's considerably less than the revenue before the pandemic.

Consumers can buy products from Louisiana fishermen and have them delivered to their homes by shopping on the website at https://louisianadirectseafoodshop.com/shop/. **Bruce Schultz**

Local farmers unsung heroes during pandemic

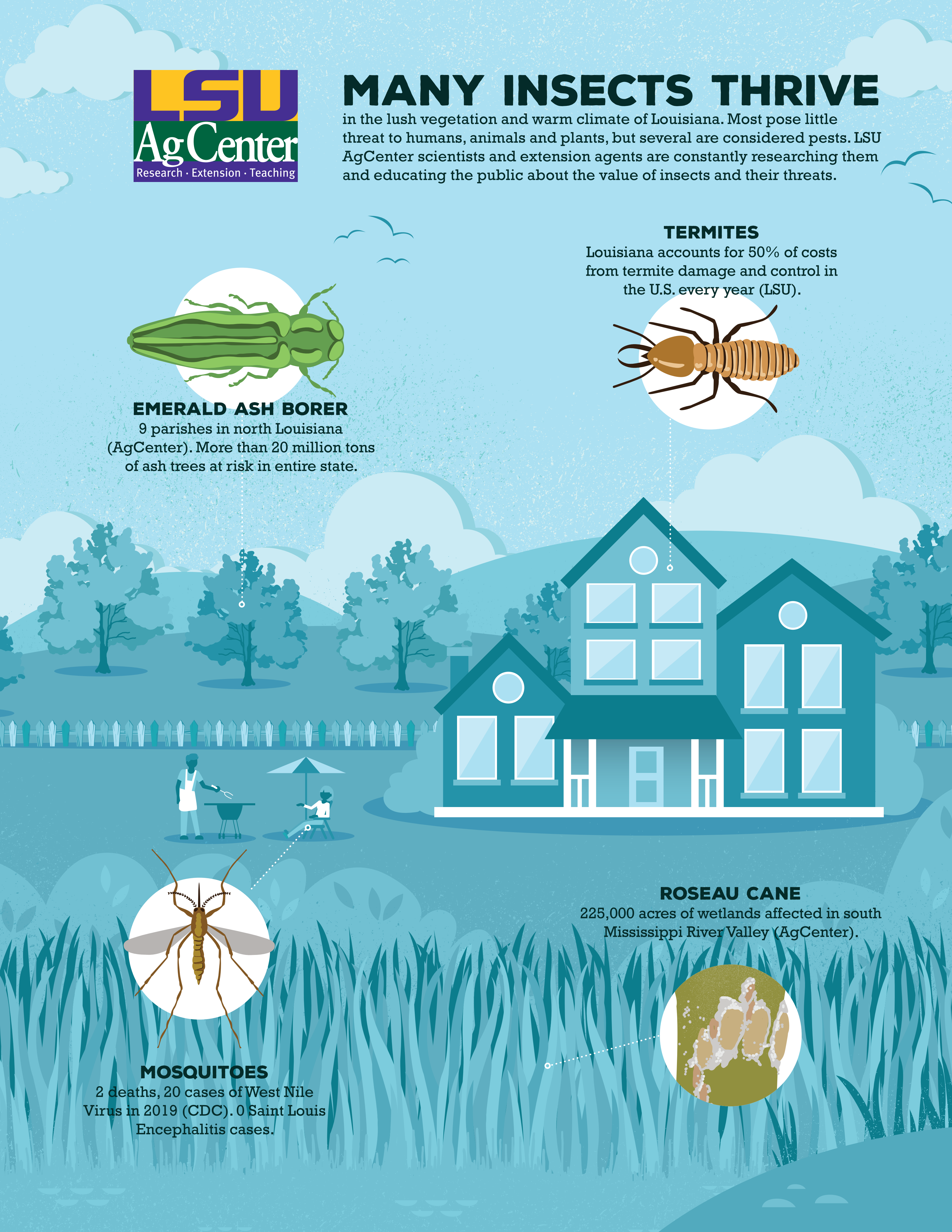
Boxes of vegetables are ready for pickup at the Red Stick Farmers Market in Baton Rouge. For several months, the regular farmers market setup was converted to a drive-thru format. Photo by Randy LaBauve

Local produce farmers have been unsung heroes during the coronavirus crisis — continuing to safely provide a steady supply of fresh, healthy produce, despite severe restrictions for public safety.

"The farmers markets and farmers are adapting," said Carl Motsenbocker, LSU AgCenter director of the Louisiana Farm to School Program. "Most of our horticultural farmers are entrepreneurs, and they see this as an opportunity."

The AgCenter Farm to School Program and the Louisiana Department of Agriculture and Forestry have developed a directory of local farms and businesses to help consumers find fresh foods near their homes. The resources can be found online at http://www.ldaf.state.la.us/covid-19/ under the "LA Farm Food Map and Directory" tab. **Randy LaBauve**

Find educational resources about the COVID-19 pandemic and links to updated information on the LSU AgCenter website at https://bit.ly/2N2DJkh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MANY INSECTS THRIVE
in the lush vegetation and warm climate of Louisiana. Most pose little threat to humans, animals and plants, but several are considered pests. LSU AgCenter scientists and extension agents are constantly researching them and educating the public about the value of insects and their threats.
TERMITES
Louisiana accounts for 50% of costs from termite damage and control in the U.S. every year (LSU).
EMERALD ASH BORER
9 parishes in north Louisiana (AgCenter). More than 20 million tons of ash trees at risk in entire state.
ROSEAU CANE
225,000 acres of wetlands affected in south Mississippi River Valley (AgCenter).
MOSQUITOES
2 deaths, 20 cases of West Nile Virus in 2019 (CDC). 0 Saint Louis Encephalitis cases.

INVESTIGATING INSECTS

Entomologists from the LSU AgCenter study insects that threaten crops and the health of humans as well as those that are beneficial and help control the populations of other pests. Out of the hundreds of thousands of insects that have been identified in America, these four are receiving a great deal of attention from scientists because of the ways they affect our lives.

Termites

The most common urban termite pest in Louisiana, the Formosan subterranean termite, is found in 41 of the 64 parishes of Louisiana. Known for swarming in the spring, Formosan termites are native to China and entered Louisiana through the port of New Orleans in the 1960s. Termite treatment and damage cost $500 million a year in Louisiana, according to a 2015 study by AgCenter researchers.

AgCenter entomologist Claudia Husseneder is studying a modified yeast that can kill gut organisms used in digestion, and AgCenter entomologist Karen Sun is studying how Formosan termites communicate chemically and how they respond to the environment. "We hope to understand why this termite is so successful and figure out ways to aid in pest control by manipulating their social behavior," Sun said.

Mosquitoes

Mosquitoes may be the most despised pest in Louisiana. In addition to annoying many animals and humans, these tiny insects also carry disease. Throughout the 1800s, yellow fever, spread by the *aedes aegypti* mosquito, could kill thousands in Louisiana each year. Mosquito-borne diseases remain dangerous. St. Louis encephalitis still sickens Americans each year, and West Nile virus kills Louisiana residents each year. To monitor and control mosquitoes, 22 parishes fund mosquito control districts. Also, AgCenter extension agents and researchers continue to study these insects and educate the public about ways to protect themselves and their animals.

Roseau cane scale

Roseau cane is an important Louisiana Gulf Coast marsh grass that provides habitat for fish, birds and other wildlife and reduces erosion. When die-offs of roseau cane in the Mississippi River Delta were noticed in 2016, scientists suspected many causes. One of the major stressors, researchers suspect, is the roseau cane scale, an invasive insect from China and Japan. The scales feed on plant tissues and are attacked by three parasitoid wasps. LSU AgCenter entomologist Rodrigo Diaz is researching the scale and is working with state and federal agencies and private citizens to better understand the problem and protect the coast.

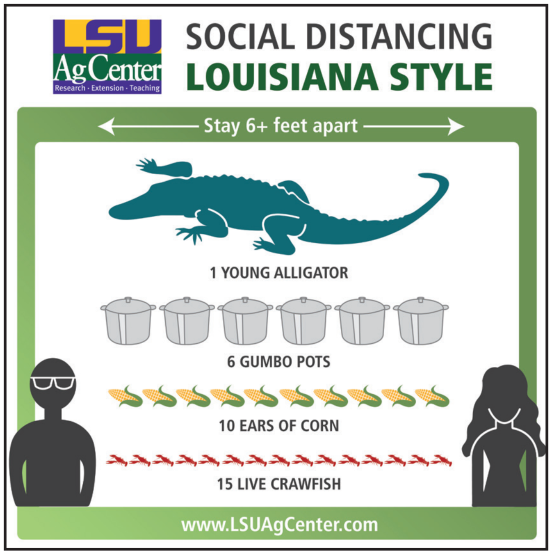
Emerald ash borer

Since its discovery in Michigan in 2002, the emerald ash borer has destroyed millions of trees in more than 30 states. In 2015, the small metallic green insect was found infesting trees in Webster Parish, Louisiana. It has now been found in nine parishes in northern Louisiana. At risk are more than 20 million tons of ash trees in rural Louisiana — 5% of hardwood trees in the state, according to an AgCenter analysis. The pest has also been found to affect olive trees and white fringe trees, both popular ornamental species in the state. AgCenter entomologist Nathan Lord has received a National Science Foundation grant to study jewel beetles, which include emerald ash borers. Lord is researching the visual systems of these beetles to determine how they see and use color. The research could make it possible to alter their vision and reduce or prevent their ability to locate mates or host plants.

From Our SOCIAL MEDIA

Join the LSU AgCenter on social media. AgCenter researchers and extension agents reach out via the web with videos, articles and helpful hints on Facebook, YouTube, Twitter and Instagram.
Join the conversation by following the LSU AgCenter.

INSTAGRAM | Follow the AgCenter at instagram.com/LSUAgCenter



APR 20 | Social distance Louisiana style! Share with your friends. #LSUAGCENTER #SOCIALDISTANCING #COVID19 #STAYSAFE #STAYHEALTHY #KEEPYOURDISTANCE #LOUISIANA

YOUTUBE | View these videos and our extensive archive at youtube.com/user/LSUAgCenter

JUNE 5 | LSU AgCenter agricultural specialists met at D & D Berry Farm in Breaux Bridge, Louisiana, to discuss their latest research and recommendations for growing blackberries. This discussion about blackberry varieties was part of the 2020 LSU AgCenter blackberry field day.

FACEBOOK | Follow the AgCenter on Facebook at facebook.com/LSUAgCenter

MAR 26 | Welcome to the LSU AgCenter's LIVE at 5 Facebook series. This livestream session is all about wild turkeys and features Bret Collier, LSU AgCenter associate professor of wildlife ecology, and Michael Chamberlain, University of Georgia professor of wildlife ecology and management. Ask any turkey questions you have!

APR 21 | 4-H Virtual Recess: All About Pigs
Tyler Braud, 4-H livestock specialist, gives a lesson on pigs, including breeds, ear notching and terminology! 4-H Virtual Recess is a program designed to keep kids' minds and bodies active through daily virtual activities/challenges during COVID-19.

TWITTER | Follow the AgCenter at twitter.com/LSUAgCenter

APR 24 | Researchers with the LSU AgCenter are exploring an early producing blueberry, the Southern highbush blueberry. #LSUAGCENTER #RESEARCH #BLUEBERRY

College of Ag NEWS

Graduate student showcases research at national meeting

LSU College of Agriculture graduate student Olanike Omolehin, center, was one of five research award winners selected by the American Phytopathological Society to present research at their national meeting in Washington, D.C. Omolehin, a Ph.D. candidate in the Department of Plant Pathology and Crop Physiology, presented "Aflatoxin management in maize through host-induced gene silencing." Her major professor is Zhi-yuan Chen.

For more information about the many opportunities in the LSU College of Agriculture, go to https://www.lsu.edu/agriculture/

Two students receive year-end awards

Elizabeth Sicard was named the Gerald and Norma Dill Outstanding Senior in the LSU College of Agriculture. Sicard is receiving a degree in natural resource ecology and management with minors in geology and oceanography. During winter 2019-2020, she was selected for a research experience at the McMurdo Station, a U.S. research station in Antarctica. During summer 2018-2019, she was selected for an Experiential Professional Learning Opportunities in Research and Education (EXPLORE) internship. Sicard also was a member of Tiger Band and Bengal Brass and provided service to the Green Force and Christ the King Service Team for BREC, which is the Baton Rouge agency for parks and recreation facilities.

Brooke Comeaux, junior studying animal sciences and agriculture and extension education, received the K.C. Toups Memorial Les Voyageurs Award. Les Voyageurs are student ambassadors for the college. Comeaux has been a Les Voyageur for two years and participated in service activities and a study abroad program in Nicaragua as part of her work with the organization. **Tobie Blanchard**

Elizabeth Sicard

Brooke Comeaux

Six students receive $2,000 scholarships

Students who received $2,000 scholarships from individuals and corporations at the Louisiana Agricultural Consultants Association annual meeting were, left to right, Bryan Ashley, Anna Coker, Megan Mulcahy, Jose Mite Caceres, Ateet Maharjan and James Noah Harper. All of the students attend LSU except Ashley, who attends the University of Louisiana at Monroe. Photo by Bruce Schultz

College of Agriculture names outstanding alumni

The LSU College of Agriculture has named Rogers Leonard and David Wilson as outstanding alumni for 2020. Marshall Hardwick received the early career alumni award.

Leonard is a three-time graduate of the college, having received a B.S. in agronomy in 1984 and an M.S. and Ph.D. in entomology in 1987 and 1990, respectively. He has served the agricultural stakeholders in Louisiana for more than 36 years in various positions with the LSU AgCenter, retiring earlier this year as associate vice president and program leader for plant, animal and natural resources. He has garnered many accolades in the field of entomology and is considered a foremost authority on cotton entomology and field crops entomology, not only in Louisiana and across the United States, but internationally as well.

Wilson is a 1979 graduate in animal sciences and recently retired after a 40-year career in farm credit. Nominators said Wilson has always been a mover and shaker in the agricultural community, participating in countless agriculture-related activities over the span of his career. In addition to his professional accomplishments, Wilson maintained a prominent presence as a livestock judge and served on the board of the East Baton Rouge 4-H Foundation.

Hardwick received a B.S. in agricultural business in 2011 and a M.S. in agronomy in 2013 from the college. He is a partner in Hardwick Planting company, an 8,000-acre family-owned farm. The farm's acres are diversified in cotton, corn, soybeans, grain sorghum, peanuts, sunflowers, wheat and timberland. Hardwick is considered a leading advocate for U.S. agriculture. **Tobie Blanchard**

Rogers Leonard

David Wilson

Marshall Hardwick

New Faculty PROFILE

Childhood Fascination Turns into Globe-Trotting Career for Nathan Lord

Tobie Blanchard

What started in Nathan Lord's backyard has led him around the world. Lord, an entomologist and director of the Louisiana State Arthropod Museum, said he was always collecting and sorting insects as a child growing up in Georgia, a fascination he said he had the good fortune to never outgrow.

"I always liked insects and beetles. I liked classifying them in some way," Lord said.

"I used my mom's jewelry box, and I would sort insects I found in there by color, by their size."

Lord was also a talented musician. He played with the Atlanta Symphony Youth Orchestra and statewide bands. He debated whether to pursue a career in music or insects. A self-guided entomology course in high school started to solidify his passion. Lord majored in entomology at the University of Georgia and kept his love for music alive as a member of university's marching band.

It was at the University of Georgia where he realized his interest in classifying insects was taxonomy and where he discovered he could travel the world doing what he had loved doing as a child.

"I got to go to Bolivia for fieldwork, and I was like OK, this is it," he said.

Lord said he spent a lot of his Ph.D. program abroad and rattled off a list of diverse countries where he conducted research: Costa Rica, Madagascar, Panama, Brazil, Rwanda, Australia, New Zealand, China, Vietnam and all over Europe.

"Some were expeditions in the remotest parts of the jungle collecting insects for weeks, and the idea there is to either grow collections or discover and describe new species," he said.

In his travels, he has encountered political unrest (and had to convince a local government he was a scientist and not a spy), a lemur trapped in his cabin, caimans in his shower, and he has received what he called the field biologist's badge of courage — a botfly buried under his skin.

After a postdoctoral position at Brigham Young University, Lord taught at Georgia College & State University for a few years before joining the faculty of the LSU Department of Entomology, where the director position for the arthropod museum suited Lord's skills and knowledge.

The museum houses the state's collection of arthropods, which number more than one million specimens. The collection serves as a resource for the state of Louisiana and a research tool for the department's faculty and students.

"It's our library of insects," Lord said. "We can compare insects, and lots of parish agents use our identification expertise and the collection as the resource."

The collection also is used for outreach purposes. The museum offers tours, and parts of the collection are used at educational events for the public.

"We can educate the public about what we do and push back that creepy-crawly bias," he said.

Lord's research lab focuses on beetles and their visual systems.

"What has always fascinated me about beetles is that they are the most diverse organism on the planet," he said. "One out of every five living things on the planet is a beetle."

Lord is particularly interested in jewel beetles and the evolution of color within that family of insects. He said most insects tend to be brown and small, but he is looking at what happens when you have this radiation of diversity in color and whether they rely on color to find one another or if they are displaying something like "don't eat me."

The destructive emerald ash borer is one of the jewel beetles. Lord said understanding color and vision could help control them.

"We are looking at the genes in the eye to figure out what they see because there are strategies we can employ to disrupt how they see or disrupt what colors they show," he said.

Lord also mentors graduate and undergraduate students in his lab, showing them they can also travel the world and collect bugs for a living.

"I still feel like I have stolen every paycheck," he joked. "Who is going to find the loophole here and correct the accounting errors that I get paid to do what I would do anyway to be a dork on the weekend?"

Lord is in the early stages of developing a collaborative project with several departments on campus including the Department of Textiles, Apparel Merchandising and Design and the College of Art and Design to create an exhibit on color and insects.

He has plans to guest-lecture in a design class and have students create garments using jewel beetle wings.

"We all work in color in different ways," he said.

Nathan Lord, assistant professor in the Department of Entomology and director of the Louisiana State Arthropod Museum.

Tobie Blanchard is director of LSU AgCenter Communications and director of Communications for the LSU College of Agriculture.

COLOR OF JEWELS:

Studies of Beetle Coloration Shed Light on Insect Sight and Communication

Nathan P. Lord

Insects outnumber all other life on the planet by a staggering margin. The discovery of a new mammal or bird is front-page news in science journals, whereas the discovery of new insect species — which can happen right in our own backyards — usually doesn't warrant even a footnote. Yet the importance of insects is undeniable. They eat our crops, kill our trees, bite our skin and crawl across our floors, sending us running for the nearest can of Raid. Moreover, insects are beneficial for humans and other species alike. Honeybees are responsible for the vast majority of pollination around the world, while praying mantises and dragonflies keep those pesky mosquitoes at bay.

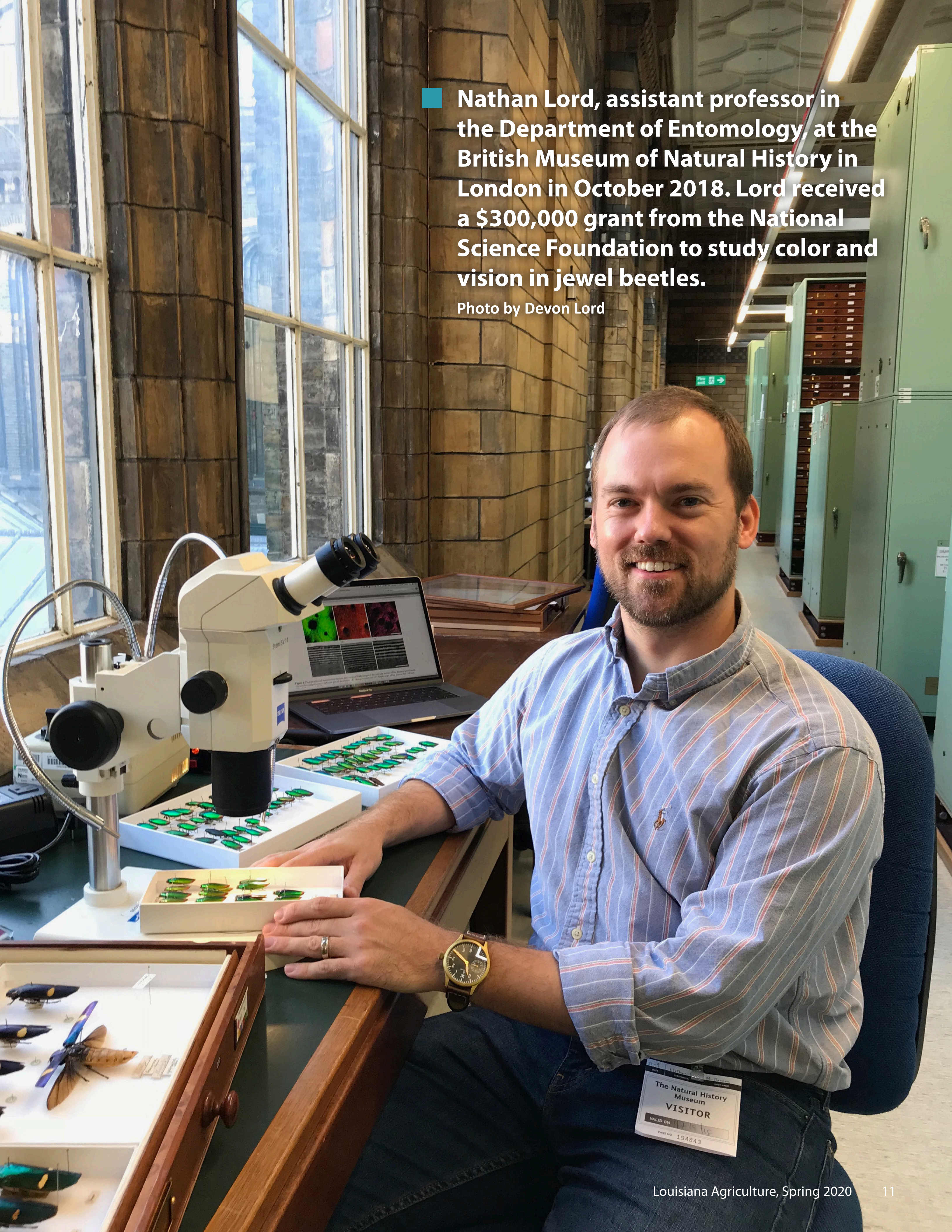
As much as insects affect our world, however, we still have much to learn about them. How many species are there? How do they behave? How do they find our crops to eat or one another to mate? Why do mosquitoes and turkey gnats bite me and not my spouse? To answer these questions, LSU AgCenter scientists are conducting studies on the ways insects experience the world. Akin to the human senses, insects experience the world in much the same way through vision (sight), chemoreception (smell and taste), and mechanoreception (touch and hearing).

Vision is a critical sense to the majority of organisms, and the ability to see in color enhances this sense. Humans are trichromatic, meaning our eyes are particularly sensitive to three portions of the visual light spectrum — blue, green and red. Insects, while also trichromats, see blue and green as people do, but they are poor at discerning red. Where they do excel, however, is seeing in the ultraviolet, a portion of the light spectrum we cannot see. Bees in particular rely on UV light to recognize and land on flowers because many flower petals contain UV patterns called flower guides that draw them in.

Some AgCenter researchers specialize in identifying insects and studying coloration and color vision, primarily in the beetles. Beetles are the most diverse order of life on the planet, with nearly half a million described species (and likely many times more that are still undescribed). Some beetles are also debilitating pests of crops and other plants and trees. In Louisiana, beetles, which include weevils, have caused damage to cotton (boll weevil), pine (Southern pine beetle), sugarcane (New Guinea sugarcane weevil) and sweet potato (sweet potato weevil). Scarab and leaf beetles like the Japanese beetle and the May-June beetles can damage both the roots and leaves of ornamental plants and crops.

Unfortunately, many of these pests are invasive and nonnative, having been introduced from other countries through global trade or the transportation of organic material into the United States. One such invasive pest is the emerald ash borer. Introduced from China in 2002, it has since spread rapidly and decimated North America's ash trees. And there is no end in sight. The emerald ash borer is just one species of the so-called "jewel beetles," a large group of insects found around the world. They get their name because of the often-spectacular coloration of most species, which is in stark contrast with the drab and dull browns and blacks of the majority of other beetles. The emerald ash borer is a brilliant emerald green and ruby red, and some evidence indicates this color is important for the beetles to find one another. Furthermore, studies by the U.S. Department of Agriculture discovered that sticky traps of a particular color perform better than others at attracting these beetles for monitoring their spread.

AgCenter researchers have been studying the visual systems of the jewel beetles and have discovered that the vast majority of these insects show sensitivity to three color ranges in the light spectrum: ultraviolet (UV), blue (short-wavelength) and green (long-wavelength). The jewel beetles, however, completely lack the blue-sensitive gene in the eye, effectively rendering them blue-colorblind. Adding to the confusion, earlier works demonstrated that the emerald ash borer is attracted to and responds to blue colors. Further AgCenter studies revealed that all jewel beetles (the Buprestidae, the larger family that includes the emerald ash borer) possess an extra set of UV and green visual genes and likely made minor tweaks to these genes to see a shade of blue once again. This work is the basis of a National Science Foundation grant that has allowed the AgCenter team to gain a better understanding of the vivid colors found across the jewel beetles, both how they are produced and if they are important in communication among one another. This research has taken Ag Center researchers to Paris, France, and Prague, Czech Republic, to study specimens in museums and will take them



Nathan Lord, assistant professor in the Department of Entomology, at the British Museum of Natural History in London in October 2018. Lord received a $300,000 grant from the National Science Foundation to study color and vision in jewel beetles.

Photo by Devon Lord

to the jungles of Vietnam to collect these beetles alive once the COVID-19 pandemic is under control.

One significant feature of jewel beetle color is its iridescence — that is, their colors shift and change as the light or viewer changes position. The beauty of iridescence is not lost on humans, as all sorts of clothing, automobile paints, makeup and daily household items are made to be iridescent. From a biological perspective, iridescence is often used by birds and fish for enhancing visual signals or even as camouflage. While pigmented colors — those most common to us — are formed from chemicals and are relatively easy to measure, iridescent colors are formed from physical structures and can be quite complex to measure and study.

AgCenter researchers are using microscopes to investigate how these iridescent colors are formed by studying the layers of the hard outer shell. This investigation is revealing that the jewel beetles have their shiny appearance because of stacks of cuticle (similar to human fingernails) and pigments, which reflect light in specific ways and in specific colors, giving them their color-shifting iridescence. The team is also quantifying the visual signals by using hi-tech imaging technology to visualize how these beetles appear not only to us, but to birds, insects and other organisms. While many of these colors seem complex, appearing as rainbows, sparkles, stripes and blotches, analyses of image data are allowing for the interpretation of these features in simpler terms like the overall colorfulness, the amount of contrast between colors and the differences between the beetles' top and bottom surfaces.

To further test whether the extra set of visual genes actually expands visual perception, collaborators at the University of Minnesota are placing these genes in the eyes of fruit flies, then shining specific wavelengths of light at the flies to measure neural response. Although this study is not on the beetles themselves, fruit flies are a common surrogate to more easily achieve accurate measurements than the hard beetles.

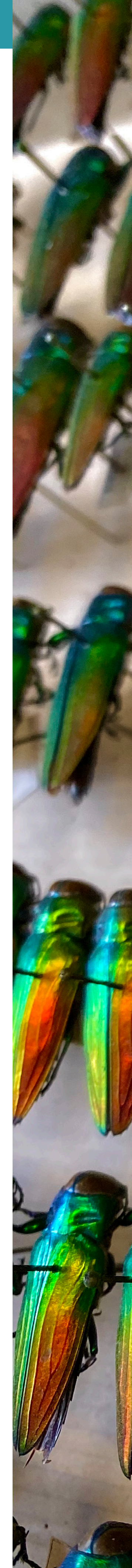
Once the colors and signals these beetles possess are better understood, the AgCenter team can move to the next phase of research: performing behavioral tests to confirm the importance of specific colors to communication or host-finding. Those steps will selectively shut down portions of the insects' visual systems or modify the insects themselves to be different colors than their natural state. For example, if beetles are found to rely heavily on UV or near-infrared colors to detect injured crops — similar to the technique farmers use to monitor their own crops with drone imagery — shutting down these particular visual pathways may disrupt their ability to locate and destroy plants. Additionally, if the emerald green color is found to be a strong attractant for emerald ash borer males to find females, an alteration of the genes that produce those stacks of cuticle could cause green beetles to instead be red and may have a drastic effect on the beetles' ability to find one another to reproduce.

Nathan P. Lord is an assistant professor and director of the Louisiana State Arthropod Museum in the Department of Entomology.

Acknowledgement: Collaboration with Bodo D. Wilts at the University of Fribourg in Switzerland, who is incorporating optical physics to accurately measure and model these structures; Hannah Weller at Brown University, Providence, Rhode Island; and Trevor Wardill and Camilla R. Sharkey at the University of Minnesota in St. Paul.

The emerald ash borer (*Agrilus planipennis* Fairmaire, 1888), dorsal. EAB is an introduced pest and attacks ash trees (*Fraxinus* spp.) Photo by Nathan Lord

The emerald ash borer (*Agrilus planipennis* Fairmaire, 1888), wings open. EAB have iridescent purple dorsal plates underneath the wings. Photo by Nathan Lord



Belionita sumptuosa, an iridescent jewel beetle. Specimens were studied by Nathan Lord and graduate student Able Chow at the Muséum national d'Histoire naturelle in Paris, France, where this photo was taken by Nathan Lord in October 2019.

Photo 1. Mexican rice borer larva tunneling inside a sugarcane stalk. Photo by Blake Wilson

Combatting Invasive Insects in Sugarcane and Rice

Blake Wilson

Sugarcane and rice have been grown in Louisiana for generations, and insect pests have attacked the crops the whole time. Insects native to Louisiana, like the rice water weevil (*Lissorhoptrus oryzophilus*), were already present in the state attacking wild grasses and jumped to rice once farmers began planting it here. Other insects, like the sugarcane borer (*Diatraea saccharalis*), were introduced shortly after cultivation of sugarcane arrived, likely because of importation of sugarcane from Central America and Mexico. The number of pests farmers have to contend with is always growing as new invasive insects enter the state.

MEXICAN RICE BORER, *Eoreuma loftini*

This moth is in the same family as the sugarcane borer and similarly attacks many grass species, including sugarcane and rice (Photo 1). It has been migrating northeastward along the Gulf Coast like a slow-moving wave for nearly four decades. LSU AgCenter entomologists began conducting proactive research in 2000 in Texas to identify pest management strategies in anticipation of the insect's arrival. The Mexican rice borer was first detected in Louisiana in 2008, and is now present in 14 parishes. Fortunately, thanks in part to early research, strategies have been developed to reduce effects on crop yields.

A borer-resistant sugarcane variety, L 01-299, was developed by the AgCenter variety development program. This variety is popular among farmers because of its high yield potential and ratooning ability to produce multiyear crops. It is now planted on nearly 60% of the state's acreage. Biological control from predatory insects and judicious use of insecticides have further limited the pest's effect on sugarcane. The borer is controlled in rice fields by insecticidal seed treatments that are already being applied for rice water weevil management.

SUGARCANE APHID, *Melanaphis sacchari*

This aphid is an invader on a global scale. Its exact origin is unknown, but the pest is on every continent except Antarctica. Infestations in Louisiana sugarcane were first reported in 1999, and the aphid quickly became widely distributed across the state.

Sugarcane aphids are sporadic pests, but heavy infestations are seen in some fields every year. Aphid adults and nymphs extract the sugary liquid from leaves (Photo 2a). Excess sugar, called honeydew, is secreted on leaf surfaces. This allows for development of black sooty mold, a fungus that covers leaves and impedes photosynthesis (Photo 2b). Unfortunately, few management tactics are available. Registered insecticides aren't effective and can even exacerbate infestations by killing beneficial predators. Research efforts are underway to develop integrated management strategies and obtain additional product registrations. New tools are needed to help Louisiana farmers battle these small, but troublesome, pests.

RICE DELPHACID, *Tagosodes orizicolus*

This small brown plant hopper (Photo 3a) is a serious pest of rice in Central America, where it transmits the damaging hoja blanca (white leaf) disease. The delphacid, as well as hoja blanca, were reported in Louisiana and Texas rice in 1957-1959 and 1962-1964. Fortunately, cold winters prevented the pest's permanent establishment and neither the delphacid or hoja blanca was subsequently observed in the U.S.

That changed in 2015, when rice growers in Texas observed large patches of "hopper burn," areas of heavy infestations where plants are brown and severely stunted (Photo 3b). The delphacid has been observed sporadically since then, and evidence suggests it may be overwintering in Texas. Hoja blanca has not been observed recently, but permanent establishment of the delphacid and the disease poses a major threat to U.S rice production. The delphacid is not known to occur in Louisiana at present. Researchers are studying its overwintering ability and monitoring for potential eastward expansion. Entomologists are also looking for collaborators in Central America who can screen Louisiana rice varieties for delphacid resistance.

BENEFICIAL INVADERS

It's not often publicized, but whether or not an invasive insect is considered a pest depends on its context in the environment. Two highly invasive ants from South America, the red imported fire ant (*Solenopsis invicta*) and the tawny crazy ant (*Nylanderia fulva*), are major economic and ecological pests in urban and natural environments. In Louisiana's sugarcane fields, conversely, both species are considered beneficial. Fire ants have long been known to be highly effective foragers and can greatly reduce borer infestations. Crazy ants have only recently become established in the state's sugarcane regions, but preliminary research suggests they are as good as, or better than, fire ants at hunting down borer larvae.

On the other hand, interactions with some sugarcane pests may not be so beneficial. Both species of ants are known to tend, or farm, aphids. The ants protect aphids from would-be predators and even help move them to better feeding sites. In return, the ants feast on the sugary honeydew aphids produce. On-going research is examining the ants' ability to exacerbate aphid infestations in sugarcane fields.

Blake Wilson is an assistant professor and field crops entomologist based at the LSU AgCenter Sugar Research Station, St. Gabriel, Louisiana.

Photo 2a. Sugarcane aphid adults and nymphs. Photo by Blake Wilson

Photo 2b. Sugarcane leaves covered in sooty mold. Photo by Blake Wilson

Photo 3a. Rice delphacid nymphs and adults on rice plants. Photo by Emily Kraus

Photo 3b. Rice field with hopper burn in Texas. Photo by Mo Way

Some of the white-tailed deer breeding herd maintained at the Bob R. Jones-Idlewild Research Station in Clinton, Louisiana. Photo by Claudia Husseneder

Fatal Virus Diseases of Deer Transmitted by Insects

Lane Foil, Mike Becker and Claudia Husseneder

Two viruses that can lead to massive disease outbreaks with death of white-tailed deer are bluetongue virus (BTV) and epizootic hemorrhagic disease virus (EHDV). These viruses are primarily transmitted between ruminants by the biting midges of the genus *Culicoides*. In Louisiana, these flies are commonly called gnats and are nasty pests that can ruin a good day in environments like coastal marshes, particularly under calm conditions because these flies are weak flyers. Approximately 22 species of *Culicoides* are found in Louisiana, and some are associated with health issues in horses and cattle. The bluetongue and epizootic hemorrhagic disease viruses, however, cause acute hemorrhagic disease of both wild and captive deer with mortality rates exceeding 50% in infected animals.

The LSU AgCenter Bob R. Jones-Idlewild Research Station near Clinton, Louisiana, hosts wildlife research projects for many AgCenter researchers and is the center for the Bob R. Jones Wildlife Research Institute. Herds of cattle, red deer, and both captive and wild white-tailed deer at the station make it the ideal location for the study of BTV and EHDV transmission.

In 2011, the researchers initiated a prospective study on the transmission of these viruses. A prospective study is one where all of the elements of a potential event are considered and measured prior to the event, such as virus transmission to deer. The primary elements were:

- Measure what proportion of the animals have antibodies and thus had previous exposure to BTV and EHDV.
- Initiate periodic collections of insects suspected to transmit virus (vectors) and test them for the presence of viral genetic material.
- Identify animals that become clinically ill and test for the presence of virus genetic material as well as culture virus from the animals that died.

One of the largest outbreaks of hemorrhagic disease in recorded history for deer occurred in the U.S. in 2012. Wildlife agencies from many states each reported more than 10,000 deer deaths considered to be from hemorrhagic disease, while Louisiana reported approximately 600 deaths. However, the insect vectors were not studied, and the cause of death was rarely confirmed because fresh tissues were not available in carcasses found in the wild. At Idlewild, approximately one-third of the 80 adult deer died due to BTV or EHDV infections confirmed by detection of virus genetic material and culture techniques. An additional one-third were exposed to one of the viruses and developed immunity. Researchers collected specimens of 14 different *Culicoides* species and found three species containing genetic material of BTV, which identified them as potential vectors.

Publication of the early studies led to a four-year study funded by the U.S. Department of Agriculture National Institute for Food and Agriculture beginning in in 2017. The objectives of that study are to:

- Continue the long-term prospective study on the transmission and maintenance of BTV and EHDV and the fate of captive deer during exposure.

- Increase the knowledge of the life cycles of the *Culicoides* species present on the research station.
- Develop a diagnostic test for confirming virus presence in the carcasses of deer found in the wild.

An important question for the long-term prospective study is whether and how herd immunity for deer is established. Herd immunity is achieved when a sufficiently high proportion of the deer population has built up immunity after prior virus exposure, preventing spread of disease. Three types of EHDV and four to six types of BTV have been isolated from deer at the research station. Immunity to one group of closely related microorganisms does not appear to offer immunity to others. Therefore, the studies on herd immunity for captive deer are complex. In 2012 and since, the researchers have tested the serum of wild deer at several managed hunts and found about 80% of the deer have antibodies for EHDV or BTV. Researchers are finding that half of the deer exposed to one of the viruses survive the infection and, thus, develop immunity, and females can pass on immunity in the milk to nursing fawns.

If a limited number of strains of the two viruses are in certain geographic ranges, the wild deer herd immunity can be high enough to explain the lower number of deaths recorded annually in Southern states with long summers and midge activity. In the Idlewild herds, the researchers have collected an annual blood sample from each animal from 2011-2019 along with their clinical histories. Over the same period, researchers have tested over 25,000 *Culicoides* specimens and have found virus-positive samples from five species of *Culicoides* collected when deer were contracting the viruses, making them top candidates as vectors.

Describing the life cycles of the different *Culicoides* species present in an area where virus transmission is key to identifying important vectors, and confidence in identification methods for the life stages of the different species is critical. Adults are sorted into species groups according to their wing patterns. Species are then confirmed by clearing the bodies, mounting them on microscope slides, and comparing internal and external structures. This is not practical for sorting thousands of specimens, and the mounting process is prohibitive for testing for viruses. The identification of immature stages is even more difficult, and most species have limited descriptions.

To overcome this limitation, the researchers use DNA barcoding, which is a tool for characterizing species according to species-specific DNA marker sequences. The researchers confirmed four species-specific DNA markers from adult females of 12 related species. DNA barcoding of collected specimen at the research station also indicated the presence of two undescribed species. Although larval habitats are poorly described for most species, tree holes are a larval habitat for certain species. The researchers collected tree-hole samples at the research station and collected both adults that developed and larvae for DNA barcoding. After comparing the DNA of adults and larvae, the researchers have found that tree holes are developmental habitats for at least six species. These studies will facilitate in describing key vector species with certainty, allowing comparisons to other regional studies and aiding in identifying larval habitats for suspected vectors of BTV and EHDV.

When deer carcasses are found in the wild, nothing but bones exist within a few days of death. Both BTV and EHDV are relatively stable viruses, and bone marrow from recent victims can be used to detect virus particles. Researchers tested bone marrow from deer that died at the research station and stored the bones of animals infected with virus in scavenger-proof cages. Researchers found that the genetic material of both viruses can be detected three to four months after death and that they can determine their specific types (although the viruses were not viable after a day). This important detection tool has already been adopted by wildlife personnel.

Lane Foil is the Pennington Regents Chair for Wildlife Research, Mike Becker is a postdoctoral research associate, and Claudia Husseneder is the Paul K. Adams Professor of Urban Entomology, all in the Department of Entomology.

An example of the methods for collecting bone marrow from the long bones of deer carcasses. Photo by Claudia Husseneder

Horse Flies and Other Insects **As Bioindicators of Marsh Health**

Claudia Husseneder, Lane Foil, Ben Aker, Darrius Davis and Patrick Rayle

In April 2010, the Deepwater Horizon oil spill in the Gulf of Mexico caused the largest ever human-made accidental marine oil spill. Almost 5 million barrels of oil were discharged in four months, which severely affected marine and coastal habitats. Coastal Louisiana received the most contamination of all Gulf states from the oil and dispersant mixture.

As pictures of dead seabirds, turtles and dolphins filled the news, people working in the marsh also noticed fewer insects, indicating a serious disturbance of the natural ecosystem. LSU AgCenter scientists conducted research combining population genetics and census studies using insects as bioindicators of marsh health.

DECLINE AND RECOVERY OF THE GREENHEAD HORSE FLY AFTER THE OIL SPILL

The greenhead horse fly, *Tabanus nigrovittatus* (Figure 1), was identified as an indicator species for toxic effects of oil intrusion and recovery of marsh. This fly is one of few insects native to spartina marshes from Texas to Nova Scotia. The carnivorous larvae develop for three to nine months as top invertebrate predators in the marsh soil. Their abundance reflects the health of the food web in the mud of tidal marshes. The AgCenter team followed the fate of horse fly populations for six years after the oil spill.

Horse flies were collected from June to October 2010-2016 from oiled locations (Grand Isle, Elmer's Isle, Grand Bayou) and locations unaffected by oil (Cameron Parish, Rockefeller Wildlife Refuge). They were captured with canopy traps and counted. The team extracted DNA and established the genetic profile of each individual via genotyping.

Immediately after the oil spill in 2010 and 2011, horse fly trap catches were significantly lower in oiled than in control sites; yet numbers increased by 2016. In 2010 and 2011, almost all oiled populations showed genetic bottlenecks, i.e. reduction in genetic diversity due to population crashes. All bottlenecks in formerly oiled locations had disappeared by 2015 and 2016, indicating recovery. No population from unoiled areas showed any genetic bottlenecks.

Population genetic analyses documented changes in genetic signatures of oiled and unaffected populations from 2010 to 2016. The 2010 populations of oiled and control areas fell into separate genetic clusters, indicating a lack of migration. In 2011, genetic signatures from control populations began showing up in oiled regions, indicating migration from unaffected to oiled regions that continued in 2015. By 2016, essentially the same genetic signatures were found in individuals and populations from oiled and unaffected regions, suggesting increasing migration of individuals from control populations into formerly oiled areas.

The research team initially expected the horse fly populations from summer 2010 would represent a pre-event baseline, since this generation emerged before the oil spill made landfall. However, polarized light reflected from oil sheens is thought to resemble that reflected from fresh water, so flying insects landing on these surfaces in search of water become trapped. This phenomenon is the likely cause of the acute adult mortality in oiled areas.

Population expansion in formerly oiled areas was likely fueled by migration, successful reproduction in oiled areas and increased survival of larvae developing in formerly oiled areas due to decreased oil residue toxicity and increased availability of their food web. Horse flies are strong fliers, and shrinking genetic distances over the years between populations from non-oiled and oiled areas indicate increasing migration rates. *Tabanus nigrovittatus* females can lay more than 200 eggs per batch and can produce the first batch without a blood meal. Pursuit of a blood meal and subsequent egg-laying ensure dispersal of flies and recovery of depleted areas. Most microalgae and 90% of tiny soil organisms, which form the base of the food web in marsh sediments, recovered within three years after the oil spill. The terrestrial invertebrate community, mostly plant-feeding insects, had largely recovered one year after the spill. The guts of horse fly larvae contain mostly DNA of plant-feeding stink bugs.

The dispersal ability, high reproduction rate and restoration of the larval food web in oiled marshes was, therefore, vital for horse fly recovery. Horse fly populations' sensitivity to oil contamination evidenced by the immediate population crash after the oil made landfall and their recovery following the recovery of spartina marsh grass and the invertebrate food web makes this species a valuable bioindicator to assess the process of marsh reconstitution.

INSECT INDICATORS TO MONITOR FUTURE CHALLENGES TO THE MARSH

Long-term costs from oiling in Louisiana marshes include erosion of marsh islands due to reduction of plant roots. Coastal restoration projects have begun to combat land loss using freshwater diversions, which are expected to decrease salinity in certain zones. To establish baselines of invertebrate communities in different salinity zones in anticipation of these changes and future challenges to the marsh, the AgCenter research team surveyed invertebrate communities in 2017 and 2018 in different marsh salinity zones in Louisiana estuaries.

Canopy trapping detected three species of horse flies in low-, mid- and high-salinity zones. Most abundant at all locations was the *Tabanus nigrovittatus* horse fly bioindicator species, with spring and fall activity peaks. Using dissection techniques, researchers found that *T. nigrovittatus* females were the only horse flies capable of producing eggs without a bloodmeal. This ability explains the higher abundance relative to the other two species because it is advantageous for survival in harsh environments like the saltmarsh.

The AgCenter researchers also identified insect species by sequencing DNA extracted from marsh sediment. While horse fly DNA was present at all sites, researchers detected only eight species of springtails, flies and plant-feeding bugs at high salinity versus 19 species of predominantly springtails, flies, moths, beetles and plant-feeding bugs at low-salinity sites.

The lower insect biodiversity detected in soil at high salinity sites was confirmed by monthly sweep net insect inventories, which showed that 39 insect families resided at high salinity compared to 61 families at low-salinity sites. From these families, 26 species were flagged as bioindicators for salinity levels. At low salinities, a damselfly, Rambur's Forktail (*Ischnura ramburii*) and a sharpshooter, *Draeculacephala portola*, were common, easily collected indicators. Rambur's Forktail is predaceous as both an immature and adult. The immatures, which develop in the water, are tolerant of the brackish water at the low-salinity sites but cannot develop in highly saline water. The sharpshooter is a specialist on spartina cordgrasses and prevalent in the southeastern Atlantic and Gulf coastline.

At high-salinity sites, a plant-feeding bug, *Ischnodemus conicus*, and the predaceous black-headed melyrid *Collops nigriceps* are useful indicators (Figure 2). Both species are associated with the highly salt-tolerant smooth cordgrass that dominates Gulf and Atlantic coast salt marshes. The presence of these insect bioindicators can be used to predict that a certain habitat belongs to the salinity level that the insects are associated with and provides specific plant hosts for the herbivoruous insects or a stable food web for the predaceous insects.

Figure 1. The greenhead horse fly (*Tabanus nigrovittatus*) was used as a bioindicator of decline and recovery of marsh health after the Deepwater Horizon oil spill. Photo by Claudia Husseneder

Figure 2. The black-headed melyrid (*Collops nigriceps*), a bioindicator of high-salinity marsh in coastal Louisiana. Photo by Nathan Lord

The AgCenter database with seasonal distributions of invertebrate predators, parasites, herbivores and detritus feeders provides important baseline data in different salinity zones for assessing changes in marsh health due to future pollution and changes in salinity caused, for example, by erosion, subsidence, sea level rise or freshwater diversions. When combined with plant inventories and land mass surveys, the invertebrate surveys will likely be indicators of future population trends of commercially important invertebrates like shrimp as well as vertebrates dependent upon tidal marsh estuaries.

Claudia Husseneder is Paul K. Adams Professor of Urban Entomology, Lane Foil is Pennington Regents Chair for Wildlife Research, and Ben Aker, Darrius Davis and Patrick Rayle are graduate students in the Department of Entomology.

Investigating Chemical Communication in Termites for Better Pest Management

Qian "Karen" Sun and Paula Castillo

The Formosan subterranean termite (*Coptotermes formosanus*) is an invasive species introduced to the continental United States in the 1950s. In Louisiana, it was first reported in Lake Charles and New Orleans in the 1960s. Over the past decades, this termite species has successfully established colonies in wooden structures and live trees in urban and rural areas of 42 parishes in Louisiana. The Formosan subterranean termite causes more than $500 million in losses in Louisiana every year, and it remains the primary structural pest in the state, and the threat is growing. The social lifestyle and cryptic habitat of these termites render integrated pest management, which combines several tactics, extremely challenging. The tactics include cultural practices, physical methods, biological control agents and chemical control. There is a need to improve management and develop new control methods that rely on a more comprehensive understanding of termite biology.

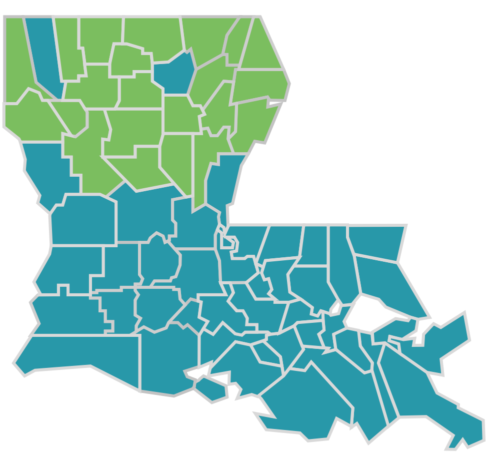
Termites are social insects that display a division of labor based on an elaborate caste system consisting of reproductives, workers and soldiers. While in human societies, people communicate primarily using visual and acoustic signals, termite colonies are composed of mostly blind individuals that heavily rely on chemicals to locate food, detect pathogens, avoid predators and perform complex social communication. Pheromones (the chemical markers termites produce) and other chemical cues from the environment profoundly influence the function of the colonies, which act as "superorganisms" to achieve ecological success and cause substantial structural damage through the wood products they consume. However, it is poorly understood how termites detect and decipher the chemical environments to perform their daily activities.

LSU AgCenter researchers are working to characterize the olfactory system, the sense of smell, of the Formosan subterranean termite, which will provide a better understanding of their chemical communication and improve its control. In insects, the olfactory system is composed of peripheral sensory organs (the antennae) and the central nervous system (the brain). The termite antenna is shaped like a chain of beads, and each antenna is covered by hundreds of tiny sensory structures called sensilla. These sensilla differ in shape and function, allowing termites to perceive changing environmental conditions. Some sensilla look like hairs, others as pegs, pits, cones or plates. They can be sensitive to chemicals (chemosensilla), temperature, humidity or tactile stimuli. Chemosensilla are characterized by the presence of microscopic pores that allow the entrance of odorant molecules to their interior, where specialized proteins carry these molecules to olfactory sensory neurons, which further transmit the signals to certain brain regions. In the brain, the olfactory input will be quickly processed to determine if the termite should move toward or away from the source of that particular smell.

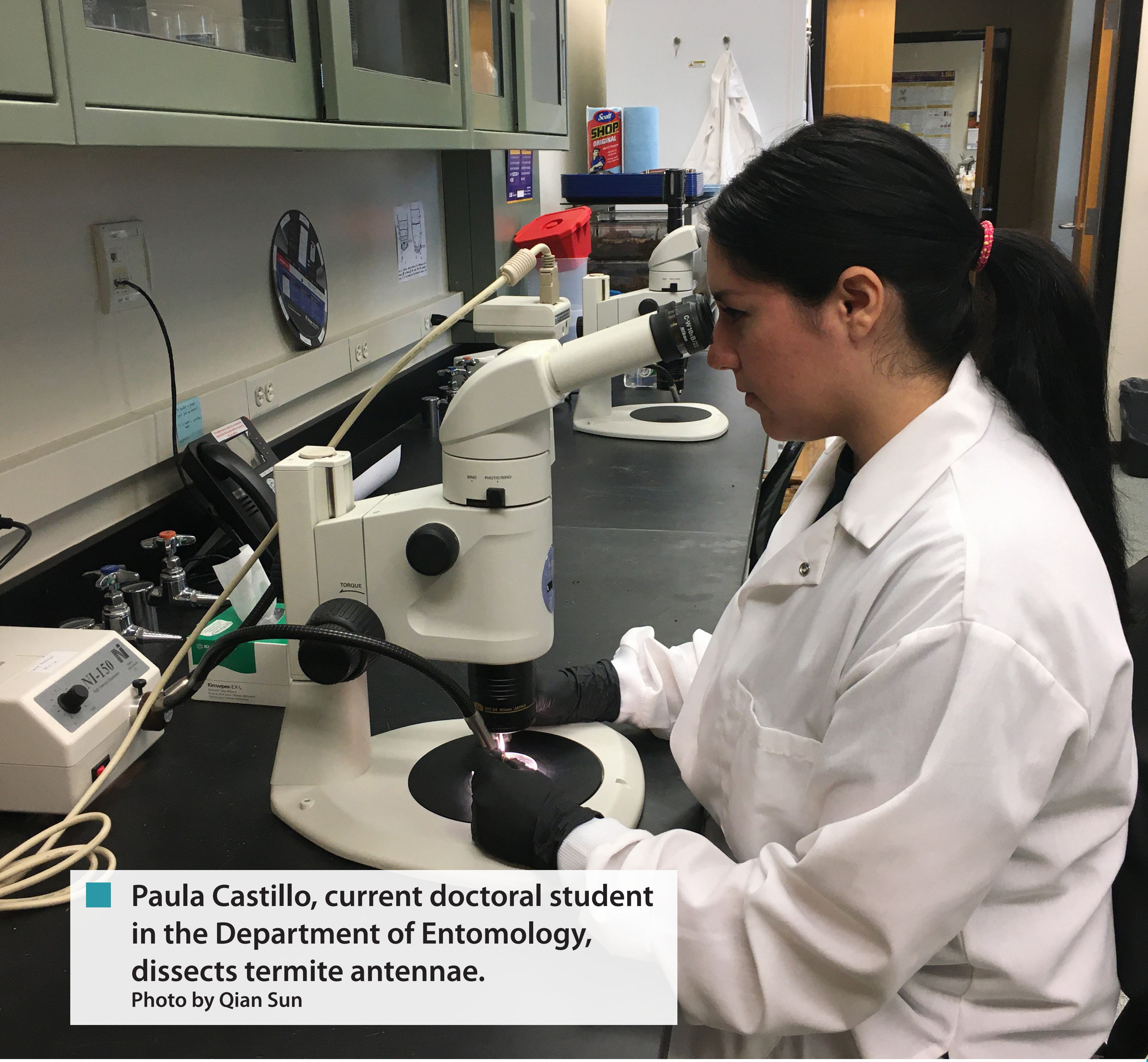
Although workers are the only caste that directly causes damage by looking for and feeding on wooden materials, the colony also relies on soldiers and reproductives to survive and prosper. AgCenter researchers found sensory level differences among the castes to accommodate their different behaviors. Swarmers, the winged reproductives that disperse and establish new colonies, have more sensilla than workers and soldiers. This enhanced sensory capability allows these young reproductives to complete a long list of tasks: finding a mate, locating a new nesting site, collecting food and rearing the brood, before workers are produced to help. The tip of the antenna, regardless of caste identity, is more densely covered with sensilla compared with the base of this organ. Just like human fingertips with increased touch sensitivity due to mechanoreceptors underneath the skin, the antenna tips of termites may have increased sensitivity for smell. By determining what termites process to make them successful, we can discover new opportunities to target the physiological or behavioral process, manipulate their social activities and even eliminate the colonies.

More research is being conducted to explore the chemosensory genes expressed in the antennae and the chemical cues that mediate social behavior, particularly foraging activities of the Formosan subterranean termites.

Qian "Karen" Sun is an assistant professor, and Paula Castillo is a graduate student in the Department of Entomology.



Known distribution (blue) of Formosan subterranean termite in 42 parishes of Louisiana as of March 2020.



Paula Castillo, current doctoral student in the Department of Entomology, dissects termite antennae.
Photo by Qian Sun

Workers and soldiers in a Formosan subterranean termite colony. Photo by John Hartgerink

INSECT PESTS OF HEMP:

Relying on the Power of Integrated Pest Management

Jeffrey A. Davis

The cornerstone of pest control in modern agriculture is integrated pest management (IPM). This concept, born from the over-reliance on insecticides in the 1950s and ’60s, was created to address insecticide resistance, environmental degradation and high chemical residues on food. Today, integrated pest management is defined as a pest management strategy that focuses on prevention of pests through a combination of multiple methods based on ecological principles and socioeconomic considerations. Each pest management system differs by crop, location and production system. By default, integrated pest management programs are dynamic to address changing crop values, input costs, environmental conditions and pest complexes. However, all integrated pest management programs have the key components of monitoring, identification, consulting action guidelines and applying control strategies.

Hemp, defined as cannabis with less than 0.3% tetrahydrocannabinol (THC), according to the Hemp Farming Act of 2018 provisions incorporated into the 2018 U.S. Farm Bill, has a unique history in U.S. farming. For many centuries, hemp production was encouraged for clothing, rope and sailcloth. In Pennsylvania, Virginia and Maryland, hemp was used as money, and in the early 1600s, Virginians were required to grow hemp by law. After the Civil War, hemp production decreased as imports of other products increased. However, at this time, marijuana became a main ingredient in medicines and was sold at pharmacies. By 1937, hemp production was banned within the U.S. with the passing of the Marihuana Tax Act.

Fast forward 81 years, and hemp production is legal again. With the passing of those decades, however, knowledge on production practices has been lost. Furthermore, insecticides, the primary tactic farmers use to control insect pests, have just begun to be registered by the Environmental Protection Agency for use in this crop. In December 2019, EPA approved adding hemp to the use sites of 10 pesticides. Specific information can be found at the EPA webpage titled Pesticide Products Registered for Use on Hemp (https://bit.ly/2XJnYEQ). Currently, the only other products available for use on hemp are those exempt from EPA regulations — those listed under Section 25(b) of the Federal Insecticide, Fungicide Rodenti-

Industrial hemp in Kentucky.

Photo courtesy of the U.S. Department of Agriculture

cide Act (FIFRA). More information can be found at the Minimum Risk Pesticides (https://bit.ly/3f2N07B) webpage. Regardless of the type of product, all must be registered with the Louisiana Department of Agriculture and Forestry.

The most important advantage hemp producers today have over those before 1937 is the 70-plus years of accumulated knowledge of integrated pest management. Louisiana producers are already seasoned practitioners in agronomic crops like cotton and soybeans and in horticultural crops such as strawberries and tomatoes. Integrated pest management strategies are used in forestry, ornamentals, urban settings and stored products. Louisiana producers do not rely just on insecticides. They practice cultural techniques, such as planting at certain dates to avoid the highest pest incidences; biological control, which means using natural enemies to control pest numbers; and host plant resistance, which means choosing varieties resistant to pest injury.

This year, 2020, will be the first year that hemp will be grown in Louisiana since 1937. The insect, weed and disease problems hemp producers will face are still largely unknown. An article was recently published describing all known accounts of insects found on hemp in the U.S. (https://bit.ly/2XH2kRG). Another source of information for insect pests in hemp (https://bit.ly/2MEdIHs) relevant to Louisiana comes from a video by Katelyn Kesheimer, assistant professor and hemp extension entomologist at Auburn University. In it, she discusses the insect problems Alabama hemp producers faced in 2019: hemp russet mite, fire ants and corn earworm. Likely, these will be insect problems Louisiana will also face.

Using the strategy of integrated pest management, entomologists along with other AgCenter scientists and agents are taking a coordinated, step-by-step approach to helping Louisiana farmers produce the best hemp crop they can.

For more information, go to industrial hemp (https://bit.ly/3h6vzVF) on the LSU AgCenter website.

Jeffrey A. Davis is a professor and field crop entomologist in the Department of Entomology.

More than 500 people participated in the LSU AgCenter's first industrial hemp informational meeting on Nov. 13, 2019, held at the State Evacuation Center near Alexandria. They got a firsthand look at hemp plants grown by LSU AgCenter plant breeder Gerald Myers. Photo by Bruce Schultz

Black Soldier Flies Turn Tons of Food Bound for Landfills into Animal Feed

Kyle Peveto

Each day, instead of heading to a landfill, mounds of uneaten food from the LSU Baton Rouge campus are consumed by some of the most impressive eaters on Earth — black soldier fly larvae.

Black soldier flies are small, sleek two-winged flies common in the southern U.S., and during their 14-day larval stage, they eat constantly and can grow up to 300%, said Devon Brits, a Ph.D. student and research associate in the LSU Department of Entomology studying the flies.

"It's pretty crazy," Brits said. "They go from about the size of the head of a pin to about almost an inch long. They're pretty efficient."

Once the larvae are done eating, they can be fed to chickens, pigs, cattle and other livestock. Some producers already use them in place of animal feed made of soy or fish meal made from menhaden and other fish.

"These insects are great," Brits said. "They allow us to repurpose waste into new food and allow us to make new food in less space with less resources."

These remarkable flies are the focus of a collaboration between the LSU AgCenter Department of Entomology and Fluker Farms, a West Baton Rouge Parish insect business that sells insects and pet supplies.

More than a decade ago, David Fluker, owner of Fluker Farms, became interested in the possibilities of black soldier fly larvae after touring a small fly operation. He bought an internet domain, soldierfly.com, that would eventually become home to his Soldier Fly Technologies company.

Then, in 2017, he decided to fund a black soldier fly research position in the Department of Entomology, and Devon Brits was hired to jumpstart the program.

Brits had learned the black soldier fly industry in his native South Africa. While earning his master's degree in entomology at Stellenbosch University, he began working for AgriProtein Technologies, one of the world's largest black soldier fly companies. He left to help start a smaller company and then saw the advertisement from LSU.

"I feel like working with black soldier fly, I feel like I'm doing something really relevant and game changing," Brits said.

Delving into the black soldier fly world was a detour for the Entomology Department, said Michael Stout, the L.D. Newsom Professor and the Entomology Department head. Researchers there typically do not raise large amounts of insects, but Stout was excited to partner with Fluker.

"We didn't have any faculty in the department that specialize in this area," Stout said. "It was a little bit of a stretch for us, but we have made it work."

The multilevel collaboration also includes LSU Campus Sustainability, which works to make the university more

The larvae of black soldier flies are being used to feed livestock and pets in place of soy, fish meal and other protein-based animal feeds. Because these larvae can be used to eat large amounts of food waste, they can transform food bound for the landfill into animal feed. Photo provided by Devon Brits environmentally responsible. One goal of the office is to reduce the amount of waste the campus sends to landfills by three-quarters by 2030, said Sarah Temple, assistant director of Campus Sustainability. They already had a way to recycle clean kitchen waste, but they had no good options for cooked food bound for landfills.

"Campus Sustainability had been looking for years for a way to compost food waste," Temple said. "We have the food, and Devon had the black soldier fly technology. Thus, a great partnership was born."

When students dispose of food at an LSU dining hall, it gets sorted from the other trash and placed into 30-gallon drums. At the black soldier fly colony at the Fluker Farms facility in Port Allen, the waste is processed in a large blender to create food for the black soldier fly larvae.

In a hot, humid room optimal for larval growth, the larvae, which are about three to six days old, are portioned into bins of food slurry. Then they eat.

After two weeks, the slurry of food becomes a compost that can be used in flower beds around the LSU campus. The larvae are sifted out, and some get sold as reptile food by Fluker Farms. Others go back to the black soldier fly colony to pupate, become adult flies and mate. Getting black soldier flies to reliably mate is the most difficult part of the process, Brits said.

"They need the right light sources. They need attractants, like the right food sources that smell good to them so they want to put their eggs down in the right place," he said. "They need the right temperatures and humidity, the right densities of flies in the same place. It's pretty difficult, but we're doing pretty great right now."

For now, selling the insect larvae as reptile food is the most lucrative market for the insect.

"That's not our focus for the project," Fluker said. "Our focus is to complement or supplement, to take some of the pressure off the world fisheries and have an insect meal that will take pressure off the fish meal."

Just 1 gram of black soldier fly eggs can produce about 38,000 larvae. Brits and his team are producing 100 grams of eggs and 3.8 million larvae a day. Last year the black soldier fly colony at Fluker Farms processed 15 tons of waste from LSU. This year the goal is 50 to 100 tons.

Brits and Fluker see the black soldier fly larvae replacing much of the feed used for livestock, and Brits sees some humans beginning to eat them. Scientists at Stellenbosch University have already created black soldier fly larvae sausage and ice creams.

"Insects are not going to be the end-all, be-all solution, but I think they are integrative," Brits said. "They make our agriculture system more circular. It's the ability to take lost nutrients — food that ends up in landfills — and turn that back into something that is viable for people to eat."

And with the world population growing every day, Brits said, that kind of efficiency is vital.

Kyle Peveto is a writer and editor with LSU AgCenter Communications.

Black soldier flies can grow 300% during their two-week larval stage. They eat almost constantly and are able to consume large amounts of food waste. Photo provided by Devon Brits

A Tribute to Entomologist
Dennis Ring, 1952-2020

Michael J. Stout

Dennis Randall Ring, professor and extension entomologist in the LSU Department of Entomology and a valued colleague and friend, passed away on May 4, 2020, after an extended illness.

Dennis was born August 6, 1952, in Texarkana, Arkansas, to Billy JD and Billie M. Ring. Dennis is survived by his wife, Sherry; daughter, Megan De Wees, and her husband, Dalton; sons, Randall Ring and Paul Ring; brother, David Ring, and wife Karen; nephews, Tim and Matthew; and five grandnieces and grandnephews. He was preceded in death by his parents; brother, Carey Ring; and niece, Patricia Ring.

Dennis grew up in Grand Prairie, Texas, where he developed his lifelong interests in insects, plants, fossil and mineral collecting, hunting and football. He graduated from Baylor University with a B.S. degree in biology in 1974. Dennis graduated in 1978 from Texas A&M University with an M.S. in entomology and a minor in horticulture. He completed a Ph.D. from Texas A&M in 1981 in entomology with minors in statistics and ecology. He developed the first computer model of the behavior of the pecan nut casebearer, which remains the basis for current models. This model has saved pecan producers more than $20 million to date. Growers have also found value beyond money. This model minimized guesswork and many said the greatest value to them was "peace of mind." His work with insect pests of pecans greatly aided the development and delivery of the first pecan integrated pest management strategy to manage pecan arthropods.

Dennis held several postdoctoral positions after receiving his Ph.D., including positions with the screw worm labs in Mission, Texas, and Chiapas, Mexico; the U.S. Department of Agriculture pecan research station in Byron, Georgia; the sugarcane entomology lab in the Texas A&M research station at Weslaco, Texas; and the cotton insects research lab at the Texas A&M research station in Corpus Christi, Texas.

Dennis was hired in 1995 as an extension entomologist with the LSU AgCenter. He spent 25 years as a highly productive and respected member of the department. His breadth of knowledge of insects, and his enthusiasm for sharing that knowledge, were unparalleled. Over his career, Dennis had extension responsibilities for pests of structures and households, pecans, rice, sweet potatoes, small fruits, stored products, fruit trees, vegetables, ornamentals, turf and other commodities. However, the pest that he spent the most time combatting was the Formosan subterranean termite. Dennis was the coordinator of the LSU AgCenter Lois Caffey Termite Training Center, served on the governor's Formosan subterranean termite task force and spearheaded Operation Full Stop, a USDA-funded program to reduce the impact of Formosan subterranean termites in the French Quarter of New Orleans.

Dennis published more than 75 scientific papers and a great many technical and nontechnical articles and received more than $9 million in grant funding. He gave more than a thousand talks on entomology-related subjects in his career and frequently lectured on pest management and applied statistics to graduate students in the LSU Department of Entomology. Dennis was an Entomological Society of America Board Certified Professional Entomologist. Among the professional awards received by Dennis were the Distinguished Achievement Award in Extension, Southeastern Branch, Entomological Society of America (2005) and the Distinguished Service Award to the Certification Board, Southeastern Branch, Entomological Society of America (2017).

Dennis loved his job with the Department of Entomology in the LSU AgCenter and developed many friendships within the AgCenter system. He spent as many hours as he could to take on as many commitments as possible, often helping with statistical design and analysis. At home, he spent many evening hours answering emails and talking on the phone to colleagues and clients. He had many stories to tell about his interactions with the people of Louisiana and his efforts to educate people on entomology.

Michael J. Stout is professor and head of the Department of Entomology.

Dennis Ring, standing at right, spent 25 years as a highly productive and respected member of the Department of Entomology. His breadth of knowledge of insects, and his enthusiasm for sharing that knowledge, were unparalleled.

Dennis Ring, 67, extension entomologist, passed away on May 4, 2020.

Resistance Development to Bt Crops in Caterpillars:

Implications for Pest Management and Cotton/Corn Production in Louisiana

Sebe Brown and Fangneng Huang

Bt cotton and Bt corn have been widely planted in Louisiana for more than two decades to manage major caterpillar pests of the two crops. Bt derives its name from the naturally occurring soil bacterium *Bacillus thuringiensis* that has been introduced into the genes of Bt crops. The bacterium produces crystalline (Cry) and vegetative (Vip) insecticidal proteins that, once ingested by target insects, are activated in the midgut and become toxic. In Louisiana, the primary target caterpillars of Bt cotton are the tobacco budworm and bollworm. Several other species, including the beet armyworm, fall armyworm and soybean loopers, are secondary pests of cotton. For Bt corn, a complex of stalk borers — including the sugarcane borer, southwestern corn borer and European corn borer — are its primary targets, while the corn earworm (same species as bollworm) and fall armyworm are considered secondary pests.

Since the introduction of Bt cotton and Bt corn several years ago, tobacco budworm and the stalk borer complex have been maintained below their economic injury levels on Bt and non-Bt plants in Louisiana without the application of chemical insecticides. In addition, both tobacco budworm and stalk borers have remained susceptible to the Bt proteins, and no signs of resistance development have been observed. Louisiana growers have recognized considerable economic and ecological benefits from the long-term use of Bt cotton and Bt corn. Louisiana cotton growers are obtaining an economic advantage of nearly $45 per acre over conventional cotton. Currently, the U.S Cotton Belt has the lowest recorded number of insecticide applications since the 1940s. The estimated net economic return for Louisiana corn growers is more than $20 million annually. The benefit from planting Bt corn could be much greater if the benefits gained from the reduced stalk and stem borer populations on sorghum and rice are included.

The benefits mentioned above will disappear, however, if the Bt crop technology is not used wisely. Just as with the use of chemical insecticides, insects can develop resistance to Bt crops. To ensure the sustainable use of the Bt technology,

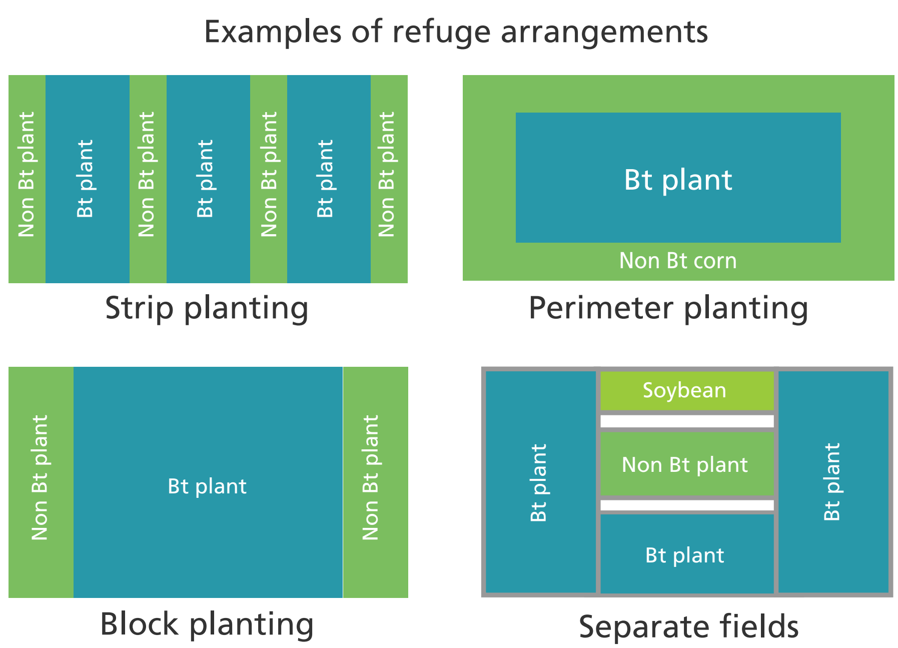


Figure 1. A schematic diagram to show some examples of non-Bt structured refuge corn arrangements for Bt corn growers.

LSU AgCenter scientists have developed and implemented a statewide Bt resistance monitoring program. Each year, sentinel plots are planted at several locations across the state, and insect survival and plant damage are inspected to watch for any unexpected field control problems. In addition, insect populations collected from different geographical locations are assayed to determine if Bt sensitivities decrease in the field populations.

Recently, the monitoring program has documented that bollworm and corn earworm resistance has widely occurred to both Cry1/Cry2 cotton and Cry1/Cry2 corn across the state. In the current Bt crop market, there are three Bt cotton varieties containing the Cry1/Cry2 genes: Bollgard II, WideStrike and Twinlink, while these two Bt proteins are expressed in several Bt corn varieties including Genuity VT Double Pro, VT Triple Pro, SmartStax and Interasect. As mentioned above, the corn earworm is a secondary pest of field corn. Studies have shown that this caterpillar usually does not cause significant economic losses on field corn in the U.S. Midsouth. However, the resistance to Bt cotton has already threatened the cotton industries of the entire U.S. Cotton Belt.

HIGH-DOSE REFUGE APPROACH

Since the first use of Bt crops in 1996, the U.S. has adopted a strategy called the "high-dose refuge" approach to counteract the resistance development. With this approach, farmers plant only a portion of the crop acreage on each farm to high-dose Bt plants. High dose refers to the amount of Bt toxin present in plants that can kill target pests that are susceptible or that are resistant heterozygous individuals that carry only one resistance gene. The remaining portion of the crop acreage is planted with non-Bt plants that serve as a refuge for susceptible insects. The susceptible populations from the refuge are expected to mate with the resistant homozygous individuals. In this way, most of their offspring will be heterozygous. Because heterozygous individuals will be killed by the high-dose Bt plants, the rates of resistance should be held at low levels in the pest populations for a long time.

In the 1990s and early 2000s, non-Bt refuge planting was required of both Bt cotton and Bt corn growers. Later, the use of a natural refuge for planting Bt cotton was approved in the U.S., and since then the natural refuge approach has been adopted. Thus, no additional refuge planting is required for Bt cotton growers in Louisiana.

For Bt corn growers in the South where cotton is also planted, the high-dose refuge strategy requires the growers plant on each farm a "structured" refuge of 50% of the acreage for single-gene Bt corn or 20% of the acreage for pyramided Bt corn. Pyramided Bt corn has multiple Bt traits that attack the same pest. The non-Bt structured refuge should be planted in strips or blocks within 800 feet of the Bt corn plants in a layout similar to what is shown in Figure 1. Studies have shown that growers' compliance with the refuge requirement is a key factor for the success of the high-dose refuge strategy. Several surveys by the Environmental Protection Agency and biotechnology companies have shown that grower compliance with the refuge planting requirement has been very low in the South. Thus, great efforts are needed to improve compliance with the requirement in Louisiana.

GENE PYRAMIDING

Another approach for managing Bt resistance in the U.S. is "gene pyramiding," which introduces two or more Bt genes with different modes of action into a plant to control the same insect pest. One example of gene pyramiding is Bollgard II cotton, which contains Cry1Ac and Cry2Ab Bt genes that control caterpillar pests such as tobacco budworm and bollworm. The principle of gene pyramiding is quite simple: If individuals in an insect population carrying resistance genetics to one Bt protein are rare, individuals possessing resistance genes simultaneously to two or more Bt proteins must be very rare, so resistance development can be greatly delayed.

Recently, biotechnology companies have introduced a novel Bt gene, Vip3A, to control the Cry1/Cry2-resistant bollworm and corn earworm. The newly introduced Vip3A protein has a distinct gene structure and a new mode of action compared to any known Cry proteins. Studies at the AgCenter have shown no cross-resistance between Vip3A and any Cry proteins. Field trials in Louisiana have demonstrated that all Bt cotton varieties and Bt corn hybrids containing Vip3A gene are effective in controlling the Cry1/Cry2-resistant bollworm and corn earworm. However, because of the limited modes of action used in the Bt crops, the Vip3A protein is the only active protein against the Cry1/Cry2-resistant bollworm and corn earworm in the current Bt market. Thus, preservation of Vip3A susceptibility in pest populations is critical for the long-term success of the Bt crops.

Based on the information available, at least two necessary activities can prolong the Vip3A susceptibility in Louisiana: 1) planting crop varieties containing Vip3A only for Bt cotton and avoiding the use of corn hybrids possessing the Vip3A gene to reduce the selection pressure; and 2) complying with the refuge requirement when planting Bt corn to provide sufficient numbers of susceptible insects to dilute the resistance genes in the pest populations. In addition, biotechnology companies are actively working to develop future pyramided technology that contains two new modes of action and plan to commercialize this technology in the near future. Perhaps the most important way to ensure the sustainability of Bt crops is to treat the technology as only one of the integrated pest management tools and use more approaches to diversify the insect mortality.

Sebe Brown is an assistant professor of entomology and extension specialist for cotton, corn, soybeans and grain sorghum insect pest management, and Fangneng Huang is a professor in the Department of Entomology.

Acknowledgment: This research was partially funded by Louisiana Soybean and Feed Grain Promotion Board.

Biological Control of Giant Salvinia:
Using New Technology in Puerto Rico

Rodrigo Diaz, Steven Woodley and Charlie Wahl

Freshwater wetlands are beautiful as well as economically important habitats. They lie at the core of culture and history in Louisiana, and they also contain vast natural resources and are home to many wildlife species. Transportation among these bodies of water relies on clean navigation channels or canals. However, freshwater wetlands in Louisiana and other countries have been under threat by the invasion of giant salvinia, a fast-growing floating fern from South America. Since its detection in the Toledo Bend Reservoir in northwest Louisiana in 1999, giant salvinia has spread exponentially and now is in every parish in the state.

In 2004, LSU AgCenter scientists began implementing biological control of giant salvinia in Louisiana using the salvinia weevil, which has been imported from South America. This weevil feeds exclusively on giant salvinia buds and stems, causing massive damage to salvinia and allowing the recovery of wetlands. The AgCenter has since established two facilities where the salvinia weevil is mass reared for distribution (Photo 1).

In the past two years, AgCenter scientists have been assisting in other areas of the world where giant salvinia is causing problems, which helps provide additional scientific information for the control of this plant pest here at home. AgCenter entomologists have been helping plant managers in Lake Ossa in Cameroon, where the salvinia has limited access to fishing by the local residents and reduced the habitat quality for an endangered manatee. In addition, Hurricane Maria in Puerto Rico facilitated the dispersal of giant salvinia on the island. Lake Las Curias near San Juan became completely covered with the plant by 2018 (Photo 2). Because of the rapid growth of giant salvinia during the warm months, lake managers rely heavily on periodic applications of herbicides, which are not always economically or logistically feasible. This creates a massive need for more tools to control giant salvinia.

“Freshwater wetlands in Louisiana and other countries have been under threat by the invasion of giant salvinia.”

Photo 1. Harvest of giant salvinia infested with weevils at the LSU AgCenter Reproductive Biology ponds in St. Gabriel, Louisiana.
Photo by Rodrigo Diaz

Photo 2. Lake Las Curias in Puerto Rico completely infested with giant salvinia in July 2019. Photo by Tito Castro

In 2019, AgCenter entomologists implemented the biological control program in Cameroon and Puerto Rico by training local personnel in the handling and monitoring of weevils. The AgCenter shipped more than 1,000 weevils to each destination, and personnel released the weevils and initiated the rearing process. In addition, a critical aspect of the implementation of biological control of giant salvinia was the education of stakeholders in Puerto Rico and Cameroon using on-site demonstrations, fact sheets, how-to manuals, workshops and YouTube videos.

Results of the initial releases of weevils in Cameroon and Puerto Rico look promising. Two shipments of weevils have been sent to Cameroon, where a local nongovernmental organization is rearing the weevils on the shores of Lake Ossa. After the release of weevils in Lake Las Curias in Puerto Rico in November 2019, AgCenter entomologists confirmed the establishment and dispersal of weevils at the release locations (Photo 3). With the help of community leaders, this local "weevil nursery" will be used to accelerate the dispersal of weevil-infested salvinia to new locations in the lake. To monitor the recovery of the ecological functions of the lake, scientists from the University of Puerto Rico are measuring the coverage and thickness of salvinia and water quality parameters, including dissolved oxygen.

Photo 3. Graduate student Giovana Matos Franco collects samples of giant salvinia at a weevil releases site in Lake Las Curias in December 2019. Photo by Manuel Godinez

The expectation is that the tropical climate in Cameroon and Puerto Rico will accelerate the growth of the salvinia weevil, thus having a faster control of the salvinia plant. If successful, the implementation of the biological control program at these locations will result in the recovery of native plants and animals and improve water quality and ecological services provided by the lakes. Moreover, economic benefits will result from the reduction in control costs involved in the use of herbicides or mechanical harvesters and from the increase in revenue because of the improved navigation and access to fishing and tourism.

For more information about the LSU AgCenter biological control program of giant salvinia, visit the AgCenter giant salvinia webpage at www.lsuagcenter.com/giantsalvinia.

Rodrigo Diaz is an assistant professor, and Steven Woodley and Charlie Wahl are research associates in the Department of Entomology.

Cooperation with Mosquito Abatement Districts **to Monitor and Combat Insecticide Resistance**

Kristen Healy

Although people often link mosquito abatement districts in Louisiana with truck-based insecticide applications, these programs actually use a wide variety of additional management strategies. One of the most common strategies in Louisiana is conducting surveillance for mosquitoes. Surveillance activities include collecting mosquitoes, identifying the species and testing them for mosquito-borne pathogens, such as West Nile virus, Eastern Equine encephalitis virus and Zika virus. When areas of high mosquito activity are identified, mosquito control programs often select from a variety of control strategies. Source reduction, which is the removal of mosquito habitat, is commonly used in Louisiana. One example is tire removal programs because many common backyard biting mosquitoes lay large numbers of eggs in water collected in abandoned tires. When source reduction is not feasible, many programs will use biorational products, which are derived from nature, to control mosquito immatures in their aquatic habitats. However, when mosquito populations are high or there is a risk of West Nile virus, mosquito control programs will use aerial and truck-based insecticide applications. A variety of control products can be used, depending on the mosquito species being targeted, product efficacy and mode of application.

One of the most important aspects of mosquito control is ensuring that insecticide products are effective. There are several ways of evaluating if a product is effective, such as with surveillance or field trials. One way is to test for insecticide resistance, which is when an insect pest develops a mechanism that renders the control product less effective. A real concern with insecticide resistance is that a control product would only reduce a small percentage of the target population.

Insecticide resistance can be determined by using multiple strategies. While each strategy has its own limitations, each has its advantages as well. For example, the bottle bioassay was developed through the U.S. Centers for Disease Control and Prevention as a way to quickly assess insecticide resistance in an area. The bottle bioassay uses clear glass bottles coated with an active ingredient. Mosquitoes are placed inside, and the time to 100% mortality is determined. While the bottle bioassay is simple and quick, it does not tell much about the level of resistance or if any products with the active ingredient might be effective. Therefore, lab tests (genetic or enzyme based) or field tests (using formulated mosquito control products) can give a bigger picture of insecticide resistance in an area.

In 2016, Zika virus became a nationally reportable disease in the U.S. The disease was responsible for local outbreaks in Florida and Texas and became a concern in areas where mosquito vectors were common. The primary concern over Zika virus was the microcephaly that occurred in developing fetuses of infected mothers. Because Louisiana was in a high-risk area for this disease, the state health department, local mosquito control programs, industry partners and university partners got together to develop plans to control Zika virus in the state. As part of this response, Louisiana received funds from the CDC to develop a statewide insecticide-resistance monitoring program. Because the LSU AgCenter lab had received training from the CDC on insecticide resistance monitoring, AgCenter researchers were an integral part of developing a statewide program. In 2016 and 2017, AgCenter researchers collected mosquito eggs from across Louisiana, conducted bottle bioassays and began evaluating genetic mutations in select populations.

Given the large numbers of mosquito control programs in the state, it was necessary to find a sustainable way to continue statewide testing following the end of the grant. The Louisiana Mosquito Control Association — which includes partners from health, university, mosquito control and industry — recently expanded early initiatives and established a statewide insecticide-resistance monitoring committee. The committee's goal is to develop annual guidelines for insecticide-resistance testing in the state. Since the inception of the statewide insecticide-resistance testing program, the Louisiana Department of Health has received additional funds through the CDC. These funds have helped establish an insecticide-resistance testing program being conducted at the Louisiana Animal Disease Diagnostic Laboratory at LSU. By establishing the program at this lab, mosquito control programs can now test for insecticide resistance in combination with West Nile virus mosquito testing. By having this combined virus and insecticide-resistance testing, mosquito control programs across the state now have large amounts of data to inform their mosquito control decisions.

Kristen Healy is an associate professor in the Department of Entomology.

Dead mosquitoes are counted.
Photo by Kristen Healy

Bottle bioassays use clear glass bottles coated with an insecticide. Mosquitoes are placed inside, and the time to 100% mortality is determined. Emily Boothe, research associate, was one of the researchers involved with this project who was trained to do bottle bioassays. Photo by Kristen Healy

LSU Entomology Alumni
Contribute to the Well-Being of Humanity

Michael J. Stout

Insects are the most diverse and abundant group of animals on earth. Because they are so ubiquitous, insects intersect with humans frequently and in numerous ways, with impacts ranging from beneficial (e.g., honey bees and other pollinators, natural enemies of crop pests) to destructive (pests of crops and structures, vectors of diseases). Accordingly, graduates of departments of entomology have a wide range of career options, and alumni of the LSU Department of Entomology, in particular, have enjoyed success in a variety of endeavors throughout the world.

Students graduating with a master's degree in entomology from LSU often choose to further their education by pursuing a Ph.D. degree. A few remain at LSU to do so, but most go on to other universities. Recent master's students from the department have continued their doctoral studies at prestigious universities such as the University of Florida, Purdue University, Texas A&M University, Colorado State University, University of Kentucky and Western Sydney University in Australia. Similarly, Ph.D. graduates from LSU who have not immediately found permanent positions have worked as post-doctoral scientists at prominent universities, including Kansas State University, Johns Hopkins University, Rhodes University in South Africa and Liverpool School of Tropical Medicine in the United Kingdom.

Our graduates have historically been valued for their practical understanding of pest management and for their hands-on experience in insect identification and field research. Some of our alumni work in the structural pest control industry. They are also well-represented in the community of agricultural consultants, who assist Louisiana farmers and ranchers in managing the pests in their fields and pastures. Of the current board of directors for the Louisiana Agricultural Consultants Association, 40% hold graduate degrees from LSU Entomology.

Many of our graduates are employed by the agrochemical industry and are engaged in the discovery, development, evaluation and marketing of chemicals (insecticides) or crop varieties used to manage pests of crops or structures. Several of our graduates over the past 25 years now hold leadership positions in major agrochemical companies. For example, Melissa Willrich Siebert (Ph.D. 2004) is global entomology program leader, and Boris Castro (Ph.D. 2002) is global technical education leader, both with Corteva Agrisciences, and Victor Mascarenhas (Ph.D. 1997) is senior field scientist for Syngenta.

The medical and veterinary entomology labs in the department have a strong tradition of placing their graduates in positions related to public health at the local, state and federal levels. Roxanne Connelly (Ph.D. 1998), for example, is chief entomologist with the Centers for Disease Control and Prevention in Fort Collins, Colorado, while several other departmental alumni have served as medical entomologists in the military or have led efforts to control arthropod-borne diseases at mosquito abatement districts in Louisiana and other states.

Still other graduates have had successful careers in research and regulatory agencies within the federal government. Several alumni have had long and successful careers in the U.S. Department of Agriculture Agricultural Research Service, with some, such as John Adamczyk (Ph.D. 1998) and Bob Danka (Ph.D. 1987), rising to roles as research leaders. Other alumni have enjoyed similar success with the U.S. Forest Service. Still others serve as regulatory officers with agencies such as the Environmental Protection Agency; Kelly Tindall (Ph.D. 2004) is a senior biol-

B. Rogers Leonard (Ph.D.1990) retired as the LSU associate vice president for agriculture and program leader for animal and plant sciences in 2020.

Bob Danka (Ph.D. 1987) is research leader at the USDA Honey Bee Breeding, Genetics and Physiology Laboratory in Baton Rouge, Louisiana.

Beverly Sparks (Ph.D. 1983) retired in 2014 after serving for seven years as associate dean for extension at the University of Georgia. She was the first woman to hold that post. She had spent 32 years in the extension service, first in Texas and then Georgia.

Linda J. Mason (Ph.D. 1987) was named dean of the Purdue University Graduate School in 2018, after having served as the associate dean, starting in 2010. She had been an entomology professor at Purdue since 1991.

Roxanne Connelly (Ph.D. 1998) is the chief entomologist with the Centers for Disease Control and Prevention in Fort Collins, Colorado.

Deanna Colby (Ph.D. 2002) is a senior regulatory specialist in the Environmental Protection Agency Office of Pesticide Programs.

Michael Roe (Ph.D. 1981) is the William Neal Reynolds Distinguished Professor, North Carolina State University. He's also an alumnus of the LSU Tiger Band.

David Ragsdale (Ph.D. 1980) is the associate director, Texas A&M Agrilife Research.

Kelly Tindall (Ph.D. 2004) is a senior biologist at the EPA Office of Pesticide Programs.

Boris Castro (Ph.D. 2002) is global technical education leader at Corteva Agrisciences.

ogist and Deanna Colby (Ph.D. 2002) is a senior regulatory specialist in the EPA Office of Pesticide Programs.

Alumni of the department have also made important contributions in academia, as professors and researchers, administrators and authors. Some of these alumni have remained with the LSU AgCenter for their entire careers. For example, Abner Hammond (Ph.D. 1967) rose through the ranks of our department and is now a professor emeritus, and B. Rogers Leonard (Ph.D. 1990) started as a student worker with the AgCenter and retired in 2020 as the associate vice president for agriculture at LSU.

Other graduates have had successful academic careers at universities throughout the United States and the world, including Korea, Jamaica, Nigeria, Brazil, Zambia and China. Notable examples include: David Ragsdale (Ph.D. 1980), associate director, Texas A&M Agrilife Research; Jeffrey Lockwood (Ph.D. 1985), professor and award-winning science writer, University of Wyoming; Beverly Sparks (Ph.D. 1983), first female director of the extension service at the University of Georgia, who retired in 2014; Michael Roe (Ph.D. 1981), William Neal Reynolds Distinguished Professor, North Carolina State University; and Linda J. Mason (Ph.D. 1987), dean of the Purdue University Graduate School.

The successes of alumni of the LSU Department of Entomology are a testament to the historical excellence of both its faculty and its students. As the department has added new faculty members over the past decade, an emphasis has been placed on broadening and diversifying the research interests and methodological approaches of the faculty to reflect the modern discipline of entomology. The addition of these outstanding new faculty members ensures that graduates of the LSU Department of Entomology will continue to contribute to the well-being of humanity.

For further information, visit us on the web at https://entomology.lsu.edu/.

Michael J. Stout is professor and head of the Department of Entomology.

Jeffrey Lockwood (Ph.D. 1985), left, a professor at the University of Wyoming and award-winning writer, gave a lecture on the LSU campus in 2013. He is with Abner Hammond (Ph.D. 1967), who is a professor emeritus in the Department of Entomology. Photo by Johnny Morgan

Melissa Willrich Siebert (Ph.D. 2002) is global entomology program leader with Corteva Agrisciences.

Research on Hurricane-Ravaged Forest **Does Not Support an Insect 'Apocalypse'**

Manoj Pandey and Timothy Schowalter

A paper published in 2018 claimed that the abundance of spiders, mites and other arthropods in a Puerto Rico forest site had declined 60%, resulting in a collapse of the food web. This sensational claim generated much media attention and, along with documented declines in arthropod abundances in Europe, suggested a global insect "apocalypse." However, a review of the site in Puerto Rico has led LSU AgCenter researchers to find this analysis was faulty.

Long-term research provides scientists an opportunity to study changes over time in the structure and function of a forest and in response to disturbances. At the Luquillo Experimental Forest in Puerto Rico, a forest frequently disturbed by hurricanes and droughts, AgCenter entomologists have been studying the numbers of insects, spiders, mites and other arthropods living in the crowns of trees that compose the forest canopy. This forest, which is administered by the U.S. Forest Service and the University of Puerto Rico, is the only tropical rainforest in the National Science Foundation Long-Term Ecological Research Network, creating an uncommon opportunity for research.

Researchers have sampled arthropods associated with common tree species in the Luquillo forest in plots established after Hurricane Hugo over a 29-year period from 1991 to 2019. Three tree species were sampled in all the plots to represent dominant early successional tree species, which are the first trees to grow in a forest after a disturbance, such as a clear cutting or hurricane wind damage. These species in the Luquillo forest were *Cecropia schreberiana*, a tall, thin umbrella-shaped tree known as the pumpwood tree; the evergreen *Miconia prasina*, a small tree that grows small white flowers; and the evergreen palm tree *Prestoea acuminata*.

Three other species were sampled to represent late successional tree species, the shade-tolerant trees that thrive in a more established forest. The late successional tree species were the tabonuco or candlewood tree (*Dacryodes excelsa*), a large evergreen tree that is dominant in the overstory of the forest; the ausubo or balata tree (*Manilkara bidentata*), which can live for hundreds of years and is an important timber tree in Puerto Rico; and the motillio tree (*Sloanea berteriana*), an

Figure 1. Branch bagging, using a long-handled insect collecting net with closeable plastic bag and a drawstring. The bag is slipped over a tree branch and enclosed by pulling the string, and the branch clipped to collect the foliage and associated arthropods.

Figure 2a. El Verde Field Station before Hurricane Maria in 2017. Photo provided by Tim Schowalter

Figure 2b. El Verde Field Station after the hurricane. Photo provided by Omar Gutiérrez del Arroyo

evergreen tree often used for fenceposts and building structures.

Researchers collected the samples by branch bagging, using a long-handled insect net with a closeable plastic bag to reach the canopy and enclose a tree branch and the arthropods on the branch (Figure 1). The arthropods collected this way include those most closely associated with the sampled tree species.

In September 2017, the Category 5 Hurricane Maria became the most intense hurricane to hit Puerto Rico in nearly a century. Severe winds uprooted and broke trees and opened most of the canopy in the forest (Figure 2). Studies of arthropods living in the forest canopy allowed researchers to compare the abundance of the animals from 2015 to 2017 before the hurricane disturbed the forest and in 2018 and 2019 after the disturbance. The abundance of individual species and the richness, or number of different species, decreased significantly on the palm, *P. acuminata*, following Maria (Figure 3). However, there were no significant changes in abundance or diversity on other tree species.

Individual arthropods, however, responded differently to hurricane disturbance. Bark lice (Psocoptera) increased in abundance (Figure 4), but tree crickets (*Cyrtoxipha gundlachi*) decreased in abundance on the ausubo tree (*M. bidentata*) (Figure 5) following Maria. An unidentified micro moth decreased in abundance on *P. acuminata* and on the dominant overstory tree, the tabonuco, (*D. excelsa*). These population responses reflect the different adaptations of insects to environmental changes caused by the hurricane.

Furthermore, the nearly 30-year database for this site allows researchers to evaluate changes in arthropod abundances over this time period. The study from 2018 claiming that arthropods' abundance had declined 60%, resulting in collapse of the food web, used open access data from this forest site, but the study used faulty analyses. The claim of arthropod decline was incorrect for this site. The cumulative abundance of arthropods, analyzed correctly, shows that their abundance in 2019 was equal to or greater than that in 1991. Furthermore, the pattern in abundance shows peaks in 1991, 2002 and 2019, representing immediate responses to major hurricanes Hugo, Georges and Maria, respectively. Peaks in abundance reflect increased abundance of arthropods in response to the altered habitat and availability of resources following hurricanes.

AgCenter researchers analyzed changes in abundance for the 10 most common arthropods

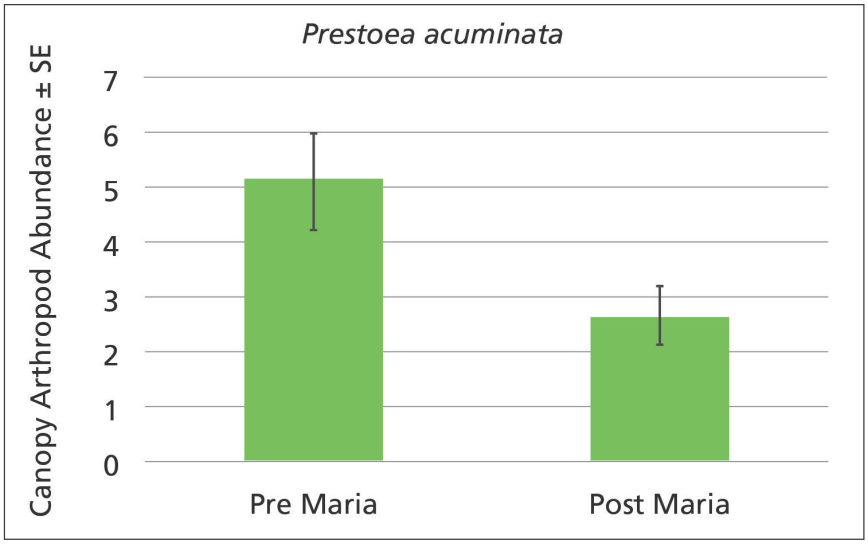


Figure 3. Canopy arthropod abundance on *Prestoea acuminata* palm trees before and after Hurricane Maria. Abundance was computed as cumulative abundance of all arthropods collected from *P. acuminata*.

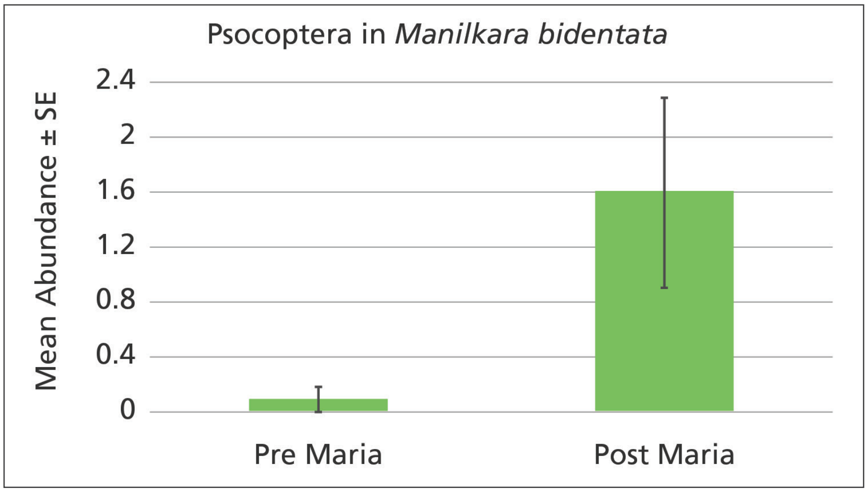


Figure 4. Mean abundance of Psocoptera (bark lice) on *Manilkara bidentata* trees before and after hurricane Maria.

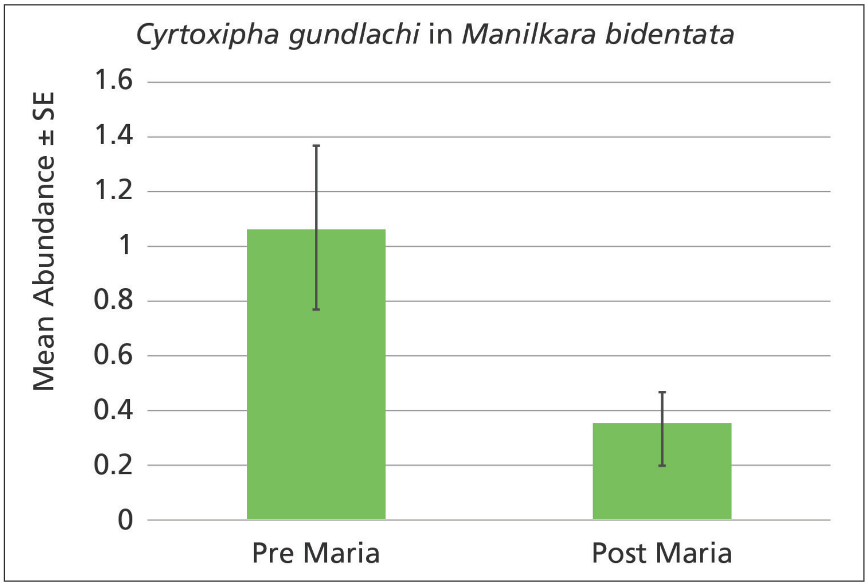


Figure 5. Mean abundance of green cricket *Cyrtoxipha gundlachi* on *Manilkara bidentata* trees before and after Hurricane Maria.

for 1991 to 2001 and 2009 to 2019. Six were common during both periods. However, two scale insects (*Vinsonia stellifera* and *Protopulvinaria pyriformis*), along with argiopid spiders and salticid spiders — primarily *Lyssomanes portoricensis* — were among the 10 most abundant from 1991 to 2001 but were replaced from 2009 to 2019 by mealybugs, galumnid (pterymorph oribatid) mites, micromoths and cockroaches, primarily *Cariblattoides guava*.

Most animals studied did not change significantly in abundance over the 29-year period. Of the five that changed significantly, tree crickets (*C. gundlachi*) and mealybugs increased, while one of the scale insects (*V. stellifera*), argiopid spiders, and salticid spiders decreased in abundance. These results demonstrate that species respond differently to the conditions created by disturbances, resulting in species turnover. In general, sap-sucking arthropods increased in abundance with the availability of young foliage immediately following hurricanes. Defoliators and predators initially declined but subsequently increased during community recovery.

The results from this long-term study indicate that the canopy arthropods are not declining in the Luquillo forest. Their numbers are primarily driven by disturbances. However, insect declines may be occurring in other regions, primarily as a result of habitat loss and other environmental changes. More long-term research using consistent sampling techniques at the same sites will help to answer questions about trends in arthropod abundances over time.

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Students Learn Critical Thinking about **Science and Public Policy**

Jim Ottea

There is a strong commitment to teaching by the faculty in the Department of Entomology, with coursework that serves students within our department, the College of Agriculture and the LSU community as a whole. In addition to instruction at the graduate level, undergraduate classes in the department attract students with general or applied interests in our discipline, as well as those wanting to explore the rich biology of insects. One undergraduate course that is somewhat unique among those in entomology is AGRI 1005, Science and Society.

Science and Society has been offered through the College of Agriculture for more than 15 years and has a unique history. At the inception, and for years after, teaching AGRI 1005 was a team effort. In the early years, it was an "orphan course," with responsibility for teaching rotated among departments. About 10 years ago, responsibility for the course fell to entomology, where it found a permanent home. The emphasis of the course shifted from a survey of biology to science literacy, and LSU granted approval to offer it as a general education elective. Enrollment soared. During the next five years, AGRI 1005 became one of the most well-attended courses in the College of Agriculture. Enrollment topped out at 270 students, mostly from nonagricultural disciplines. Eventually, enrollment was reduced and capped at two sections, each with 100 students. Most recently, the content of AGRI 1005 was modified for presentation in a discussion-intense format, which is now offered as a seminar (Science for Citizens, HNRS 1035) in the LSU Roger Hadfield Ogden Honors College.

The attraction of the course is its content, which is limited to scientific issues directly relevant to the students. Often, discussions of science in the news include controversies students may read about on their Facebook pages or Twitter feeds. These are interesting times, and there never seems to be a shortage of such topics. For example, this year, we had just discussed pandemics when SARS-COV-2 emerged in China and began spreading across the globe. Students understood how viruses are transmitted, how they attack cells and how vaccines provide protection. Similarly, in 2018, we learned about CRISPR-Cas9, the revolutionary gene-editing tool, and discussed the social ramifications of its potential use for modifying human genes. Later that semester, He Jiankui, an associate professor in Shenzhen, China, used CRISPR- Cas9 to create the first gene-edited human babies. Other topics of current interest discussed in the class include human impact on climate change, current predictions regarding population growth and resource availability, the safety of genetically modified crops, and the genetics and biochemistry of addiction.

The Science for Citizens class helps students develop an intellectual foundation to think critically about scientific issues, which is increasingly essential in today's world as the interface between scientists and public policy broadens. Throughout 2020, this interface will be dominated by the impact of COVID-19 on global society. However, although the current pandemic has eclipsed them, other issues are looming and will require engagement of a technically literate populace for discussion and resolution.

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Inside:

LSU AgCenter scientists continue their battle with the insect pests that threaten Louisiana's sugarcane and rice crops. *See page 14*

The Formosan subterranean termite is an extremely difficult pest to control. One new technique aims to disrupt their means of communicating with one another, which they do through chemical cues. *See page 20*

Because it is now legal to grow hemp in Louisiana, LSU AgCenter scientists are developing ways to control the pests, including insect pests, that can hamper profitable production of this crop. *See page 22*

Black soldier flies, about the size of a pin head, can eat tons of food waste and quickly grow into little worms (larvae) that can be fed as a nutritious meal to livestock. LSU AgCenter scientists are studying this process as a way to provide business opportunities for Louisiana farmers. *See page 24*

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