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PROJECT REPORT

SOUTHWEST SUBTERRANEAN PROGRAM: ROOST AND WATER CONSERVATION FOR POLLINATING AND INSECT-EATING BATS

PREPARED FOR

USDA NATURAL RESOURCES CONSERVATION SERVICE:
CONSERVATION INNOVATION GRANTS

FINAL REPORT

DECEMBER 2011

Conserving the world's bats and their ecosystems to ensure a healthy planet.

CONSERVATION INNOVATION GRANTS
Final Report

Grantee Name: **Bat Conservation International, Inc.**	
Project Title: **"Southwest Subterranean Program: Roost and Water Conservation for Pollinating & Insect-Eating Bats"**	
Agreement Number: **NRCS 69-3A75-9-164**	
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Executive Summary:

Conservation Innovation Grants (CIG) accelerate the adoption of promising approaches to address some of the nation's most pressing natural resource concerns. Bat Conservation International (BCI) has used multi-year grant funding to benefit agricultural producers by providing more options for environmental enhancement that improve conservation outcomes for the nation's bats and increase awareness of the value and vulnerability of bat species that provide pollination and pest management across the western United States.

During the grant term we worked directly with producers, training them on bat conservation actions that lead to healthier bat populations through improvements to water access and protections for roosts. We worked across the Southwest to assess roost sites for pollinating and insect-eating bat species and implement management plans and site protection actions to guard against losses of these valuable species. One of the Federally Endangered pollinating bat species occurring in New Mexico and Arizona will benefit from monitoring protocols developed as part of CIG funding, and our University of Arizona research partners are continuing the work beyond the grant interval to distribute the findings of the work.

Education and outreach efforts reached many constituencies—from farmers and ranchers attending workshops and conferences where programming was present to publications and presentations for specialty growers and schoolchildren in rural agricultural communities. The data gathered in our "What Bats Eat" agricultural research has already secured BCI invitations to work with producers and will be used in the coming years to engage new audiences of agricultural producers with more detailed documentation of the eco-services that America's bat species provide. This will spur increased adoption of best practices for conservation, guaranteeing continued health of valuable bats across agricultural landscapes and adjacent wild spaces.

Project Introduction:

The Conservation Innovation Grants program is a vehicle to stimulate the development and adoption of conservation approaches that have been studied sufficiently to indicate a likelihood of success, and to be candidates for eventual institutionalization. This project was designed to advance the general understanding and adoption of conservation approaches that take into account the connection between bats and agricultural production. In so doing, our project addressed two of the natural resource concerns listed in the 2009 RFP, which were intended to be objectives for selected projects:

1. to implement approaches for environmentally sound wildlife habitat management while sustaining agricultural productivity—specifically related to pollinator protection and biodiversity.
2. to implement approaches to improve habitat for wildlife while maintaining, restoring, or enhancing water quality and/or quantity in predominantly agricultural land areas.

Project Background:

Most people recognize that bees are important pollinators, but most are not aware that many species of butterflies, bats, and birds are also key pollinators. They are so essential to reproduction that much of the world's plant life could not exist without them. Despite the critically important services they provide, pollinators have been taken for granted and are in jeopardy. Two out of the three pollinating bat species in the United States are on the Federally Endangered list. According to the US Department of Agriculture (USDA), we are facing an "impending pollination crisis" in which both wild and managed pollinators are disappearing at alarming rates. Declines are believed to be the result of pesticides, reduced availability of nectar, destruction of habitat, modern agricultural practices, and invasive species.

From Arizona into Central America, various plant species, including agaves and columnar cacti like the saguaro, depend strongly (and in some cases almost entirely) on nectar-feeding bats, including lesser long-nosed bats (*Leptonycteris yerbabuenae),* for pollination. The agaves have an economic importance, not the least of which is for the production of tequila, and saguaros are important in the culture of many regional Native American tribes such as the Tohono O'odham Nation of Arizona. When the U.S. Postal Service created its series of *Pollination* stamps, the lesser long-nosed bat was featured nosing into a saguaro cactus blossom.

Bats are also primary predators of night-flying insects, consuming countless agricultural pests nightly and directly reducing pesticide use. Multi-state (Hatch Act funded) research by the USDA and Cooperative State Research, Education and Extension Service (CSREES) has determined that colonies of Mexican free-tailed bats (*Tadarida brasiliensis),* which are predators of crop insect pests, save cotton producers in the Texas Winter Garden region about $740,000 annually in the form of avoided crop losses and pesticide treatments. Our project has been headquartered in Arizona—one of the leading

cotton-producing states in the nation. (Pima County, Arizona is best known for its cotton production—hence the name Pima cotton.) Most California bats are insectivorous, with the exception of one desert species in the extreme southern portion of the state that feeds on nectar and pollen. Although the role that insectivorous bats play in agricultural pest control is difficult to quantify, an average sized maternity colony of 150 big brown bats (*Eptesicus fuscus*) can consume more than a million insects each year. *California Agriculture* magazine undertook eight years of research in attracting bats to farms, and the University of California Cooperative Extension website encourages farmers to value bat habitats as more studies are indicating that bats can significantly reduce insect numbers in croplands. The studies also show that in cropland environments bats eat adult moths of armyworms, corn earworms, cutworms, and codling moths, as well as stinkbugs, cucumber beetles, and leafhoppers.

Bats are vital to Southwest ecosystems—yet are severely threatened, particularly by the disturbance and destruction of critical mine and cave roosts, and the decline in availability of pooled water sources for drinking. Cave-dwelling species are especially sensitive to disturbance in maternity colony roosts.

BCI applied for funding for our Southwest Subterranean Program to advance the conservation and management of mine and cave roosts, and drinking resources for bats that have a vital impact on agricultural production. This project focused on a host of bat species, including the federally endangered lesser long-nosed bat, two highly vulnerable species, the California leaf-nosed bat (*Macrotus californicus*) and Townsend's big-eared bat (*Corynorhinus townsendii*), and several other species such as the cave myotis (*Myotis velifer*) and the economically valuable Mexican free-tailed bat.

Project Objectives:

This long-term conservation initiative was designed to benefit multiple species, including the most imperiled bat species in the target eco-region. It used a partnership-based model to implement actions supporting regional agricultural producers and to meet species protection priorities explicitly identified by the US Fish and Wildlife Service (USFWS) and multiple southwestern states' Wildlife Action Plans. Innovation is reflected by the project's exploration of conservation activities that have been adapted for implementation by producers and present incentives for adoption. See Attachment 1 for a map displaying the project's regional scope and the locations of on-the-ground project sites.

Project objectives address four of the highest-priority needs for the target species:

Objective 1: Develop and implement a scientifically rigorous monitoring protocol for the federally endangered lesser long-nosed bat;

Objective 2: Identify, develop, and initiate conservation and management plans for key roosts;

Objective 3: Identify, evaluate, and prioritize (for conservation action) water sources deemed vital for the survival of local bat populations;

Objective 4: Educate the research and resource management communities, private stakeholders, and the general public about the importance and benefits of the target species.

Project Results:

A) Objective 1: Develop and implement a scientifically rigorous monitoring protocol for the federally endangered lesser long-nosed bat

BCI partnered with Dr. Bob Steidl, professor at the University of Arizona, to accomplish the goals of this objective, which were to design a new monitoring protocol for the lesser long-nosed bat – a pollinating bat species that is Federally Endangered. In the fall of 2009, Dr. Steidl selected a master's degree student, Ana Cerro, to work with him on this project. In February 2010, Dr. Steidl and Cerro organized a meeting with representatives from BCI, Arizona Department of Game and Fish, and US Fish and Wildlife Service to discuss the project and the best strategies for meeting our goals. Throughout the period of this grant, Dr. Steidl and Cerro consulted with representatives from BCI, Arizona Department of Game and Fish, National Park Service, US Fish and Wildlife Service, and the academic community to discuss project goals and further refine the project plan along the way. To obtain broader support for the project, the plan was presented at the Annual Arizona Lesser Long-nosed Bat meeting where biologists involved in past monitoring efforts for the species discussed trends, challenges, and needs.

The importance of completing such projects on understudied and thus poorly understood pollinating species cannot be underestimated. Until we increase our knowledge of population trends and behavioral patterns, we will never be able to fully understand the extent of the ecosystem and agricultural benefits they provide. For species such as the lesser long-nosed bat whose abundance varies naturally, both temporally and spatially, monitoring efforts can be especially challenging, requiring a rigorous sampling framework to detect temporal trends despite the high inherent variation in abundance. For these species, monitoring will only be successful when performed under a rigorous sampling framework that has been designed carefully and can be implemented over long time horizons. What follows is a brief description of our project design and its results at the two-year mark. Although published final results are not yet available, the completed monitoring protocol is on schedule.

The areas we studied encompassed much of southern Arizona and a small portion of northern Sonora, Mexico, where maternity roosts and transient roosts (non-breeding) of lesser long-nosed bats occur. We surveyed seven roosts in 2010, three maternity and four transient roosts (Attachment 2: Table 1), and nine roosts in 2011, three maternity and six transient roosts (Attachment 2: Table 2); six of these roosts were surveyed in both years

to estimate year-to-year variation in abundance of bats at roosts. We selected roosts to span the geographic range of known roosts in southern Arizona and northern Mexico.

To characterize spatial and temporal variation in abundance of lesser long-nosed bats, we surveyed roosts weekly or bi-weekly from May through October or November in 2010 and 2011 (Attachment 2: Table 1 and Table 2). We used video cameras (Sony Handycam DCR-SR45) with night-vision enhancement along with infrared lighting to record emerging bats. For emergences that were recorded, we counted the number of bats emerging by playing back the recording in slow motion, and recorded counts at one-minute intervals. We developed a systematic sampling scheme that allowed us to estimate the total number of bats emerging from a roost with high efficiency and high precision.

In addition to bat counts, we also quantified phenology of flowering plants important as food for lesser long-nosed bats, including saguaro (*Carnegiea gigantea*), organ pipe cactus (*Stenocereus thurberi*), and Palmer's agave (*Agave palmeri*) within a 24-kilometer radius of each roost.

We surveyed roosts on 46 different occasions in 2010 and 65 occasions in 2011, yielding a total of 92 recorded emergences in 2010 and 130 emergences in 2011 from 21 different entrances (Attachment 2: Table 1 and Table 2). Abundance of bats varied widely across roosts as well as across the season within roosts (Attachment 2: Table 3). Relative number of bats at maternity roosts peaked in mid-June (Attachment 2: Figure 1), which coincided with peak flowering of organ-pipe cactus (Attachment 2: Figure 2). Peak flowering of saguaro cacti occurred prior to the peak in abundance of bats at maternity roosts (Attachment 2: Figure 2). Relative number of bats at transient roosts peaked between mid-August and mid-September (Attachment 2: Figure 1), which coincided with peak flowering of Palmer's agave (Attachment 2: Figure 2).

In general, seasonal patterns in bat abundances and flowering of forage plants were similar between years, although a higher proportion of plants flowered in 2010 than in 2011. Flowering of saguaro cacti peaked while abundances of bats at maternity roosts were still increasing. In contrast, peak flowering of organ-pipe cacti coincided with peak abundances of bats at maternity roosts. Lastly, peak flowering of Palmer's agaves coincided with abundances of bats at transient roosts. These three distinct flowering peaks suggest that timing of flowering phenology may coincide with arrival of bats to maternity roosts, persistence at maternity roosts, and arrival at transient roosts.

Today, after more than two years, the study is in its final stages. Ongoing data analysis and compilation will produce a statistically rigorous and scientifically sound monitoring protocol addressing the challenges of monitoring a migratory species that winters in Mexico and summers in the southern region of Arizona. Results from this study will consist of two interrelated components. First, we will examine how variation in abundance of bats is explained by roost location, time of year, and flowering phenology. We are especially interested in assessing the association between abundance of bats at different roosts and phenology of forage plants. Secondly, we will use the information

obtained to develop a reliable and statistically robust monitoring protocol, including when, where, and how frequently to survey key roost sites to ensure that trends in the population can be detected for this endangered species. Our final report on the protocol will be completed by May 2012.

To complement our work monitoring roosts and designing a monitoring protocol for pollinating lesser long-nosed bats, BCI collaborated with the National Oceanic and Atmospheric Administration's (NOAA) Severe Storms Laboratory to conduct trials to determine if mobile marine radar can effectively locate undiscovered roosts of long-nosed bats and other species in the southwestern United States. With support from the National Park Service and the US Fish and Wildlife Service, we conducted tests with the radar and collected acoustic bat data in west Texas and western Arizona for several weeks in July and August of 2010. Analyses of both radar and acoustic data are still underway and will be completed within the next year to evaluate the potential for this method in assisting in searches for unknown roosts for lesser long-nosed bats and other species. Preliminary analyses indicate that roosts can be found with mobile marine radar in the borderlands, but it has limited range in areas with rough topography; limited road access in mountainous areas constrains deployment of the radar and therefore the area surveyed.

BCI also continued to collaborate with the US Fish and Wildlife Service, the Arizona Game and Fish Department, the University of Arizona and the town of Marana, Arizona on a CITIZEN SCIENCE study concerning hummingbird feeder visitation by nectar feeding bats in southern Arizona. This study provides insight into the arrival and departure of nectar-feeding bats in Arizona and their urban habitat preferences (e.g., lighting conditions, proximity to natural vegetation flyways). The past several years' data and comments from participants are being evaluated currently in order to make any necessary adjustments to the effort for the coming summer and fall. Data are being analyzed and prepared for presentation at a scientific meeting, and a popular article is being written for publication to benefit the participants and the general public.

Finally, BCI biologists attended several state and national level meetings to present results from our work with America's endangered pollinating bats. These meetings allowed us to connect with other regional and national researchers and land managers to learn about new projects and strategies related to nectar-feeding bats and other relevant work. Among others, we attended the following meetings to discuss topics related to bats and pollination:

- North American Society for Bat Research (October 2010)
- New Mexico Bat Working Group (November 2010)
- Arizona meeting on White-nose Syndrome (November 2010)
- The Wildlife Society, Arizona and New Mexico chapter meetings (February 2011)
- The Western Bat Working Group meeting (April 2011)

- The Department of Defense White-nose Syndrome (WNS) workshop held at Fort Huachuca, Arizona (August 2011)

Summary of Actions/Activities completed toward Objective 1 during the grant interval:

1) The multi-year goal of designing new monitoring protocols for key pollinating bat species was established and data analysis continues;
2) BCI staff and Dr. Robert Steidl of the University of Arizona created a work plan and recruited a graduate student to conduct the work;
3) All data have been collected and preliminary results from the monitoring study have been prepared;
4) The finalized protocol will be ready for release in the summer of 2012.

B) Objective 2: Identify, develop, and initiate conservation and management plans for key roosts

As part of our comprehensive subterranean roost assessments carried out over the two-year period of this project, we identified priority sites, either known roosts or potential roosts, for rapid assessments and the initiation of management plans to contribute to the conservation and protection of the species/habitat found at those sites. In two years, BCI conducted more than 500 rapid field assessments of cave and mine roosts for which we collected data and developed recommendations regarding habitat quality, bat species presence, bat colony size, historical bat use, and need for protective measures or closure actions. These surveys have laid the foundation for the development of site-specific management plans at all sites deemed important and currently without a management plan. An added benefit of these surveys is that they lead to new discoveries of previously unknown bat roosts (sometimes for endangered pollinating species like the lesser long-nosed bat), and they help gain a better understanding of the spatial distribution of various bat species across the region.

As a result of the rapid assessments and the site-specific management recommendations we developed, dozens of deserving cave and mine features were recommended for protective measures, such as entrance gates, fencing, and or signage. Protective measures were recommended at all sites containing sensitive species where threats of human disturbance or safety hazards are present. Because cave/mine dwelling bats congregate in large groups, remarkably large populations of individual species are vulnerable until protective measures are in place. Oftentimes, the results of BCI's surveys are the only thing standing in the way of potentially critical pollinator and pest-managing bats being entombed or made homeless through destructive closures of these mine entrances. And, the construction of a specialized, bat-friendly gate is oftentimes the only barrier that prevents vandals or unknowing adventurers from entering sensitive sites and inflicting serious damage to bat colonies and their habitat.

Eagle Creek Bat Cave and the Last Chance Mine, both in Arizona, are two examples of subterranean roost sites where BCI, along with a host of partners, installed bat-friendly gates during this grant interval. Both sites have long been deemed worthy of protective measures, but challenges due to site location, ownership logistics, and or availability of funding have in the past frustrated efforts to accomplish long-term solutions to safeguard the bat colonies that call these sites home.

Eagle Creek Bat Cave, located in southeastern Arizona, serves as one infamous example of what can happen when large cave colonies of bats are left unprotected, leaving these valuable agricultural pest managers vulnerable to human disturbance and population decline. Eagle Creek Bat Cave once sheltered one of the largest maternity colonies of Mexican free-tailed bats in the US, with many millions of bats reported in the 1960s. But the cave's easy access brought repeated disturbances, including major acts of vandalism. The population crashed until barely 30,000 bats remained by the 1970s. Conservationists, including BCI, have been struggling to gate the cave, which is beneath both private and public land, since at least 1986, but one effort after another failed for a variety of reasons. In November 2010, BCI and our partners successfully installed a bat-friendly gate over the cave's entrance. Now the future is brighter for the bats that will be able to roost and raise their young undisturbed, while also providing valuable insect-eating services to the farmers of the nearby Gila Valley. This long-sought success resulted from a partnership of BCI, the Arizona Game and Fish Department, Freeport McMoRan Inc., the US Bureau of Land Management and the Wildlife Habitat Council.

Eagle Creek Cave Gate Project
Feedback from the Arizona Game & Fish Department:

"It is very exciting, one of those things that deserves an article write up, and a bit more attention. It is a monster size gate, for a monster size roost - the size of the gate and the understanding of what it took to get the materials back to such a remote spot - breathtaking! It was a long time coming, and shows the need to sometimes realize that patience and perseverance are key to getting things done. It had been on the to-do list for long, in fact, it was one of the first things I was contacted about when I started this job in 2003. Timing and people are everything. It is inspiring to see things come to fruition that are so multi-faceted, have been bogged down and could remain that way, if not for the dedication and determination of people who continually refocus on how to get things done, rather than lamenting about how hard it is to get things done."

Angie McIntire, Bat Specialist
Arizona Game and Fish Department
President, Western Bat Working Group

The Last Chance Mine is located within Grand Canyon National Park. Biologists first discovered a maternity colony of Townsend's big-eared bats inside the mine in 1988, and at that time wildlife managers recommended closing the mine's three openings with bat-friendly gates to protect both people and bats. Unfortunately, that is where things sat for two decades, until BCI and Grand Canyon National Park joined forces to gate the mine's entrances in September 2009. After confirming the importance of the Last Chance Mine and the need for gating to protect the ecologically and economically valuable bat colony, we secured the necessary funding from Freeport McMoRan Inc., but nothing is ever easy in the Grand Canyon. Two of the mine entrances emerge along the side of a 300-foot (90-meter) cliff. The gating contractor, MineGates Inc., assembled an experienced team and the Park Service provided a manager and other staff, as well as aviators and a helicopter. In September 2009, three crews went to work on three gates. The Grand Canyon National Park pilots proved remarkably adept at placing tons of materials and gear exactly where they needed to be, and the crews required just a day and a half to get the prefabricated gates in place. After months of planning and decades of waiting, the Last Chance Mine was gated and its bats are protected.

One of the most exciting results from our work under this grant was the discovery of three previously unknown roosts for the federally endangered pollinator, the lesser long-nosed bat. This pollinating bat species migrates seasonally between Mexico and southern Arizona, and its presence in the US lasts only for a few short months during the summer. Given this temporal constraint, efforts to locate caves and mines used as roosts by this important species often relied upon identifying signs of historical use, through analysis of what are called "guano splats." Unlike insectivorous bats, whose guano usually resembles small pellets, the lesser long-nosed bat and other pollinating species typically leave behind unique guano splats that specially trained biologists can identify. Throughout this grant period, we did find evidence of historical roosting by pollinating bats in several subterranean features, but the location of a roost with lesser long-nosed bats present at the time of survey was a much rarer occurrence.

In the summer of 2011, through a combination of targeted cave and mine assessments, electronic monitoring and radio telemetry with the Arizona Game and Fish Department and the Arizona Mine Inspector's Office, we were able to identify three new roosts for lesser long-nosed bats. The results from our assessments at these sites can be summarized as follows:

Buckelew Cave - one radio tagged lesser long-nosed bat was tracked to a day-roost in Buckelew Cave on private property within one mile of the Coronado National Forest. To minimize disturbance to the roost, only a partial rapid assessment of the cave was performed, confirming the presence of larger amounts of roost staining (an indicator of extended and relative greater amounts of use by bats) and many lesser long-nosed bats. Accurate and complete counts throughout the cave were not attempted to minimize disturbance to this important roost.

Private Hay Barn – one radio tagged lesser long-nosed bat was tracked to a night-roost in a hay barn in the Dos Cabezas Mountains region on private producer property approximately 13 miles from the Coronado National Forest. Estimates suggested that several hundred bats were present in this seasonal night roost. Additional work is

required to fully understand the importance of this roost to the regional lesser long-nosed bat population.

Unknown/unnamed mine – the same radio tagged lesser long-nosed bat that led to the night roost in the private hay barn was subsequently tracked to a day-roost in a mine in the Dos Cabezas Mountains on Bureau of Land Management lands approximately 13 miles from the Coronado National Forest. We could not gain permission to access the site and will continue to work with the Arizona Game and Fish Department and the Bureau of Land Management to access the site.

Summary of Actions/Activities completed toward Objective 2 during the grant interval:

1) Conducted internal surveys on more than 500 subterranean sites (abandoned mines and natural caves) to locate and protect new roost locations for several species of sensitive bats and federally endangered bats that provide pollination and pest management services to regional agricultural producers. This included research into micro-habitat requirements and self-selecting roost preferences of mine and cave roosting bats;
2) Developed site-specific management recommendations, later leading to management and protection plans;
3) Oversaw the planning and installation of protective measures at entrances to key subterranean roost sites following assessments;
4) Began construction and population of a GIS-referenced database of roosts and resource sites for target species (current "draft" database is Microsoft Access);
5) Trained biologists working in the region to conduct subterranean bat surveys, helping to expand the effort.

C) Objective 3: Identify, evaluate, and prioritize (for conservation action) water sources deemed vital for the survival of local bat populations

BCI's Water for Wildlife program made exceptional progress from 2009 to 2011 improving the quality and availability of essential water sources for bats and other wildlife on thousands of acres of producer, public, and tribal rangelands across the seven-state region of this project. Throughout the grant interval we continued to expand the program's scope and effectiveness by working more closely with an array of agricultural producer groups, consisting of livestock associations, private ranchers, Native American tribal grazing associations, agricultural extension offices, grassroots conservation initiatives, and federal, state, and county natural resources agencies. The program's coordinator, Dan Taylor, collaborated with dozens of partners to evaluate, plan, or implement restoration efforts on more than 50 springs, wetlands, and range water developments in Arizona, California, Colorado, New Mexico, and Texas. Together with our partners, BCI also conducted workshops and gave educational presentations on the ecological importance of bats and techniques for enhancing, restoring, and creating water resources for bats and other wildlife, reaching more than 200 new ranchers and natural resource managers.

In two years, BCI has literally impacted hundreds of thousands of acres of western lands by increasing the availability of drinking water for bats and other wildlife species with narrow water requirements. All species of bats must drink while in flight (like swallows and swifts—birds that also provide pest management services to agricultural producers) so they can only drink from pooled or slow-moving water, further restricting the number of suitable drinking sites. Because livestock water troughs and stock ponds provide pooled water and are well-distributed across the landscape, they have become an essential resource for bats. The following is a sampling of the more than 50 water site evaluations and improvement projects undertaken during this grant interval:

- In the fall of 2010, Taylor visited private ranches in New Mexico to discuss potential range water redevelopment projects with ranch owners, including: on the 130,000 acre C-S Ranch in Cimarron, New Mexico; the 45,000 acre Bar-W Ranch in Carrizozo, New Mexico; the 30,000 acre Ranney Ranch near Corona, New Mexico; the Pritizlaff Ranch near Las Vegas, New Mexico; the Gillespie Ranch near Mayhill, New Mexico; and the Navajo Nation's Pitt Ranch near Crownpoint, New Mexico.
- In May 2011, BCI and the Center for Wetland and Stream Restoration (CWSR) worked with the Navajo Nation Department of Agriculture to transform a degraded spring and stock pond into a reliable water source for bats and oasis for wildlife and pollinators on the Navajo Nation's Pitts Ranch in Crownpoint, New Mexico.
- In June 2011, BCI developed restoration plans for nine degraded springs and wetlands in Arizona's Sky Islands and Mogollon Rim regions for bats, endangered frogs and fish, pollinators, and other wildlife. Partners included Upper Eagle Creek Watershed Association ranchers, Coconino National Forest, Bureau of Land Management, and Arizona Game & Fish biologists.
- In September 2011, BCI completed a second year-long landscape level analysis of seven water sites in five drainages of the Upper Rio Penasco Watershed on the Sacramento Ranger District of the Lincoln National Forest. This work was part of a project with the New Mexico Fish and Game Department's Share with Wildlife Program.
- In August 2010, Taylor worked with ranchers that are grazing permittees and resource managers on the Sacramento, Smokey Bear, and Guadalupe Ranger Districts of the Lincoln National Forest to evaluate more than two dozen range water developments, springs, and wetlands for restoration or enhancement. Detailed restoration plans were completed for each site, and two of the most important have been slated for implementation in 2011, Bailey Springs on the Sacramento Ranger District and Long Canyon Tank on the Gillespie Ranch, Sacramento Ranger District.
- In September 2010, Taylor finished a year-long landscape-level assessment of water resources and other habitat features for bats on 20,000 acres of the Bonito Watershed of New Mexico's White Mountains. Seven existing water sites were evaluated for bat visitation and three were prioritized for restoration. Two of these sites, a degraded spring, and a seasonal pond and elk wallow were restored and a new wetland water source was created in the Littleton Canyon drainage.

Education is another key element in our Water for Wildlife programming, and BCI's biologists conducted dozens of speaking engagements and hands-on workshops from 2009 to 2011, allowing us to compile a producer constituent list across the multi-state region that will enable follow-up trainings and replication efforts (Attachment 3). Conducting regional and local workshops and training sessions for agricultural producers, ranchers and range and wildlife managers is one of the most effective and long-lasting methods BCI uses to achieve our conservation goals. Making these events affordable and easily accessible to on-the-ground resource managers and producers ensures excellent participation, and the effects are magnified as the knowledge gained is implemented on the tens of thousands of acres of public and private lands.

In 2010, BCI began conducting a new workshop that includes techniques for the restoration, enhancement, and creation of naturally-functioning springs, ponds, and wetlands, including the transformation of agricultural/rangeland stock ponds into valuable habitat for bats and other wildlife, while improving livestock management. This approach has been expanded in 2011, and it has the potential to fundamentally change the way that livestock water developments are managed on millions of acres of western rangelands, benefiting countless bats and other wildlife whose services to agricultural producers are vital. The following is a sampling of the hands-on workshops and educational presentations conducted by BCI during this grant interval, allowing us to reach more than 200 agricultural producers and natural resource managers with vital information about the ecological importance of bats and techniques for enhancing, restoring, and creating water resources on their lands:

- In March 2010, Taylor was invited to give a presentation on integrating water, wildlife, and livestock management to more than 30 Forest Service grazing permittees at a continuing education session organized by the Coronado National Forest, Santa Cruz County Resource Conservation District, and the USDA-Natural Resources Conservation Service in Sonoita, Arizona.
- In September 2010, the Water for Wildlife Program held its first collaborative workshop on creating wetlands and ponds with the Center for Wetlands and Stream Restoration (CWSR) and the Lincoln National Forest. The workshop was attended by more than two-dozen natural resource managers from a multi-state area representing more than a dozen agencies and organizations. The workshop taught low-cost techniques to restore and create wetland and pooled water habitats. During the two and a half day workshop, the attendees assisted in the creation of three small spring-fed ponds and the restoration of a large forest pond, improving its value for bats, amphibians, and many other wildlife species.
- In October of 2010, Taylor gave an invited presentation to 25 Navajo ranchers and agriculturists on improving range water developments for bats and other wildlife at the inaugural Navajo Nation Agricultural Conference in Window Rock, Arizona. After the presentation, Taylor was approached by several Navajo ranchers interested in collaborating on water restoration projects on tribal lands, which led to our planned Pitt Ranch spring restoration.

- In April 2011, Taylor presented an invited paper on the Water for Wildlife Project to more than 100 biologists at the Western Bat Working Group's bi-annual conference in Las Vegas, Nevada.
- In May 2011, BCI and the US Fish and Wildlife Service's Partners for Fish and Wildlife held a workshop on wetland and pond restoration for Native American natural resource managers on the White Mountain Apache Reservation in Hon-Dah, Arizona. The workshop was attended by 25 Native American natural resource managers representing seven tribal nations in Arizona, New Mexico, and Utah. Participants helped create a new wetland pond for bats, pollinators, and other wildlife at a nature center in Pinetop, Arizona.
- In September 2011, BCI, CWSR, Lincoln National Forest, and the New Mexico Fish & Game Department held a workshop on wetland and pond creation attended by 28 ranchers and natural resource managers.

The accomplishments of BCI's Water for Wildlife program did not go unnoticed in 2010, as the program coordinator, Dan Taylor, was recognized by two outside agencies with achievement awards: Taylor received the Quivira Coalition's 2010 Outstanding Leadership in the Radical Center Award for Conservation, and he was recognized with the USDA-Forest Service's 2010 "Wings Across the Americas" program for Outstanding Achievement in Conservation.

Summary of Actions/Activities completed toward Objective 3 during the grant interval:

1) Identified and assessed water sites across the multi-state region deemed to be vital for the survival of local bat populations of value to agricultural producers;
2) Developed site-specific management recommendations, later leading to water site improvement projects;
3) Trained private landholders, resource managers, and agricultural producers on bat habitat and pooled surface water conservation measures to ensure bats and other wildlife can access key water sources;
4) Compiled a list of producers reached through this project from across the region, enabling follow-up trainings and replication efforts (Attachment 3).

D) Objective 4: Educate the research and resource management communities, private stakeholders, and the general public about the importance and benefits of the target species

One of the primary means through which BCI achieves its mission is broad educational programming. Until and unless popular perceptions of bats can be improved from widespread myths and negative stereotypes, we cannot expect bat conservation initiatives to reach their full potential.

In recent years, scholars have published articles documenting the value of bats to agricultural production, but these may not be read widely beyond certain academic circles. For example, the April 2011 issue of *Science* contained an article by Boyles et al.

entitled "Economic Importance of Bats in Agriculture," in which the authors estimate the value of bats to North American farmers at more than $3.7 billion per year (see Attachment 4). Such vital knowledge should not be contained by the limited readership of one magazine, especially when the wellbeing of bat populations in our country is at stake.

Therefore, educating the general public, in addition to producers and land managers, regarding the immense environmental and economic benefits offered by healthy bat populations was a key strategy we used during this grant interval, and we were able to reach more than 50,000 people. In particular, raising awareness about bats as pollinators and pest managers varies across the targeted region—for instance in communities in southern Arizona (where nectar feeding bats are most common) and central Texas (where insectivorous bats are common) education is important for gaining broad support for conservation measures to protect economically and environmentally valuable species. Overall, BCI's outreach efforts, together with partners, have been met with great interest, and the many requests for additional educational events demonstrate their importance and appeal.

BCI partnered with researcher Veronica Brown at the University of Tennessee on an ambitious project to better document the benefits of insect-eating bats in the US. The goal was to craft a database of bat species in the US, searchable by their insect diets, the crops impacted by their feeding, and available pesticide information related to efforts to reduce insect populations with harmful chemicals. Now completed, this database serves as a valuable educational tool for BCI to use when making presentations to agricultural producers, as it demonstrates the enormous pest management services provided naturally and "free of charge" by bats. The data gathered for the database will ultimately be organized into regionally-specific brochures for distribution to agricultural producers and for publication in appropriate media.

BCI and Brown have already begun putting the results of this project into action, as Brown attended the Arizona Pecan Growers Association Meeting, held in Tucson, Arizona on September 16, 2011. Brown also recently published an article on the topic of bats as natural pest control in *Acres U.S.A.*, a popular magazine covering commercial-scale organic farming (see Attachment 5). Additionally, BCI's *BATS* magazine featured a cover story "Pecan Orchards Welcome Bats" in our Summer 2011 issue (see Attachment 6). Copies of this issue have been distributed to producers in the target states.

In addition to the Water for Wildlife presentations and workshops described in the previous section, BCI's broad-level educational programming consisted of public events with large crowds, presentations to schoolchildren and other targeted groups, intensive workshops for conservation professionals, and interpretive tours at Bracken Bat Cave – home to the world's largest colony of bats. Over the course of this two-year grant, these combined efforts allowed us to reach more than 50,000 people with the intent of transforming popular opinions and raising the level of public awareness about the importance and benefits of local bat species. The following list describes the impact of BCI's education and outreach work during this grant interval:

- National Pollinator Week (June 21-27, 2010): In partnership with the Tucson Audubon Society, the Pollinator Partnership, and Tohono Chul Park, BCI organized a 3-day celebration which included six presentations, a pollinator photo contest, and an open house at Tohono Chul Park. A total of 12 organizations were involved in the event, which educated over 370 community members on the ecological value of bats and other wildlife and environmental issues (each organization focused on their unique mission).
- Earth Day (April 23, 2010): BCI participated in an event for the Tucson school system and reached 400 children, teachers, and parents with a strong conservation message about the ecological importance of bats to ecosystems and to ranchers and farmers.
- BCI also completed two presentations at a popular Tucson "bat bridge" where over 90 citizens received information on bats; we had waiting lists with more people than could be accommodated in the programs and in one instance the waiting list was discontinued at 70 people.
- BioBlitz in the Whetstone Mountains in southern Arizona (April 24-25, 2010): BCI participated in this event, which was organized by our partner organization, Sky Island Alliance. We sampled for bats and educated the 35 participants on the importance of bats for the integrity of the local ecosystems.
- Bat Night – Tucson, Arizona (September 11, 2010): BCI collaborated with other organizations in Tucson for this celebration and awareness event. Final crowd counts are still underway, but we anticipate there were more than 3,000 people in attendance – exceeding the mark set in 2009.
- Night of the Bat – Austin, Texas (June 6, 2010): The City of Austin organized this event, and BCI was a key participant. More than 5,000 people filled the streets in support of the Mayor declaring the bat as the city's official animal, and BCI's founder received formal recognition for his lifelong efforts on behalf of bats. BCI distributed educational materials to the crowds and answered questions from the general public about why bats are worthy of conservation.
- Bat Fest – Austin, Texas (August 21, 2010): BCI took part in this year's annual Bat Fest, held in downtown Austin. The festival drew more than 15,000 visitors, and BCI was able to highlight the essential role of bats in ecosystems by answering questions and handing out educational materials, including our popular "Bat Facts" pamphlets, as well as collecting email addresses from the general public to add to our distribution list for informative newsletters and important announcements regarding bat welfare around the globe.
- Ag Fair for Medina County 4th Grade Students (March 25, 2010): Two BCI staff-members prepared a booth and gave 13 oral presentations to the different classes of 4th grade students from elementary schools in Medina County, Texas. The booth and presentations featured agricultural products that benefit from the pest management and pollination services of bats. Overall, more than 300 teachers and students in this agricultural zone of Texas learned about why bats are important for economic and ecological reasons.
- Bat Conservation and Management Workshops (28 May – June 8, 2010): BCI held two 4-day workshops at the Southwest Research Station near Portal, Arizona. Total attendance for both workshops exceeded 30 participants, staff, and

outside instructors. Participants and instructors represented several constituencies: USDA's Forest Service and Animal & Plant Health Inspection Service; the Arizona Game & Fish Department; the Stone Zoo-New England; Ecology & Envrionment, Inc.; St. Lawrence University; USDI National Park Service, US Fish & Wildlife Service, and Bureau of Land Management; Oregon Department of Fish & Wildlife; US Air Force.

- Bracken Bat Cave education tours (summer 2010): More than 1,500 people visited Bracken to view the nightly emergence of millions of Mexican free-tailed bats and to learn about the interaction between these bats and the ecosystems of central Texas. To bolster the educational experience for visitors, BCI began designing more than 30 interpretive signs to install along the existing nature trail that circles the bat cave. BCI worked with a professional contractor, Frank Binney of Interpretive Planning and Media Development, to create the signage. Binney is an interpretive planner and writer, specializing in nature and his experience includes signage for many national and state parks, including Yosemite and the Grand Canyon. Members of the nearby Guadalupe County Native Plant Society worked to identify and label native trees and plants along the trail to facilitate correct signage. The new signage and expanded trail system will help visitors of all ages understand the relationships between native landscapes, conservation programming, healthy ecosystems and the value of bats.
- Fort Hood 2011 Earth Fest, Fort Hood, Texas (April 29, 2011): BCI operated a booth and conducted educational programs focused on the environmental importance of bats for those in attendance, including active-duty military personnel and their families. Attendance at this event exceeded 10,000 people.
- Advanced Capture Techniques Workshop, Portal, Arizona (May 14-18, 2011): Each year, BCI holds intensive, four-day workshops at the Southwest Research Station in the Coronado National Forest. This year's Advanced Capture Techniques Workshop was attended by a total of 10 participants, representing government agencies, environmental consulting firms, and the military.
- Acoustic Monitoring Workshop, Portal, Arizona (May 19-24, 2011): The Acoustic Monitoring Workshop held this year at the Southwest Research Station attracted 14 participants from various public and private industry backgrounds.
- National Pollinator Week, Tucson, Arizona (June 20-26, 2011): In cooperation with the Pollinator Partnership, Tohono Chul Park, and Tucson Audubon Society, BCI organized a celebration that included four evening presentations with different pollinator topics such as hummingbirds, nectar feeding bats, and pollinator-friendly gardening. On June 26th a pollinator film festival was held at Tohono Chul Park and the winners of the 2011 pollinator photo contest were announced. Seven organizations were involved in the event, which educated over 170 community members on the ecological value of bats and other pollinators.
- Austin Bat Fest/International Night of the Bat (August 27, 2011): BCI took part in this year's annual Bat Fest, held in downtown Austin on the Congress Avenue Bridge – home to the largest urban bat colony in the world. The festival drew more than 10,000 visitors, and BCI was able to highlight the essential role of bats in ecosystems by answering questions and handing out educational materials, including our popular "Bat Facts" pamphlets, as well as collecting email

addresses from the general public to add to our distribution list for informative newsletters and important announcements regarding bat welfare around the globe.

- Bracken Bat Cave education tours, San Antonio, Texas (summer 2011): More than 4,000 people came to Bracken to view the nightly emergence of millions of Mexican free-tailed bats and to learn about the interaction between these bats and the ecosystems of central Texas from talks given by BCI employees.
- Bat Ambassador and General Bat Education Events, various locations (throughout the grant interval): BCI's Education and Marketing teams are always busy traveling to and preparing for public education events, such as the Texas Wildlife Association annual conference, Lady Bird Johnson Wildflower Center event, Austin City Limits event, and the Bastrop-Caldwell County Wildlife Management Association event.

Summary of Actions/Activities completed toward Objective 4 during the grant interval:

1) Trained and educated more than 50,000 individuals, representing a wide array of stakeholders, from farmers and ranchers, to researchers and natural resource managers as well as schoolchildren, and the general public about the vital ecosystem and economic services provided by the bats living all around us – and particularly about our target pollinator and insectivore species.

Project Benefits and Transferability:

This project features habitat and water resource conservation of multiple species of bats (including Federally Endangered species) in the southwestern United States. As pollinators and insect eaters, these species have appreciable value to agricultural production in the area. Working with agricultural producers across the US, BCI has demonstrated the likelihood and value of maintaining/attracting healthy bat populations to a region. Water resources and roosts where bats find shelter are critically important to the long-term conservation of bat populations and, in turn, the health of ecosystems—including surrounding farming and ranching operations. In order to protect the large and economically valuable bat populations, BCI has worked to advance knowledge of the importance of bats and their ecological needs, through both targeted and broad-scale research, education, and outreach. We worked to create programming that served multiple constituencies, including producers, conservation professionals, and the general public. Since the conclusion of this CIG-funded work, BCI has secured funds from private foundation sources in the Southwest to continue multiple components of this programming. In December 2011, we received $60,000 for projects in Arizona to be completed by BCI's Dan Taylor and Jason Corbett.

BCI has been involved with conserving lesser long-nosed bats and their roosts for many years. In fact, BCI contributed data that helped with listing the lesser long-nosed bat as a federally endangered species in 1988. Despite years of data accumulation that had advanced conservation and management at some roosting sites, the US Fish and Wildlife

Service and other agencies recognized the need for new monitoring and conservation strategies for this rare and difficult to study species. Therefore, in 2009 BCI joined with private, state, and federal entities in Arizona, as well as in Mexico and New Mexico, to "fast-track" the development of this protocol. Based on our CIG-funded work, BCI has applied for additional funds to strengthen protection of these migratory pollinating bats on the southern end of their migratory corridor and we are expanding our partnerships in Mexico to further those goals.

Under the guidance of BCI, Dr. Bob Steidl and master's student Ana Cerro of the University of Arizona have now completed two years of field work, and their final reports are scheduled for completion in May 2012. Upon their completion of the protocol, improved monitoring techniques will be available for use in tracking population trends of endangered lesser long-nosed bats, allowing better detection of declines in their populations or reductions in their geographic distribution. Although a few roosts on federal lands are monitored intensively, the vast majority of roosts inhabited by lesser long-nosed bats are monitored sporadically, principally through efforts of volunteers. In most years and for most roosts, monitoring consists of recording emergences of bats only once or twice, usually in June at maternity roosts and once in August at transient roosts. These surveys are timed to coincide with what are thought to be the dates of peak abundance of bats in the region; however, until our survey efforts over the last two years, no systematic efforts have been made to gauge reliably the seasonal variation in abundances of bats across their entire geographic distribution. Given the rates of within- and across-year variability in abundances we observed, region-wide estimates of abundance from previous monitoring efforts were likely unreliable. By quantifying seasonal and geographical patterns in abundance of lesser long-nosed bats across the region, we have generated a foundation upon which to develop an efficient and reliable strategy for monitoring abundance of bats, so that trends in abundance and distribution can be detected reliably. By developing a practical and sound sampling framework, we can encourage state and federal agencies to adopt a more systematic approach to monitoring lesser long-nosed bats to ensure persistence of the species.

Both new and persistent threats are adversely impacting bat roosts throughout the Southwest and particularly along the US/Mexico border. By focusing our resources on sites within these particularly vulnerable regions, we have identified key roost-sites that still need protection, and we have developed and initiated site-specific management plans to ensure adequate protection will be implemented for the resident pollinating and insect-eating bat species. After all, by providing long-term protection to the bat colonies roosting in these priority sites, we are helping to ensure the maintenance of the ecological and economic services that they provide, impacting agricultural producers as well as promoting overall environmental wellbeing.

As in all of our efforts, BCI cooperated with a number of partners when conducting roost surveys and developing follow-up site plans. These valued partners are already putting into action the steps BCI recommended following our cave and mine assessments, and many have expanded their evaluations and implementation of protective measures to additional roosting sites beyond those surveyed by BCI. The proactive approach of these

partners continues to increase the overall positive impact on bat conservation and demonstrates an encouraging level of sustainability for our programming.

Notwithstanding the importance of viable roosting habitat and protection against human disturbance, the long-term survival of healthy bat populations in the American Southwest depends heavily on the continued provision of water. Although the distribution and abundance of natural water sources on western forest and rangelands has declined precipitously over the last century, putting countless numbers of wildlife species at risk, BCI has built significant momentum working against the tide of drought and mismanagement by reaching hundreds of ranchers and rangeland managers with water conservation and creation training, as well as implementing dozens of on-the-ground restoration and water site improvement projects.

BCI's Water for Wildlife program has successfully leveraged its available funding to accomplish widespread, valuable conservation work. Even while our primary focus has rested on ranchers and agency natural resource managers—as many are still not aware of just how important livestock water developments are to bats and other wildlife, nor how important bats are to human economies and ecosystems—we have gradually expanded our scope from cattle tanks and troughs to include the restoration and enhancement of degraded natural water sources such as springs, wetlands, and ponds. Our first workshop on wetland and pool creation was a tremendous success and will become a central component of future efforts. This has led to increased collaboration with other organizations and conservation efforts such as those aimed at threatened and endangered amphibian conservation, keystone wildlife species like beaver, and the targets of traditional wildlife management such as deer, elk, turkey, and bear. Integrating these new wetland creation and restoration techniques with the enhancement of livestock ponds greatly benefits bats and countless other wildlife species as well as ranchers, and has the potential to fundamentally change management practices across the entire western US.

"We protect what we value, we value what we understand" – Bats play pivotal roles in natural ecosystems, and they are surprisingly important to human economies as well. Annually in the US, bats consume crop-, forest- and yard-destroying insects, as well as disease-spreading pests. Around the world, hundreds of different plants rely heavily on bats for survival—plants that are used for food, medicines, timber, forage for keystone species, and more. Despite the many benefits that bats bring to both human economies and the environment, they are among the most misunderstood and threatened species on earth. Bats fall victim to both intentional and unintentional extermination by people who are simply uninformed about their true value. BCI has demonstrated, however, that a little education can go a long way toward helping people change their attitudes and practices toward bats, and many former skeptics are now among the most active protectors of bats and their imperiled habitats.

Our educational outreach efforts during this grant interval have engaged a growing network of stakeholders in the American Southwest, including farmers, ranchers, natural resource managers, and even the general public. From our on-the-ground water site restoration projects and our intensive bat conservation and management training

workshops to our work with partners to protect critical pollinator and insect-eating bat roosts and our educational presentations at large public events, BCI has successfully raised the level of popular awareness about the importance of bats. Our hope is that greater levels of understanding among stakeholders will lead them to apply a higher value to bats, so that ultimately they will become partners with BCI in implementing the necessary "win-win" conservation solutions that benefit both bats and humans.

Provide the following in accordance with the Environmental Quality Incentives Program (EQIP) and CIG grant agreement provisions:

1. A listing of EQIP-eligible producers involved in the project, identified by name and social security number or taxpayer identification number;

A list of the participating producers can be found in Attachment 3. No money has been paid to the participating producers so social security and/or taxpayer identification numbers have not been included.

2. The dollar amount of any direct or indirect payment made to each individual producer or entity for any structural, vegetative, or management practices. Both biannual and cumulative payment amounts must be submitted.

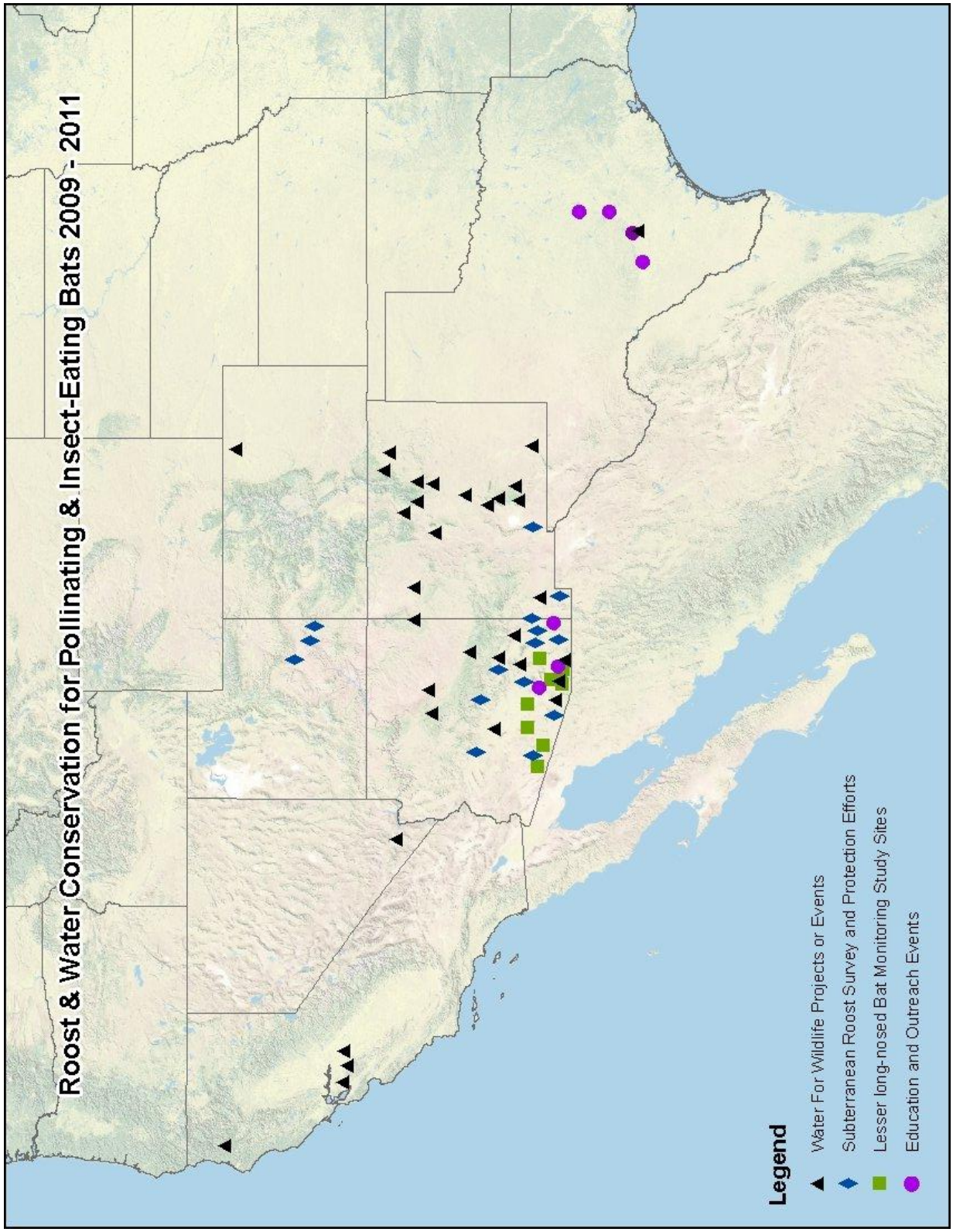
BCI has not made any payments to producers as part of this grant project.

3. A self-certification statement indicating that each individual or entity receiving a direct or indirect payment for any structural, vegetative, or management practice through this grant is in compliance with the adjusted gross income (AGI) and highly-erodible lands and wetlands conservation (HEL/WC) compliance provisions of the Farm Bill.

Not applicable.

Attachment 1

Project Map



Attachment 2

Tables & figures related to the lesser long-nosed bat monitoring study

Table 1. Roosts surveyed and dates at which emergences recorded, 2010.

Bluebird	Copper Mtn.	Pinacate	Mustang	Little Dragoons	Papago	Montezuma
26-May	12-May	18-May	24-Jul	1-Jul	15-Jul	20-Jul
8-Jun	19-May	24-May	3-Aug	9-Jul	2-Aug	4-Aug
19-Jun	25-May	22-Jun	22-Aug	12-Jul	9-Aug	10-Aug
13-Jul	2-Jun	30-Jun	29-Aug	20-Jul	21-Aug	27-Aug
27-Jul	9-Jun	28-Jul	11-Sep	3-Aug	25-Aug	10-Sep
17-Aug	23-Jun	18-Aug	7-Oct	9-Aug	14-Sep	29-Sep
	28-Jun			31-Aug		
	26-Jul			17-Sep		

Table 2. Roosts surveyed and dates at which emergences recorded, 2011.

Bluebird	Copper Mtn.	Old Mammon	Mustang	Little Dragoons	Pyeatt	Papago	Montezuma	Helena
11-May	12-May	14-May	6-Jul	27-Jul	23-Jun	19-Jul	18-Jul	28-Jul
23-May	24-May	1-Jun	28-Jul	10-Aug	12-Jul	2-Aug	1-Aug	11-Aug
6-Jun	7-Jun	18-Jun	8-Aug	24-Aug	26-Jul	17-Aug	16-Aug	22-Aug
18-Jun	18-Jun	7-Jul	20-Aug	7-Sep	9-Aug	23-Aug	31-Aug	3-Sep
13-Jul	14-Jul	25-Jul	30-Aug	21-Sep	29-Aug	1-Sep	8-Sep	16-Sep
3-Aug	4-Aug	15-Aug	17-Sep	5-Oct	12-Sep	11-Sep	19-Sep	22-Sep
20-Aug	20-Aug			19-Oct	26-Sep	20-Sep		30-Sep
	4-Sep				10-Oct	27-Sep		
					25-Oct	6-Oct		

Table 3. Characteristics of the number of emergences of lesser long-nosed bats (*Leptonycteris yerbabuenae*) from maternity and non-maternity roosts in southern Arizona, USA and northern Mexico, 2010-2011.

Roost	Roost type	Year	N	Min.	Max.	Mean	SD
Bluebird Mine	Maternity	2010	6	2,589	6,117	4,306	1,268
		2011	7	4,736	7,133	5,817	2,585
Copper Mountain Mine	Maternity	2010	8	18,992	33,354	28,699	797
		2011	8	15	42,882	27,522	979
Little Dragoons	Non-maternity	2010	8	6	4,271	1,381	4,532
		2011	7	85	5,508	2,300	2,780
Montezuma Mine	Non-maternity	2010	6	2	6,234	1,618	14,635
		2011	6	12	2,100	835	2,909
Mustang Cave	Non-maternity	2010	6	623	11,529	4,913	2,478
		2011	6	70	7,448	1,952	1,285
Papago Cave	Non-maternity	2010	6	27	2,916	1,113	1,756
		2011	9	74	2,236	933	23,345
Pinacate Cave	Maternity	2010	6	2,088	59,772	38,347	1,842
Helena Mine	Non-maternity	2011	7	5	7,412	2,803	4,775
Old Mammon Mine	Maternity	2011	6	481	7,450	2,641	845
Pyeatt Cave	Non-maternity	2011	9	66	13,038	5,400	4,272

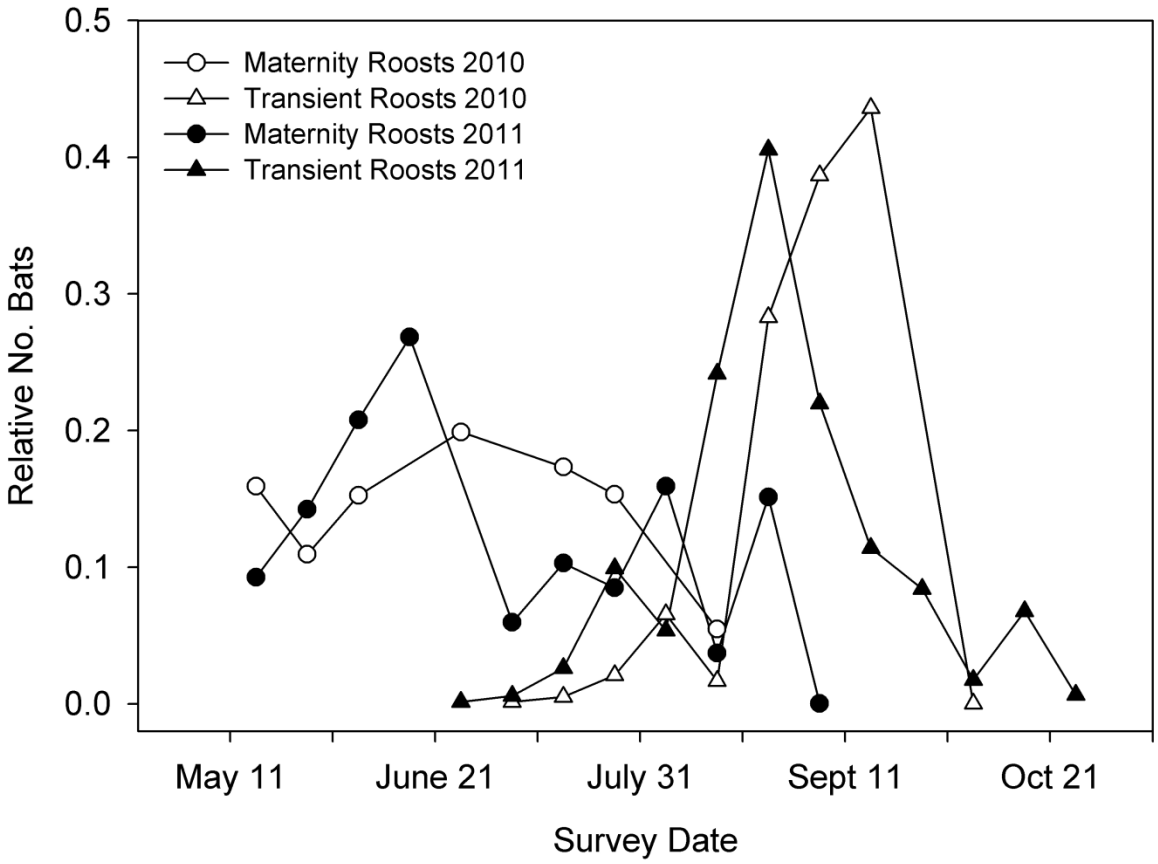


Figure 1. Relative abundance of bats over time, which we calculated as the number of bats emerging on a given date divided by the total bats emerging across all survey dates for a site in a given year. We then averaged all surveys across sites for each 10-day period across the season. season.

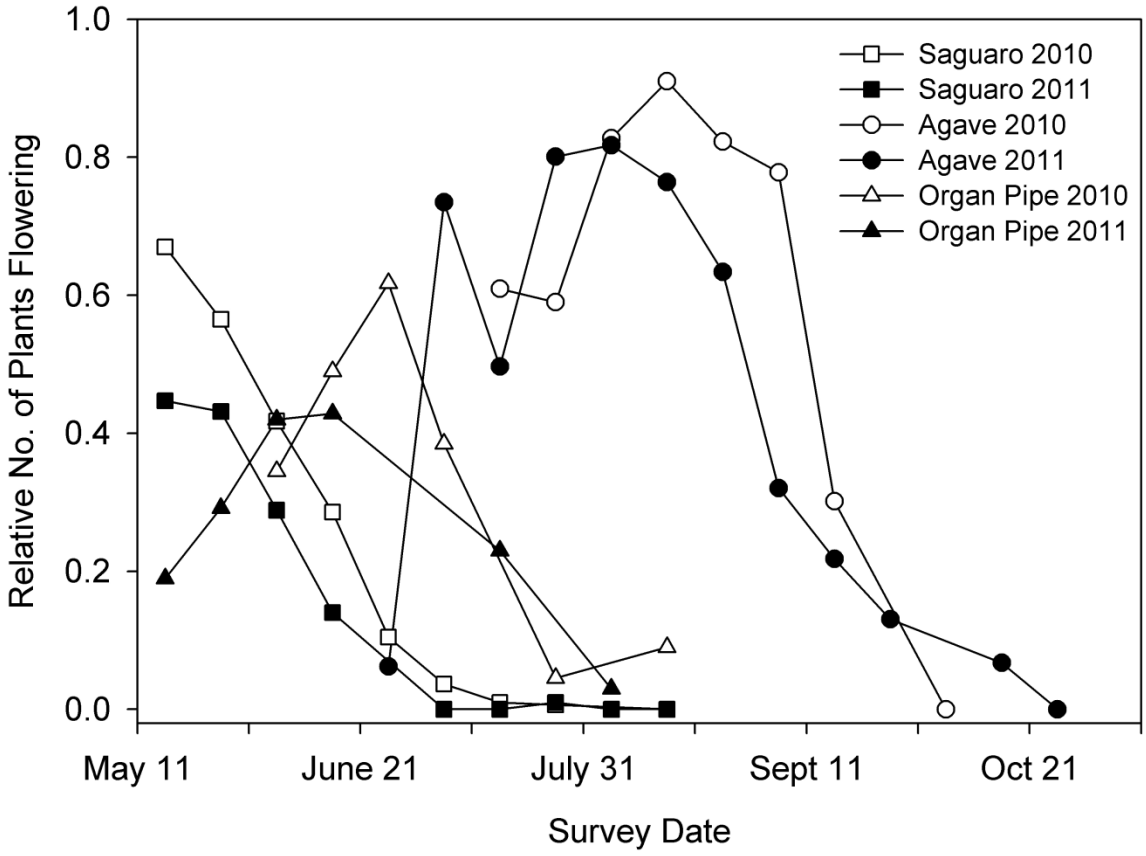


Figure 2. Proportion of forage plants flowering over time, averaged for all surveys across sites for each 10-day period across the season.

Attachment 3

List of participating producers

Participant	Affiliation	Event Type
Jose Lopez	Ysleta Del Sur Pueblo	Livestock & Wildlife Water Workshop held in Pueblo of Santa Ana, NM
Arturo Lopez	Ysleta Del Sur Pueblo	
Angus Martinez	Laguna Pueblo	
Ricky Speakman	Laguna Pueblo	
Leon D. Saracino	Laguna Pueblo	
Alfred Ramero	Laguna Pueblo	
Darwin Deloris	Laguna Pueblo	
Abel Camerena	Pueblo of Isleta	
Frank Jiron	Pueblo of Isleta	
David Lente	Pueblo of Isleta	
Brian Wimberly	Pueblo of Santa Ana	
Cathy Nishida	Pueblo of Santa Ana	
Chermanji Shu-Nyamboli	San Felipe Pueblo	
Leonard Bird	Santo Domingo Livestock Assn.	
Percy Reano	Santo Domingo Livestock Assn.	
Randy Lujan	Pueblo of Isleta	
Fred Jiron	Pueblo of Isleta	
Kevin Lente	Pueblo of Isleta	

Leonard Bell	Crow Valley Grazing Assoc.	Livestock & Wildlife Water Workshop held near Greeley, CO
Craig Lawrence	Crow Valley Grazing Assoc.	
Bruce Bowman	Crow Valley Grazing Assoc.	
Allen Diehl	Crow Valley Grazing Assoc.	
Andy Lawrence	Crow Valley Grazing Assoc.	
Craig Lawrence	Crow Valley Grazing Assoc.	
Doug Adema	Pawnee Grazing Assoc.	
Steve O'Hare	Pawnee Grazing Assoc.	
Jim Sturrock	Pawnee Grazing Assoc.	
Gary Dollerschell	Pawnee Grazing Assoc.	
Carl & Jill Klawonn	Pawnee Grazing Assoc.	
Fred Fangmeier	Pawnee Grazing Assoc.	

James Ray Evrage	Dinner Hill Ranch	Livestock & Wildlife Water Workshop held in Carlsbad, NM

Tim Koopman	Equip Eligible	Livestock & Wildlife Water Workshop held in Livermore, CA
Jed Freitas	Equip Eligible	
Toni and Bill Bunch	Equip Eligible	
Mike Miller	Equip Eligible	
Marlyn Russel	Equip Eligible	
Holly Sears	Equip Eligible	
Mark Sutherland	Equip Eligible	
Bob Veira	Equip Eligible	
Escobars	Equip Eligible	
Livingstons	Equip Eligible	

Donnie Dawaseveya	Hall/257 Grazing District	Livestock & Wildlife Water Workshop held in Birdsprings, AZ
Marlene Yazee	District 5 Grazing Assoc.	
Larry Lewis	Tolani Lake	
Sadie Curlie	District 5 Grazing Assoc.	
Johnny Monroe	District 5 Grazing Assoc.	
Jonathon Lomayestaw	Hopi, Burro Spring	
Rarebill Walkerr	Birdsprings	
Hank Willie	District 5 Grazing Assoc.	
Febo Aegh	Dilkon	
Thomas Walker Sr.	Birdsprings	
Sally Williams	D10 Grazing District	
Robert Adams	D6 Grazing District	
Dewey Samhea	D6 Grazing District	
Raymond Matthews	Tolani Lake	
Lloyd McCabe	Grand Falls	
Bill Ub	Many Farms	
Gerald Peabody	Ute Mtn. Ute Tribe	

Robert Heilig	Double Bar R Ranch	Coronado NF Permittee Workshop held in Sonoita, AZ
Sara Barcher	Rainbow Ranch	
Dan Bell	ZZ Cattle Corporation	

Chase Caldwell	6K6 Ranch	Upper Eagle Creek Watershed Association Seminar, Upper Eagle Creek, AZ
Otis & Judy Wolkins	Blue River Ranch, AZ	
Crystal & Cash Noland	Noland Ranch, AZ	
Morgan Gust	Mule Creek Ranch, NM	
Scott & Carrie Stone	Mallett Ranch, AZ	
Gary & Darcy Ely	Four Drag Ranch, AZ	
Nick & Pamela Ewing	U-Wing Ranch	
Twig & Shirley Winkle	Tule Spring Ranch	
Jim & Clarice Holder	Baseline and Horse Springs Ranch	
Bill Bunnel	Downs Ranch	
Josh Ross	T-Link Ranch	
Barbara Marks	Upper Blue River Ranch	
Carl & Martie Cathcart	Wildbunch Ranch	
Rob & Dawnee Robinson	4 Bar mesa Ranch	
Eric & Jean Schwennsen	Cold Creek Ranch	

Julia Davis	C-S- Ranch	Ranch Water evaluations for bats and other wildlife
Chase Caldwell	6K6 Ranch	
Wilma and Doug Jenkins	Double Circle Ranch	
Jim and Clarice Holder	Holder Ranch	
Ross Humphreys	San Rafael Cattle Company	
A.T. & Cinda Cole	Pitchfork Ranch	
Tim Koopman	KoopmanRanch	
Quivira Coalition	Red Canyon Ranch, NM	

Attachment 4

"Economic Importance of Bats in Agriculture" in *Science* (April 2011), by Justin G. Boyles, Paul M. Cryan, Gary F McCracken, and Thomas H. Kunz

EMBARGOED UNTIL 2:00 PM US ET THURSDAY, 31 MARCH 2011

CONSERVATION

Economic Importance of Bats in Agriculture

Insectivorous bat populations, adversely impacted by white-nose syndrome and wind turbines, may be worth billions of dollars to North American agriculture.

Justin G. Boyles,[1]* Paul M. Cryan,[2] Gary F. McCracken,[3] Thomas H. Kunz[4]

White-nose syndrome (WNS) and the increased development of wind-power facilities are threatening populations of insectivorous bats in North America. Bats are voracious predators of nocturnal insects, including many crop and forest pests. We present here analyses suggesting that loss of bats in North America could lead to agricultural losses estimated at more than $3.7 billion/year. Urgent efforts are needed to educate the public and policy-makers about the ecological and economic importance of insectivorous bats and to provide practical conservation solutions.

Infectious Disease and Wind Turbines

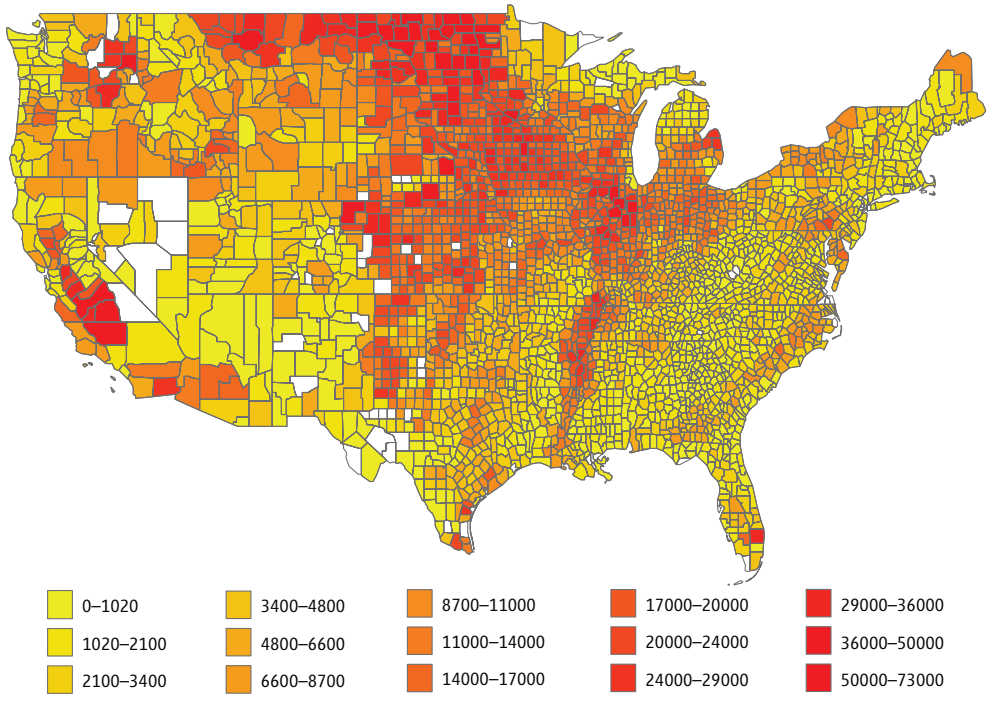
Insectivorous bats suppress populations of nocturnal insects (*1*, *2*), but bats in North America are under severe pressure from two major new threats. WNS is an emerging infectious disease affecting populations of hibernating cave-dwelling bats throughout eastern North America (*3*). WNS is likely caused by a newly discovered fungus (*Geomyces destructans*). This fungus infects the skin of bats while they hibernate and is thought to trigger fatal alterations in behavior and/or physiology (e.g., premature depletion of energy reserves) (*3*, *4*). Since February 2006, when WNS was first observed on bats in upstate New York, *G. destructans* has spread west of the Appalachian Mountains and into Canada. To date, over one million bats have probably died, and winter colony declines in the most affected region exceed 70% (*5*). Populations of at least one species (little brown bat, *Myotis lucifugus*) have declined so precipitously that regional extirpation and extinction are expected (*5*).

At the same time, bats of several migratory tree-dwelling species are being killed in unprecedented numbers at wind turbines across the continent (*6*, *7*). Why these species are particularly susceptible to wind turbines remains a mystery, and several types of attraction have been hypothesized (*6*). There are no continental-scale monitoring programs for assessing wildlife fatalities at wind turbines, so the number of bats killed across the entire United States is difficult to assess. However, by 2020 an estimated 33,000 to 111,000 bats will be killed annually by wind turbines in the Mid-Atlantic Highlands alone (*7*). Obviously, mortality from these two factors is substantial and will likely have long-term cumulative impacts on both aquatic and terrestrial ecosystems (*5*, *7*). Because of these combined threats, sudden and simultaneous population declines are being witnessed in assemblages of temperate-zone insectivorous bats on a scale rivaled by few recorded events affecting mammals.

Economic Impact

Although much of the public and some policy-makers may view the precipitous decline of bats in North America as only of academic interest, the economic consequences of losing so many bats could be substantial. For example, a single colony of 150 big brown bats (*Eptesicus fuscus*) in Indiana has been estimated to eat nearly 1.3 million pest insects each year, possibly contributing to the disruption of population cycles of agricultural pests (*8*). Other estimates suggest that a single little brown bat can consume 4 to 8 g of insects each night during the active season (*9*, *10*), and when extrapolated to the one million bats estimated to have died from WNS, between 660 and 1320 metric tons of insects are no longer being consumed each year in WNS-affected areas (*11*).

Estimating the economic importance of bats in agricultural systems is challenging, but published estimates of the value of pest suppression services provided by bats ranges



The worth of insectivorous bats. Estimated annual value of insectivorous bats in the agricultural industry at the county level. Values (×$1000 per county) assume bats have an avoided-cost value of ~$74/acre of cropland (*12*). (See SOM for details.)

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from about $12 to $173/acre (with a most likely scenario of $74/acre) in a cotton-dominated agricultural landscape in south-central Texas (*12*). Here, we extrapolate these estimates to the entire United States as a first assessment of how much the disappearance of bats could cost the agricultural industry [see supporting online material (SOM)].

Assuming values obtained from the cotton-dominated agroecosystem in Texas, and the number of acres of harvested cropland across the continental United States in 2007 (*13*), we estimate the value of bats to the agricultural industry is roughly $22.9 billion/year. If we assume values at the extremes of the probable range (*12*), the value of bats may be as low as $3.7 billion/year and as high as $53 billion/year. These estimates include the reduced costs of pesticide applications that are not needed to suppress the insects consumed by bats (*12*). However, they do not include the "downstream" impacts of pesticides on ecosystems, which can be substantial (*14*), or other secondary effects of predation, such as reducing the potential for evolved resistance of insects to pesticides and genetically modified crops (*15*). Moreover, bats can exert top-down suppression of forest insects (*1*, *2*), but our estimated values do not include the benefit of bats that suppress insects in forest ecosystems because economic data on pest-control services provided by bats in forests are lacking. Even if our estimates are halved or quartered, they clearly show how bats have enormous potential to influence the economics of agriculture and forestry.

Although adverse impacts of WNS on bat populations have occurred relatively rapidly, impacts of wind energy development appear to pose a more chronic, long-term concern. WNS has caused rapid and massive declines of hibernating bats in the northeastern United States, where this disease has persisted for at least 4 years (*5*). Thus, the coming growing season may be the first in which the adverse effects of this disease will become noticeable. Because of regional differences in crop production, the agricultural value of bats in the U.S. Northeast may be comparatively small relative to much of the United States (see the figure) (SOM). However, evidence of the fungus associated with WNS was recently detected in the Midwest and Great Plains, where the estimates of the value of bats to agriculture are substantial (see the figure). Additionally, because this region has the highest onshore wind capacity in North America, increased development of wind energy facilities and associated bat fatalities in this region can be expected (*16*). Thus, if mortality of bats associated with WNS and wind turbines continues unabated, we can expect noticeable economic losses to North American agriculture in the next 4 to 5 years.

Policy

A recently stated goal of the United Nations Environment Programme is to demonstrate the value of biodiversity to policy-makers and the public (*17*). In keeping with this goal, we hope that the scale of our estimates and the importance of addressing this issue will resonate both with the general public and policy-makers. Bats provide substantial ecosystem services worldwide, and their benefits to human economies are not limited to North America. For example, pioneering research in tropical ecosystems shows the importance of plant-visiting bats in the pollination of valuable fruit crops (*18*, *19*). Although the economic impacts of mass mortality of bats associated with WNS appear to be confined, at present, to North America, wind turbines are also causing bat fatalities in Europe (*20*), and the potential for WNS to spread to other parts of the world is unknown.

We suggest that a wait-and-see approach to the issue of widespread declines of bat populations is not an option because the life histories of these flying, nocturnal mammals—characterized by long generation times and low reproductive rates—mean that population recovery is unlikely for decades or even centuries, if at all. Currently, there are no adequately validated or generally applicable methods for substantially reducing the impacts of WNS or wind turbines on bat populations. To date, management actions to restrict the spread of WNS have been directed primarily toward limiting anthropogenic spread (e.g., cave and mine closures and fungal decontamination protocols) (*21*). Other proactive solutions for understanding and ameliorating the effects of WNS include developing improved diagnostics to detect early-stage infections and fungal distribution in the environment; defining disease mechanisms; investigating the potential for biological or chemical control of the fungus; and increasing disease resistance through habitat modification, such as creation of artificial or modified hibernacula that are less conducive to disease development and transmission (*11*, *22*). Other approaches, such as culling of infected bats have been widely discussed and dismissed as viable options for control (*23*). New research also shows that altering wind turbine operations during high-risk periods for bats significantly reduces fatalities (*24*, *25*). Specific action on these issues will benefit from scientific research carefully aimed at providing practical conservation solutions for bats in the face of new threats and at assessing their economic and ecological importance. We as scientists should also make concerted efforts to develop and use more effective methods for educating the public and policy-makers about the ecosystem services provided by bats.

Bats are among the most overlooked, yet economically important, nondomesticated animals in North America, and their conservation is important for the integrity of ecosystems and in the best interest of both national and international economies. In our opinion, solutions that will reduce the population impacts of WNS and reduce the mortality from wind-energy facilities are possible in the next few years, but identifying, substantiating, and applying solutions will only be fueled in a substantive manner by increased and widespread awareness of the benefits of insectivorous bats among the public, policy-makers, and scientists.

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Supporting Online Material

www.sciencemag.org/cgi/content/full/332/6025/41/DC1

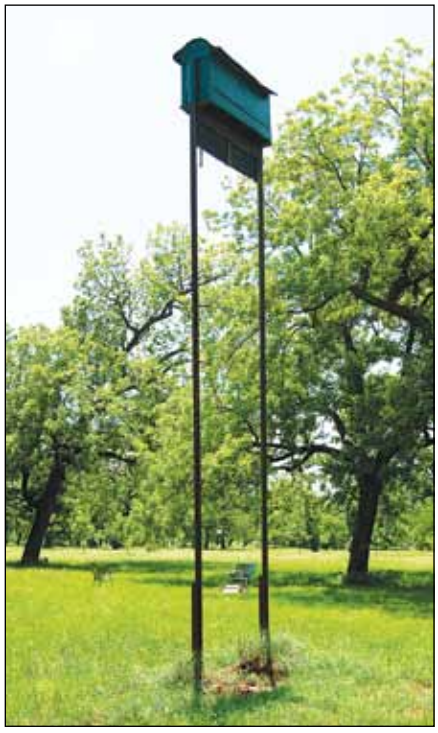
10.1126/science.1201366

Attachment 5

"Death from Above: Attracting Bats for Natural Pest Control," *Acres U.S.A* (November 2011), by Veronica Brown

Death from Above

Attracting Bats for Natural Pest Control



This medium-sized bat house can hold several hundred bats. It is made of two smaller bat houses placed back to back on two poles, roughly 20 feet off the ground.

by Veronica Brown

As creatures of the night, bats have a bad reputation. In reality, bats can be a farmer's best friend by providing free and effective pest control services over farm fields and orchards.

Most bat species in the United States are generalist insect predators, which means they will consume most medium-sized flying insects. Determining exactly what insects bats eat is often difficult, since bats feed in the sky at night. Until recently, scientists studied the diet of bats by dissecting fecal pellets under a microscope and identifying insect fragments, such as pieces of exoskeletons or legs, that survived the digestive tract of the bat. With the exception of hard-shelled insects, including some stinkbugs and beetles, this rarely allowed for identification

This large bat condo can hold over a thousand bats.

of insects to species level. Scientists could confirm that bats ate moths but could not confirm that bats were consuming specific pests of economic interest.

Modern techniques in the field of genetics now allow scientists to recover DNA from fecal samples and identify the insect remains found in bat feces by sequencing the insects' DNA. Using these modern techniques, bat researchers across the country have identified to species level almost 200 insects that are consumed by bats, and many of these insects cause substantial economic loss. Most of the insects consumed in the United States are beetles and moths.

Merlin D. Tuttle, Bat Conservation International, www.batcon.org

A Mexican free-tailed bat (Tadarida brasiliensis) *eating a moth.*

While it is generally the larval form of moths that damage crops, bats are benefiting the crops by consuming the adult flying forms, therefore preventing the insects from further reproducing.

Several of the most damaging agricultural pests consumed by bats include spotted cucumber beetles (also known as southern corn rootworms; *Diabrotica undecimpunctata)*, brown stinkbugs (*Euschistus servus)*, beet armyworm *(Spodoptera exigua)*, fall armyworm *(Spodoptera frugiperda)* and large yellow underwings (a cutworm species; *Noctua pronuba)*. All of these pests are known to damage a variety of crops across the nation, including alfalfa, corn, cotton, rice, soybean, tobacco and many other fruits, vegetables and grasses, costing farmers and growers large sums of money in lost crops and pesticides. In addition to crop pests, bats also consume many insect pests responsible for destroying millions of trees nationwide, including Asiatic oak weevils (*Cyrtepistomus castaneus*), emerald ash borers (*Agrilus planipennis*), and gypsy moths (*Lymantria dispar*).

Research done at the University of Tennessee focuses on bat consumption of corn earworms (also known as cotton bollworms; *Helicoverpa zea*) in the corn and cotton fields of the Winter Gardens region of Texas. Corn earworm larvae are very destructive insects, damaging corn, cotton, tomatoes, tobacco, sunflowers, wheat, rice, and many other crops. In the Winter Gardens area, Mexican free-tailed bats (*Tadarida brasiliensis*) live in summer colonies of hundreds of thousands of bats roosting in caves and under bridges. The research showed that bats save farmers $741,000 annually in just this one area by reducing the number of pesticide applications required, as well as reducing crop damage. Farmers in this region are benefiting greatly from the large colonies of bats that live naturally in the area and provide free pest-control services.

BAT-FRIENDLY HOUSING

One way to encourage bat activity is by installing bat houses, similar to birdhouses, which will provide an artificial roost for native bat species. A few pecan growers in Georgia and Texas now have completely organic orchards where they do not need to spray expensive chemical insecticides because they installed bat houses in their orchards. Both orchards' bat houses are now home to thousands of bats, mostly Mexican free-tailed bats, which protect the orchards from insect pests. Researchers at the University of Tennessee and Boston University showed that bats living on these orchards are consuming several crop pest species, including pecan nut casebearers (*Acrobasis nuxvorella*), hickory shuckworms (*Cydia caryana*), southern green stink bugs (*Nezara viridula*), and green stink bugs (*Acrosternum hilare*). Pecan nut casebearers are only known to damage pecans and hickory shuckworms damage both pecans and hickory trees, so the pecan orchards are seeing direct benefits from the bats' presence. These two stink bug species attack many important food crops, so the presence of the large colonies of bats is benefiting the farm fields surrounding the pecan orchards as well.

Some insects can hear the ultrasound calls of the bats and may avoid areas of intense bat activity. Bats are nature's own pesticide and simply increasing the number of bats on an orchard or farm may deter activity of some insects. Bat houses provide one of the best ways to encourage the presence of these native, generalist predators. In addition to providing protection from insect damage, sizeable colonies of bats living in bat houses will produce large amounts of guano, which can be collected and used as fertilizer with naturally high levels of phosphorus and nitrogen.

Many farmers and growers have had great success in decreasing the damage of insects to their crops by installing bat houses. Bat houses come in a variety of styles and it is important to know what type of house is the most likely to attract bats in your area.

Many people are skeptical of encouraging large numbers of bats near their homes. Like all mammals, bats are capable of carrying rabies and other wildlife diseases, but as long as people do not handle bats, there is no reason to fear them. Contrary to the movies that portray bats as attacking people, bats generally avoid humans, preferring instead to search the night skies for insects to consume.

Funding for this project was provided by Bat Conservation International (BCI) through a NRCS Conservation Innovation Grant from the USDA. BCI is a nonprofit organization located in Austin, Texas whose mission is conserving the world's bats and their ecosystems in order to ensure a healthy planet.

Visit Bat Conservation International's website for more information on bat houses and tips on how to install a successful bat house at *www.batcon.org*. Veronica Brown received her master's degree in ecology from the University of Tennessee, where she currently works as a research coordinator. She is working with Bat Conservation International to make scientific research on bat diets more accessible to farmers and growers.

A pheromone lure for monitoring pecan nut casebearer in a pecan orchard.

Attachment 6

"Pecan Orchards Welcome Bats and Bats Return the Favor," *BATS* (Summer 2011), by Elizabeth Braun de Torrez

and

"Pests on the Menu for Bat-House Bats," *BATS* (Summer 2011), by Veronica Brown

Pecan Orchards Welcome Bats
& bats return the favor

by Elizabeth Braun de Torrez

PHOTO BY MICHAEL DURHAM / MINDEN PICTURES /BCI

Pecan orchards offer attractive roosts and foraging habitat for species such as this evening bat, which is among those that hunt down expensive insect pests of pecans.

Commercial pecan orchards sprawl across some 240,000 acres (97,000 hectares) of Texas, transforming vast stretches of natural woodlands. Conservation studies usually portray fragmented agricultural landscapes as damaging to wildlife populations. But preliminary results from my three years of research paint a different picture, at least in central Texas. I found greater activity and diversity of bats within pecan orchards than in the adjacent natural landscape of mesquite and juniper woodlands, suggesting that this agriculture can provide important habitat for bats.

The results, which hold for both conventional and organic orchards, also suggest that thoughtful orchard management can probably increase bat activity – with payoffs in natural pest control. Through this research, my colleagues and I have proven that these bat are hunters of night-flying pecan nut casebearer moths, one of the most devastating pests of pecan nuts in the United States and Mexico.

The ultimate objective of this study, which was supported by BCI Student Research Scholarships, is to produce a predictive model to estimate the economic benefits of bats within pecan woodlands based on a variety of ecological factors. Much more analysis is required, however, before that will be available. Specific economic benefits should provide a powerful tool for encouraging landowners to incorporate the needs of bats into land-management decisions. And the support of farmers is crucial as bats increasingly adapt to life in landscapes dominated by humans.

Pecans are grown commercially in 14 states, and the U.S. Department of Agriculture estimates the value of the 2010 crop at $556 million. This research was conducted in the orchards and surrounding natural landscapes of San Saba County in the Hill Country of central Texas. The county bills itself as the Pecan Capital of the World and is home to hundreds of orchards.

My study sites included: three "organic native orchards" with lightly

COURTESY OF ELIZABETH BRAUN DE TORREZ

Field assistant Luyi Zheng sets up thermal-imaging equipment outside a cave. The cameras were used to document bat-colony roosting patterns in relation to the emergence periods of insect pests.

managed native pecan trees, no pesticide use and native grasses; five "conventional orchards" with pesticide use, fertilization, heavy tillage, tree cropping and flood irrigation; and three "mesquite/juniper woodlands," unmanaged areas of mesquite, Ashe juniper, American elm and a shrub-grass understory.

Pecan nut casebearer (PNC) moths are remarkably destructive pests that depend entirely on pecans. The moths, active at night, lay their eggs on nut clusters. The larvae feed on the buds, then invade the developing nuts by cutting a hole in the base. As many as four generations of larvae may cause severe, cumulative damage during the growing season.

Controlling PNC typically involves the application of various pesticides. Some Texas pecan growers, however, have reported anecdotal evidence that bats may suppress PNC moths. Our study is the first to investigate this claim.

Through dietary analyses conducted in conjunction with the University of Tennessee (see "Pests on the Menu for Bat-house Bats," page 5), we have confirmed that five species of bats in our study sites consume PNC moths to varying degrees: eastern red bats (*Lasiurus borealis*), cave myotis (*Myotis velifer*), Mexican free-tailed bats (*Tadarida brasiliensis*), evening bats (*Nycticeius humeralis*) and tri-colored bats (*Perimyotis subflavus*). We also captured silver-haired bats (*Lasionycteris noctivagans*) and hoary bats (*Lasiurus cinereus*) in the orchards, but we were unable to collect guano samples from those individuals, so we don't know if they, too, consume PNC moths.

Our finding that multiple bat species consume these moths at different times throughout the season demonstrates the importance of maintaining species diversity.

The first two years of field studies indicate greater activity and diversity of bats within pecan orchards, but also suggest that orchard management can affect how each of these species uses the orchard habitat.

Evening bats, for example, were captured more frequently in native organic orchards than in conventional orchards, perhaps because their larger and more mature pecan trees serve as roosting sites for this cavity-roosting species. Female evening bats were captured in greatest numbers during their reproductive period in May and early June. They may depend on the mature orchards for roosts during periods of pregnancy and lactation, when their energy demands are greatest.

Red bats, meanwhile, were captured most frequently in conventional orchards, possibly because this foliage-roosting species favors an abundance of leafy, mid- to low-hanging branches.

Factors other than roosting sites also likely help determine where bats feed. Understanding the foraging and roosting ecology

PHOTOS COURTESY OF ELIZABETH BRAUN DE TORREZ

These pecan nutlets growing at a Texas orchard face a host of destructive pests before they're ready for market. The interior of this pecan (*inset*) has been damaged by pecan nut casebearer larvae, one of which is visible inside the nut.

of bat species in this pecan agroecosystem will provide important clues about their role and impact as predators of pecan pests.

The latest phase of my study examines variations of bats' foraging and roosting behavior during PNC emergences. Using acoustic monitoring (bat detectors), thermal-imaging cameras and radiotelemetry, I am evaluating the influence of such factors as microclimate, vegetative characteristics and insect availability on bat activity and roosting ecology.

We used bat detectors and recording units mounted on 12-foot (4-meter) poles to assess bat activity in each site. In 2010 alone, we recorded 459,119 files containing bat calls. Analysis continues, but the average number of bat files per night varied sharply, with the lowest (117) recorded in a mesquite-juniper site and the highest (1,309) near a bat house in an organic orchard. Preliminary results indicate consistently greater bat activity in pecan orchards than in the woodlands.

The study sites include an organic orchard with three artificial roosts that had been previously installed by the owner. Only one of the bat houses maintained a consistent bat colony, so we focused on that roost for three years. The bat house primarily hosted male Mexican free-tailed bats. Weekly counts showed colony size ranging from about 220 to 2,400 bats. Pecan nut casebearer activity, measured with pheromone insect traps, also varied throughout the season.

But, contrary to our expectations, statistical analyses of bat and PNC activity revealed no positive relationship – and, in fact, hinted at a borderline negative relationship. Outside temperatures most strongly correlated to colony size, with the population decreasing as daily temperature increased. This suggests that weather may be more important in explaining the roosting ecology of these bats than the availability of a single prey species.

We also radiotagged and tracked 25 evening bats and 7 eastern red bats to a combined total of 75 roost trees. We focused on the roosting and foraging behavior of these two species based on our confirmation of PNC in their diets and of their apparently close association with pecan orchards.

Both species roosted primarily in pecan trees (68 percent of evening bats and 94 percent of red bats) in both organic and conventional orchards, but they were also found occasionally in other local tree species and in one bat house.

Evening bats were confirmed roosting in abandoned woodpecker holes, in cavities formed from split branches and under loose bark of old pecan trees. Their colonies ranged from one to 101 individuals. Eastern red bats always roosted in foliage, hanging from the stalks of leaves. They roosted alone or in family groups of up to four individuals. Red bats never roosted in the same tree on consecutive days.

As I complete my evaluation of factors that influence habitat selection by bats, the data should offer critical guidance in making sound management and conservation decisions. My results will also provide potential strategies that landowners can use to attract and maintain bats in their orchards.

Bat houses can provide roosting opportunities for Mexican freetails, cave myotis and, to a lesser extent, evening bats. But species such as evening, red, hoary, silver-haired and tri-colored bats, which depend heavily or entirely upon tree cavities and foliage for roosting, could be attracted instead by changes in woodland structure and microclimate.

Throughout this study, I periodically presented my work and preliminary results to pecan growers at a variety of gatherings in Texas. The growers have been very interested in the project and had many questions about bat-house design and other ways to attract bats to their orchards. I've also been collaborating with Texas A&M AgriLife Extension Service entomologist Bill Ree to integrate my results into the state's Integrated Pest Management program for pecans.

Proving the economic benefits of bats will go a long way toward encouraging farmers to maintain habitat that supports these valuable animals. And it offers a creative, effective working relationship with a sector of the society that is sometimes resistant to conservation efforts.

ELIZABETH BRAUN DE TORREZ is a Ph.D. candidate at Boston University in the Department of Biology. Originally from Oregon, she received her Bachelor degree from Purdue University, followed by two years in the Peace Corps in Bolivia.

PHOTOS COURTESY OF ELIZABETH BRAUN DE TORREZ

This hoary bat (*left*) was among bats of seven species captured in commercial pecan orchards in San Saba County, Texas. Elizabeth Braun de Torrez (*right*) sorts insects collected in the orchards.

Pests on the Menu for Bat-house Bats

by Veronica Brown

American farmers produced about $560 million worth of pecans last year. To secure that harvest, they had to deal with a rogues' gallery of damaging insects that attack pecan trees or their nuts. That typically means chemical insecticides, which levy both direct economic costs to farmers, and indirect costs to the environment and public health.

Pest-control strategies, however, are moving to "integrated pest management," which combines biological and chemical controls. Some organic farmers, who rely entirely on nonchemical methods, use bat houses to attract bats to their farms. Bats are well known as predators of many night-flying insects, but my study, supported by a BCI Student Research Scholarship, is the first to document the diet of bats in pecan orchards.

Using sophisticated techniques to analyze DNA found in guano from beneath bat houses at an organic pecan orchard in Georgia and another in Texas, I have confirmed that bat-house bats are consuming some of the most destructive pests of pecans. Attracting them may very well enhance natural pest control.

Pebble Hill Grove, a 27-acre (11-hectare) orchard in Quitman, Georgia, installed bat houses in 1996. Some 3,500 bats, mostly Mexican free-tailed bats (*Tadarida brasiliensis*) and evening bats (*Nycticeius humeralis*), roost in those houses. King's Crossing, a 100-acre (40 hectare) orchard in San Saba, Texas, has about 1,500 bats, primarily Mexican freetails, evening bats and some cave myotis (*Myotis velifer*) using bat houses installed in 2003.

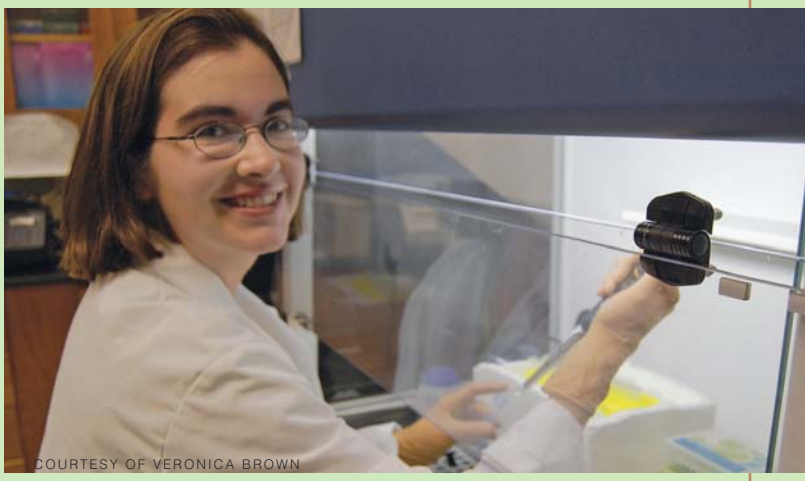
Both orchards report reduced insect damage since bats began moving into the houses. Pecan nut casebearers, hickory shuckworms and several stinkbug species are among the most damaging pests in pecan orchards.

Predator-prey relationships can be challenging to document in these fast-flying animals that hunt mostly in darkness. Researchers traditionally tried to determine bat diets by dissecting guano pellets under a microscope to find insect fragments. But with small, soft insects such as moths, the surviving bits and pieces are hard to identify in detail. Current genetic techniques, however, permit relatively rapid and inexpensive analyses of feces that can identify prey species with much greater detail and confidence.

This study used quantitative polymerase chain reaction, a highly sensitive method of amplifying a specific insect DNA sequence from within a sample of DNA, as from a guano pellet. This technique was developed in the lab of Gary McCracken of the University of Tennessee, a BCI Science Advisor, to document consumption of corn earworm moths by Mexican free-tailed bats.

We collected guano in cups attached to boards beneath the bat houses during summer 2008 and in May 2009. DNA was extracted from one guano pellet in each collection cup.

To document patterns of insect abundances and obtain insect tissue for our genetic analysis, we used scent-based lures with sticky and black-light traps to collect pecan pests, as well as corn earworm moths, which are not known to attack pecans but are one of the most destructive pests of many crops throughout the world. I extracted DNA from these insects and prepared identifying segments, called primers, for each target species.



COURTESY OF VERONICA BROWN

Veronica Brown uses sophisticated DNA analysis to identify insects in bat guano.

The vast majority of bat-house bats at both sites were Mexican freetails. We confirmed that pecan nut casebearer and hickory shuckworm moths were consumed by freetails and evening bats, although the frequency of consumption appeared to be quite low (sometimes less than 2 percent). We also documented corn earworm moth DNA in the feces of freetails and evening bats.

I used direct sequencing of insect fragments, another method shown to identify prey in bat guano, to document the consumption of southern green stinkbugs by bats in the Georgia orchard.

This study verifies that bats are indeed consuming pests of pecan orchards. Increased sampling may provide a more complete picture of a colony's diet. However, pecan nut casebearers and hickory shuckworms are small moths that stay close to pecan orchards and exhibit sharp peaks of abundance. The Mexican freetails that dominate the houses forage in open areas and at high altitudes, which may limit their ability to detect local peaks of insect abundance within orchards.

Evening bats, however, tend to forage in clearings within forests and may more frequently encounter insects that remain below the canopy in orchards. Several other bat species common to pecan orchards are also known to consume these pests.

It is also possible that the mere presence of bats has a deterrent effect. Research finds that many insects can detect bats' echolocation calls and may avoid areas where bats are hunting. Additional research should expand these results.

In any event, documenting that bats are consuming these destructive insects should provide a strong incentive for pecan growers to welcome bats to their orchards.

VERONICA BROWN was a graduate student in the Ecology and Evolutionary Biology Department at the University of Tennessee in Knoxville, where she is now a research coordinator.