USDA

United States Department of Agriculture

Innovative Solutions to Human-Wildlife Conflicts

National Wildlife Research Center Accomplishments, 2015

Animal and Plant Health Inspection Service
Miscellaneous Publication No. 1612

United States Department of Agriculture
Animal and Plant Health Inspection Service
Wildlife Services

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The mission of the National Wildlife Research Center (NWRC) is to apply scientific expertise to resolve human-wildlife conflicts while maintaining the quality of the environment shared with wildlife. NWRC develops methods and information to address human-wildlife conflicts related to the following:

- agriculture (crops, livestock, aquaculture, and timber)
- human health and safety (wildlife disease, aviation)
- property damage
- invasive species
- threatened and endangered species

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Cover Photos: Wildlife Services' National Wildlife Disease Program (part of NWRC) and its State and Federal partners recently led a highly pathogenic avian influenza surveillance effort in wild birds. *Photos by Kevin Keirn; Centers for Disease Control and Prevention; U.S. Department of Agriculture; and U.S. Fish and Wildlife Service*

Message From the Director

Larry Clark, NWRC Director *Photo by USDA, Gail Keirn*

It takes a team. Every year, we highlight important contributions to wildlife damage management in the NWRC Accomplishments Report. As impressive as these achievements are, they only tell part of the story. Behind every end product is a lot of work that is largely anonymous but just as critical as the research involved.

New modelling methods, analytical methods, disease diagnostics, vaccines, devices, repellents, reproductive inhibitors, toxicants, evaluations, and management recommendations all require a host of support activities. To be successful, NWRC must take an integrated approach to scientific collaboration and have strong support networks across all of its administrative, regulatory, logistical, and technical units.

When I take visitors on tours of NWRC, one of the most common comments I hear is that they had no idea about the breadth of work involved in damage management research and development endeavors. They are always truly impressed. I am, too.

Figure 1 represents one such effort. Rodenticides are a valuable tool for controlling rodent damage, but their use is becoming more restricted and many are losing their effectiveness. To maintain these tools for wildlife damage management, NWRC scientists and

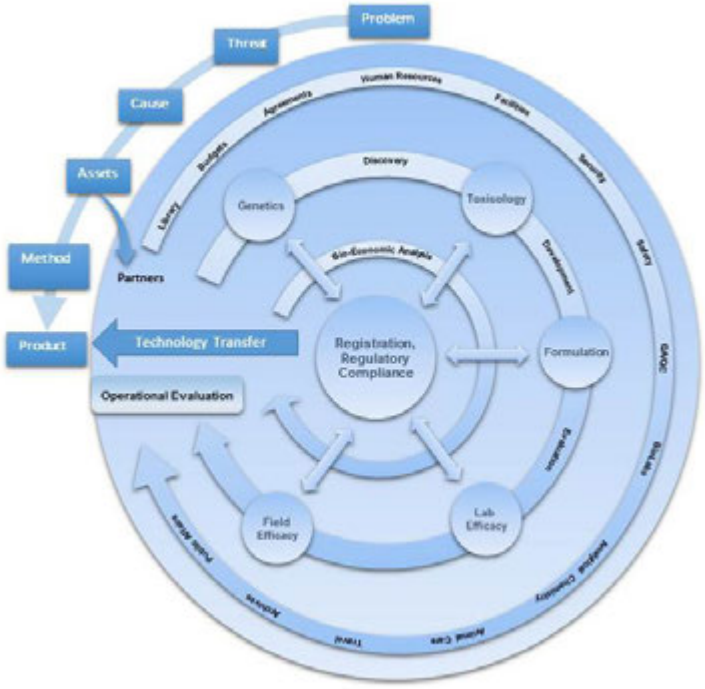

FIGURE 1 • NWRC takes an integrated approach to science. It encourages researchers to work on multidisciplinary teams and provides strong networks across its administrative, regulatory, logistical, and technical units. The end goal is to develop and transfer technologies for use in wildlife damage management.

support staff from multiple disciplines work together to design, develop, evaluate, and register new products, as well as transfer the technology and promote, record, and archive the Center's research data and results. This kind of work requires a remarkable level of coordination and expertise to be successful.

For example, science advances and builds upon the efforts of those who have preceded us; we document and read about past efforts in the literature, which our library staff helps our researchers access. Administrative support personnel help our scientists maintain appropriate staffing and make sure financial agreements are in place. The facility maintenance staff keeps our buildings and research infrastructure in good working order, while our quality assurance and registration groups monitor regulatory compliance and Good Laboratory Practices and maintain records to ensure process and result integrity. A number of units provide technical research support. Through outreach and communication efforts, our staff also makes sure that stakeholders and other interested parties receive NWRC-related information.

During all research and development endeavors, we must also continually assess whether to proceed, change course, or abandon them based on current economic and other factors. And when the research and development is done, we must make sure that the product and results find their way to stakeholders and markets as practical wildlife management tools. As I stated earlier, it takes a team to ensure success. This year, we recognize those teams and their contributions in our spotlights section, along with summarizing our basic findings.

It is with great pride and pleasure that I present to you this year's report of NWRC research highlights.

Larry Clark, Director
National Wildlife Research Center
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Research Spotlights

The National Wildlife Research Center (NWRC) is the research arm of Wildlife Services (WS), a program within the U.S. Department of Agriculture's (USDA) Animal and Plant Health Inspection Service (APHIS). NWRC's researchers are dedicated to finding biologically sound, practical, and effective solutions to resolving wildlife damage management issues. The following spotlights highlight the breadth and depth of NWRC's research and support services expertise and its holistic approach to addressing today's wildlife-related challenges.

Spotlight: Highly Pathogenic Avian Influenza Research and Emergency Response

APHIS is an emergency response organization. In addition to their daily program duties, APHIS employees are trained to serve as first responders to the Nation's animal health emergencies as part of the agency's incident command system.

Since its inception in 2005, APHIS' National Wildlife Disease Program (NWDP, part of NWRC) has hired and trained wildlife disease biologists to serve as first responders in wildlife-related emergencies, such as disease outbreaks, floods, oil spills, and other natural disasters. The NWDP also coordinates a national pest and disease surveillance system in wildlife, conducts disease surveillance at international borders, and establishes global partnerships to enhance wildlife disease surveillance worldwide. Through these efforts, APHIS can quickly respond to wildlife emergencies at local, State, and regional levels, including the recent highly pathogenic avian influenza (HPAI) outbreak.

HPAI Surveillance in Wild Birds

Nearly 10 years ago, NWDP and its State and Federal partners designed, developed, and carried out the largest-ever national avian influenza surveillance effort in wild birds. NWDP wildlife disease biologists and their partners collected more than 400,000 wild bird and environmental samples from across the United States to try to detect the HPAI H5N1 strain that had been decimating domestic poultry flocks in Asia and Europe. At the time, no one had ever attempted to conduct such a comprehensive wildlife disease surveillance program. Although neither the H5N1 strain nor any other HPAI strain was found at the time, NWDP employees set the gold standard for such efforts. Their work resulted in the largest database of avian influenza samples in the United States. NWRC scientists and others have tapped into it to learn more about the prevalence and ecology of avian influenzas and to develop more strategic surveillance plans.

Fast forward to more recent times and the value of those efforts becomes apparent. In 2015, APHIS responded to an HPAI outbreak that was the largest animal health emergency in the country's history.

The spread of HPAI H5N2, H5N8, and H5N1 viruses in commercial poultry and backyard flocks in the spring of 2015 affected nearly 50 million domestic birds, cost over $800 million, and required the

Information gathered from NWRC disease surveillance and research helps guide HPAI emergency response and strategic planning efforts.

expertise of more than 600 APHIS employees and 2,700 contractors and Federal partners.

As the first signs of the outbreak in domestic poultry in British Columbia, Canada, were unfolding in November 2014, NWDP biologists and their State and Federal partners increased surveillance of wild birds near the U.S.-Canada border and other locations in the Pacific Flyway. This led to the first detections of the novel Eurasian lineage of HPAI H5N8 and reassorted HPAI H5N2 viruses in wild birds in North America. It also eventually led to a much larger national surveillance effort. From July 2015 to March 2016, NWDP and its State and Federal collaborators collected nearly 41,000 samples from apparently healthy wild birds in targeted areas throughout the United States. This work was based on guidance provided by the Interagency Steering Committee for Surveillance for HPAI in Wild Birds, which included experts from APHIS' WS and Veterinary Services programs, U.S. Geological Survey, U.S. Fish and Wildlife Service, Centers for Disease Control and Prevention (CDC), and the National Flyway Council.

"Wildlife Services' previous work has helped us to be more prepared for today's challenges," notes Tom DeLiberto, HPAI Incident Command Group and Wildlife Unit Leader for the APHIS National Incident Command. "Waterfowl movement patterns and information from our 2006–2011 surveillance effort were analyzed and used to determine the most appropriate species and sampling locations to make the 2015 effort as efficient and informative as possible."

As part of the national HPAI surveillance effort, WS disease biologists and their State partners collected nearly 41,000 samples from wild birds throughout the United States. *Photo by USDA, Gail Keirn*

For instance, from 2007 to 2010, NWRC researchers and partners analyzed samples collected from 13,574 blue-winged teal. Results revealed that during late summer staging (July–August) and fall migration (September–October), birds less than 1 year old were more likely than older birds to be infected. However, there was no difference between age groups for the remainder of the year (winter, spring migration, and breeding period), likely due to younger birds' maturing immune systems.

Another analysis of the 2006–2011 surveillance effort showed that dabbling ducks accounted for 92 percent of all avian influenza detections. Because of these and

NWRC researchers studied birds and mammals found on HPAI-infected farms to learn more about how the virus spreads between wild and domestic animals. *Photo by USDA*

other findings, the 2015–2016 effort focused mostly on sampling live-captured and hunter-harvested dabbling ducks, such as American black ducks, American green-winged teal, mallards, wood ducks, and northern pintails. Additionally, NWDP and its State and Federal partners collected environmental fecal samples from waterfowl and samples from wild bird morbidity and mortality events. Surveillance results will be incorporated into national risk assessments and preparedness and response planning efforts to reduce HPAI risks in commercial and backyard poultry, wild and falconry birds, game bird farms, wild bird rehabilitation facilities, and captive bird collections at zoos and aviaries.

HPAI Research

Avian influenza viruses are found naturally in waterfowl and other wild bird species. Low pathogenic avian influenza (LPAI) viruses—which account for most avian influenza cases—cause no or only minor clinical signs of infection in birds. Unfortunately, LPAI H5 and H7 strains can mutate into HPAI viruses, so they are closely monitored.

HPAI causes severe illness and death in domestic birds and raptors. Because of the disease's devastating impacts on poultry and its potential impacts on wild birds, experts are studying how HPAI viruses spread among species and the environment.

As part of the 2015 HPAI response, NWRC researchers collected more than 2,600 samples from 426 birds and mammals found on 10 poultry farms in Iowa (5 HPAI-infected and 5 HPAI-uninfected).

"Our sampling focused on common species on farms, such as house sparrows, European starlings, pigeons,

and house mice. But we were also able to catch other species, such as swallows, deer mice, cottontail rabbits, shrews, and raccoons," says NWRC research biologist Susan Shriner. "From each specimen, we collected cloacal, nasal, oral, and/or external body swabs for avian influenza virus testing. We also collected blood and tissue samples from a few select specimens for further analysis."

Of the 2,184 screened tissue samples and oral, cloacal, and external swabs, one tested positive for avian influenza viral ribonucleic acid (RNA). The positive sample was from the lung tissue of a juvenile European starling captured on an infected farm. It was captured using a mist net that targeted a cavity nest built on a walkway between two poultry barns. Of the 252 blood samples taken from birds, 7 tested positive for exposure to influenza A virus in initial screenings and were sent for confirmatory testing at the USDA's National Veterinary Services Laboratories in Ames, IA. Further testing confirmed that five samples (two American robins, two European starlings, and one house sparrow) were HPAI-positive.

"It's important to note that the majority of the sampling on the infected farms occurred after the poultry had been depopulated," says Shriner. "The likelihood of detecting the virus at that time is much lower than if we had sampled when the poultry were alive. However, the fact that we did find evidence of exposure to HPAI in American robins, European starlings, and house sparrows indicates the need for further studies with these species." Shriner also stresses that the low number of positive results does not imply that wildlife is not a potential biosecurity threat. "We still don't know how the virus is spreading from farm to farm," she adds. "Hopefully, results from other studies will shed more light on this complex disease issue."

For the past several years, NWRC scientists have conducted a series of studies with captive animals to learn more about avian influenza transmission routes. For instance, studies have investigated how long and how much virus waterfowl shed and whether previous infections affect viral shedding if birds are reinfected. NWRC has also examined the ecology and prevalence of avian influenza viruses across the United States. This information has been used to identify "hotspots" where the virus has the highest chance of spreading from the environment into domestic poultry.

Through more recent studies, NWRC scientists have discovered that experimentally infected striped skunks and cottontail rabbits shed large amounts of avian influenza viral RNA and may influence virus spread in certain areas. They have also found that captive raccoons are more likely to become infected with avian influenza from contaminated water versus eating contaminated animals or eggs. Insights about how wild animals carry and move the viruses help us develop better biosecurity methods for domestic poultry facilities.

Next Steps—NWRC research on HPAI and LPAI will continue with an emphasis on understanding primary influenza virus transmission routes in natural hosts, identifying wildlife species that might contribute to intercontinental HPAI spread, and evaluating the role that wildlife species living near people play in moving HPAI viruses within and between farms. Current enhanced surveillance efforts are funded through the spring of 2016. If enhanced surveillance is not extended, NWDP experts will revert back to low-level avian influenza monitoring in wild birds. Wild bird surveillance helps APHIS detect HPAI in the United States before it infects U.S. poultry.

The field of wildlife genetics helps us locate, track, monitor, and study wildlife in new, innovative ways.

Spotlight: Genetics in Wildlife Damage Management

How do you find something that does not want to be found—something that has evolved to be cryptic or elusive?" This and many other questions are often asked of NWRC geneticist Antoinette Piaggio.

"Information about wildlife populations and pathogens can be difficult to obtain with traditional sampling techniques. This is especially true for rare or elusive wildlife and emerging diseases," says Piaggio.

Piaggio and her team on NWRC's Wildlife Genetics Project use deoxyribonucleic acid (DNA) samples collected from tissue, blood, hair, feces, saliva, and water to uncover valuable information about animals and their presence or absence, abundance, behavior, and evolution.

"The field of wildlife genetics helps us to locate, track, monitor, and study wildlife in ways that have rarely been done before," continues Piaggio. "Genetic approaches include such things as DNA forensics, noninvasive sampling for species abundance and monitoring, kinship and relatedness studies, gender determination, and species or individual animal identification. Such approaches may help us to detect invasive, rare, or elusive animals more efficiently than traditional methods."

Since 2000, scientists at NWRC's wildlife genetics laboratory have used their expertise to monitor endangered and invasive species, detect invasive species using environmental DNA (eDNA) found in water, study the intercontinental movement of pathogens, and understand gene movement within and among animal populations. Below are highlights of some of the Center's more recent genetics research.

Predator Management

NWRC geneticists use DNA forensics to identify predator species that have killed livestock, endangered and threatened species, and species of concern. For example, they analyze DNA samples collected from blood and saliva at bite wounds on livestock and wildlife carcasses to determine the species involved in predation incidents. By knowing which predator species was involved, managers can select the most appropriate methods for preventing future damage.

Similar techniques are used to identify predators of greater sage-grouse eggs. NWRC experts developed a method for collecting salivary DNA left on depredated eggshells. So far, researchers have used the method to identify coyotes, dogs, skunks, and mice as egg predators. These results were sometimes verified with trail cameras on nests. Understanding predators' impacts on declining species and species of concern, such as the greater sage-grouse, is critical to their successful management.

In an ongoing effort to improve sample collection techniques, NWRC scientists recently assessed several DNA collection methods and estimated the degradation rates of predator DNA on depredated lambs and calves. They determined that removing the portion of hide with saliva on it and sending it to the lab to be swabbed is a better way to collect samples than swabbing in the field. The researchers also found that most DNA on a carcass begins to degrade after 24 hours.

NWRC's geneticists have also developed a genetic method for identifying, monitoring, and estimating endangered Mexican wolf populations in Arizona. Instead of capturing, marking, and releasing animals, which can be stressful and dangerous for animals and people, the method identifies Mexican wolves using DNA obtained from fecal samples. This allows the U.S. Fish and Wildlife Service, State management agencies, and Native American tribes to monitor recovery populations without having to see or handle animals. The method can also distinguish among Mexican wolf, coyote, and domestic dog feces. In field tests, population estimates based on the new method closely matched collared and tracked wolf counts, indicating that it effectively monitors this endangered species.

Wildlife Disease

New genetic techniques have also helped scientists better understand disease pathogen transmission and evolution.

Biting midges in the genus *Culicoides* are known to transmit highly pathogenic viruses and parasites between wildlife and livestock. Bluetongue virus (BTV) and epizootic hemorrhagic disease viruses (EHDV) are the most notable of these pathogens. These viruses cause serious disease in ungulates such as sheep and white-tailed deer. They can also impact dairy and beef production by causing febrile illness and aborted fetuses in cattle.

A greater sage-grouse hen cautiously watches a nearby coyote. NWRC researchers used genetic techniques to identify species that eat greater sage-grouse eggs.
Photo by USDA

Predicting, responding to, and mitigating BTV and EHDV outbreaks is difficult because little is known about the biology and ecology of biting midges and other vector species in North America or the diversity of wildlife and livestock they feed upon. NWRC scientists are working to fill these gaps by developing genetic tools that investigate the genetic relationships among *Culicoides* species, quantify their distributions, and help identify them. Experts are applying genetic methods to isolate DNA from blood meals in wild-caught *Culicoides* to identify the wildlife and livestock species upon which they feed. High-throughput sequencing technology is also being used to sequence blood meals and all organisms in a homogenized insect trap, streamlining vector surveillance. The work will aid in rapidly identifying species and transmission pathways during BTV and EHDV outbreaks.

NWRC geneticists are collecting blood meal and DNA samples from biting midges (*Culicoides* sp.) as part of an effort to detect bluetongue and other ungulate diseases.
Photo by USDA

In addition to studying ungulate diseases, NWRC geneticists have shed light on the diversity of avian influenza viruses in wild birds. For instance, experts recently analyzed 75,000 bird fecal samples collected in 2006 and 2007 as part of the national HPAI surveillance effort in wild birds in the United States. They isolated and amplified 160 hemagglutinin (HA) DNA sequences from these samples. The sequences accounted for a broad diversity of HA subtypes, with 13 of the possible 16 subtypes represented. NWRC used this and other data from around the world to generate information about relationships among and between HA subtypes of avian influenza virus. The researchers found evidence of intercontinental exchange within some subtypes and a broad diversity of lineages unique to the United States. Through this extensive genetic surveillance effort, they detected some subtypes in areas where they had not been previously documented. Such information helps identify areas with high avian influenza virus diversity, where outbreaks may be more likely to occur.

Endangered Species Translocation

Proactive endangered species conservation and management often involve reintroducing animals to historical ranges. This increases the overall number and geographic distribution of populations and lessens the chance that an isolated random event could cause the complete extinction of a species.

There are two recognized subspecies of white-tailed deer in the Pacific Northwest, the Columbian white-tailed deer (*Odocoileus virginianus leucurus*) and the Northwest white-tailed deer (*O. v. ochrourus*). The Columbian white-tailed deer is listed as an endangered subspecies with two remaining isolated populations in Washington and Oregon. NWRC geneticists investigated genetic variation, connectivity, and hybridization in the Columbian white-tailed deer populations. They found that Columbian white-tailed deer and Northwest white-tailed deer in the Pacific Northwest originated from a single historic gene pool. This calls into question the two subspecies' current taxonomic status. Also, the results indicated that the current populations are genetically isolated but may have hybridized with black-tailed deer in the past. Despite the taxonomic ambiguity, the study revealed the presence of some unique genetic variation within each population, which supports ongoing conservation efforts. Such genetic investigations help to guide important endangered species management and translocation decisions.

Invasive Species

Unfortunately, the need to control and manage invasive species is a growing problem that costs the United States at least $120 billion per year in damages and control costs. Feral swine are one of the most destructive invasive species threatening habitats, native wildlife, agricultural resources, and property in the United States.

"Feral swine are generalists and thrive in a variety of habitats, eating almost anything and everything they find—berries, nuts, herbs, grass roots and shoots, grubs, earthworms, insects, ground-nesting birds, eggs, deer fawns, fish, lizards, snakes, dead animals, and trash. You name it, they've probably eaten it," notes NWRC geneticist Antoinette Piaggio.

To better understand the diversity of plant and animal species feral swine impact, NWRC geneticists are using high-throughput sequencing technology to analyze the remains of plants and animals found in feral swine feces. Samples from Florida, California, and Texas indicate that feral swine feed upon quail and salamanders, both of which are experiencing major population declines.

Genetics research can also be used to evaluate invasive species eradication efforts and help prevent new invasions. For example, it is important to determine whether invasive rats detected after eradication efforts are the result of incomplete control or recolonization. Using genetic analyses, NWRC researchers determined that rats' reemergence on Congo Cay in the U.S. Virgin Islands and on Lehua Island in Hawaii was likely due to failed eradication attempts. This finding has led to reevaluating rat eradication strategies and efforts on these islands.

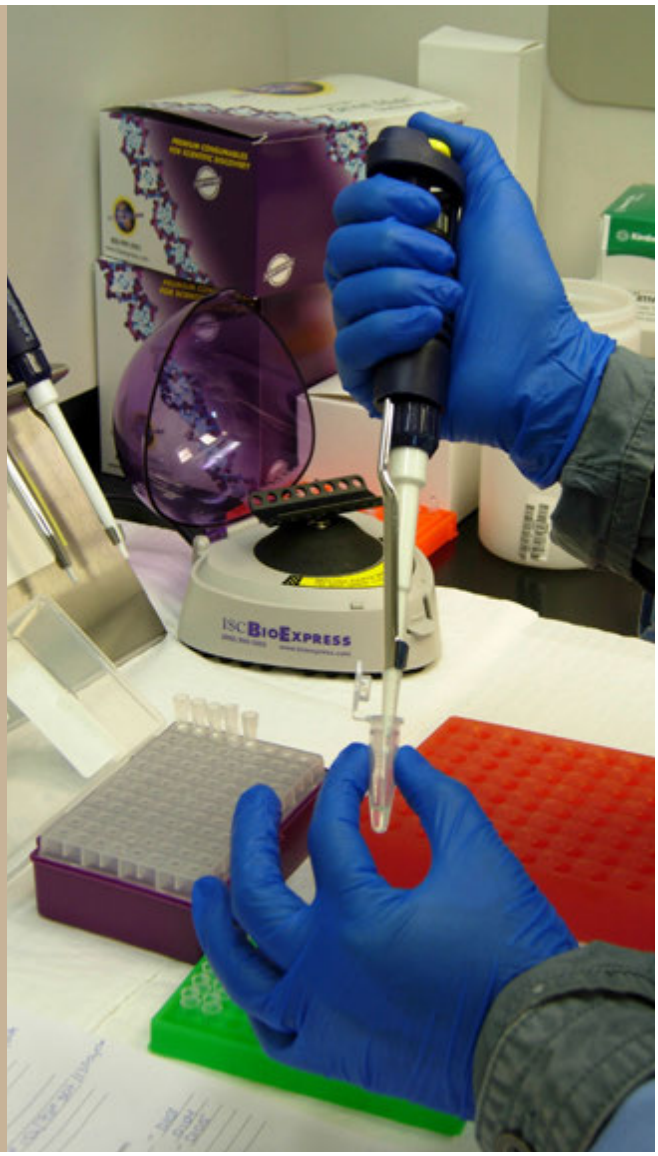
Similarly, NWRC researchers are helping managers on Kauai, HI, identify the source of invading Indian mongooses. The Indian mongoose was originally released on many tropical islands to help control invasive rats and mice, but it is now seen as a pest that impacts native birds, reptiles, insects, fruits, plants, and amphibians. In some areas, they also carry and transmit the rabies virus. In Hawaii, there are ongoing mongoose control efforts on the islands of Oahu, Maui, Hawaii, and Molokai. In 2012, two mongooses were captured on Kauai, an island previously without this pest. NWRC geneticists are using DNA to determine the source of the mongooses, which will help managers prevent future invasions.

In controlling invasive species, managers need tools that can help them efficiently direct their activities. The NWRC Wildlife Genetics Project staff has developed new tools to detect invasive species like feral swine. Recent studies have shown that eDNA from animals can be detected in bodies of water. eDNA refers to DNA shed by an organism into the environment (e.g., water, soil, or air). The genetic material could come from shed skin, hair, scales, mucous, urine, or feces.

In dry areas where water is limited, being able to determine if feral swine are present helps managers decide whether to invest in search and control efforts. The eDNA method can also tell managers when feral swine control efforts have been successful. In addition, it can indicate if residual populations are due to failed eradication efforts or reinvasions.

In trials with captive feral swine, researchers learned that eDNA can be detected from a single boar wallowing for 15 minutes in a pool of water and that it degrades after 3.5 days. Researchers also learned that eDNA from multiple wallowing animals takes almost twice as long to degrade. Developing a lab assay that could detect low-quality and -quantity eDNA found in turbid water was challenging. However, NWRC researchers tested many ways to capture and purify eDNA and developed best practices for working with this type of water. Being able to determine if feral swine are present in an area will help managers monitor their distribution nationwide. It will be particularly useful in areas declared free of feral swine, which require surveillance and rapid confirmation of new invasions.

Applying eDNA methods to other invasive species control efforts shows promise, too. The Burmese



NWRC geneticists developed techniques for finding fragments of python and feral swine DNA in water and soil samples. The tools are being used to help monitor these invasive species' distribution. *Photo by USDA*

python is a semiaquatic snake that has invaded Florida, where its elusive nature and cryptic coloration make it difficult to detect. Also, while invasive, the python is not evenly distributed across the Everglades. A detection method that eliminates the need to directly observe or handle snakes and quickly and reliably tells managers whether they are present in an area would make management activities more economical and efficient.

To help Florida wildlife managers remove invasive Burmese pythons, NWRC researchers developed a diagnostic polymerase chain reaction (PCR) test that detects python DNA in water. Using captive Burmese pythons, researchers verified the new test and showed that python DNA can be detected in water for up to 96 hours. Researchers also field tested the method by sampling water from six sites in south Florida. Samples from five sites with prior Burmese python sightings tested positive for their DNA. The final site, which had no prior evidence of Burmese pythons, tested negative. This promising new tool is now being used to monitor Burmese python distribution in Florida and inform managers where search and control efforts should take place.

Next Steps—eDNA continues to shed new light on wildlife ecology and behavior. The NWRC Wildlife Genetics Project plans to pursue the development of new assays and other eDNA techniques for use with invasive, rare, or elusive species such as Nile monitors and nutria. NWRC scientists continue to assess the differences in DNA degradation rates between predator and prey species for use in forensics.

Spotlight: Supporting the Science

NWRC employs more than 150 scientists, technicians, and support personnel. They work on multidisciplinary teams to develop new tools and techniques for managing wildlife damage. Throughout the year, NWRC experts are involved in hundreds of studies related to the Center's 16 core projects (see Appendix 1).

In addition to administrative, budget, and facilities personnel who ensure the Center's efficient and successful daily operations, NWRC has support staff in chemistry, genetics, biological laboratories, animal care, the Institutional Animal Care and Use Committee, registration, quality assurance, and

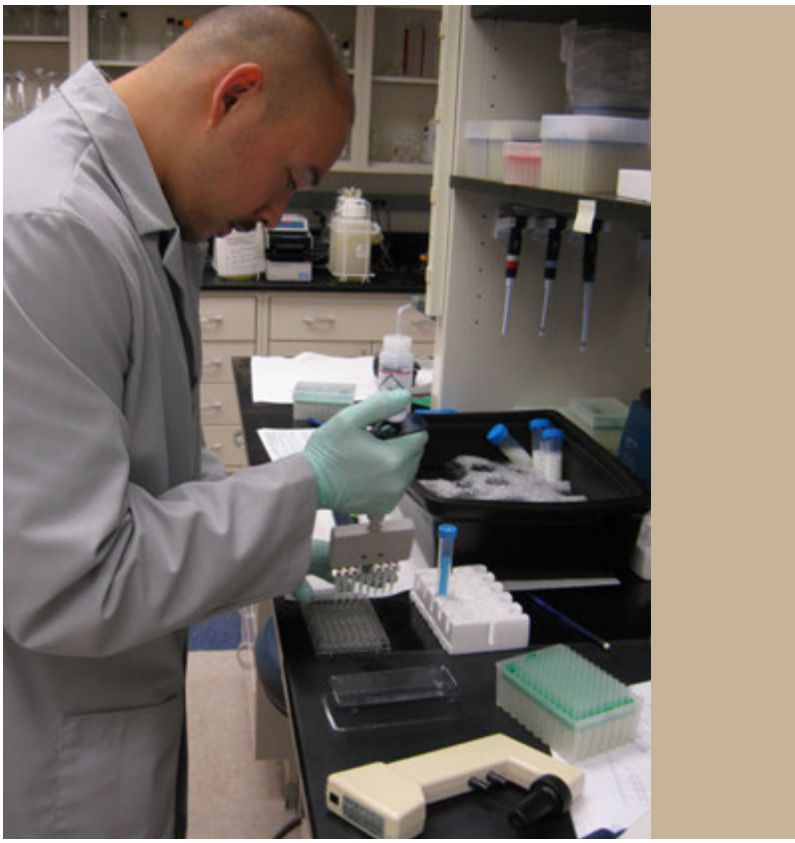
NWRC research and support staff work together to develop and deliver innovative, practical, and scientifically sound information and products for managing wildlife damage.

information services. These specialists provide valuable skills and assistance in developing, completing, distributing, and promoting NWRC's research findings.

Chemistry and Formulations

NWRC's Analytical Chemistry and Formulations laboratories support all NWRC scientists and WS operational programs, as well as other Federal and State agencies that need help with chemical screening, analysis, formulation, and modeling. This work supports a variety of research topics, ranging from wildlife contraceptives and wildlife disease to invasive species eradication and wildlife repellents.

NWRC's chemistry and formulations staff are experienced in a variety of scientific disciplines, including pharmacology, environmental fate, chemical synthesis, toxicology, chemical ecology, computer modeling, and formulations process development. Experts design methods to identify, analyze, and develop new drugs, repellents, toxicants, and other chemically based wildlife damage management tools. They also enhance the delivery of compounds to target species through microencapsulation and by developing food products, baits, and lures that are stable in various environments and situations. Such methods enhance NWRC's research efforts and support product registration with the U.S. Environmental Protection Agency (EPA) and U.S. Food and Drug Administration (FDA).



NWRC has numerous chemistry, formulation, disease, and genetics laboratories to support wildlife damage management research. *Photo by USDA*

Genetics

Information about wildlife populations and diseases can be difficult to obtain with traditional sampling techniques. This is especially true for rare or elusive wildlife and emerging diseases. The field of wildlife genetics uses DNA samples collected from tissue, blood, hair, feces, saliva, water, and soil to uncover valuable information about animals and their abundance, behavior, and evolution.

FIGURE 2 • Specialized Equipment Available Through the NWRC Support Units

Chemistry and Formulations	• Mass spectrometers • Gas and liquid chromatographs • Ion chromatograph • Flow and liquid scintillation analyzers • Pharmaceutical tablet press • Feed pellet mill • Freeze-dryer • Spray-dryer • Fluid-bed coater and pan-coater • Extruder • Spheronizer
Genetics	• PCR machines/thermocyclers • DNA extraction robots • Genetic analyzers (fragment analysis and Sanger sequencing) • Facilities dedicated to low-quantity and -quality DNA
Biological Laboratories	• Automated nucleic acid extraction equipment • Real-time-PCR instruments • Varioskan Flash spectral scanning multimode reader • BioPlex suspension array system • Operetta High Content Imaging System • Chef-mapper pulse-field gel electrophoresis instrument

In addition to conducting basic research, the NWRC Genetics Project assists other researchers and WS operational programs by developing applied genetics tools for managing wildlife damage. Such tools can aid in DNA forensics, species abundance and monitoring, kinship/relatedness and gender determination, and species or individual animal identification. For example, the team has evaluated the effectiveness of rodent eradication efforts, developed noninvasive sampling techniques for monitoring predators, conducted DNA forensics on predation incidents, and created methods for detecting invasive Burmese pythons and feral swine using eDNA. Please see the previous spotlight, "Genetics in Wildlife Damage Management," for more information on NWRC's genetics research.

Biological Laboratories

The NWRC Biological Laboratories Unit was formed in 2013 to provide laboratory management and assistance across all Center projects. Its goals are to (1) provide a pool of support scientists and technicians with skills and knowledge in numerous laboratory and field disciplines (i.e., serology, PCR technology, and enzyme-linked immunosorbent assay techniques); (2) eliminate and reduce redundancy in equipment and supply purchases; (3) maintain laboratory equipment; and (4) provide laboratory safety and methods training to employees.

Team members also have expertise in collecting, preparing, and analyzing tissue samples. Recent activities included analyzing 1,153 environmental samples and 2,733 wildlife samples collected as part of APHIS' HPAI emergency response effort; training 87 WS personnel and international wildlife diagnosticians in field sample collection techniques; and creating a system for tracking and documenting more than 330,000 biological samples stored at the NWRC headquarters, while autoclaving and/or disposing of approximately 2,500 pounds of undocumented or unclaimed biological material.

Animal Care

The Center's Animal Care Unit consists of a supervisory attending veterinarian and approximately 10 biological science and veterinary professionals. These specialists are responsible for the daily feeding,

FIGURE 3 • NWRC Field Station Facilities

Florida Field Station	The 26-acre site is located 3 miles east of the University of Florida. The main 5,800-square-foot building has offices, a chemical laboratory, and a necropsy room. A new 1,050-square-foot animal care building is due to complete construction in June 2016. The field station also includes two 1,575-square-foot roofed outdoor aviaries for housing wild birds. In addition, there are eight 10- by 30-foot enclosures and three large flight pens (one-third to one-half of an acre in size) where behavioral studies involving reptiles and birds can be conducted throughout the year under natural environmental conditions.
Hawaii Field Station	Located in Hilo, HI, the 1.1-acre field station consists of a 2,500-square-foot animal holding and laboratory building and a 3,000-square-foot office building. Two outdoor covered structures are also available for experiments. Rats, mice, mongooses, coqui frogs, feral hogs, pheasants, francolins, and other invasive vertebrates have been housed and studied at the field station.
Mississippi Field Station	The 3-acre field station is located on Mississippi State University's South Research Farm. The station includes an outdoor aviary with three 1-acre ponds. It also has a 40- by 80-foot disease research building that contains twenty-six 5- by 10-foot animal holding pens and a 16- by 60-foot laboratory and storage space.
Ohio Field Station	The field station is located at Plum Brook Station, a 6,000-acre fenced facility operated by the National Aeronautics and Space Administration. The contiguous wildlife habitat and agricultural land provide unique opportunities for wildlife damage research. Field station facilities include an indoor aviary for holding captive birds, ample shop space, and a video laboratory used for behavioral experiments.
Utah Field Station	This 165-acre site is located in Millville, UT, on Utah State University land. The facility houses up to 100 adult coyotes in more than 50 outdoor pens. Coyotes are involved in studies on ecology, learning, behavior, and physiology to reduce human-wildlife conflict. The facility also has two pens solely used to rehabilitate orphaned black bear cubs for the Utah Division of Wildlife Resources.

husbandry, and veterinary medical care of the animals at NWRC headquarters and field stations. They are also available to assist with special procedures, such as anesthesia, sampling, radiology, ultrasound, and surgery, and provide immobilization and euthanasia training to WS employees and outside entities.

At any given time, the Animal Care Unit is responsible for the care of several hundred to several thousand animals housed at NWRC facilities. Most of these animals include wild mammals, birds, reptiles, and amphibians, but there are also traditional laboratory animals such as mice and rats. The Center's headquarters campus includes a 28-acre Outdoor Animal Research Facility with 20 animal buildings and 4 related support structures. The headquarters campus also includes 2 large indoor animal holding facilities containing 24 animal rooms, 4 simulated natural environment rooms, a 2,500-square-foot biosafety level 3 suite, a surgery suite, a necropsy room, food preparation rooms, veterinary treatment rooms, a quarantine room, a pharmacy, a digital x-ray suite, an incinerator, a fabrication shop, and a cage wash area. Many of NWRC's field stations also include animal holding facilities (Figure 3).

NWRC's animal care specialists are responsible for the health and well-being of research animals at the Center's headquarters and field station facilities.
Photo by USDA, Anson Eaglin

These facilities give scientists a unique opportunity to study wildlife species in semi-natural settings. New tools and techniques can be tested, evaluated, and modified at the Center prior to conducting field studies.

Institutional Animal Care and Use Committee

Under the Animal Welfare Act (AWA), organizations and facilities that conduct research, testing, or teaching using warm-blooded animals must have an Institutional Animal Care and Use Committee (IACUC). The AWA regulations require, among other things, that the IACUC include at least three people: a chairperson, the facility's attending veterinarian, and a nonaffiliated person to represent a voice of the general public.

NWRC's IACUC currently has eight members (the three core members and five NWRC researchers and technicians). The IACUC's role is to review and approve proposed components of research activities to ensure animals' humane care and use. During fiscal year 2015, the NWRC IACUC reviewed and approved more than 80 proposed study protocols, 125 amendments, and 10 standard operating procedures (SOPs). The IACUC also inspected NWRC's animal holding facilities and evaluated the facility's overall animal care and use program.

To receive research funding from the U.S. Public Health Service (e.g., National Institutes of Health [NIH] or CDC), NWRC must receive an assurance from the Office of Laboratory Animal Welfare (OLAW) that verifies compliance with the AWA regulations and the National Research Council's Guide for the Care and Use of Laboratory Animals. With help from its IACUC, NWRC has received an OLAW assurance and can obtain grant funds or conduct collaborative research activities with other organizations or facilities funded by the NIH or CDC.

Registration

Many of the wildlife damage management tools and products developed by NWRC researchers, including vaccines, repellents, and toxicants, must be registered with the appropriate regulatory agency. The NWRC Registration Unit provides data and information to support regulatory approval of new and existing tools and products. The unit works closely with APHIS headquarters staff in Riverdale, MD, and NWRC scientists to ensure that studies meet EPA and FDA regulatory guidelines.

Currently, APHIS holds product registrations with the EPA for rodenticides, predacides, avicides, repellents, a snake toxicant, an avian repellent, and a contraceptive vaccine. It also holds Investigational New Animal Drug applications* with the FDA for immobilizing agents used in wildlife damage management. The NWRC Registration Unit coordinates maintaining and expanding the authorized use of these products.

Without the support of the Registration Unit, many of NWRC's products would be unavailable to WS operations personnel, natural resource managers, and others to address wildlife damage issues and protect agriculture, human health, and endangered species or critical habitats.

The library and archives at NWRC headquarters provide researchers, WS operations personnel, students, and others with access to recent scientific publications, historical data, and outreach materials related to wildlife damage management. *Photo by USDA*

Quality Assurance

The Quality Assurance Unit (QAU) monitors research activities that are documented in NWRC protocols and SOPs to maintain conformance. The QAU reviews and processes incoming study materials from NWRC researchers for accuracy, completeness, proper format, content, and State and Federal compliance. The QAU also ensures that research data and findings are available for future reference. An archiving system is maintained to store and retrieve raw data, documents, protocols, specimens, reports, analytical methods, laboratory notebooks, and SOPs. The Center's quality assurance experts also provide individualized training to researchers as needed.

Information Services

NWRC's Information Services Unit (ISU) is responsible for the Center's library, archive, records management, and Web functions. The ISU specializes in preserving and providing access to historical materials, training users on information technology and resources, migrating and preserving data and metadata, and making information available online and via other outlets. For example, ISU experts support NWRC and WS operational staff by quickly searching for, identifying, and providing current and historical information related to wildlife damage management and WS' mission. With the help of APHIS' Legislative and Public Affairs, the unit also promotes NWRC research through Web, social media, and other outreach channels.

* An official designation from the FDA that allows for use of new compounds and drugs in research and limited management applications

2015 Accomplishments in Brief

NWRC employs approximately 150 scientists, technicians, and support staff who are devoted to 16 research projects (see Appendix 1). Below are brief summaries of select findings and accomplishments from 2015 not previously mentioned in this year's report.

Devices

- **Changes to Aircraft Lighting Increase Bird Awareness.** Collisions between birds and aircraft (also known as bird strikes) are expensive, risk human lives, and increase bird mortality. Because birds see differently than people, changes to aircraft lighting have been proposed as a way to make birds avoid aircraft. NWRC researchers and partners from Purdue University investigated brown-headed cowbirds' responses to aircraft lighting systems tuned to match the birds' visual capabilities.

  Using a remote-controlled aircraft fitted with 470-nanometer lights that exhibit the "blue" portion of the human visual spectrum, scientists observed that cowbirds showed alert behaviors in less than half the time it took with the lights off. However, for approaching aircraft with pulsing lights, the cowbirds' alert responses were delayed as aircraft speeds increased. This was not the case with approaching aircraft with nonpulsing lights. Also, researchers observed that high ambient noise levels delayed the birds' avoidance of the aircraft, possibly by causing sensory overload and distracting the birds.

  Researchers believe that placing 470-nanometer lights on aircraft or at airports may improve some birds' abilities to detect and avoid aircraft. The approach may also make wind turbines, towers, and other large stationary structures involved in bird collisions more detectable.
  Contact: Brad Blackwell

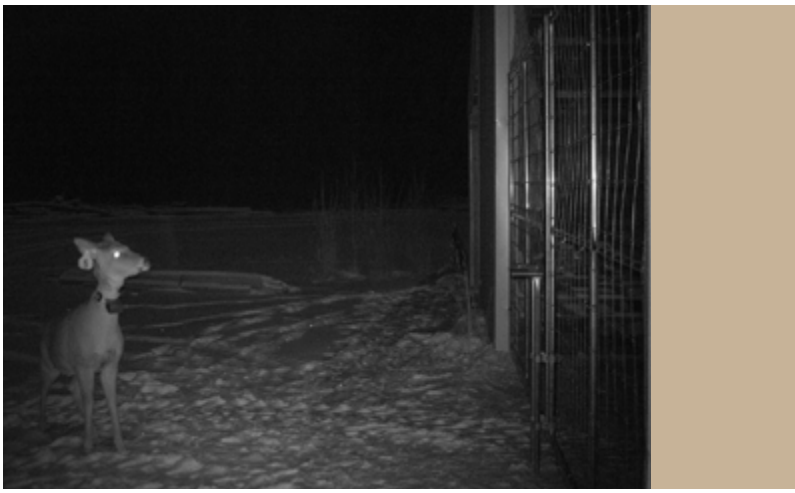
- **Reducing Negative Effects of Road Lighting on Wildlife.** Driver and pedestrian safety concerns typically govern the type and amount of artificial lighting found along roads. However, such lighting also impacts the well-being of ecosystems. Light is a natural stimulus that affects all organisms' physiology, behavior, and movements. NWRC researchers note that, where lighting is needed, engineers and planners can minimize negative effects on wildlife in several ways: making sure light shines downward rather than upward or sideways; limiting downward light emissions outside the required area; restricting the use of short wavelength lights (i.e., less than 500 nanometers); and eliminating needless lighting by zoning and spacing light units and programming them to turn on/off when appropriate.
  Contact: Brad Blackwell

- **Preventing Deer Access to Stored Cattle Feed.** Disease and damage from white-tailed deer threaten the livelihood of agricultural producers in Michigan. When high-quality cattle feed is stored for future use in areas adjacent to deer habitat, deer often attempt to access it. This can result

in feed loss and contamination. However, recent efforts to keep cattle and deer apart and reduce the deer population in Michigan have helped to reduce the spread of bovine tuberculosis (bTB) through contaminated feed.

Although fences used in disease management efforts are not new, they are most effective when maintained and used consistently. Results from an NWRC study tracking the movement of global positioning system (GPS)-collared deer at several sites with and without exclusionary fences showed that such fences reduced cattle feed loss and potential contamination by more than 82 percent. They also caused deer to move away from developed livestock-related areas, further decreasing deer and livestock interaction.

When combined with other management strategies like decreasing deer populations, fencing may further reduce bTB spread between free-ranging deer and livestock. Such strategies are examples of direct management actions that producers can take to help ensure farm biosecurity and create a broader, healthier environment for neighboring wildlife populations.
Contact: Michael Lavelle



Results from an NWRC study tracking GPS-collared deer's movement at several sites with and without exclusionary fences showed that such fences reduced the animals' use and potential contamination of stored cattle feed by at least 82 percent. *Photo by USDA (trail camera)*

Pesticides

- **Rodenticide Exposure in Urban Coyotes.** People in cities and towns across America rely on rodenticides to minimize rat and mice damage. Second-generation anticoagulant rodenticides, which interrupt the blood's ability to clot, are often used because they can poison a rodent in a single dose. Unfortunately, they also persist longer in the rodent's liver, which can lead to secondary poisoning of nontarget wildlife such as raptors and other animals that feed on rodents. During a recent study in the Denver metro area, experts from NWRC, Utah State University, and Colorado Parks and Wildlife found second-generation anticoagulant residues in the livers of five radio-collared urban coyotes. They determined that the amount of rodenticide present in at least two of the animals likely contributed to their deaths. These findings are consistent with other studies that have determined anticoagulant rodenticides are contributing to urban wildlife deaths.
Contact: Stewart Breck

A recent study by NWRC, University of Utah, and Colorado Parks and Wildlife experts led to the discovery of rodenticide residues in five radio-collared urban coyotes' livers. Researchers determined that the amount of rodenticide present in at least two of the animals likely contributed to their deaths. *Photo by USDA, Sharon Poessel*

NWRC research discovered that a tea oil byproduct reduced densities of invasive earthworms in study plots and may help reduce bird-strike hazards around airport runways. *Photo by USDA, Tom Seamans*

- **Chemical Control for Invasive Earthworms.** Though gardeners and fishermen love them, earthworms can be a problem for airport managers trying to prevent bird strikes. Earthworms are food for many birds, including gulls and European starlings, which can be a hazard to aircraft. For example, after a rainstorm at Calgary International Airport in 2004, two aircraft struck gulls that were feeding on earthworms and sustained damage during takeoff. Currently, no toxicants or repellents are registered for earthworm control in the United States. In a series of laboratory and field studies, biologists at NWRC's Ohio field station found that tea-seed cake pellets (TSP), a byproduct of tea oil, caused earthworms to come to the surface and dry up, temporarily reducing two non-native earthworm populations. TSP contain triterpene saponins (natural detergents used in soaps) that irritate earthworms' mucus membranes. Researchers also studied the impact of the repellent on ring-billed gulls and saw no adverse effects to birds that fed on TSP-killed earthworms. Although effective, TSP may need to be applied several times a year to ensure continued control.
  Contact: Thomas Seamans

Repellents

- **Anthraquinone-Based Bird Repellent for Specialty Crops.** Specialty crops (also known as perishable crops) include fresh and dried fruits, vegetables, tree nuts, and horticultural and nursery crops. In the United States, specialty crops are a $60-billion-a-year industry, yet account for only about 3 percent of the country's harvested cropland. Horned larks, great-tailed grackles, and American crows significantly damage specialty crops like lettuce, citrus fruits, and almonds. Anthraquinone, which occurs naturally in some plants, produces a negative post-ingestive effect in these bird species when eaten. To determine appropriate anthraquinone concentration levels for use in a bird repellent for specialty crops, NWRC researchers conducted several repellency trials with the three bird species. Study results showed that Avipel Shield effectively repelled them at varying concentrations.

Bird Species	Anthraquinone Concentration	Repellency Effect
Horned lark	168–3,010 parts per million (ppm)	38–100%
Great-tailed grackle	2,060–35,400 ppm	90–100%
American crow	2,980–31,500 ppm	80–100%

These laboratory efficacy data provide a reliable basis for planning future field applications of anthraquinone-based bird repellents to protect specialty crops. NWRC researchers recommend field efficacy testing for: (1) horned larks exposed to lettuce seeds (i.e., preplant seed treatments,

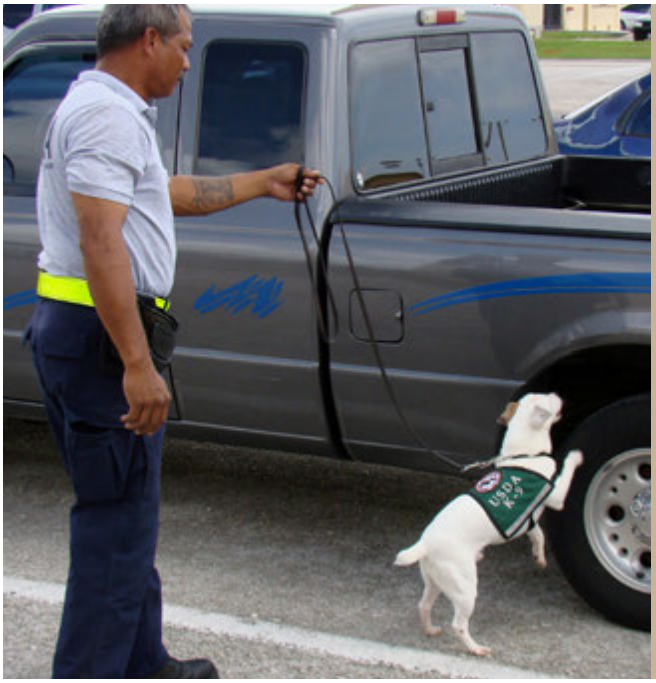
including repellent-treated clay coatings) and lettuce seedlings (foliar applications to emergent seedlings) treated with ≥3,000 ppm anthraquinone; (2) great-tailed grackles exposed to ripening melons treated with ≥2,000 ppm anthraquinone; and (3) American crows exposed to ripening almonds treated with ≥3,000 ppm anthraquinone. *Contact: Scott Werner*

Other Chemical and Biological Methods

- **Thermal Fumigation To Flush Invasive Snakes From Cargo.** Since the early 1990s, NWRC has collaborated with the U.S. Territory of Guam and U.S. Department of Defense to reduce the number of brown treesnakes on Guam and keep them from spreading to other islands in the Pacific. To prevent their spread, NWRC and its partners use fumigants and snake detector dogs to remove snakes from cargo leaving Guam. Recently, NWRC researchers used heated air to flush brown treesnakes from hiding places in a holding pen designed to mimic a cargo shipping container. By applying temperatures between 48–52 degrees Celsius (118–126 degrees Fahrenheit) at moderate delivery rates (3.4 cubic meters per minute), researchers were able to encourage snakes to exit their hiding places within 5 minutes. Developing a portable heat-delivery system based on these findings could prevent the unintentional transport of snakes off the island in cargo, weapons, vehicles, or airplane wheels. *Contact: Randy Stahl*

- **GonaCon Use in Feral Cattle.** Contraceptives may be a humane, effective way to manage some overabundant animal populations. GonaCon is a single-shot immunocontraceptive vaccine developed by NWRC scientists and registered for use in white-tailed deer, feral horses, and burros. Several collaborative studies with universities and other organizations have also shown the vaccine to be effective in other mammal species, including rodents, ungulates, and marsupials. In Hong Kong, an estimated 1,250 South China feral cattle exist as free-roaming animals. They are not actively managed and have caused traffic disturbances and accidents, as well as damaged crops and natural habitats. NWRC researchers provided GonaCon vaccine doses to international collaborators to test in feral cattle.

  Of the 12 cattle treated with GonaCon, 4 became pregnant. The animals' weight, body condition, temperature, and feeding behaviors were monitored for 1 year to determine whether the vaccine had any adverse effects. Researchers concluded that GonaCon did not compromise the animals' welfare and effectively reduced cattle fertility. GonaCon may be a viable way to help manage feral cattle populations in China. Further collaborative studies involving NWRC and the United Kingdom's



To prevent the spread of invasive brown treesnakes from Guam to other islands, NWRC and its partners currently use fumigants and snake detector dogs to remove snakes from cargo. Recently, NWRC researchers used heated air to flush the snakes from hiding places in an experimental holding pen designed to mimic a cargo shipping container. *Photo by USDA*

NWRC and Washington State researchers used stress hormones in elk feces to assess how human disturbances affect elk. *Photo by USDA*

Animal and Plant Health Agency are being conducted to evaluate GonaCon in water buffaloes. *Contact: Doug Eckery*

- **Impacts of Human Disturbance on Elk.** Measuring the level of glucocorticoid and other stress hormones in animal feces is one way to assess the effects of human disturbances, such as road activity and hunting, on wildlife populations. Previous research has shown that fecal glucocorticoid metabolite (FGM) levels in elk feces increase with human disturbance levels. However, researchers note that these results may be confounded by seasonal differences in food and water availability. NWRC, university, and State researchers recently analyzed FGMs from elk at study sites in Washington with differing levels of human disturbance, temperature, and rainfall over the course of 1 year.

  On average, FGM levels of elk sampled at sites with high human activity were over twice as high as those sampled at the site with low human activity. Monthly differences in stress hormone concentrations were most evident at the low disturbance site, where FGMs were 50 to 70 percent higher on average during the spring. At high disturbance sites, FGMs were consistently high year round. Researchers also found that FGMs in elk decreased as precipitation and temperature increased at low disturbance sites. This was not the case at high disturbance sites, indicating that climatic variables were not as influential as human stressors at those locations. This study further demonstrates that human disturbance is a key source of wildlife stress.
  Contact: Brian Washburn

Disease Diagnostics, Surveillance, Risk Assessment, and Management

- **Pathogens in Feral Swine.** NWRC's National Wildlife Disease Program (NWDP) conducts wildlife disease monitoring and surveillance throughout the United States on a variety of species, including feral swine. Feral swine are known to carry over 30 diseases and 37 parasites that can be transmitted to livestock, people, pets, and wildlife. To better understand the prevalence of some of these pathogens in feral swine, NWDP biologists collected serum samples from 162 feral swine and tonsils from 37 feral swine. At right is a summary of the type and percentage of antibodies detected.

  More than 15 percent of animals presented antibodies against both *Mycoplasma hyopneumoniae* and *Actinobacillus pleuropneumoniae* simultaneously. Researchers conclude that feral swine are a potential reservoir for several endemic diseases found in domestic pigs and several zoonotic agents that could impact people.
  Contact: John Baroch

Pathogen	Antibody Prevalence in Samples	Disease or Illness Caused
porcine reproductive and respiratory syndrome virus	2.5 percent	porcine reproductive and respiratory syndrome in swine
porcine circovirus type 2	25.3 percent	systemic infections, pneumonia, enteritis, reproductive failure, and porcine dermatitis and nephropathy syndrome
Mycoplasma hyopneumoniae	19.7 percent	porcine enzootic pneumonia in swine
Actinobacillus pleuropneumoniae	69.7 percent	porcine pleuropneumonia in swine
Lawsonia intracellularis	80 percent	intestinal hyperplasia in swine
Salmonella	49.4 percent	diarrhea, fever, and cramps in people
Streptococcus suis	94.4 percent (tonsils only)	meningitis and sepsis in people

NWDP collects samples from wildlife, including feral swine, for disease surveillance. Recent efforts have shown feral swine to have high antibody prevalence for several pathogens that cause disease in people. *Photo by USDA*

- **Leptospirosis in Feral Swine.** Leptospirosis infects most mammals and is one of the most widespread diseases in the world. It is caused by a slender, spiral-shaped motile bacteria called a spirochete. People can become infected with *Leptospira* bacteria after direct contact with contaminated animal urine or indirectly from contaminated water. Typical symptoms in people include fever, chills, and intense headaches, but more severe illness can lead to death. In the United States, most leptospirosis cases have been linked to people who work in slaughterhouses or on farms. Yet, more recently, outdoor recreationalists have been exposed through contaminated water.

To better understand the disease's geographic extent and prevalence in feral swine, NWRC tested samples from 2,055 feral swine from across the country. About 13 percent of the samples tested positive for *Leptospira* bacteria, suggesting the pathogen is common in feral swine and not limited to certain regions of the country. As feral swine continue to expand their range in the United States, it will be important to understand their role, if any, in leptospirosis outbreaks.
Contact: Kerri Pedersen

- **Improving Rabies Bait Delivery.** In North America, more than 50 percent of all confirmed rabies cases in terrestrial wildlife are found in raccoons. As a result, most baiting and management efforts to prevent disease spread target raccoons. Although these efforts have greatly reduced the westward expansion of raccoon-variant rabies, bait acceptance and vaccination rates for raccoons remain relatively low (between 30 and 40 percent). Models indicate that at least a 70-percent vaccination rate is needed to eliminate the disease in free-ranging populations. Inadequate baiting densities and distribution patterns, bait consumption by nontarget wildlife like Virginia opossums, low bait palatability, timing of vaccine distributions, and habitat differences are potential reasons for low vaccination rates in raccoons.

  NWRC and University of Georgia researchers evaluated the use of stratified bait distribution (SBD) models—which are based on species' habitat use patterns—to determine optimal baiting densities and strategies to improve vaccination rates. SBD models account for density differences and competition among species in different habitats. For instance, when baiting in habitats near agricultural crops, managers need to account for the fact that such crops often support larger densities of raccoons than traditional forested habitats.

NWRC scientists work with WS National Rabies Management Program staff to develop, test, and strengthen the effectiveness of oral rabies vaccine bait.
Photo by USDA, Jordona Kirby

Moreover, Virginia opossums can also occur at high densities in agricultural ecosystems and consume baits intended for raccoons.

To test the SBD models' ability to improve bait uptake, researchers conducted a study in Indiana during which they distributed placebo baits and then trapped and checked 478 raccoons and 108 opossums for the presence of rabies biomarkers (i.e., measurable substance in an animal indicating that a bait has been consumed). Only 26 percent of raccoons exhibited rabies biomarkers and 20 percent of opossums had consumed baits. The baiting created a buffer up to 240 hectares larger than the bait distribution zone, with marked animals captured up to 753 meters beyond the bait zone. However, these animals likely comprised a small minority of the population. Also, there was no difference in bait uptake rates between areas using SBD bait density recommendations versus those not using them.

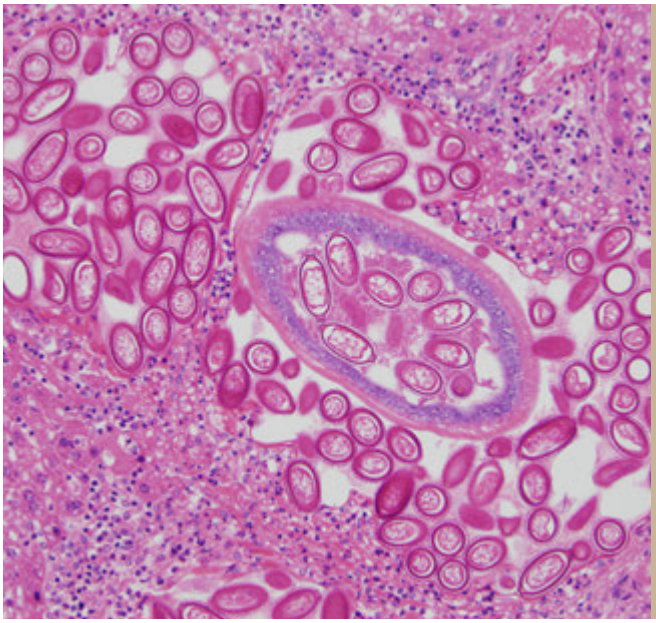
The results confirmed that bait uptake decreases with increasing distance from bait zone interiors. Researchers conclude that while targeted baiting based on SBD models creates a buffered area of treated individuals around bait zones, repeated treatments are needed to achieve sufficient uptake to eradicate disease.
Contact: Kurt VerCauteren

- **Testing Oral Baits for Control of Intestinal Parasites in Raccoons.** *Baylisascaris procyonis* is a common gastrointestinal parasite in raccoons that spreads to other animals and people through contaminated feces. Although rare, it can cause nausea, fatigue, loss of coordination and muscle control, blindness, and comas in people. Raccoons thrive in human-dominated landscapes, and the lack of an effective treatment for *B. procyonis* is a serious threat to public health. Distributing vaccine-laden or medicinal bait to manage the parasite in raccoons may help to reduce its spread. NWRC researchers tested the suitability of using anthelmintic fishmeal polymer bait to manage *B. procyonis*. Anthelmintic drugs expel parasitic worms and other internal parasites from the body by stunning or killing them.

  Through a series of laboratory and field studies, researchers examined if consumed bait clears *B. procyonis* infection in naturally infected raccoons and if free-ranging raccoons eat anthelmintic baits relative to standard fishmeal polymer baits. In a laboratory study, 16 naturally infected raccoons were fed one anthelmintic bait, and their feces were monitored for *B. procyonis* eggs for approximately 90 days. *B. procyonis* infections cleared for 9 of 12 raccoons that consumed more than 10 grams of the 15-gram bait.

  During a field study in Indiana, researchers used remote cameras to monitor free-ranging raccoons' bait consumption. Both anthelmintic and standard baits were quickly consumed, with no differences in the consumption rate between bait types. However, after initial bait contact, raccoons were more likely to consume standard baits while often ignoring anthelmintic baits. While initial anthelmintic bait trials show promise, researchers note that the bait dose and palatability could be improved.
  Contact: Shylo Johnson

- **Detecting Rat Lungworm DNA in Infected Rats' Blood.** *Angiostrongylus cantonensis* is a nematode that causes human eosinophilic meningitis and ocular angiostrongyliasis that is characteristic of rat lungworm (RLW) disease. People can become infected with RLW by eating raw or undercooked snails or slugs infected with the parasite. Currently, RLW is diagnosed by finding the *A. cantonensis* larvae in cerebral spinal fluid or by using a custom immunological or molecular test. To find a less invasive and costly diagnostic test, NWRC and University of Hawaii researchers tested how well



NWRC's invasive rodent research has involved the study of parasitic nematodes, such as *Angiostronglyus cantonensis* and *Capillaria hepatica* (pictured). Both parasites can cause illness in people. *Photo by Colorado State University, Terry Spraker (from microscope)*

High densities of invasive black rats on Diego Garcia may place island residents at risk of infection with the parasitic nematode *Capillaria hepatica*.
Photo by U.S.Department of Defense, Scott Vogt

quantitative polymerase chain reaction (PCR) detected *A. cantonensis deoxyribonucleic* acid (DNA) in experimentally infected rats' blood or tissues.

Researchers were able to detect parasitic DNA in the cardiac blood of all 10 rats infected at either high- or low-dose levels. They were also able to detect parasitic DNA in 8 of the 10 infected rats' tail tissues. Further studies showed that parasitic DNA can be detected as early as 1 hour after infection in peripheral blood samples. This demonstrates that parasite DNA can be found in peripheral blood at various times throughout infection in rats. Quantitative PCR may be used to measure the RLW contamination rate of rats in a given area and detect the parasite in people who accidentally ingest raw snails and slugs.
Contact: Aaron Shiels

- **Zoonotic Parasites in Invasive Black Rats.** Black rats are among the most harmful invasive species worldwide, damaging crops, native ecosystems, stored food, dwellings, and other structures. They can also carry and spread diseases and parasites to other mammals, including people. In a recent black rat population density study on the island of Diego Garcia in the British Indian Ocean Territory, NWRC researchers first discovered *Capillaria hepatica*, a parasitic nematode, in the rats. Histology revealed that 75 percent of the rats sampled had a current or previous infection with *C. hepatica*. Parasitic infections in humans due to *C. hepatica* are rare, but they are typically associated with unsanitary conditions or large rodent populations. The parasite can cause capillariasis and hepatitis in humans. The rat density on Diego Garcia is extremely high, measuring up to 187 rats per hectare in some areas, and may place residents at risk of infection.
Contact: Are Berensten

- **Effects of Barred Owl Range Expansion on the Prevalence of Avian Blood Parasites.** The barred owl historically could be found from South-Central Mexico up through the Southern United States and into the Eastern United States and Canada. However, in the early 1900s, its range began expanding westward, reaching northern California in 1976. Expanding barred owl populations pose a significant threat to federally listed northern spotted owls in the Pacific Northwest because they compete with them. NWRC and Colorado State University researchers recently collected blood samples from western and eastern barred owls, as well as northern spotted owls, to study how barred owls' range expansion may impact the spread of avian blood parasites in northern spotted owls.

  Analysis showed that birds from all three populations were infected with *Haemoproteus* parasites,

with the highest prevalence in eastern barred owls and the lowest prevalence in western barred owls. Results were consistent with the Enemy Release Hypothesis, which states that infection prevalence is lower in a host species' invasive range than its native range. Researchers also found some support for the Parasite Spillback Hypothesis, which predicts that invasive hosts act as a new reservoir for native parasites. This study highlights some of the ways that species' range expansions may alter relationships among invasive and native parasite hosts.
Contact: Alan Franklin

- **Identifying Wildlife Hosts of Heartland Virus.** Heartland virus is a novel phlebovirus recently discovered in Missouri. People are likely infected with Heartland virus through the bite of an insect or tick such as the Lone Star tick. Symptoms include fever, fatigue, headaches, muscle aches, and loss of appetite. In an effort to identify mammal and bird amplification hosts for the virus, experts from NWRC and the Centers for Disease Control and Prevention sampled ticks and collected blood from wildlife. They collected samples from 160 mammals (including 8 species) and 139 birds (including 26 species) captured near residences in northwest Missouri where Heartland virus was confirmed. Heartland virus antibodies were found in 43 percent of raccoons, 17 percent of horses, 14 percent of white-tailed deer, 8 percent of dogs, and 4 percent of Virginia opossums. They were not found in birds. Given the high level of virus antibodies found in raccoons and white-tailed deer, researchers note it may be useful to monitor these species for disease surveillance purposes.
Contact: Jeff Root

- **Estimating Prion Infection in Elk.** Chronic wasting disease (CWD) is a neurodegenerative disease in deer, elk, and moose caused by misshaped proteins called prions. It was first discovered in free-ranging deer and elk in 1981 and is a health threat to wild and captive cervids. It is estimated that CWD prevalence in wild elk may be as high as 13 percent in Colorado. Infected animals shed prions into the environment through saliva, feces, urine, and antler velvet, but little is known about how long animals live and shed prions once they become infected. Immunohistochemistry (IHC) is considered the gold standard for diagnosing CWD, but it may be unable to detect animals in the early stages of infection.

NWRC and Colorado State University researchers studied the impacts of barred owl range expansion on northern spotted owls and the prevalence of avian blood parasites.
Photo by USDA

In a series of studies with captive American white pelicans and other fish-eating birds, NWRC researchers found that pelicans serve as hosts for *Bolobophorus damnificus* trematodes and may spread the parasite in the environment. This trematode costs the Mississippi catfish industry approximately $27 million in damages each year. *Photo by USDA*

NWRC researchers and partners compared and assessed the ability of IHC and serial protein misfolding cyclic amplification (sPMCA) to detect CWD prior to the onset of clinical signs. They analyzed brain and lymph tissue samples from 85 wild elk to estimate the IHC and sPMCA tests' sensitivity and specificity. Sensitivity estimates were higher for sPMCA than IHC. Further analysis and modeling predicted that the prevalence of prion infection in elk may be higher than previously thought—18.9 percent versus prior estimates of 13 percent. Data also revealed a previously unidentified sub-clinical prion-positive portion of the elk population that could represent silent carriers capable of significantly impacting CWD ecology. These findings will aid in the management of CWD in captive and wild deer.

Contact: Kurt VerCauteren

- **Detecting Bovine Tuberculosis in Deer Feces.** White-tailed deer serve as a reservoir for *Mycobacterium bovis*, a bacterium that causes bovine tuberculosis, and can be a source of cattle infection in the United States. Controlling tuberculosis in deer has relied on restricting baiting and supplemental feeding of deer and reducing deer populations through hunting. Experimentally treating deer with the *M. bovis* Bacille Calmette-Guerin vaccine has effectively protected deer from the disease and is being considered as an additional management tool. Currently, however, there is no simple method for monitoring tuberculosis in deer.

  In a recent study, NWRC researchers evaluated whether fecal volatile organic compounds (VOCs) could be used to distinguish between vaccinated and non-vaccinated deer before and after *M. bovis* inoculation. VOCs are chemicals that emit unique odors and release patterns. Because of these unique characteristics, VOCs have been identified as potential disease surveillance tools. Using gas chromatography and mass spectrometry, researchers were able to identify 17 compounds to distinguish among vaccinated and non-vaccinated deer fecal samples before and after inoculation. Detecting disease-specific VOCs in feces could provide a simple method for testing captive deer and has great potential for use in remote disease surveillance

Issue	Surveillance Efforts
Avian Influenza	NWDP sampled more than 6,000 wild birds for highly pathogenic avian influenza (HPAI). In addition, NWDP developed and implemented the Interagency Wild Bird HPAI Surveillance Plan, Wild Bird HPAI Implementation Plan, and HPAI Procedures Manual in support of collecting 41,000 wild bird samples from July 1, 2015, through March 31, 2016.
Feral Swine Disease	NWDP sampled more than 4,200 feral swine in 34 States and Guam for pseudorabies, swine brucellosis, classical swine fever, porcine reproductive and respiratory syndrome, leptospirosis, toxoplasmosis, trichinellosis, and influenza A virus.
Plague and Tularemia	NWDP routinely carries out opportunistic wildlife surveillance for exposure to the causative agents of plague (*Yersinia pestis*) and tularemia (*Francisella tularensis*) in conjunction with other surveillance activities. In fiscal year 2015, NWDP biologists and their cooperators collected blood samples from 1,939 animals across the United States. This sample set was spread over 28 different species, although the vast majority of samples were collected from coyotes.
Bluetongue and Epizootic Hemorrhagic Disease	NWDP sampled more than 1,600 deer in 20 States and the U.S. Virgin Islands for bluetongue virus and epizootic hemorrhagic disease.

efforts. This was the first study to use fecal VOCs to identify deer with tuberculosis.
Contact: Randy Stahl

- **Pelican and Cormorant Parasitology and Disease Epidemiology.** NWRC researchers conducted several studies with pelicans, cormorants, and other fish-eating birds to determine their role in spreading *Bolobophorus damnificus* trematodes and the virulent strain of *Aeromonas hydrophilia* (VAH) on aquaculture farms. The *B. damnificus* trematode costs the Mississippi catfish industry approximately $27 million in damages each year. Study results indicated that adult *B. damnificus* trematodes were found only in American white pelicans, the parasite's definitive host. In other studies, researchers found that cormorants, wood storks, great egrets, and pelicans could shed viable VAH after consuming infected fish—implicating them as a disease reservoir and a vector capable of spreading the pathogen to uninfected areas. These studies stress the need to reduce predatory feeding and scavenging on commercial catfish operations.
Contact: Fred Cunningham

- **NWDP Surveillance Accomplishments.** Each year, NWDP conducts wildlife disease monitoring and surveillance throughout the United States. The chart above summarizes its 2015 efforts.

Wildlife Damage Assessments

- **Collisions Between Eagles and Aircraft.** Because of their large size, eagles can cause significant damage to aircraft and pose a high safety risk to aircraft passengers and crew. Recently, NWRC scientists reported on eagle-aircraft collisions' trends and patterns. Of the 234 eagle collisions with civil and military aircraft reported to the Federal Aviation Administration, U.S. Air Force, and U.S. Navy from 1990 to 2013, 52 percent caused aircraft damage. During this 23-year period, bald eagle-aircraft collisions increased by 2,200 percent, and golden eagle-aircraft collisions rose by 400 percent.

The WS Airport Wildlife Hazards Program works with the Federal Aviation Administration to reduce wildlife hazards at airports. NWRC supports these efforts by studying the nature of wildlife hazards and developing management tools and strategies to reduce them. *Photo by National Transportation Safety Board*

Eagle-aircraft collisions occur mostly during daylight hours and typically within the airfield area. Eighty-three percent of bald eagle strikes and 81 percent of golden eagle strikes occurred when the aircraft was at or below 305 meters above ground in the final stages of landing or taking off.

Although aircraft collisions are a very minor source of golden eagle mortality, increasing and expanding bald eagle populations will likely result in more eagle-aircraft collisions. Given the current widespread public interest in eagles and a strong concern for eagle protection, these findings point to the need for more effective, socially acceptable methods to reduce hazards posed by eagles at airports.
Contact: Brian Washburn

- **Carnivore Incidents With Aircraft.** From 1990 to 2010, more than 100,000 wildlife-aircraft collisions were reported through the Federal Aviation Administration's National Wildlife Strike Database (NWSD). Although most research on wildlife-aircraft collisions has focused on birds, incidents involving mammals often cause more damage. NWRC and Mississippi State University scientists queried the database to learn more about the number and type of incidents between mammalian carnivores and U.S. civil aircraft.

  More than 1,000 carnivore-aircraft incidents were reported between 1990 and 2012. Sixteen species were identified, with coyotes being the most frequently struck species. California and Texas had the most reported incidents, and they were more likely to occur at night from August to November. Overall estimated carnivore damage to aircraft from 1990 to 2012 was $7 million. As the amount of air traffic increased over the years, so did the rate of carnivore-aircraft incidents. Although the incident rate increased 13 percent per year, the rate of damaging incidents remained fairly constant. Researchers recommend increasing runway patrols at night from July through November and maintaining high-perimeter fences to exclude medium- and large-sized mammals.
  Contact: Travis DeVault

- **High Cost of Canine Rabies.** The World Health Organization estimates that, on average, about 55,000 people die of rabies each year, and 99 percent of these deaths are attributable to canine rabies in Asia and Africa. To provide a more complete assessment of canine rabies' global impact, NWRC economists extended current economic estimates to include the cost of human death risk. Human death risk is quantified by how much people are willing to pay to reduce their chances of dying or, conversely, how much people must be paid to tolerate increased risk. Researchers also accounted for both direct and indirect costs of rabies post-exposure prophylaxis, dog vaccination and control, rabies diagnostic testing, and cattle deaths.

Using Monte Carlo computer simulation models, they estimated the global burden of canine rabies to be about $124 billion per year. The results also highlighted important regional differences. Researchers found that the global burden from canine rabies falls most heavily on Asia, which accrues more than 80 percent of the nonhuman death costs. Africa, on the other hand, accounts for only 3 percent of nonhuman death costs but 45 percent of human deaths. This study illustrates the potential benefits of canine rabies elimination and provides an important benchmark for comparing rabies elimination campaign costs.
Contact: Aaron Anderson

- **Modeling Economic Impacts of Cormorants to a Recreational Fishery.** The double-crested cormorant population in the Great Lakes region increased from 32,000 breeding pairs in the 1970s to more than 226,000 pairs in the 1990s (most recent data available). This is good news for the birds, but the impacts, if any, to other wildlife, fish, and the economy in the region are still being explored. Some university studies have shown that large numbers of cormorants negatively impact other birds, particularly nesting great blue herons and black-crowned night herons. Other studies have shown cormorants to be the main cause of reduced walleye and yellow perch populations.

  To get a better feel for how cormorants might impact the economy, NWRC economists looked at the costs associated with reduced fishing opportunities and nonresident angler tourism spending (i.e., licenses, lodging, food, gas) in the Oneida Lake region of New York. The overall cost estimate was based on the assumption that real and perceived cormorant impacts on fish stocks play a role in the number of nonresident fishing licenses sold. Fewer licenses mean fewer anglers around to spend money. Researchers used an IMPLAN model to create a mathematical representation of the regional economy, including all the links among economic sectors (e.g., agricultural, retail, service, manufacturing, and industrial). The model allowed them to estimate the total economic impact of cormorant damage to the fisheries.

  Results showed that the economic loss was on average $5 million to $66 million per year, as well as 66 to 929 job-years annually from 1990 to 2009. This approach to calculating wildlife damage's economic impacts can be applied to other wildlife to provide a more accurate estimate of total economic impacts.
  Contact: Stephanie Shwiff

NWRC studies have looked at double-crested cormorants' economic impacts on the catfish industry and recreational fisheries. *Photo by USDA*

Production costs for catfish farming increase as cormorant predation levels increase. NWRC researchers found that the maximum increase in production costs is 14.3 cents per kilogram. However, they note that losses due to cormorant predation are partially offset by increases in individual fish growth due to lower catfish densities.
Photo by USDA

- **Cormorant Predation on Multiple-Batch Production of Channel Catfish.** Double-crested cormorants are the primary bird predator on commercially produced channel catfish. To learn more about cormorants' economic impacts on catfish farms, NWRC researchers simulated different levels of cormorant predation on channel catfish in a multiple-batch cropping system. A multiple-batch cropping system contains ponds that include fish of varying sizes. This method allows faster growing fish to be selectively harvested while fingerlings are added to replace the harvested fish. The process continues for years without draining the pond. Results of varying predation levels on 40 0.05-hectare catfish ponds showed that production costs for catfish farming increase as cormorant predation increases. The maximum increase in production cost is $0.143 per kilogram. However, researchers note that losses due to cormorant predation are partially offset by increases in individual fish growth due to lower catfish densities.
Contact: Brian Dorr

- **Colonial Waterbird Impacts on Island Habitats.** Colonial waterbirds, such as double-crested cormorants, gulls, and American white pelicans, impact island ecosystems throughout their breeding range by changing vegetation and soil characteristics with their fecal matter and physical destruction of vegetation. NWRC researchers studied how excluding these birds from island habitats in Lake Michigan impacts plant diversity and growth; soil chemistry; and the survival of black elderberry, a woody perennial that provides forage and cover for many wildlife species.

  Results showed that while exclusion increased non-woody plant growth, it did not increase woody

plant regeneration, possibly due to poor soil conditions or a lack of viable suckers and seedlings. The soil from islands with nesting waterbirds was more acidic and had greater nutrient concentrations than that from islands without nesting waterbirds. Researchers note that while excluding or removing nesting waterbirds from islands can improve overall vegetation growth, successfully restoring woody vegetation, such as black elderberry, may require significant soil manipulation and planting.
Contact: Brian Dorr

Wildlife Management Methods and Evaluations

- **Difficulties Associated With Relocating Beaver To Improve Salmon Habitat.** The American beaver's reputation as nature's engineer is well known. A beaver can drastically alter its habitat to make it more suitable for itself and other wildlife species. Recently, some scientists and land managers have suggested that beavers and their damming behaviors could be used to help enhance in-stream habitat for salmon in the Pacific Northwest. Oregon and Washington have passed laws that allow landowners to relocate beavers for management purposes. To evaluate whether relocating beavers can improve coho salmon habitat in Oregon, NWRC and Oregon State University researchers trapped, radio-marked, and relocated 38 nuisance beavers using State relocation guidelines. They released animals into areas with the potential for beaver dams to improve the habitat for coho salmon, a federally protected species.

  Results showed that all relocated beavers moved from their initial release sites, one as far as 18 miles. Thirty-seven percent of the relocated beavers died from either predation or disease within the first few months of their release. Most predation occurred within the first week post-release. Also, very few beaver dams were built, and none of them withstood high water flows. Results indicate that current beaver relocation options for Oregon landowners are not effective for helping to restore stream habitat for coho salmon. Researchers encourage land managers and others who want to use beaver relocation as a management tool to educate landowners about the risks of beavers dispersing out of target areas and causing damage on nearby properties.
  Contact: Jimmy Taylor

- **Effects of Mountain Beaver Management and Tree Thinning on Tree Growth.** Mountain beavers are native burrowing mammals that damage commercial coniferous trees in the Pacific Northwest.

To assess whether relocating beavers can improve coho salmon habitat in Oregon, NWRC and Oregon State University researchers trapped, radio-marked, and relocated 38 nuisance beavers using State relocation guidelines. Thirty-seven percent of the beavers died from either disease or predation within the first few months of their release. *Photo by USDA*

The small Indian mongoose is an invasive species in Hawaii, Puerto Rico, and the U.S. Virgin Islands. In these island ecosystems, they have caused substantial threats to or extinction of native bird, amphibian, reptile, and mammal species. They can also carry rabies, leptospirosis, and canine distemper. *Photo by USDA, Tiana Maple*

Since mountain beaver damage occurs in thinned and unthinned stands, silviculturists do not know the best management approach for promoting tree growth in mountain beaver areas. To provide some guidance, NWRC researchers compared Douglas fir trees' growth and survival at study sites in Washington after implementing the following damage management strategies: (1) trapping mountain beavers, (2) trapping mountain beavers and thinning trees to 65 trees per hectare, (3) not trapping mountain beavers but thinning trees to 65 trees per hectare, (4) not trapping mountain beavers but thinning trees to 146 trees per hectare, and (5) not trapping mountain beavers or thinning trees.

One hundred trees with visible mountain beaver damage and 100 trees without apparent damage were monitored in 5 stands for 4 years after treatment. Removing more than 90 percent of the mountain beavers temporarily reduced their activity in thinned and unthinned stands. Tree height was greatest in trapped areas, whether trees were thinned or not. Basal diameter growth and diameter growth at breast height were greatest for areas thinned to 65 trees per hectare. Overall, the short-term removal of mountain beavers along with precommercial thinning promoted the most crop trees.
Contact: Richard Engeman

- **Improving Trapping Success of Invasive Mongoose.** The small Indian mongoose is an invasive species in Hawaii, Puerto Rico, and the U.S. Virgin Islands. In these island ecosystems, mongooses have caused substantial threats to or extinction of native bird, amphibian, reptile, and mammal species. Mongooses are also carriers of rabies, leptospirosis, and canine distemper. In certain areas, natural resource managers try to reduce mongoose populations using traps and rodenticides. To improve upon these efforts, NWRC researchers used radio telemetry and implanted microchips in 34 mongooses to evaluate their movement patterns, population densities, home ranges, and foraging efforts in Hawaii. They also tested five novel bait flavors, including fish, egg, hot dog, coconut, and beef.

  The monitored mongooses foraged over a large area and readily investigated the novel baits. The fish-, egg-, and beef-flavored baits received the most visits. Researchers also found that most mongooses in a given area could be trapped in a short period and that new individuals' migration into established habitats was relatively slow. Based on resident mongooses' home ranges, daily travel distances, and broad overlapping habitat use patterns, NWRC researchers suggest that managers consider increasing trap or bait station spacing from the current 25–100 meters to 150–200 meters and place traps along habitat edges and transition zones with easily accessible roads. The study findings also suggest that maintaining fresh baits in traps may not be as important to

NWRC and Island Conservation researchers monitored the fate of rodenticide residues on soil, water, and nontarget animals following a rodent eradication effort on Palmyra Atoll in the South Pacific. They detected residues from the aerial broadcast bait in 84 percent of the analyzed animal samples.
Photo by USDA, Are Berensten

trap success as previously thought. Decomposing animal-based baits attracted mongooses from long distances.
Contact: Robert Sugihara

- **Rodent Eradications on Tropical Islands: Short-Term Costs Versus Long-Term Benefits.** The use of rodenticides to control or eradicate invasive rats for conservation purposes, especially on islands, has increased in the past few decades. To better understand the impacts of such efforts on nontarget species, NWRC and Island Conservation researchers monitored the fate of rodenticide residues on soil, water, and animals from a 2011 rodent eradication on Palmyra Atoll in the South Pacific. Brodifacoum 25W: Conservation—a second generation anticoagulant rodenticide—was aerially broadcast twice over the entire 232-hectare atoll and then hand-broadcast in the atoll's more developed areas.

  Approximately 14 to 19 percent of the bait entered the marine environment along the shoreline. Researchers collected 84 animal carcasses representing 15 species of birds, fish, reptiles, and invertebrates, as well as other specimens, for rodenticide residue analysis. They detected Brodifacoum residues in 84 percent of the animal samples, including two species of conservation concern (bristle-thighed curlews [*Numenius tahitiensis*] and Pacific golden plovers [*Pluvialis fulva*]). The extent and concentrations in many parts of the food web were greater than expected. Partner organizations' subsequent monitoring

has revealed no rats on the atoll. In addition, partner organizations report that native vegetation is rebounding after decades of rat damage to seedlings, two new land crab species have been identified on the atoll since removing the rats, and several bird species' nest success has improved.

Risk assessments should carefully consider application rates and entire food webs prior to rodenticide use, as well as weigh the short-term nontarget mortality costs against the long-term ecosystem recovery gain.
Contact: Are Berentsen

- **Best Management Practices for Rat Eradication on Tropical Islands.** Methods to eradicate rats from islands are well established, and there have been over 580 successful eradications to date. Unfortunately, rat eradications on tropical islands have a lower success rate than those in temperate areas. In an effort to identify why and find solutions, the University of Auckland in New Zealand held a workshop with 34 experts in rat eradication, tropical rodent and island ecology, and toxicology. Two of the NWRC's scientists attended and helped in writing the workshop's proceedings. The workshop, which gathered leading experts from around the world, resulted in a list of best management practices for eradication efforts using aerial broadcast of Brodifacoum bait.

  Recommendations included developing a nontarget species inventory, conducting a peer-reviewed environmental assessment, applying additional bait to the forest canopy to reach rats while preventing ground-based land crabs from eating them, obtaining climate and seasonal data to help plan and time bait drops, and conducting a bait availability trial to inform application rates. Although current success rates for aerial broadcast rat eradication efforts in tropical environments are high (89 percent), experts hope these recommendations will further increase rates to those obtained in temperate locations (97 percent).
  Contact: Aaron Shiels

- **Protecting Endangered Sea Turtle Nests From Predation.** On Florida's Keewaydin Island, raccoon and feral swine predation poses major threats to sea turtle nests. Using 6 years of nesting data for endangered sea turtles, NWRC researchers partnered with WS Operations and the Conservancy of South Florida to study the impacts of feral swine and raccoon predation on nests. Researchers also examined the benefits of eradicating feral swine from the island and caging sea turtle nests to protect them from predation.

  Swine began preying on nests midway through the 2007 nesting season and destroyed all sea turtle nests on the island. The swine were later eradicated before the 2008 nesting season. Eradication costs totaled $14,020, while the value of the

An international workshop attended by NWRC and other rodent experts led to developing best management practices for eradicating rodents on tropical islands. One recommendation highlighted the importance of applying bait to forest canopies where it is accessible to rodents but not land crabs. *Photo by USDA, Kacy Hayes*

hatchlings lost to swine predation in 2007 was 27 times higher at $379,100. Although not studied, researchers note that an added benefit of removing feral swine may be increased colonial shorebird nesting success. Also, swine eradication has lasting ecological and economic benefits that accrue across all future years without swine predation.

When studying the benefits of caging sea turtle nests, researchers found that from 2005 to 2010, raccoon predation rates for caged nests were significantly lower than for uncaged nests every year except 2009, when little raccoon predation occurred. For feral swine, caging did not prevent predation in 2007, but caged nests remained intact almost 12 days longer than uncaged nests. In short, eggs in caged nests have a greater chance of hatching before feral swine eat them. Researchers note the use of cages and other barriers as well as the removal of predators are effective strategies for protecting not only sea turtle eggs, but also other threatened and endangered plants and animals.
Contact: Richard Engeman

- **Speed Kills: Ineffective Bird Responses to Oncoming Vehicles.** How birds respond to approaching objects greatly impacts their ability to detect predators, forage, flock, and avoid collisions. Understanding variations in animals' visual capabilities and other sensory systems may shed light on how they detect and avoid threats from approaching aircraft, other vehicles, wind turbines, and communication towers.

  To better understand birds' responses to approaching vehicles, NWRC researchers placed captive brown-headed cowbirds into a simulation chamber where they watched videos of vehicles approaching at various speeds. Researchers watched the birds' reactions to the videos and noticed that while they could successfully avoid slower moving vehicles, cars moving faster than 75 miles per hour overwhelmed the birds' escape strategies. Instead of adjusting their escape time to the car's speed, the birds only evaluated the distance between themselves and the vehicle. No matter how fast the car approached, the birds usually took off when it was roughly 90 feet away.

  Helping birds overcome this apparent fixed avoidance distance threshold will enable researchers to develop aircraft and other vehicle lighting systems that will help birds respond to approaching objects sooner and avoid collisions.
  Contact: Travis DeVault

- **Integrating Nonlethal and Lethal Bird Management Strategies.** Bird damage to crops is an economically important problem worldwide. Affected farmers often advocate lethal methods based on the perceived need to take quick action to avoid serious economic losses. Recently, NWRC researchers and colleagues from Argentina and Uruguay examined the use of lethal control for reducing agricultural damage caused by blackbirds, dickcissels, eared doves, and monk parakeets in North and South America. Researchers noted that perceived risk toward effective lethal management of these species included public resistance; low cost-effectiveness; difficult logistics; and potential environmental risks, especially to nontarget birds. The perceived risk toward effective nonlethal management included techniques' ineffectiveness in the face of vast numbers of depredating birds.

  Researchers recommend an integrated approach using lethal and nonlethal methods. For instance, farmers should consider using lethal control to reduce populations before using a repellent, scare device, or contraceptive. Researchers also caution that lethal methods should not be open-ended. Instead, they should be implemented with clear, measurable goals and objectives. Researchers

emphasize that responsible wildlife damage management decisions must take into account not only the involved wildlife species' biology and ecology, but also current laws, policies, economics, environmental and social considerations, and the practicality of various tools and techniques. *Contact: Michael Avery*

Wildlife Population Monitoring Methods and Evaluations

- **Validating Abundance Monitoring Methods.** Free-ranging animals are difficult to detect and monitor. Indices of relative abundance provide a practical method for monitoring populations. Until recently, validation of indexing has been limited. Researchers from NWRC and the Robert Wicks Pest Animal Research Center in Australia applied methods commonly used to validate mathematical models to an index of relative abundance called the passive tracking index (PTI). Using published data, researchers first examined the rationality of the PTI method, how conceptually animal activity and abundance are related, and how alternative methods are subject to similar biases or produce similar estimates and trends. The researchers compared PTI trends against a prediction that adjacent populations of the same species will have similar abundance values and trends in activity.

  Researchers note that although PTI abundance estimates are subject to environmental and behavioral randomness, the PTI method shows high detection probability, accurate abundance values, and, generally, low variability between surveys, suggesting that it provides a sensitive and credible index of abundance. This and similar validation approaches can be applied to other indices to show their credibility and justify their use. *Contact: Richard Engeman*

- **Modeling and Mapping the Spread of Feral Swine in the United States.** Experts from NWRC, APHIS' Veterinary Services program, Colorado State University, and Conservation Science Partners modeled the current feral swine distribution in the United States to better understand the physiological and ecological factors that may determine their invasive potential and to guide future study and eradication efforts. Using national-scale feral swine occurrence data reported by wildlife management professionals between 1982 and 2012, researchers estimated the probability of feral swine occurrence across the United States based on environmental characteristics that may affect their distribution.

  Results suggest that feral swine distribution in the United States was most strongly limited by cold temperatures and water availability and that the animals were most likely to occur where potential home ranges had higher habitat diversity, providing access to multiple key resources including water, forage, and cover. Researchers caution that more

Free-ranging animals are difficult to detect and monitor. Indices of relative abundance that involve counting animal tracks or other signs are one way that managers can survey the abundance or density of these animals. *Photo by USDA, Richard Engeman*

Experts from NWRC, APHIS' Veterinary Services program, Colorado State University, and Conservation Science Partners modeled the current distribution of feral swine in the United States to better understand the physiological and ecological factors that determine their invasive potential. *Photo by USDA (trail camera)*

studies are needed to better understand whether low temperatures actually limit feral swine distributions. By highlighting areas in the United States that the animals may invade, the model helps managers identify locations that need active feral swine management.
Contact: Tom Gidlewski

- **Controlling Feral Swine Populations in Great Smoky Mountains National Park.** Invasive feral swine were first seen in Great Smoky Mountains National Park (GSMNP) in the late 1940s. They impact park resources by eating native plants and animals, competing with native wildlife for resources, and spreading disease. Since 1959, park officials have tried to control the feral swine population by shooting and trapping, but limited data make it difficult to evaluate the effectiveness of those efforts. Previous research has shown that feral swine are likely to have larger litters and reproduce more when food resources are plentiful. NWRC researchers and partners developed an individual-based model for feral swine in GSMNP to determine the impact of annual control efforts and available food resources on the population.

  Results suggest that the GSMNP has a 20-percent annual feral swine harvest rate and that eliminating control efforts would result in a 24-percent increase in the feral swine population from 2013 to 2019. Projections indicate that an annual feral swine harvest rate of over 40 percent is required to decrease the population. To model the impact of acorn and nut availability on the feral swine population, researchers varied the amount of food available to the animals based on forest type and historical acorn and nut production. Modeling results showed that variations in acorn and nut production affected feral swine movement and reproductive success. Researchers note that these food fluctuations are a natural population regulator. In years of low acorn and nut production, feral swine leave the park to find food and their reproductive success is limited.
  Contact: Kurt VerCauteren

NWRC and university researchers compared 16 years of data on cougars from both heavily harvested and semi-protected populations. The goal was to determine whether hunting adds to or offsets the number of cougars that die from natural mortality. *Photo by U.S. Fish and Wildlife Service, Justin Shoemaker*

- **Understanding Impacts of Human-Caused Versus Natural Mortality in Cougars.** Depending on where they are located in the Western United States, cougar populations are managed to reach different natural resource goals. These goals range from preventing cougar predation on native and domestic ungulates, to providing trophy hunting opportunities, to protecting cougars from human disturbances. Whatever the goal, cougar populations can only be maintained if the interplay between human harvest or exploitation and natural mortality is understood. Humans' exploitation of carnivores has long been thought to offset the number of natural deaths among survivors. If human exploitation exceeds natural mortality, it can have an additive effect and place populations in jeopardy.

  To test whether compensatory or additive mortality influences are at play, NWRC and university researchers compared 16 years of data on cougars from both heavily harvested and semi-protected populations in Utah. Cougar populations under heavy harvest pressures generally declined as hunting was additive to natural mortality. In the semi-protected population, researchers found evidence of partial compensation for hunting through reduced natural mortality. Researchers note that managers must address and minimize uncertainty in cougar population estimates to better inform management recommendations.
  Contact: Eric Gese

- **Mark-Resight Technique for Monitoring Resident Canada Geese.** The number of resident Canada geese in the United States has increased dramatically from 2.5 million in 1990 to more than 5 million today. With these high numbers comes an increased risk of disease transmission, habitat degradation, and bird-aircraft collisions. In a recent study, NWRC and North Carolina State University researchers used a novel mark-resight method to estimate goose populations and monitor their movements, eliminating the need for more costly telemetry studies.

  Researchers resighted 763 neck- and leg-banded resident Canada geese two to three times per week in and around Greensboro, NC, for 18 months. By using spatial mark-resight models, they determined that Canada goose densities varied seasonally and reflected changes in goose behavior and physiological requirements. Goose densities ranged from 11 individuals per square kilometer in the spring during the breeding season to 16 individuals per square kilometer in the fall. The technique represents an improved, cheaper way to estimate and monitor the density of free-ranging wildlife. *Contact: Brian Washburn*

NWRC and North Carolina State University researchers used a novel mark-resight method to estimate Canada goose populations in urban environments, eliminating the need for more costly telemetry studies. *Photo by USDA, Brian Washburn*

- **Role of Genetic Diversity on Monk Parakeets' Successful Invasion.** Invasive species cause millions of dollars in damages every year. Identifying characteristics that make a species a successful invader may help to prevent its spread. Several studies have investigated the impact of genetic diversity on species' abilities to establish themselves in new environments. It is thought that a more genetically diverse founder population is likelier to include individuals with traits that are well suited to the new environment, making it more successful.

  To understand the role genetic diversity may have played in establishing invasive monk parakeet populations around the world, NWRC and university scientists, as well as experts from Australia, Canada, and Spain, compared genetic data collected from native monk parakeet populations in South America with data from invasive populations in the United States, Europe, and Africa. They analyzed the data to determine whether the genetic diversity found in invasive populations was reflective of their native populations or a result of genetic bottlenecks (loss of diversity) after introduction.

  Results showed that genetic diversity varied among the invasive populations and was overall lower than in the native populations. Although these patterns indicate that genetic bottlenecks probably reduced invasive populations' diversity compared to the native source, many of the invasive populations are thriving. The low genetic diversity observed in invader populations does not support the hypothesis that high genetic variation inherently favors biological invasion or that invasion is favored by the combining or mixing of genetic variation from multiple source populations. In the case of

Invasive monk parakeets are found in many areas around the world. NWRC scientists and their international colleagues in Australia, Canada, and Spain investigated the role genetic diversity plays in the species' ability to invade and become established in new areas.
Photo by USDA, Michael Avery

invasive monk parakeets, other traits like their ability to build their own nests instead of relying on cavities for breeding, their tolerance of human disturbances, and their flexible and diverse diets may be responsible for their success.
Contact: Michael Avery

- **Optimizing Noninvasive Genetic Sampling for Carnivores.** Noninvasive genetic sampling is used to monitor species that are rare, elusive, or otherwise difficult to survey with traditional techniques. Genetic material obtained from feces, hair, and feathers can help scientists identify species and individuals, population genetic structure, genetic diversity, connectivity, and sex ratios. To help improve the accuracy and cost-effectiveness of noninvasive genetic sampling for use in carnivore population studies, NWRC and University of Idaho researchers developed a model to account for differences in fecal sample accumulation and DNA degradation rates in kit foxes and coyotes. They collected droppings for both species on the U.S. Army Dugway Proving Ground in western Utah during summer and winter. Researchers evaluated the success of using mitochondrial DNA and nuclear DNA tests to amplify genetic material found in 20 fresh feces per species per season from 1 to 112 days post collection.

  Results showed that feces accumulation rates for coyotes were nearly three times higher than those for foxes. Across species and seasons, mitochondrial DNA amplification was 95-percent successful until 21 days post collection, versus only 50–70 percent for nuclear DNA. Researchers also looked at the costs associated with gathering viable samples based on the time of year and intervals between sampling, as well as conducting laboratory activities. They determined that sampling for kit foxes and coyotes simultaneously over a 14-day period produced the most savings by optimizing sampling activities, allowing for the collection of the most viable samples, and reducing laboratory costs. Researchers stress the need to design noninvasive sampling studies in a way that balances field and laboratory costs along with feces deposition and DNA degradation rates.
  Contact: Eric Gese

Registration Updates

- **Acetaminophen Product Label Now Allows Mechanical Application.** The U.S. Environmental Protection Agency (EPA) has approved acetaminophen as a toxicant for controlling invasive brown treesnakes in Guam. The NWRC Registration Unit petitioned the EPA for amended pesticide product label directions that authorize the legal use of a new automated acetaminophen bait production

and delivery system. The ability to use this new tool saves WS time and money.
Contact: Jeanette O'Hare

- **APHIS Pesticide Products and EPA's Registration Review.** The NWRC Registration Unit continues to address the EPA Pesticide Registration Review of DRC-1339 (an avian toxicant) and the gas cartridge (a rodent fumigant). EPA's Office of Pesticide Programs is charged with protecting threatened and endangered species from potential risks associated with legal pesticide use. The Registration Unit, in cooperation with other WS Pesticide Coordination Committee members, is continuing to work with EPA as they conduct their multi-year risk assessments and develop risk mitigation measures. USDA supports EPA's efforts to protect threatened and endangered species and natural and human resources through responsible pesticide use.
Contact: Jeanette O'Hare

- **Registration Support Partnerships.** EPA, the U.S. Food and Drug Administration, and USDA regulate the development and use of new vaccine, repellent and pesticide products for animals. The regulatory process is complicated and overlapping. NWRC lends regulatory expertise to partners developing wildlife damage management tools. Two recent projects include (1) the development of an oral vaccine for sylvatic plague to protect prairie dogs (and endangered black-footed ferrets who feed on them) in select areas and (2) the development of prevention and treatment options for controlling white-nose syndrome in bats.
Contact: Jeanette O'Hare

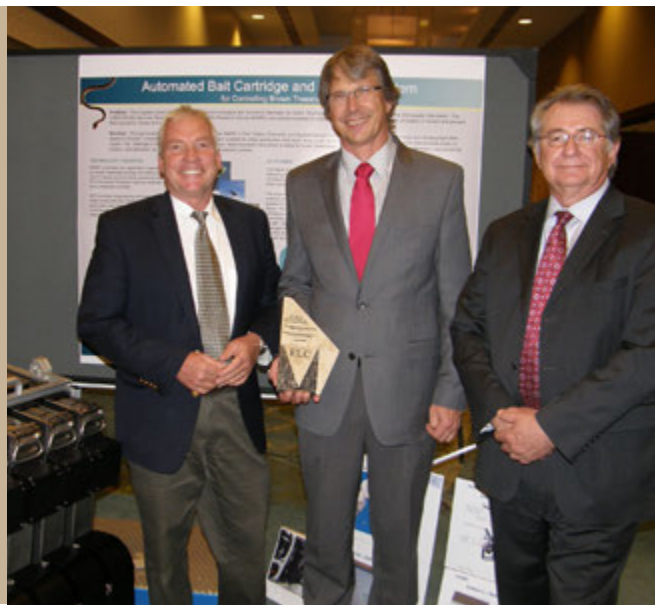
Technology Transfer

- **Developing Chemical Repellents for Birds.** NWRC scientists have been working for decades to develop chemical-based bird repellents to alleviate crop depredation and other nuisance situations. Many useful tools have resulted from these efforts. On September 15, 2015, the U.S. Patent and Trademark Office issued a patent to APHIS and Scott Werner, an NWRC research wildlife biologist, for an "Ultraviolet Strategy for Avian Repellency" (US 9,131,678 B1). This method for repelling birds from a crop or other resource is unique. First, a bird repellent is applied to the target crop in sufficient quantities to repel birds. Then, one or two subsequent treatments are applied to the crop, which include the repellent and a visual cue that exhibits an ultraviolet absorbance spectrum or color similar to that of the repellent. This allows future repellent treatments to be applied at significantly lower amounts than the initial treatment. This APHIS technology may save applicators money and be used to develop a unique bird management tool, so private businesses are very interested in licensing it. A license was issued in early 2016.
Contact: Scott Werner

- **Licensing GonaCon-Equine.** GonaCon-Equine is a contraceptive vaccine developed by APHIS and registered with EPA for use in wild and feral horses and burros. In 2010, the U.S. Patent and Trademark Office issued a patent for this vaccine's technology under the title "Vaccine Composition and Adjuvant" (US 7,731,939 B2). Humane Breakthrough, a newly established public benefit company, recently finalized a license under this patent and will begin producing and selling GonaCon-Equine in 2016. This license allows the company to market GonaCon-Equine within the United States and internationally. In addition, the license and registration sets the groundwork for the company to partner with another organization, SpayFIRST!, to develop other applications and markets for GonaCon.
Contact: John Eisemann

Awards

- **Federal Laboratory Consortium's Award for Excellence in Technology Transfer.** On April 29, 2015, NWRC received the Federal Laboratory Consortium's (FLC) 2015 Award for Excellence in Technology Transfer for its role in developing an automated bait cartridge and delivery system to control invasive brown treesnakes. The system was first conceived in 2009 when NWRC researchers entered into cooperative agreements with Applied Design Corporation (a private engineering and design firm in Boulder, CO) to develop a cost-effective, environmentally safe, and efficient system for distributing toxicant baits to brown treesnakes in remote and inaccessible areas on Guam. Three patents are being pursued as a result of this work.



NWRC and its private partner Applied Design Corporation received the Federal Laboratory Consortium's 2015 Award for Excellence in Technology Transfer for developing an automated bait cartridge and delivery system to control invasive brown treesnakes on Guam. *Photo by USDA, Gail Keirn*

The system includes a biodegradable bait cartridge containing acetaminophen (a registered toxicant for brown treesnakes) and an automated delivery system that can disperse up to four bait cartridges per second by helicopter or fixed-wing aircraft. The delivery system allows the cartridges to open and become entangled in the forest canopy as they fall. Since brown treesnakes are an arboreal species, canopy entanglement is key for baiting. This technology can be adapted to deliver other loads and could greatly benefit other invasive species management efforts. Obvious uses would include delivering rodenticides or vaccines to arboreal animal populations.

The FLC Award for Excellence in Technology Transfer recognizes Federal laboratories that have accomplished outstanding work in transferring a technology to the commercial marketplace. NWRC is one of 15 Federal laboratories that received the award in 2015. On August 26, 2015, the Center also received FLC's Mid-Continent Regional Award for Notable Technology Development for the same system.

- **2015 NWRC Publication Award.** Each year, the NWRC Publication Awards Committee, composed of NWRC scientists, reviews over 120 publications generated by their NWRC colleagues. The resulting peer-recognized awards honor outstanding contributions to science and wildlife damage management. In 2015, the award for outstanding NWRC research publication was presented to Antoinette Piaggio, Richard Engeman, Matthew Hopken, John Humphrey, Kandy Keacher, William Bruce, and Michael Avery for the article "Detecting an elusive invasive species: a diagnostic PCR to detect Burmese python in Florida waters and an assessment of persistence of environmental DNA" (*Molecular Ecology Resources* 14: 374–380).

The NWRC awards committee was unanimous in recommending this publication for the 2015 NWRC Outstanding Publication Award. For this research, the authors developed a new PCR-based monitoring tool to detect water-borne environmental DNA (eDNA) that will help manage the invasive Burmese python (*Python bivittatus*) in Florida. In developing the tool, they conducted laboratory studies using captive animals to first determine if reptilian DNA could be isolated and amplified from water samples and to optimize DNA extraction methods. Using these methods, they detected a fragment of the Burmese python's mitochondrial cytochrome b gene in water samples and then designed primers for the gene to ensure species specificity. In field studies, water samples from five sites where Burmese pythons had been observed tested positive for eDNA, while samples from a site where there was no prior python evidence tested negative.

This was the first demonstration that water-borne reptilian DNA can be amplified from environmental samples and used to monitor a specific species. The method is a significant improvement over existing detection and monitoring methods for Burmese pythons and presents a promising new monitoring tool for other vertebrate species. This publication was recognized for its high technical quality, being released in an excellent journal, and being a great example of fulfilling NWRC's mission.

- **NWRC Employee of the Year Awards.** The winners of this award are nominated by their peers as employees who have clearly exceeded expectations in their contributions toward the NWRC mission. The winners this year are:

  - **Stephanie Shwiff**
    Research Grade Scientist; Economic Research of Human-Wildlife Conflicts Project; Fort Collins, CO

  - **Michael Lavelle**
    Support Scientist; Management of Ungulate Disease and Damage Project; Fort Collins, CO

  - **Matthew Hopken**
    Technician; Genetic Methods to Manage Livestock-Wildlife Interactions Project; Fort Collins, CO

  - **Kelli Lundy**
    Budget Technician, Administrative Support Unit; Gainesville, FL

2015 Publications

The transfer of scientific information is an important part of the research process. NWRC scientists publish in a variety of peer-reviewed journals that cover a wide range of disciplines, including wildlife management, genetics, analytical chemistry, ornithology, and ecology. (Note: 2014 publications that were not included in the 2014 NWRC accomplishments report are listed here.)

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Appendixes

Appendix 1

More information about these projects is available on the NWRC Web page at: **www.aphis.usda.gov/wildlifedamage/nwrc**

List of 2015 NWRC Research Projects

Methods Development and Population Management of Vultures and Invasive Wildlife
Project Leader: Michael Avery

Defining Economic Impacts and Developing Strategies for Reducing Avian Predation in Aquaculture Systems
Project Leader: Fred Cunningham

Improving Management Strategies To Reduce Damage by Forest and Aquatic Mammals
Project Leader: Jimmy Taylor

Developing Control Methods, Evaluating Impacts, and Applying Ecology, Behavior, Genetics, and Demographics To Manage Predators
Project Leader: Julie Young

Development of Injectable and Mucosal Reproductive Technologies and Their Assessment for Wildlife Population and Disease Management
Project Leader: Douglas Eckery

Development of Management Strategies To Reduce Wildlife Hazards to Aircraft
Project Leader: Travis DeVault

Improving Rodenticides and Investigating Alternative Rodent Damage Control Methods
Project Leader: *Gary Witmer*

Developing Methods To Evaluate and Mitigate Impacts of Wildlife-Associated Pathogens Affecting Agricultural Health, Food Security, and Food Safety
Project Leader: Alan Franklin

Economic Research of Human-Wildlife Conflicts: Methods and Assessments
Project Leader: Stephanie Shwiff

Defining Economic Impacts and Developing Control Strategies for Reducing Feral Swine Damage
Project Leader: Kurt VerCauteren

Methods and Strategies for Controlling Rabies
Project Leader: Amy Gilbert

Management of Ungulate Disease and Damage
Project Leader: Kurt VerCauteren

Methods and Strategies To Manage Invasive Species Impacts to Agriculture, Natural Resources, and Human Health and Safety
Project Leader: Shane Siers

Methods Development and Population Biology of Blackbirds and Starlings in Conflict with Agriculture, Concentrated Animal Feeding Operations, and Urban Environments
Project Leader: Page Klug

Chemical and Metabolic Approaches for Minimizing Human-Wildlife Conflicts
Project Leader: Bruce Kimball

Genetic Methods To Manage Livestock-Wildlife Interactions
Project Leader: Antoinette Piaggio

Development of Repellent Applications for the Protection of Plant and Animal Agriculture
Project Leader: Scott Werner

Appendix 2

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Davis, Amy	(970) 266-6313 amy.j.davis@aphis.usda.gov	Feral swine
DeVault, Travis	(419) 625-0242 ext. 11 travis.l.devault@aphis.usda.gov	Project Leader: aviation hazards
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Appendix 3

Acronyms and Abbreviations

APHIS	Animal and Plant Health Inspection Service
AWA	Animal Welfare Act
bTB	Bovine tuberculosis
BTV	Bluetongue virus
CDC	Centers for Disease Control and Prevention
CWD	Chronic wasting disease
DNA	Deoxyribonucleic acid
eDNA	Environmental DNA
EHDV	Epizootic hemorrhagic disease viruses
EPA	U.S. Environmental Protection Agency
FDA	U.S. Food and Drug Administration
FLC	Federal Laboratory Consortium
FGM	Fecal glucocorticoid metabolite
GonaCon	GonaCon Immunocontraceptive Vaccine
GPS	global positioning system
GSMNP	Great Smoky Mountains National Park
HA	Hemagglutinin
HPAI	Highly pathogenic avian influenza
IACUC	Institutional Animal Care and Use Committee
IHC	Immunohistochemistry
ISU	Information Services Unit
LPAI	Low pathogenic avian influenza
NIH	National Institutes of Health
NWDP	National Wildlife Disease Program
NWRC	National Wildlife Research Center
NWSD	National Wildlife Strike Database
OLAW	Office of Laboratory Animal Welfare
PCR	Polymerase chain reaction
ppm	Parts per million
PTI	Passive tracking index
QAU	Quality Assurance Unit
RLW	Rat lungworm
RNA	Ribonucleic acid
SBD	Stratified bait distribution
SOPs	Standard operating procedures
sPMCA	Serial protein misfolding cyclic amplification
TSP	Tea-seed cake pellet
USDA	U.S. Department of Agriculture
VAH	Virulent strain of *Aeromonas hydrophilia*
VOCs	Volatile organic compounds
WS	Wildlife Services

Issued May 2016