USDA

United States Department of Agriculture

Innovative Solutions to Human-Wildlife Conflicts

National Wildlife Research Center Accomplishments, 2013

Animal and Plant Health Inspection Service
Miscellaneous Publication No. 1610

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:

- 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 Photo: Invasive Burmese pythons have made a home in Florida, where they compete with and feed on native wildlife. NWRC researchers have developed several new tools, including a live trap and a monitoring method using environmental DNA, to help control the snakes.
Photo by National Park Service, Lori Oberhofer

Message From the Director

Larry Clark, NWRC Director
Photo by USDA, Gail Keirn

Successful organizations do many things, but the one common force driving them is a culture of leadership. What do I mean by that? To me, leadership is not defined by a specific position description or title. It is a philosophy and pattern of behavior exercised by everyone in the workplace. A culture of leadership empowers employees from all levels and positions to share their unique skills and visions and motivate their colleagues to produce something far beyond the ordinary.

Every NWRC study relies on collaborative networks to achieve its goals. These networks are easily counted: 86 percent of all studies at NWRC involve some collaboration with NWRC colleagues, Wildlife Services operational units, nongovernmental organizations, other Federal agencies, State and local governments, or with the private sector. Less quantifiable is the social fiber that makes these collaborations possible and leads to concrete findings, as well as the practical use of products and information.

Many people have weighed in on what makes a good leader. The Animal and Plant Health Inspection Service has published a leadership handbook for its employees, and the Internet is full of essays on the subject. Most say that good leaders are distinguished by their external awareness, self-awareness, self-direction, political savvy, vision, social awareness, and ability to motivate. But of all the definitions of leadership I have read, I like this one the best. It comes from the University of California (Los Angeles) Higher Education Research Institute:

> *A leader is not necessarily a person who holds some formal position of leadership or who is perceived as a leader by others. Rather, a leader is one who is able to effect positive change for the betterment of others, the community, and society. All people, in other words, are potential leaders. Moreover, the process of leadership cannot be described simply in terms of the behavior of an individual; rather, leadership involves collaborative relationships that lead to collective action grounded in the shared values of people who work together to effect positive change.*

The essence of the collaborative relationship is to inspire positive action for the benefit of others—and it is often a powerful motivator for people to participate in Government service.

This year's accomplishments report is a catalog of positive actions. Each research summary reflects a shared vision to resolve human-wildlife conflicts in a socially responsible manner and to excel in doing so. Each is the result of external and internal collaboration, of people working together to solve a problem or develop a method to be used by others. Although formal publications often ascribe success to a specific person or institution, we all recognize that the credit belongs to a team whose individual members have contributed their own type of leadership.

The individual descriptions of outcomes in this report are compelling, but it is the aggregate success of NWRC, in my opinion, that is particularly stunning in its breadth, depth, and simplicity. It is the elegant and useful product of the NWRC research community's collective culture of leadership. I am pleased to present this year's research highlights and recognize the fruits of our work together.

Larry Clark, Director
National Wildlife Research Center
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Contents

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 three spotlights for 2013 show the depth and breadth of NWRC's research expertise and its holistic approach to addressing today's wildlife-related challenges.

Spotlight: Aviation Strike Hazard Management

Aircraft collisions with birds and other wildlife—known as wildlife strikes—pose a substantial safety and financial threat to civil and military aviation worldwide. Globally, wildlife strikes have claimed more than 250 lives and more than 229 aircraft since 1988. In the United States, the Federal Aviation Administration received reports of 131,096 wildlife strikes (97 percent involving birds) between 1990 and 2012, representing $957 million annually in direct and indirect losses.

Expanding wildlife populations, more air traffic, and a trend towards faster and quieter aircraft all have contributed to an observed increase in wildlife strikes. Along with the increase in these strikes has come greater emphasis on wildlife strike hazard research and airfield management. NWRC researchers are at the forefront of aviation safety research to reduce wildlife strikes. Their efforts focus on managing habitat at airports; dispersing, removing, and excluding wildlife; detecting and predicting wildlife movements and behaviors so that aircraft can avoid high-risk activities; and manipulating visual stimuli (such as landing lights) to help birds detect and avoid aircraft. Below are a few case studies highlighting these efforts.

Alternative Land Uses at Airports

The average commercial airport in the contiguous United States is approximately 2,000 acres. About 39 percent of that area is covered by grasses. However, few studies have evaluated the economics and safety of these grasses relative to other types of land cover. Managed turf grasses are expensive to maintain and can attract wildlife hazardous to aircraft, such as Canada geese, gulls, and large flocks of European starlings.

To determine whether changes in land use increase the risk of bird-aircraft collisions, NWRC researchers and collaborators recently studied how birds use solar arrays and adjacent airport grasslands in Arizona, Colorado, and Ohio.

Photo by USDA, David Bergman

"NWRC scientists are helping to make the skies safer for people and wildlife by developing tools and methods for preventing wildlife collisions with aircraft."

An attractive alternative to turf grasses on some portions of airport properties is land cover that attracts fewer wildlife and generates income instead of consuming airport resources—especially at general aviation airports, which often operate on limited budgets. Growing certain crops and installing sets of solar panels (solar arrays) are two examples of how to produce viable land cover options.

"Converting airport grasslands to biofuel, solar, or wind production may not only provide more environmentally sound alternative energy sources for our country, but also increase revenue for airports and reduce the local abundance of potentially hazardous wildlife to aircraft," says Travis DeVault, NWRC's Ohio Field Station leader. "Such efforts may be particularly beneficial for rural economic development, as many rural airport properties contain expansive grasslands that potentially could be converted to biofuel crops or other renewable energy sources."

NWRC researchers and collaborators recently studied the ways birds respond to two different kinds of airport environments—areas with solar arrays and adjacent grasslands—in Arizona, Colorado, and Ohio to determine whether changes in how the land is used increase the risk of bird-aircraft collisions. Although researchers observed more birds in the areas with solar arrays than in the grasslands, those observed represented fewer and less hazardous species than those in the grasslands. Overall, researchers observed 37 species of birds in the areas with solar arrays compared to 46 in the grasslands. A bird hazard index (BHI) based on the mean seasonal mass of birds per area surveyed showed that the BHI was influenced by the seasons and was higher in summer than in fall and winter. The results suggest that even though birds were found in areas with solar arrays, the number and type of birds there do not necessarily increase the risk of bird-aircraft collisions and do not conflict with safety regulations concerning wildlife at airports. Solar arrays could play a major role in efforts to design and operate "greener"—and safer—airports.

NWRC researchers are also working with experts at Mississippi State University to investigate how wildlife use experimental biofuel plots containing switchgrass and mixed warm-season native grasses. The long-term goal is to identify biofuel crops that are less attractive to wildlife hazardous to aircraft and are compatible with safe airport operations.

Researchers note that the profitability of biofuel, solar, or wind production will vary markedly and will depend primarily on yield, establishment and maintenance costs, opportunity costs of land (for instance, land rental or revenue from other commodities), and processing or utilization costs. For many airports where land is currently available, the benefits may outweigh the costs.

Animal Detection and Response to Vehicle Approach

Vehicle collisions with animals are a costly problem. Little is known, however, about what goes wrong from an animal's perspective when it collides with an

automobile, boat, aircraft, or wind turbine blade. For an animal to avoid a vehicle on a collision course, it must successfully detect the vehicle, recognize it as a threat, and take appropriate evasive action. This means there are sensory, cognitive processing, and behavioral hurdles that must be overcome to successfully avoid an oncoming vehicle. Failure at any point can result in a collision.

"Birds primarily rely on antipredator behaviors to avoid vehicles," notes Brad Blackwell, a research wildlife biologist with NWRC's Ohio Field Station. "Unfortunately, modern automobiles and aircraft are much faster than natural predators. Birds may be ill-equipped in terms of being able to adequately detect and respond to these vehicles in time to avoid collision, given the vehicles' speed."

To better understand birds' responses to approaching vehicles, NWRC researchers conducted several experiments looking at flight initiation distances (FIDs)—that is, the distances at which an animal starts moving away from disturbing stimuli such as predators, humans, or other threats. In a field experiment with turkey vultures, the FID responses typically increased with the speed of an oncoming vehicle. However, researchers also observed much variability in the vultures' responses. Researchers suspect that differences in FIDs and escape responses may have been based, in part, on hunger levels, prior experiences with vehicles, and variations in individual vultures' tolerance to disturbance. The findings suggest that turkey vultures' escape responses are successful only up to a certain threshold speed, and that it is more difficult for them to avoid vehicles approaching at high speeds.

Researchers suggest that more emphasis should be placed on studies aimed at better understanding how animals detect and respond to high-speed vehicles, and on research that explores how to help animals avoid collisions by outfitting vehicles with special lights, paint schemes, or other visual cues. In an effort to study animal responses to high-speed vehicles such as aircraft, researchers are looking at using video playback of approaching vehicles in a laboratory setting.

Wildlife strikes to rotary-wing aircraft, such as this U.S. Air Force Pave Hawk, are a serious issue for civilian and military flight operations in the United States and overseas.
Photo by U.S. Air Force

Helicopters and Bird Strikes

Although helicopters are commonly used in military operations, no assessment of wildlife strikes to military helicopters had been conducted until recently, when NWRC researchers launched the first scientific analysis of this phenomenon. The analysis included data from all four military branches and the Federal Aviation Administration's National Wildlife Strike Database for civil airports.

"Our analysis showed the number of bird strikes to helicopters was highest during fall and lowest during winter," says Brian Washburn, an NWRC research wildlife biologist. "Also, raptors and vultures were commonly associated with the most damaging helicopter strikes."

The analysis indicated that temporal patterns of wildlife helicopter strikes were similar to those for fixed-wing aircraft, but that the spatial patterns were different. Almost half of the reported strikes to helicopters occurred while the aircraft was en route (not taking off or landing), while the frequency of strikes for fixed-wing aircraft was lowest during this time. Larks, perching birds, doves, and pigeons were the birds most frequently struck by military aircraft. This difference in the patterns of bird strikes depending on aircraft types warrants further study, to determine where solutions exist.

As with fixed-winged aircraft, bird strikes to helicopters are costly. Available data showed the average cost of a damaging strike to military helicopters ranged from $12,184 to $337,281 per incident. Bird strikes to civil and military helicopters resulted in 61 human injuries and 11 lives lost since 1990.

New Book Highlights Latest Tools for Preventing Wildlife Strikes

The forced landing of US Airways Flight 1549 in the Hudson River on January 15, 2009, after Canada geese were ingested into both engines of the Airbus 320, demonstrated to the public that wildlife strikes are a grave threat to aviation safety. Biologists, airport managers, and other personnel who deal with wildlife at airports know that effective solutions and management to prevent such incidents are based on principles from wildlife ecology, physiology, and behavior.

NWRC researchers teamed up with other experts to document what is currently known about managing wildlife in airport environments and the latest tools and techniques for preventing wildlife strikes. *Wildlife in Airport Environments: Preventing Animal-Aircraft Collisions Through Science-Based Management* is the first in the series Wildlife Management and Conservation, published in 2013 by the Johns Hopkins University Press in association with The Wildlife Society. The book is organized into three main parts: (1) wildlife management techniques (deterrents, exclusion methods, translocation strategies, and population management); (2) resource management (food and water); and (3) wildlife monitoring (animal movements, avian radar, and survey methods). The chapters cover research on important tools and techniques currently used to reduce wildlife-aircraft collisions, ranging from traditional management of airport vegetation to more modern methods such as avian radar and the installation of devices on aircraft designed to prompt avoidance behavior in birds. The book provides readers with an understanding of the research that forms the basis for current best-management practices.

Next Steps—Future NWRC research will evaluate the suitability of replacing turf grasses and traditional agriculture with monoculture switchgrass on some portions of military airfields to reduce wildlife collisions with aircraft. Scientists are also expanding and applying their research findings on birds' visual capabilities, foraging behavior, and FIDs to reduce bird use of airport grasslands.

Spotlight: Reproduction and Wildlife Damage Management

Since the early 1900s, wildlife conservation efforts in the United States have focused on restoring, protecting, and managing populations of many wildlife species. In some cases, such as with white-tailed deer and Canada geese, these efforts have been so successful that these animals now overpopulate certain areas. Such "overabundant" species can cause a variety of conflicts with humans, ranging from minor nuisance issues to serious habitat and crop destruction, the spread of disease, and vehicle and aircraft collisions. Hunting and trapping have been the traditional methods used to manage wildlife populations. However, in urban and suburban areas,

"Wildlife contraceptive vaccines and other fertility control methods offer new options for managing wildlife conflicts in certain areas."

where most human-wildlife conflicts occur, these management practices are often legally restricted, impractical, or socially undesirable. Wildlife contraception—when used as part of an integrated approach with other methods—may be one way to help manage overpopulations of wildlife in these settings. NWRC scientists are at the forefront of wildlife contraceptive research.

First Registered Immunocontraceptive Vaccine: GonaCon

NWRC research on wildlife contraceptives began in the early 1990s. After years of effort, the first single-shot, multiyear immunocontraceptive vaccine for mammals, called GonaCon, was developed and registered for use with white-tailed deer by the U.S. Environmental Protection Agency (EPA) in 2009. GonaCon targets a key reproductive hormone—called gonadotropin releasing hormone (GnRH)—that prompts the production of sex hormones such as estrogen, progesterone, and testosterone. The vaccine stimulates the production of antibodies that bind to GnRH and reduce its ability to activate the release of these sex hormones. All sexual activity is decreased, and the vaccinated animals remain in a nonreproductive state as long as sufficient levels of antibodies are present. Since GonaCon was registered, NWRC experts have refined it and optimized the process of manufacturing it. In collaborative studies with universities and other organizations, the vaccine has proved effective in a number of species, including rodents, ungulates, and marsupials.

In early 2013, GonaCon's registration expanded to include feral horses and burros. Overpopulation of feral horses and burros is a significant concern in the United States, as these animals can overgraze native plant species and compete with livestock and local wildlife for food and habitat. The U.S. Department of the Interior's Bureau of Land Management (BLM) estimates that approximately 37,300 wild horses and burros are roaming on BLM-managed rangelands in 10 Western States, exceeding the lands' capacity to support them and other resources. GonaCon provides another option to wildlife managers working to reduce these species on public lands.

Not only does GonaCon limit reproduction in many mammal species, but it may also play a role in preventing the spread of infectious diseases among wildlife, livestock, and people.

"Along with our colleagues in APHIS' Veterinary Services program, we're exploring how the GonaCon vaccine can aid in brucellosis management in bison," says NWRC project leader Doug Eckery. "Brucellosis is a bacterial disease that causes infertility, abortions, and lowered milk production in cattle and bison. The disease is transmitted through contact with bodily fluids, such as milk and afterbirth tissues, of infected animals. GonaCon could potentially break the cycle of this disease and reduce transmission by preventing reproduction in infected animals."

A multiyear study currently underway in Montana is investigating whether brucellosis-infected bison that are vaccinated with GonaCon will stop reproducing and spreading the disease. If so, managers may be able to use GonaCon instead of culling infected wild bison in some areas.

NWRC experts and partners are also investigating the use of GnRH vaccines to manage brucellosis in feral swine, tuberculosis in European badgers, and rabies in feral and free-ranging dogs. Although canine rabies was eradicated from the United States in 2007, the risk of reintroduction or crossover from wildlife populations is still high in areas with feral and free-ranging dogs. Rabies continues to challenge public health systems in developing countries, especially in Africa and Asia, where many of the world's estimated 55,000 to 65,000 annual human rabies deaths occur. In these areas, the threat of rabies transmitting to humans from feral and free-ranging dogs increases as dog populations and densities go up. NWRC scientists and partners are conducting studies to explore whether a combined series of rabies and GnRH vaccines would be an effective strategy for reducing stray dog populations and the occurrence of rabies.

NWRC and collaborators are developing an injectable vaccine to inhibit fertility in dogs that may help decrease free-roaming dog populations and reduce the spread of rabies.

Photo by SpayFirst, Ruth Steinberger

Oral Contraceptive Baits

Although injectable contraceptives effectively block fertility in animals, they can be impractical for many wildlife managers to use because capturing and handling wildlife is expensive and time-consuming. For more efficient delivery, NWRC scientists are developing oral contraceptive baits for a variety of species.

OvoControl is a commercially available oral contraceptive bait that targets resident or urban Canada geese and feral pigeons. It was developed by NWRC scientists and Innolytics, LLC. OvoControl contains nicarbazin, a compound traditionally given to broiler chickens to prevent the disease coccidiosis, one of the more common and costly diseases in poultry. Side effects of nicarbazin include decreased egg production and hatching rates. Nicarbazin inhibits sperm from fertilizing the egg and affects the hatchability of eggs by changing the pH of the yolk and weakening the yolk membrane, allowing the albumin and yolk to mix. When OvoControl is fed to Canada geese and pigeons during their breeding season, the nicarbazin reduces the hatching success of eggs. When nicarbazin is withdrawn from the diet, egg production and hatchability rates return to normal within a few weeks.

Another compound proving to be an effective oral contraceptive for wildlife is Diazacon (20,25 diazacholesterol). Diazacon was originally developed to lower cholesterol in humans. By mimicking cholesterol in the body, Diazacon inhibits the production of cholesterol and the formation of sex hormones necessary for reproduction. Diazacon can be administered orally as a bait block or as a coating on seeds, oats, or corn. NWRC and collaborator studies with black-tailed prairie dogs, tree squirrels, and invasive monk parakeets have shown that an oral Diazacon bait can reduce reproduction in these species. Although it is not currently registered by the EPA for use in wildlife, Diazacon holds promise as another contraceptive tool for some wildlife species.

NWRC researchers are partnering with experts in Norway to develop vaccines to control reproduction in farmed salmon.
Photo by Ivar Gulla

The Future of Wildlife Contraceptives

The future of wildlife contraceptive research and management is encouraging. In addition to the Federal registration of several wildlife contraceptive products, State natural resource agencies are developing and implementing wildlife contraception policies and regulations. To date, three States—New Jersey, Maryland, and North Carolina—have approved the use of GonaCon for deer management. OvoControl is registered for use in controlling pigeon populations in all 50 States and several foreign countries.

It is important to note, however, that contraceptives alone cannot rapidly reduce wildlife overpopulations to healthy levels. Instead, these tools may be most helpful when used in specific, limited situations in conjunction with other wildlife management methods, such as recreational hunting or professional deer removal operations. Immediate population goals can be met only by removing problem animals. Contraceptives can then be used to slow the rate of population growth in these managed areas.

In recent years, NWRC scientists have concentrated largely on developing GonaCon. While efforts to maintain the momentum generated by GonaCon will continue, greater emphasis will be placed on developing direct acting reagents, chemosterilants, and vaccines that are better able to induce permanent sterility, as well as on methods that are suitable for oral delivery, produce high rates of infertility, and are cost effective. Efforts will also address the effects of fertility control on the size of wildlife populations.

Next Steps—NWRC contraceptive research will continue to focus on new vaccines, oral and intranasal delivery methods, chemicals for use in oocyte (egg) depletion, bivalent vaccines for disease prevention, and the effects of fertility control on the size of wildlife populations.

Spotlight: Technology Transfer of Wildlife Damage Management Tools and Strategies

Did you ever wonder who invented the breakaway snare, the bird repellent methyl anthranilate, or the livestock protection collar? These and many other wildlife damage management tools and techniques are the result of the ingenuity of NWRC scientists, with the help of WS technicians and field specialists, collaborators at universities, other Federal and State agencies, and private partners.

"Because wildlife damage management products often have very limited and specialized markets, the NWRC partners with private-sector industries to develop new tools and techniques," says NWRC Technology Transfer Program Manager John

"Many of the tools used in wildlife damage management today are the result of the ingenuity and creativity of Wildlife Services scientists, field specialists, and collaborators."

In 2013, the U.S. Patent and Trademark Office issued a patent to USDA-Wildlife Services for a live snake trap that uses two trip pans to capture large, heavy snakes such as the invasive Burmese python. The trap was developed in conjunction with Tomahawk Live Trap, LLC.
Photo by USDA

Eisemann. "We work hard to promote the adoption of our research outcomes by end users. Our efforts often support the creation or diversification of small businesses that can provide these new tools to the people that need them."

NWRC's technology transfer activities are varied and include publishing research findings, producing technical notes and factsheets, presenting at scientific meetings, hosting demonstrations and workshops, and protecting and licensing inventions for developing commercial products.

The Federal Technology Transfer Act of 1986 changed how Federal Government research and development agencies, such as NWRC, do business. The act allows Federal laboratories and industry to form commercial partnerships that enhance the development of new technologies and move them to the marketplace. NWRC strives to transfer and market new technologies related to wildlife damage management from its research. It has formed numerous partnerships using Cooperative Research and Development Agreements. WS works in cooperation with USDA's Office of Technology Transfer, housed in the Agricultural Research Service, to facilitate and coordinate these partnerships.

The future success of wildlife damage management depends on developing new tools and technologies. Traditional methods and tools face increased scrutiny by regulatory agencies, and few private companies are financially willing or able to pursue new registrations or handle the risks associated with developing new products. Government can play a valuable role in absorbing these risks and encouraging innovation and discovery through research.

The summaries on the next two pages highlight the diversity of wildlife damage management tools that NWRC and its predecessor agencies have developed. Specific examples include radiotelemetry equipment and rodent management products. For information on the latest technology transfer efforts, please see the Technology Transfer writeup in the 2013 Accomplishments in Brief section of this report.

Decades of Tool and Method Development

NWRC and its predecessor laboratories have a long history of developing materials and methods for managing mammals, birds, reptiles, and amphibians and the damage they cause. These tools and methods include aversion techniques, attractants, baits, chemical repellents, delivery devices, exclusion devices, fertility control agents, scare devices, surveillance and monitoring devices, toxicants, traps and other capture devices, and vaccines.

NWRC's history reflects a consolidation of many early U.S. Biological Survey programs. Between 1935 and 1938, the Bureau of Biological Survey had a rodent field station in Hilo, HI. In 1940, the Control Methods Laboratory of the Division of Predator and Rodent Control was combined with the Denver Unit of Food Habits Research to become the Denver Wildlife Research Laboratory. At this time, the Biological Survey was transferred from USDA to the U.S. Department of the Interior. In the 1950s, research was expanded to include wildlife on public lands, wetland ecology, and migratory birds, and in 1959 the laboratory was renamed the Denver Wildlife Research Center (DWRC). Finally, in 1985, the DWRC was reassigned to USDA and renamed the National Wildlife Research Center. Regardless of the name or placement within Government programs, NWRC has not only been influential in exploring, developing, and maintaining legal uses of many traditional wildlife management tools but has also served as a world leader in innovation.

Recently, NWRC's technology transfer program manager compiled a database of all the tools and techniques the center has developed over the years. The database contains information on all vertebrate pest management methods made public through scientific publications or patent applications. The earliest documented public release of a method was in 1943, for a new predator management device known as the "humane coyote getter." Since that time, NWRC has provided 106 devices, methods, techniques, or other tools for the wildlife manager's toolbox.

NWRC and its predecessor, the Denver Wildlife Research Center, were instrumental in developing and miniaturizing radio telemetry and other tracking equipment for wildlife.
Photo by USDA

Miniaturization of Radiotelemetry Equipment

During the 1960s and 1970s, large wildlife transmitters were manufactured by commercial companies, but miniature transmitters for use on rodents were not available. To collect information on the movements of small mammals and birds, and to evaluate the effect of control applications, NWRC engineers developed specialized expertise in the manufacture of miniature radio transmitters. Telemetry had been used by NWRC scientists and WS field specialists for a variety of wildlife management issues, while research continued to make field applications of telemetry equipment ever more practical. For instance, NWRC scientists developed practical radiocollar attachment mechanisms for mammals and birds. Previously, a collar was adjusted and set to a certain frequency on an anesthetized animal by soldering. Using new plastic fasteners, a collar could be attached in only a few seconds. NWRC's engineering staff also designed, built, and evaluated miniature transmitters for use in research.

They worked with commercial companies to ensure quality materials were available until the mid-1990s, when the use of radio transmitters had become a routine part of rodent damage control research.

Today, the sale and manufacture of radiotelemetry equipment is primarily a private-sector endeavor, in part owing to the early contributions of NWRC researchers and engineers. NWRC researchers continue to evaluate and improve methods for transmitter use, recently including the use of implantable units for subterranean rodents.

Rodent Management Tools and Methods

For nearly 75 years, NWRC researchers and their predecessors have developed tools and methods for managing rodent damage. Nonetheless, rodents continue to cause billions of dollars of damage to crops and commodities around the world and to threaten human health and safety—making NWRC's research all the more important. This research has focused on species ecology and identification, damage assessment, population assessment, rodenticide development and registration, repellent development, reproductive inhibitors, baits and attractants, delivery systems, marking agents, exclusion devices, habitat management, and capture devices.

Despite widespread use of traditional rodenticides, there are growing concerns about their risks to people, domestic animals, and nontarget wildlife. Changes in agricultural practices, market uncertainty or market volume, regulatory changes, environmental changes, or human health concerns may also lead to the potential loss of these tools for managing rodent damage. The continuing need for new approaches is not a new problem, but one that scientists and policy makers should anticipate.

NWRC scientists and administrators recognize the need to emphasize rodent research, which will continue to be an important part of the center's research program. For instance, NWRC researchers are currently testing the addition of bird repellents to rodenticide formulations to reduce risks to seed-eating birds. Researchers are also refining the designs of bait stations used in rodent-eradication efforts on islands so that they are less accessible to nontarget animals, even as they provide rodents full access.

Next Steps—Future technology transfer is focusing on rabies vaccine delivery methods, new fertility control methods, and rodenticide development.

2013 Accomplishments in Brief

NWRC employs approximately 150 scientists, technicians, and support staff who are devoted to 15 research projects (see Appendix 1). Below are brief summaries of select findings and accomplishments from 2013 not previously mentioned in this year's report.

Devices

- **Efficacy of Plastic Mesh Tubes To Reduce Nutria Damage to Trees.** The nutria is an invasive, semiaquatic rodent native to South America that harms riparian and wetland habitats worldwide. Management tools and techniques are needed to reduce the damage that nutria foraging and burrowing causes—particularly in the course of wetland restoration projects, when tree seedlings are most vulnerable. In collaboration with Portland State University and the U.S. Geological Survey, NWRC researchers evaluated the effectiveness of standard Vexar plastic mesh tubes in reducing nutria damage to newly planted woody vegetation. All of the plantings protected with tubes survived, compared to only 17 percent of plantings without tubes. Vexar plastic mesh tubing can be an effective short-term mitigation tool in habitats that do not have large nutria populations.
  Project Contact: Jimmy Taylor

- **Comparing Capture Methods for Urban Nutria.** Trapping is the most widely used and cost-effective method for controlling nutria. In collaboration with Portland State University and the U.S. Geological Survey, NWRC researchers compared the efficacy of a new nutria multiple-capture cage trap (MCT), which uses a one-way funnel, to that of a standard two-door cage trap. Nutria captured in the MCTs were 55 percent larger than nutria captured in the standard traps, weighing an average of 14 pounds and 9 pounds respectively. The MCTs did not capture any nutria weighing less than 8 pounds. MCTs were also more target specific: 50 percent of the animals captured in the standard traps were nontarget animals. As designed, the MCTs may allow smaller animals to escape. However, simple design modifications, such as changing the trap door size or the addition of a rotating paddle door or hinged door, could improve the MCT's performance.
  Project Contact: Jimmy Taylor

NWRC researchers and partners evaluated the effectiveness of standard Vexar plastic mesh tubes in reducing invasive nutria foraging damage to newly planted woody vegetation.
Photo by Portland State University, Trevor Sheffels

A new automatic monitoring system using passive integrated transponder (PIT) tags and radiotelemetry was used in Hawaii to record visits by small Indian mongooses to bait stations and evaluate the attractiveness of the bait.
Photo by USDA, William Pitt

NWRC researchers demonstrated that a 4-foot-tall electric fence consisting of 4 strands of bipolar tape was 80 percent effective at excluding deer from livestock feed.
Photo by USDA, Michael Lavelle

- **Recording Bait Station Visits.** Bait stations are often used to deliver toxic baits to invasive species, especially in environmentally sensitive areas where the risks to nontarget species may be high. The stations are designed to be very selective, attracting or allowing entry only to target species. Using passive integrated transponder (PIT) tags in conjunction with radiotelemetry, NWRC researchers developed a monitoring system that automatically records bait-station visits and evaluates the attractiveness of bait in two separate field studies involving brown treesnakes in Guam and small Indian mongooses in Hawaii. Researchers found that although visitation rates by brown treesnakes to toxic bait stations were low (32 percent), most adult snakes attracted to the stations consumed the bait. The delivery device was not attractive to juvenile snakes, suggesting that the device, its placement in the trees, and/or the bait type (dead neonate mice) were ineffective for young snakes. Mongooses were attracted to the new food baits, traveled up to 2,000 feet (600 meters) to baits, and displayed fidelity to food sources. The study suggested that perimeter trapping and increased trap spacing could be effective if used with preferred baits to attract resident mongooses. The automatic PIT tag monitoring system successfully allowed researchers to collect important information on the foraging behavior of target species and the attractiveness of selected baits and to document individual visits to bait delivery systems in a way other field techniques cannot. Researchers note the system can be adapted to monitor other small mammals, birds, reptiles, or amphibian species, as well as various activities of interest.
Project Contact: William Pitt

- **Novel Fence Design for Excluding Deer From Stored Feed.** Where cattle and free-ranging white-tailed deer coexist, they often share space and food resources. Preventing deer from eating stored livestock feed reduces not only feed costs, but also the risks of disease transmission between deer and cattle. Woven wire fences are considered to be the most effective barrier for excluding deer. However, identifying a quick and easy method for temporarily excluding deer could be useful—especially during late winter, when deer are most physiologically

stressed and motivated to consume food meant for cattle. NWRC researchers demonstrated that a 4-foot (1.2-meter) electric fence consisting of 4 strands of bipolar tape was 80 percent effective at excluding deer from feed piles. This system could provide temporary protection of stored feed before a more permanent woven-wire fence is installed. Although effective, the fence should not be used as the only means of excluding deer in areas with known disease transmission risks (for instance, bovine tuberculosis) because the risk could remain unacceptably high even if few deer access stored feed. Researchers note the bipolar fence may also reduce deer depredation in gardens, small orchards, or other localized or seasonal resources.
Project Contact: Kurt VerCauteren

- **Deer-Activated Bioacoustical Frightening Device.** The number of white-tailed deer in urban and suburban areas has increased dramatically over the past several decades, causing damage to ornamental plantings as well as crops and stored feed. As a result, demand for effective nonlethal methods for deterring deer in these sensitive areas has increased. NWRC researchers and collaborators at the University of Nebraska tested the efficacy of a frightening device that, when activated by an infrared motion sensor, played the prerecorded distress calls of an adult female white-tailed deer. The frightening device reduced the number of deer entering protected sites by 99 percent and bait consumption by 100 percent. It shows promise for use in deterring deer from a wide variety of developed landscapes and agricultural settings.
Project Contact: Kurt VerCauteren

- **New Isoflurane Anesthesia Induction System for Raccoons.** Wildlife researchers often need to handle animals daily and use immobilizing drugs, such as injectable and inhalation anesthesia. NWRC researchers developed a new, small-volume (24-liter), conical-shaped isoflurane anesthesia induction chamber to use with artificial den chambers in captive-animal holding facilities. The device was tested and compared to three conventional stand-alone induction chambers (two clear acrylic plastic chambers and a cylindrical-shaped chamber) to determine its usefulness for short daily manipulations of captive raccoons. With the new device, researchers minimized the need to handle the animals before they were anesthetized. They also eliminated the need for injectable anesthetics, thus avoiding the side effects normally associated with these drugs. The average anesthesia induction time using the new conical-shaped chamber was 3.4 minutes. The conventional chambers worked well, with induction times ranging from 2.7 to 5.4 minutes. Because the conventional, stand-alone chambers do not rely on den chambers, they may prove especially useful for field work. However, the conical-shaped induction chamber provides an option for anesthetizing captive raccoons for a short period and may be used with other species and in other research settings.
Project Contact: Alan Franklin

- **Evaluating Cattle-Operated Bump Gates and Exclusion Fences To Minimize Disease Transmission Risks.** Bovine tuberculosis (bTB) is prevalent in wildlife in south-central Spain, infecting red deer, wild boar, and domestic cattle. As part of an international collaboration with the Instituto de Investigación en Recursos Cinegéticos, NWRC researchers evaluated the effectiveness of exclusion devices, such as cattle-operated bump gates and fencing, for reducing bTB transmissions between domestic cattle and wild ungulates at Spanish watering holes. Researchers first monitored six watering holes with cameras at a bTB-positive cattle farm to quantify wildlife-

cattle interactions. Then, three watering holes were designated "cattle-only" sites and three "wildlife-only." Cattle-only watering holes were surrounded with a wildlife-proof fence 8 feet (2.5 meters) high and a cattle-specific gate. Many cows learned to operate the cattle-specific gates quickly, and other cows learned from them. Within 2 weeks, approximately 70 percent of the cows actively entered and exited through the cattle-specific gates. Wildlife-only watering holes were surrounded by a fence 4 feet (1.2 meters) high that wild ungulates could breach but cattle could not. Wildlife-only fences were 100 percent effective in preventing cattle from entering the watering holes and did not impede wildlife use. The study demonstrates how simple, low-cost fencing strategies can serve as biosecurity measures to reduce direct and indirect contact—and disease transmission—between cattle and wild ungulates.
Project Contact: Kurt VerCauteren

- **Image Recognition Hazing System for Canada Geese.** The Goose Guardian is an image-recognition, real-time hazing system that uses audio/visual tools to scare birds away. As part of a cooperative agreement with TKO Enterprises, Inc., which produces the system, NWRC researchers evaluated how effectively it disperses Canada geese. In studies with captive Canada geese, the image-recognition component of the Goose Guardian successfully detected geese 3 to 9 meters away from the image sensor and accurately detected 93 to 96 percent of the geese throughout the study. In areas where the Goose Guardian was activated, goose occupancy decreased from 86 to 42 percent. Researchers recommend additional testing of the device in agricultural and other field settings.
Project Contact: Scott Werner

Pesticides

- **Residual Levels of Alpha-Chloralose in Duck Tissues.** WS experts often assist local, State, and Federal agencies and organizations with removing or relocating nuisance birds such as Canada geese. One tool for removing these birds is an immobilizing drug known as alpha-chloralose (AC), an investigational-use drug regulated by the U.S. Food and Drug Administration (FDA). Currently, the drug cannot be used 30 days before waterfowl hunting season—or during the season—because of food safety concerns related to a lack of information on how much of the drug remains in duck tissues following exposure, and how long it remains there. Birds immobilized with AC within 30 days of or during open hunting season must be either euthanized or held in captivity for 30 days before they are released. To provide the data necessary for determining a science-based restriction period on use that protects food safety, NWRC researchers conducted an AC absorption, distribution, metabolism, and excretion study. Researchers orally administered a 30-milligram/kilogram dose of AC to captive mallard ducks to analyze the level of AC in their edible tissues (breast muscle, liver, and skin) following euthanasia. This dose was akin to what birds receive when captured in the field. The results suggest that tissues from mallard ducks are safe for human consumption 48 hours after dosing, which is a significantly shorter period than the 30-day period FDA requires. This finding supports shortening the moratorium.
Project Contact: Dave Goldade

- **Effects of the Rodenticide Diphacinone on Eastern Screech Owls.** Anticoagulant rodenticides are used to control rodents in urban and suburban settings, in agricultural areas, and in island restoration projects. Even though these rodenticides are widely used, there are growing concerns about the risks

they pose to people, companion and domestic animals, and nontarget wildlife. In the United States, new restrictions have been placed on using some second-generation anticoagulant rodenticide baits in and around buildings. This regulatory action may lead to expanded use of some first-generation anticoagulant rodenticides (for instance, chlorophacinone, diphacinone, and warfarin) that are considered less hazardous than second-generation anticoagulant rodenticides. However, first-generation anticoagulants have been implicated in the accidental deaths of nontarget wildlife such as hawks, eagles, and owls. NWRC researchers examined clotting time and rodenticide residues in the tissues of captive Eastern screech owls that were fed prey treated with diphacinone. They also examined cell and tissue recovery and residue clearance in the owls following exposure. The findings showed that continuous dietary exposure to the kinds of diphacinone concentration levels that Eastern screech owls might encounter in the wild can cause intoxication, prolonged clotting time, and anemia in a matter of days. Clotting disorders arose when diphacinone concentrations in the liver exceeded approximately 0.1 microgram/gram in wet weight. However, owing to diphacinone's short half-life in tissues, tissues recovered rapidly once the exposure was terminated. These results provide more realistic and accurate estimates of the risks that anticoagulant rodenticides pose for target and nontarget species, and will help regulators determine the appropriate use of diphacinone.
Project Contact: Katherine Horak

- **Vole Resistance to Anticoagulant Rodenticides.** Voles are small rodent pests that cause serious damage to orchards, nurseries, and numerous field crops in the United States. To help reduce vole damage, growers have historically relied on anticoagulant rodenticides such as diphacinone and chlorophacinone to manage rodent populations. Although they were once quite useful, such anticoagulant rodenticides may be losing their efficacy and there are reports of voles becoming resistant to diphacinone. Voles trapped from high anticoagulant-use areas metabolized significantly more anticoagulant in their livers than animals trapped in areas where anticoagulants had not been used. These findings suggest that alterations in metabolic function may play a role in anticoagulant resistance and may aid in the development of future rodenticides.
Project Contact: Katherine Horak

- **Toxicants for Invasive Bullfrogs.** Although they are native to the eastern United States, American bullfrogs have been introduced to western North America and most other continents, as well as to many islands around the world. Control methods are needed to manage invasive American bullfrogs in areas where they outcompete or act as predators on native vertebrate and invertebrate species.

Voles are small rodents that cause serious damage to agricultural crops, such as artichokes, in the United States. NWRC research has shown that voles trapped in areas where anticoagulant rodenticides are used heavily metabolize significantly more anticoagulant in their livers than animals trapped in areas where the rodenticides have not been used.
Photo by USDA, Katherine Horak

Current methods of managing them, such as hand or net capture, are labor intensive and often ineffective. No toxicants have been identified or registered for American bullfrogs, but such tools could provide a cost-effective control alternative. NWRC researchers identified and tested the efficacy of 10 potential toxicants for controlling invasive bullfrogs. Caffeine, chloroxylenol, and a mixture of rotenone with permethrin resulted in 100 percent mortality. Additional studies on delivery systems and nontarget hazards associated with these three compounds may result in effective management tools for reducing populations of invasive American bullfrogs.
Project Contact: Gary Witmer

- **Evaluating Toxicity of Citric Acid to Endangered Hawaiian Hoary Bats.** Spray applications of citric acid, a registered minimum-risk pesticide, are used in Hawaii to control invasive coqui frog populations. NWRC researchers investigated the potential impacts of citric acid applications on endangered Hawaiian hoary bats, using the more-common big brown bat as a surrogate species. Hoary bats are endemic to Hawaii and roost alone in foliage that may also be used by coqui frogs. In field and laboratory studies using big brown bats, researchers determined (1) how toxic citric acid is to bats, (2) the quantity of citric acid solution a bat might consume, (3) the effects of spraying citric acid solution on bats, (4) the amount of citric acid solution that a bat's fur might retain, and (5) the amount of citric acid Hawaiian hoary bats might encounter in the course of actual ground and aerial spray operations that use a 16-percent citric acid solution. Absorbent bat effigies exposed to ground and aerial spraying retained 1.54 grams and 0.02 grams of citric acid solution, respectively. The amount of citric acid toxic to big brown bats that ingested it was between 0.10 and 0.14 milliliters. Bats sprayed with 5 milliliters of citric acid solution showed no evidence of intoxication through grooming or absorption. In field situations, it is unlikely that bats would be sprayed directly or ingest much citric acid retained in their fur or in water sources. Based on their observations, researchers believe Hawaiian hoary bats are at low risk from harmful exposure to citric acid during frog control operations.
Project Contact: William Pitt

Repellents

- **Application Strategies for an Anthraquinone-Based Repellent.** Although anthraquinone is a naturally occurring substance that is effective at reducing bird damage to many crops, no anthraquinone-based repellents are currently registered for agricultural applications in the United States. If registered, anthraquinone-based repellents could be included in chemical applications that producers commonly use to reduce pest damage. These single applications often include a combination of insecticides, fungicides, and repellents. NWRC researchers tested the effectiveness of anthraquinone in preventing blackbird damage to sunflowers when applied in conjunction with either an insecticide or fungicide. In studies, more than 80 percent of captive red-winged blackbirds were repelled from sunflowers treated with either anthraquinone and an insecticide (Asana XL) or fungicide (Headline)—a result similar to that found for sunflowers treated only with anthraquinone. Given that anthraquinone formulations are not affected by the addition of either the insecticide or the fungicide, it is likely that anthraquinone-based repellents can be effectively added to tank mixtures that include these commonly used, late-season pesticides. However, additional tests are needed to determine whether anthraquinone-based repellents retard the efficacy of insecticides and fungicides.
Project Contact: Scott Werner

Ultraviolet feeding cues, like other visual and taste cues, may influence avian foraging behavior in wild turkeys.
Photo by NBII, Randolph Femmer

- **Ultraviolet Feeding Cues in Wild Turkeys.** Most birds are able to see ultraviolet (UV) light, which often plays a part in plumage signaling and mate selection. Little is known, however, about how birds use cues in UV light to select their food. NWRC researchers studied whether wild turkeys would avoid foods treated with UV after consuming a UV-absorbent repellent (anthraquinone). Researchers hypothesized that if UV feeding cues, like other visual and taste cues, influence avian foraging behavior, then wild turkeys conditioned with anthraquinone would avoid foods treated with a UV-absorbent cue—even if there were no negative consequences from eating these foods. (There is nothing intrinsically repellent about UV cues.) Turkeys not previously conditioned with anthraquinone consumed 58 percent more food treated with a UV-absorbent cue than untreated food. In conditioning studies with captive turkeys, male and female turkeys ate untreated food but avoided 75 to 99 percent of foods treated with anthraquinone. Consistent with the hypothesis, turkeys that ate 100 milligrams of anthraquinone subsequently avoided food treated only with a UV-absorbent cue. Researchers conclude that UV cues could be used to enhance the effectiveness of chemical repellents and, once birds gain experience, could be used to fool them into avoiding treated crops that do not have repellent applications. Future studies will address what a sufficient reinforcement application schedule would be. These findings will aid in future development of bird repellents. A patent is pending for this method.
Project Contact: Scott Werner

- **Aerosolized Chemicals To Flush Brown Treesnakes From Cargo.** Numerous local and Federal agencies are involved in efforts to reduce the invasive brown treesnake population on Guam and prevent the species' spread to other islands in the Pacific. Many of those efforts focus on Guam's seaports and airports, to ensure outbound cargo is free of snakes. New repellents to deter snakes from entering cargo and encourage their exit from cargo are needed. To be practical, a snake repellent must be quick, economical, easy to apply, and

NWRC evaluated five chemical aerosols to use in flushing brown treesnakes from cargo leaving Guam.
Photo by USDA

nearly 100 percent effective to avoid any delays of commercial and military transport. NWRC researchers evaluated the effectiveness of five chemical aerosols to flush snakes from hiding places. Although previous research showed that aerosols of cinnamon and wintergreen oil drew strong responses in snakes, snake movements and the percentage of snakes flushed from hiding were small in this study, which tested the effects of wintergreen (0 percent), cinnamon (18 percent), and eucalyptus oil (11 percent). In contrast, snakes moved when exposed to aerosols of chloroform (94 percent) and trichloroethylene (100 percent), but only chloroform succeeded in flushing them into the open (94 percent versus 6 percent). Further testing of these agents using actual cargo will determine whether this technology can be made operational.
Project Contact: William Pitt

Other Chemical and Biological Methods

- **eDNA of Burmese Pythons in Water.** Understanding the distribution of an invasive species and having an efficient method for detecting its range expansions are critical to control efforts. The Burmese python is a semiaquatic reptile species that has invaded Florida, where its elusive nature and cryptic coloration make detection difficult. Development of a detection method that eliminates the need for direct observations or handling of snakes would greatly enhance management of this invasive species. Recent studies have demonstrated that it is possible to detect environmental DNA (eDNA) from aquatic vertebrates in bodies of water. Consequently, NWRC researchers set out to develop a diagnostic polymerase chain reaction (PCR) to detect Burmese pythons using waterborne eDNA. First, captive pythons were used to determine if their DNA could be isolated and amplified from water samples. Researchers also evaluated the efficacy of two DNA isolation methods and two DNA extraction

WS often donates the meat from Canada geese collected during operational activities. To address food safety issues, NWRC researchers analyzed wild goose breast meat for residual concentrations of several environmental contaminants and compared the results to levels found in commercially raised poultry.
Photo by USDA, Anson Eaglin

kits commonly used in eDNA preparation. A fragment of the mitochondrial cytochrome *b* gene from the pythons was detected in all water samples isolated with a sodium-acetate precipitate and the QIAamp DNA Micro Kit. Researchers designed primers specific to Burmese pythons and assessed the degradation rate of python eDNA in water. The primers did not amplify the DNA from closely related species, and the python DNA was consistently detectable up to 96 hours. Water from six sites in south Florida was then sampled to test the efficacy of the method in the field. Samples from five sites where Burmese pythons have been observed tested positive for their eDNA. The final site, which had no prior documented evidence of Burmese pythons, tested negative. This method presents a promising new monitoring tool that could help determine the current distribution of Burmese pythons in Florida and help monitor them efficiently.
Project Contact: Toni Piaggio

- **Environmental Contaminants in Canada Goose Tissues.** WS donates more than 60 tons of wild game—from deer, moose, feral swine, goats, geese, and ducks—to charitable organizations each year. These donated meats are a vital source of food to many people. Although commercially produced meat routinely undergoes screening for contaminants, little is known about the level of environmental contaminants in wild game. Animals can be exposed to environmental contaminants through the air, soil, and water, as well as through the food they eat. NWRC researchers and WS Operations experts worked collaboratively to collect goose breast meat from 194 captured Canada geese from 11 States and analyze it for residues of environmental contaminants including arsenic, cadmium, calcium, cobalt, copper, iron, lead, magnesium, manganese, mercury, molybdenum, selenium, thallium, zinc, dichlorodiphenyldichloroethylene (DDE), and polychlorinated biphenyls (PCB). The results were compared to contaminant levels found in commercially raised poultry. Although there were exceptions, the majority of the wild goose meat samples contained contaminant concentrations below recommended thresholds of concern. The residue levels for most of the contaminants were similar to published residue concentrations

in food for human consumption. Researchers did note that animals with high concentrations of one compound often had high concentrations of other compounds as well, suggesting that certain animals may frequent a relatively limited number of sites containing contaminants. These findings provide information about contaminant concentrations in goose meat and potential exposures associated with meat consumption based on probabilistic models and enable others to make informed decisions about the risks associated with consumption of wild game.
Project Contact: Katherine Horak

Disease Diagnostics and Methods

- **Avian Influenza Detection From Fecal Odors.** Many diseases cause a change in body odors. NWRC scientists and partners at the Monell Chemical Senses Center and Colorado State University studied changes of fecal odors in mallards infected with the avian influenza (AI) virus. Laboratory mice were trained to discriminate between feces from AI-infected and uninfected ducks, indicating a change in odor. Chemical analysis then found the volatiles (compounds that emit unique odors or emission patterns) associated with the odor changes to be acetoin and 1-octen-3-ol. These compounds have also been identified as potential biomarkers for diagnosing gastrointestinal diseases in humans. Researchers hypothesize that metabolites resulting from viral infection interact with bacteria in the gastrointestinal system of ducks to produce "odor signatures" indicating the presence of the AI virus. Future research will focus on whether odor changes can be used for surveillance of AI in waterfowl. In particular, researchers are interested in whether the odor change is specific to the AI pathogen or if it is merely a general response to a variety of pathogens normally found in birds.
Project Contact: Bruce Kimball

- **Improving the Formulation for Rabies Vaccines.** In North America, rabies is maintained by wildlife reservoirs. To reduce the prevalence of rabies, RABORAL V-RG oral rabies vaccines are distributed to wild carnivores in the United States east of the Appalachian Mountains, as well as portions of Ohio, Arizona, New Mexico, and Texas. Improvements to bait uptake and seroconversion (successful vaccination) are sought to improve the cost-effectiveness and efficiency of the vaccination program. The RABORAL V-RG vaccine is delivered as a liquid in a plastic sachet. Under optimal conditions, when an animal's teeth pierce the sachet, the vaccine is released into its mouth and absorbed. While foxes and coyotes tend to pick up the entire bait with their mouths, releasing a full dose of vaccine as they chew, raccoons hold the vaccine sachet on the ground and bite only small portions at a time, allowing the open sachet to leak. Pen trials have repeatedly shown that raccoons spill much of the liquid in the sachet. NWRC researchers evaluated the possibility of using two benign compounds, chitosan and N,N,N trimethylated chitosan (TMC), that could to act as adjuvants to intensify the raccoons' immune responses. These compounds also make the vaccine more viscous, which helps ensure the raccoons ingest it more readily. (Chitosan is deacetylated chitin, a nontoxic polymer that naturally occurs in crustaceans, insects, and mushrooms. When chitin is converted to chitosan, it becomes a gelatinous precipitate that enhances the transport and absorption of vaccines or drugs.) In pilot studies with captive raccoons, the addition of TMC to RABORAL V-RG allowed raccoons to consume baits more easily and without leakage and did not interfere with the vaccine's effectiveness. These encouraging results have led to joint patent development with the private sector and will result in further product enhancement and evaluations of raccoon vaccination success rates.
Project Contact: Kurt VerCauteren

- **Evaluation of ONRAB Bait Flavors for Coyotes, Mongooses, and Domestic Dogs.** The spread of rabies in wildlife throughout the United States is primarily controlled through oral rabies vaccination. The need to improve bait acceptance and vaccination (seroconversion) rates in some target species has prompted researchers to look for new rabies vaccines. In Canada, ONRAB Ultralite bait (Artemis Technologies, Inc.) is a new rabies vaccine used to vaccinate raccoons and striped skunks. Studies comparing the effectiveness of various rabies vaccine baits found higher seroconversion rates among raccoons that ingested ONRAB. In a series of studies, NWRC researchers determined the ONRAB flavors that coyotes, mongooses, and domestic dogs select and prefer. Coyotes chose fish- and cheese-flavored baits more frequently than bacon and sugar-vanilla flavors; mongooses selected cheese- and fish-flavored baits more frequently than those flavored with coconut. In flavor preference tests with domestic dogs, seven bait flavors (bacon, cheese, dog food, hazelnut, sugar-vanilla, peanut butter, and sardine) were offered. Dog food was selected first 56 percent of the time and more frequently than any other type of bait. Researchers note that this selection may be confounded by the study dogs' familiarity with commercial dog food as their daily food source. Bacon, cheese, and sardine flavors were selected with a similar frequency to that of dog food. Such food sources may not be available in developing nations, where the diets of feral dogs range from human waste and animal carcasses in Zimbabwe to invertebrates and small mammals in Brazil and human-derived garbage in India. Researchers also note that the selection of an appropriate bait flavor for oral rabies vaccination programs in developing nations may be site specific and require further investigation.
  Project Contact: Are Berentsen

- **Coyotes and Plague.** Plague is a fleaborne bacterial disease that affects humans and other mammals. People can get plague after being bitten by an infected flea or by handling an animal infected with plague. Although antibiotics are effective in treating plague, the disease can cause serious illness or death without prompt treatment. Plague has greatly affected native wildlife such as prairie dogs and other rodents in the western United States. Canid species such as foxes and coyotes can survive infection and produce detectable antibodies. These species are often used in animal-based disease surveillance programs, serving as sentinels of disease. To learn more about the immune responses of coyotes to plague, WS National Wildlife Disease Program biologists and colleagues experimentally infected coyotes via oral and intradermal routes. The intradermal route was used to mimic natural exposure via a flea bite. Coyotes fed infected rat carcasses first showed an antibody response 8 to 14 days after inoculation. Their antibody levels peaked between 20 and 30 days and were undetectable by 6 to 8 months after inoculation. Coyotes that were inoculated orally had higher levels of antibodies than those exposed intradermally, which had an antibody response that peaked at day 10. No other physiological changes were observed in either group. The results from this study provided insight into interpreting serologic plague results from the field and indicate that current methods used to confirm plague infection in canids may not be adequate. Researchers recommend using isotype analysis to better determine and distinguish among infection types (for instance, acute, convalescent, and distant past) in sentinel coyotes.
  Project Contact: Tom Gidlewski

Studies examining the human health risks associated with wild elk and deer feces showed that 11 percent of elk fecal samples in urban areas contained Shiga-toxin-producing *E. coli*. This bacterium causes an estimated 265,000 clinical cases of intestinal illnesses, 3,700 hospitalizations, and 31 human deaths in the United States each year.

Photo by USDA, Gail Keirn

Invasive European starlings are the most common and numerous bird species found at dairy farms in Ohio. The frequent presence of these birds in feed bunks and watering troughs is associated with the increased likelihood of foodborne pathogens in cattle.

Photo by Nick Dunlop

Disease Surveillance, Risk Assessment, and Management

- **Pond-Level Risk Factors Associated With Columnaris Disease at Catfish Farms.** Columnaris is the second most prevalent bacterial disease in farm-raised catfish, usually causing an infection of the fish's skin, fins, and gills. To help identify pond-level risk factors associated with the disease, NWRC researchers gathered data from a large commercial catfish enterprise encompassing over 500 food-fish ponds from 5 Mississippi Delta farms. To identify the risk factors affecting the susceptibility of farm-raised channel catfish to columnaris disease, a catfish management database was developed and data analyzed using several models. In one model, pond depth and reduced feed consumption by fish for a 14-day period prior to disease outbreaks were associated with columnaris disease. In a second model, in which water quality variables were also considered, pond depth, reduced feed consumption, shorter intervals from stocking to disease outbreaks, and levels of ammonia nitrogen were all associated with the appearance of columnaris. Identifying risk factors will aid producers in managing this disease before outbreaks occur. *Project Contact: Fred Cunningham*

- **Risk of *E. coli* Exposure From Elk Identified.** Shiga-toxin-producing *E. coli* (STEC) has been implicated in many high-profile outbreaks of disease in humans, causing an estimated 265,000 clinical cases of intestinal illnesses, 3,700 hospitalizations, and 31 human deaths in the United States each year. Wildlife may contribute to these exposures in previously underappreciated ways. For example, in 2008, children playing on a soccer field in Colorado were sickened with a strain of STEC, which was later linked to feces from wild elk that had been grazing on the same field. In response to this outbreak,

NWRC researchers set out to quantify the broader risks that wild elk and deer grazing in urban areas represent to public health. The results showed that the prevalence of STEC in wild elk feces was much higher in urban recreational areas (11 percent) than in natural, nonurban areas (2 percent). STEC in elk feces also increased as maximum daily temperatures increased. Of the STEC-positive samples, 25 percent contained *stx1* strains, 34 percent contained *stx2,* and 13 percent contained both *stx1* and *stx2*. Additionally, *eaeA* genes were detected in 54 percent of the positive samples. Serotypes O103 and O146 were found in elk and deer feces, which also have the potential to cause human illness. These findings show that elk feces may represent a significant public health risk, and management and mitigation actions are warranted.
Project Contact: Alan Franklin

- ***E. coli* in Dairies and Starling Roosts.** *E. coli* O157:H7 is a foodborne bacterial pathogen that causes major public health problems throughout North America. Infections can lead to gastroenteritis and hemolytic uremic syndrome, which can be fatal to humans. Cattle are the major reservoir of *E. coli* O157:H7 in North America, but this pathogen has also been found in deer, rodents, rabbits, and wild birds, including European starlings. Starlings are the most common and numerous bird species found at dairy farms in Ohio. The frequent presence of these birds in feed bunks and watering troughs is associated with the increased likelihood of foodborne pathogens in cows. To better understand the role starlings play in disseminating *E. coli* among livestock, and possibly identify control points to disrupt pathogen transmission, NWRC researchers examined the prevalence of *E. coli* O157:H7 in large starling night roosts and whether these roosts contributed to *E. coli* infection among dairy cows. Over several years, researchers collected fecal samples from cows and starlings in 150 northeastern Ohio dairy farms. Isolates of *E. coli* O157:H7 recovered from these samples were genetically subtyped. Genetic analysis showed that samples from farms were closely related to subtypes from nearby starling roosts. Because birds from roosts travel to multiple farms, starlings are likely a significant risk factor in disseminating *E. coli* O157:H7 among dairy farms. Roost control may be an efficient means to decrease transmission of *E. coli* O157:H7 among farms.
Project Contact: Jeff Homan

- **Wildlife Contact at Artificial Feeding Sites.** Much debate surrounds the use of artificial feeding sites for deer, elk, and other game species. While the food is intended to supplement natural resources that may be limited and enhance survival, many worry the sites may increase the transmission of disease pathogens. In Texas alone, hunters and wildlife watchers distribute approximately 300 million pounds of kernel corn for deer and other wildlife. Until now, little was known about which species were benefiting, how many were involved, and how often they visited these sites. In 2009, researchers trapped and marked 38 raccoons, 39 collared peccaries, 63 feral swine, 2 opossums, and 1 fox squirrel with passive integrated transponder (PIT) tags at 3 sites in Texas. Then, researchers placed one kernel corn feeder system containing a PIT tag reader near each of the three trap sites. Readers recorded 62,719 raccoons, 103,512 collared peccaries, 2,923 feral swine, 1,336 fox squirrels, but no opossums. Researchers determined that contact occurred when 2 different PIT tags were detected by the readers within 5 seconds. Analysis of contact rates within and between species in this study was extrapolated to the entire State and provided an annual expected estimate of 5.2 billion unnatural contacts occurring among wildlife at artificial feeding sites in Texas. Given the high number of unnatural contacts, it is highly likely that pathogens are shared between and within species.
Project Contact: Susan Shriner

Wild raccoons are naturally exposed to avian influenza (AI) viruses. Researchers tested whether AI can be transmitted to raccoons through contaminated eggs, water, or bird carcasses.
Photo by USDA

- **Avian Influenza Virus Transmission to Raccoons.** Understanding the routes of disease transmission is useful in identifying possible control points for disease management. Raccoons are naturally exposed to avian influenza (AI) viruses and are common at animal production facilities. Consequently, how this species may be exposed to AI and whether the exposure routes can be managed are important considerations for developing farm biosecurity measures. However, the mechanisms associated with natural exposures are not well understood. NWRC researchers tested three potential routes for AI transmission (water, eggs, and scavenged waterfowl carcasses) that may explain how raccoons in the wild are exposed to AI. Raccoons were exposed to either water or eggs spiked with a low-pathogenic AI subtype (H4N6), as well as mallard carcasses inoculated with the same virus. Three of the four raccoons exposed to the high-dose water treatment showed potential evidence of nasal shedding. None of the animals associated with the egg and mallard carcass treatments shed the virus. The results indicate that virus-laden water could provide a natural route for raccoons, and possibly other mammals associated with aquatic environments, to be exposed to AI. However, this association appears to be strongly related to the concentration of the AI virus in the water—meaning that raccoons may have to be exposed repeatedly to water with high AI concentrations for transmission to occur. Eggs and carcasses contaminated with AI did not appear to be effective vehicles of transmission in this study; however, higher doses in eggs or carcasses might yield different results. Managing AI at farmside water sources deserves further investigation as a means to enhance farm biosecurity.
Project Contact: Jeff Root

- **Predicting Avian Influenza Virus in Waterfowl.** Avian influenza (AI) viruses in wild birds contribute to new human influenza strains and threaten the domestic poultry industry with millions of dollars in losses. Given the broad distribution of wildlife reservoirs for the virus, fully understanding its spread and distribution requires understanding ecological processes on both local and continental scales. Using data on low-pathogenic AI in migratory U.S. waterfowl and a new application of bird banding and recovery data, NWRC researchers and partners at Colorado State University and APHIS' Veterinary Services identified potential mechanisms that control the distribution of the virus. Researchers found the strongest predictors of AI distribution included waterfowl demography and water temperature as opposed to tracking bird migration patterns or regional movements of the virus. These results support a role for AI virus transmission at local (that is, county) levels that then affects overall continental distributions of the AI virus, which has important implications for developing surveillance and risk assessment for humans and domestic animals.
Project Contact: Alan Franklin

- **Optimizing ORV Vaccination Timing for Young Raccoons.** The National Rabies Management Program, administered by WS, is tasked with controlling the spread of rabies in terrestrial wildlife through distributing oral rabies vaccination (ORV) baits. RABORAL V-RG (V-RG, Merial Inc.) is currently the only effective oral vaccine licensed for use in free-ranging raccoons and coyotes in the United States. However, vaccinating young animals can be problematic because they lack fully developed immune systems and harbor temporally transient maternal antibodies that may interfere with vaccinations. Knowing the antibody status of young raccoons is important in developing optimal program vaccination times during the raccoons' annual cycle. In studies with captive raccoons, NWRC researchers monitored the antibody responses of very young raccoons to RABORAL V-RG and subsequent rabies vaccine exposure. Researchers found not only that vaccinated young raccoons had antibody responses to the RABORAL V-RG vaccine, but that some unvaccinated raccoon kits had them as well, likely due to their contact with vaccinated littermates. At approximately 9 months of age, all of the kits were inoculated with a different rabies vaccine. The kits that initially responded to the RABORAL V-RG oral vaccination or contact with vaccinated littermates had a rapid antibody response. In contrast, the RABORAL V-RG nonresponders and those with acquired maternal antibodies had rabies-virus-neutralizing antibody levels that were substantially lower. These findings suggest that the naïve contact kits and the nonresponsive kits most likely remained susceptible to rabies virus infection, but that the ones responding to RABORAL V-RG did not.
  Project Contact: Kurt VerCauteren

In studies with captive raccoons, NWRC researchers monitored the antibody responses of young raccoons to the oral rabies vaccine RABORAL V-RG.
Photo by USDA, Anson Eaglin

- **Oral Rabies Vaccination Programs in Urban Environments.** In 1977, rabies was detected in a raccoon in West Virginia, and since the mid-1980s raccoon variant rabies has spread throughout the eastern United States and moved west as far as the eastern edge of Cleveland, OH. The primary tool to combat this spread is the distribution of oral rabies vaccine (ORV) baits. A thorough knowledge of raccoon behavior and movement is critical in determining bait placement, particularly in urban areas. To develop better vaccination strategies for urban landscapes where traditional aerial baiting programs may not be feasible, NWRC researchers monitored raccoons in urban areas of Cleveland, calculated the size of their home ranges, and monitored their movements with respect to potential barriers and habitat features. The home ranges were estimated to be 53 acres (21.5 hectares) in summer and 45 acres (18.2 hectares) in the fall. Raccoons crossed interstate highways and rivers, suggesting that these features do not impede their movements. Their habitat use indicates that ORV baiting in urban environments should be concentrated in habitat patches and trees adjacent to human structures and industrial sites to take advantage of raccoon behavior.
  Project Contact: Are Berentsen

- **Rabies in Bobcats.** Rabies control efforts focus on species that are able to maintain and transmit the disease to other mammals. In addition to identifying viable rabies hosts, control efforts could benefit

from a tool to screen for rabies. Thermal imaging may potentially be such a tool, since it is able to detect the temperature changes in animals that result from infection. In 2007, several bobcats were diagnosed with the gray fox rabies variant in Texas. To determine whether bobcats are a viable new host for the virus and assess thermal-imaging use for rabies screening, NWRC researchers inoculated four bobcats with the gray fox rabies variant, collected thermographic images during the course of the disease, and examined tissues for rabies infection. Three bobcats were positive for rabies, indicating that these animals are viable hosts for transmitting the virus. The results regarding the effectiveness of thermography as a diagnostic tool for rabies in this species were variable but are informing current efforts with other species. Researchers are optimistic that thermography may be useful for determining which bats in a roost are diseased.
Project Contact: Kurt VerCauteren

- **Health Evaluation of African Lions, Wild Dogs, and Spotted Hyenas.** As part of a comprehensive wildlife disease exposure study in Zambia, NWRC researchers and international partners collected blood and tissue samples from African lions, African wild dogs, and spotted hyenas to evaluate the potential exposure of these species to rabies virus, canine distemper virus (CDV), and canine parvovirus (CPV). In addition, domestic dogs in the study region were evaluated for exposure to CDV and rabies. NWRC researchers were invited to participate in this study because of their unique expertise in rabies research, carnivore ecology, and prior experience conducting ecological work in Africa. Twenty-one lions, 20 hyenas, 13 wild dogs, and 38 domestic dogs were sampled in both regions. Laboratory results showed that approximately 11 percent of the domestic dogs, 5 percent of the hyenas, and 8 percent of the wild dogs sampled were positive for CDV exposure. All of the lions were negative. Exposure to CPV was 10 percent and 5 percent for hyenas and lions, respectively. All of the wild dogs were negative, and domestic dogs were not tested due to insufficient serum samples. All of the species sampled were negative for rabies-virus-neutralizing antibodies except lions—40 percent of them tested positive. Because these lions appeared clinically healthy, this finding represents the first documentation of rabies-virus-neutralizing antibodies consistent with rabies exposure that did not lead to clinical disease in free-ranging African lions from this region. As the human population continues to encroach on wildlife habitat, transmission of diseases such as rabies, CDV, and CPV from domestic dogs to wild carnivores poses a risk to threatened and endangered wildlife. Gaining a more complete understanding of the transmission risks can assist in developing mitigation methods such as domestic dog vaccination programs.
Project Contact: Are Berensten

- **Coyote and Feral Swine Exposure to *Neospora caninum*.** *Neospora caninum* is a parasite that can cause abortion in dairy and beef cattle. The economic impacts associated with this parasite are substantial, with annual losses in individual U.S. States approaching tens of millions of dollars. To date, the only identified primary hosts or carriers of the parasite are canids, including coyotes, wolves, and domestic dogs. To better understand *N. caninum's* presence in the environment, WS National Wildlife Disease Program biologists and colleagues screened blood samples from coyotes, a definitive host, and feral swine, an invasive species that is expanding its range and abundance, for *N. caninum* antibodies. Samples from 394 coyotes and 467 feral swine in New Mexico, Oklahoma, and Texas were screened. Overall, 18 percent of the coyotes and 16 percent of the feral swine sampled had been exposed to the parasite. This is the first report of exposure in U.S. feral swine populations. Analyses suggest that the

parasite is present throughout the environment and that exposure is not temporally or spatially linked to antibody-positive coyotes. Antibody-positive feral swine were found in an area where the only definitive hosts are domestic dogs, indicating that wild canids are not required to maintain the parasite in the environment.
Project Contact: Sarah Bevins

- **Understanding Disease Hotspots.** Avian influenza (AI) viruses have been implicated in all human influenza pandemics in recent history. However, little is known about how these viruses are maintained and spread in their natural bird hosts. Surveillance has identified a disease "hotspot" in shorebirds at Delaware Bay, where AI virus prevalence is estimated to exceed other monitored sites by an order of magnitude. To better understand the factors that create an AI virus hotspot, WS National Wildlife Disease Program biologists and colleagues developed a model to study the impacts of multiple host species, seasonal breeding, bird migration patterns, and disease transmission routes. Researchers also examined the potential for an AI virus hotspot to serve as a gateway for the spread of new viruses into North America. Findings showed that Delaware Bay may serve as a potential amplification site for the virus when ruddy turnstones are present or during the hatching season, when more naïve and susceptible birds are present.
Project Contact: Kerri Pedersen

- **Pseudorabies in Feral Swine.** Pseudorabies, also referred to as Aujeszky's disease, is an infectious, often fatal, viral disease of the nervous system. Swine are the only known reservoir of the virus, though many other mammal species are susceptible to infection. The economic impacts of the disease to domestic swine producers include high mortality in piglets, respiratory disease in juvenile and adult pigs, and abortions or stillbirths in pregnant sows. WS' National Wildlife Disease Program coordinates a national feral swine surveillance program that monitors high-risk areas for the introduction of this and other diseases with regulatory implications. From 2009 to 2012, biologists collected approximately 8,500 blood samples from feral swine across the United States. Of these, 18 percent were positive for pseudorabies in 25 of 35 States sampled. Researchers note that the expansion of feral swine populations represents a threat to the pseudorabies-free status of U.S. commercial swine, as well as to other domestic animals and wildlife.
Project Contact: Kerri Pedersen

- **International Gathering of Wildlife Disease Experts.** From August 6 to 8, WS' National Wildlife Disease Program, the Chinese Academy of Sciences, Chinese State Forest Administration, Colorado State University, and EcoHealth Alliance convened the 6th Annual Workshop on Regional Surveillance and Research for Wildlife-Borne Diseases. The 2013 workshop was held at NWRC in Fort Collins, CO, marking the first time this annual event was held in the United States. More than 80 scientists and

The 6th Annual Workshop on Regional Surveillance and Research for Wildlife-Borne Diseases was held at NWRC in August 2013.
Photo by USDA, Gail Keirn

managers from 15 countries attended. The goal of the workshop was to enhance communications and collaborative surveillance activities among wildlife disease experts. The agenda included presentations on a variety of species and topics, such as bats, bison, coyotes, rhinos, avian influenza, rabies, African swine fever, and economic modeling of disease risks. Discussion topics focused on expanding existing collaborations.
Project Contact: Dale Nolte

Wildlife Damage Assessments

- **Feral Swine Damage to Archaeological Sites.** Feral swine are an invasive species well known for their ability to degrade native habitats, damage agricultural crops, and spread disease. However, until now little was known about their impacts on archaeological sites. NWRC scientists and colleagues from the Avon Park Air Force Range (Avon Park) recently documented the potential for feral swine to disturb and destroy archaeological sites in south-central Florida. The study was conducted at Avon Park, a base comprising more than 98,000 acres and containing hundreds of archaeological sites. Scientists examined potential feral swine impacts to 36 sites at Avon Park that are eligible for registration with the National Register of Historic Places. Of the 36 sites, 20 are prehistoric, 8 are historic, and 8 have both prehistoric and historic components. Researchers found widespread potential for artifacts to be damaged or displaced by feral swine rooting and wallowing at these sites. Seventy-nine percent of the sites had artifacts within 8 inches of the surface, making them highly vulnerable to damage by feral swine. Even more troubling was the discovery that 42 percent of the sites already showed signs of swine damage. Soon after the study concluded, a fence was erected around a site of extraordinary archaeological importance. However, researchers note this is not a feasible remedy for all locations. A combination of methods, including the lethal removal of feral swine, likely will benefit archaeological site preservation the most. The study is the first to quantify swine impacts on archaeological sites over a wide area. Its findings shed light on how feral swine affect archaeological resources and aid managers in their efforts to protect the sites.
Project Contact: Richard Engeman

- **Bat-Aircraft Collisions.** Wildlife collisions with aircraft threaten human safety and cause substantial economic loss. Although more than 97 percent of wildlife collisions with U.S. civil aircraft involve birds, damage is more than 4.5 times more likely to occur when mammals such as deer and coyotes are involved. Bats are the only mammals with the potential to be struck by aircraft outside the airport environment (at least 500 feet above ground). NWRC researchers examined the Federal Aviation Administration's National Wildlife Strike Database from 1990 to 2010 to estimate the frequency of bat collisions with aircraft within the United States and the risk bats pose relative to other wildlife. Of the 417 bat incidents studied, more occurred during August (28 percent) than any other month. Also, most bat collisions took place at night (82 percent), primarily at dusk (57 percent). More incidents occurred as aircraft were landing (85 percent). Aircraft sustained minor damage on only two occasions, but no damage costs were reported. The incidents coincided with bat migration, hibernation, juvenile recruitment, and other activities. Researchers conclude that bat incidents pose little risk to U.S. civil aircraft and have a minimal economic effect on the U.S. civil aviation industry.
Project Contact: Travis DeVault

- **Estimating the Cost of Rabies.** The World Health Organization estimates that about 55,000 people die of rabies each year, and that 99 percent of these deaths are attributable to canine rabies in Africa and Asia. NWRC economists estimated the economic impact of canine rabies in Latin America, Africa, and Asia. Accounting for the direct and indirect costs of rabies prophylaxis after exposure, dog vaccination and control, rabies diagnostic testing, and cattle mortality, the analysis showed that the overall global cost of canine rabies is approximately $124 billion annually. Decreases in consumer spending from canine rabies cause the additional loss of more than 6,000 jobs and $600 million in income annually. These results illustrate the potential benefits that could be realized if canine rabies were eliminated and provide an important benchmark against which the cost of potential eradication campaigns can be compared.
Project Contact: Stephanie Shwiff

NWRC researchers and municipal partners are studying the temporal and spatial patterns of human-coyote conflicts in urban environments.
Photo by by USDA, Sharon Poessel

- **Patterns of Human-Coyote Conflicts in the Denver Metropolitan Area.** In many cities throughout North America, human-coyote conflicts are an emerging problem. Little research has described the temporal and spatial patterns of these conflicts, although such information is important for developing and optimizing management efforts. NWRC and Colorado State University researchers analyzed 4,006 reports from 22 entities in the Denver Metropolitan Area (DMA) that provided information on coyote observations and conflicts. The reports included 78 signs of a coyote presence (such as track, scat, vocalizations); 3,023 sightings; 395 encounters; 26 incidents (defined as confrontations in which a coyote bares its teeth, growls, or threatens a human); 471 attacks on pets; and 13 attacks on humans. A strong seasonal pattern emerged: the number of both observations and conflicts was highest from December to March and lowest from July to September. The conflicts were disproportionately more common in open space areas, commercial development sites, and suburban housing areas. Conflict hotspots were apparent in the southern region of the DMA, where natural areas border urban areas and possibly provide coyotes with easier access to development and interaction with residents. More coyote conflicts were reported in these areas, likely because there were more opportunities for people, pets, and coyotes to cross paths. This pattern reflects not only space use of coyotes, but also how many humans are available to interact with them and report conflicts. These findings help target management efforts, particularly those involving education and outreach, but also highlight the critical need for improved methods of collecting conflict information via a standardized reporting mechanism to help reduce bias.
Project Contact: Stewart Breck

- **Blind Mole Rat Damage in Armenia.** A National Wildlife Disease Program biologist with a background in field rodent damage management traveled to Armenia in early June 2013 to advise Armenian Department of Agriculture and Plant Protection officials on methods to reduce crop damage caused by Nehring's blind mole rat. The visit was arranged cooperatively through NWRC and the Food and

Agriculture Organization of the United Nations, in response to a request from the Government of Armenia. The visit was short, allowing for just 5 days in Armenia to assess the situation and make recommendations for integrated pest management solutions. It was followed by a report on blind mole rat biology and recommendations for mitigating the damage, which is as much from the large soil mounds these rodents create as from direct crop consumption. Recommendations included consolidating Armenia's many small farm fields into larger units and switching to annual crops in affected areas to facilitate frequent plowing, which will disrupt burrows. Intensive trapping was also recommended. The Government of Armenia has requested a return visit in May 2014 to conduct more training.
Project Contact: John Baroch

Wildlife Management Methods and Evaluations

- **Invasive Black Spiny-Tailed Iguanas on Gasparilla Island, Florida.** The black spiny-tailed iguana is native to southern Mexico and Central America. However, in 1979, three pet iguanas were released on Gasparilla Island in southwest Florida, and the population now numbers in the thousands. In response to complaints of property damage from residents and threats to native species, local officials and WS experts began removing iguanas in 2008. Although the iguanas are primarily plant eaters, they will opportunistically eat other lizards, small birds, rodents, invertebrates, and threatened juvenile gopher tortoises. By 2011, trappers had removed 9,467 iguanas from the island. The number removed declined from 32 iguanas per day in 2008 to about 2 per day in 2011, even as the control effort remained constant. NWRC researchers necropsied 2,757 of the iguanas removed to document various aspects of the population's natural history. In general, the biology of the invasive population on Gasparilla Island resembles that of native populations in Central America, although there are no large iguanas on the island. Researchers suggest that short days and colder temperatures create suboptimal environmental conditions for individual growth compared to conditions in the species' native range. Four years of removal efforts greatly reduced the iguana population, which bodes well for the ultimate control of these and similar invasive reptiles—provided dedicated, persistent removal efforts are devised, initiated, and maintained.
Project Contact: Michael Avery

- **Detecting and Preventing Mouse Invasions.** Invasive house mice pose a threat to the native flora and fauna of islands, causing significant damage wherever they are introduced. A better understanding of how house mice behave when they are first introduced to a new environment would help managers develop effective biosecurity techniques to protect against new invasions. To address this issue, NWRC researchers conducted a controlled laboratory experiment that simulated an invasion by wild house mice into a new environment. Researchers quantified and compared the reactions of these mice to various odors and other attractants including food, shelter, water, and other mice. The results showed that the most common immediate reaction of the mice was to seek shelter in a den box. Secondarily, the mice were interested in food scents, particularly cheese, bacon grease, almond extract, and peanut butter. Females investigated male urine and fecal odors more often than males investigated female odors. Based on the findings, researchers surmise that a secure den box with certain food and mouse odors might entice and hold house mice in a restricted area for a short time in a new environment. If handled properly, this arrangement could be used for early detection and response to new invasions of house mice.
Project Contact: Gary Witmer

- **Protecting Seedlings From Rodent Damage.** Solid waste landfills are common in urbanized and industrialized regions of the world. If designed, managed, and restored properly, they can be reclaimed and converted to useful land areas. However, restoring trees and shrubs at landfill sites can be difficult when animal damage occurs. NWRC researchers evaluated how two changes to habitat (mowing and a pea-gravel barrier) and rodenticides could protect tree seedlings from meadow voles at restored landfill sites in Brooklyn, NY. The treatment sites included either plots with mowed grass or a ring of pea gravel about 3 inches deep around tree seedlings. The documented damage rodents caused to tree seedlings in the plots—including killing them—ranged from 40 to 73 percent, regardless of species. Substantial losses occurred regardless of the treatment used, although there were fewer losses at sites with pea-gravel barriers. While the pea-gravel treatment reduced seedling losses by approximately 55 percent, more research is needed to identify efficient ways to reduce seedling losses to rodents in restoration plantings.
  Project Contact: Gary Witmer

- **Benefits of Targeted Versus Sport Hunting Predator Management.** Nonlethal methods for reducing livestock predation can be cost effective but may also be impractical or insufficient in some situations. As a result, lethal predator control is often used. To varying degrees, lethal methods employed by professional wildlife managers can selectively target individual predators that have killed or are likely to kill livestock. Although sport hunting may also help, as it reduces or limits the size of local predator populations, it is unlikely that hunters will target individual predators suspected of killing livestock. The distinction between these two methods is an important one. NWRC economists developed a simple method to estimate the benefits to livestock that targeted lethal removal of predators can provide relative to the benefits of sport hunting. Using data on lynx predation on sheep in the French Jura Mountains, economists found that the benefits of targeted removal outweigh those of sport hunting by up to 175 percent. Several conclusions can be drawn about the benefits of targeted removal relative to sport hunting based on the developed framework. Targeted removal is preferred when the value of the vulnerable livestock is high and predation rates are variable. However, when predation rates are consistently high, sport hunting is preferred, likely because a high predation rate implies that removing any given animal is likely to protect livestock.
  Project Contact: Aaron Anderson

Habitat manipulations and rodenticides were tested to reduce rodent damage to tree seedlings at restored landfills on Long Island, NY.
Photo by USDA

- **Use of Patch Selection Models as a Decision-Support Tool.** Human-wildlife conflicts are increasing worldwide. Often, these conflicts are associated with the availability of food sources generated by humans, such as crops or garbage. To reduce conflict, wildlife managers are increasingly turning to nonlethal methods, which can include public education campaigns to change human behaviors (for instance, improving livestock husbandry to prevent predation or enforcing no-litter laws) or aversive conditioning that alters wildlife behavior (such as hazing, or chemical or physical deterrents). Understanding how these strategies affect wildlife foraging decisions is key to reducing human-wildlife conflicts. Patch selection models provide a framework for evaluating how management actions might affect how and where wildlife forage, and so are useful tools for guiding management decisions. NWRC researchers and colleagues examined how changes in the costs and benefits associated with foraging in human habitats influence the foraging behavior of black bears. Using the model, researchers incrementally reduced the availability of human food sources (benefit reduction) and increased the energetic costs of bear movement in response to aversive conditioning (cost increase) to determine the point at which the bears would avoid human habitats. If benefits were reduced by 55 percent or more in urban areas and 70 percent or more in urban-interface areas, bears would avoid those areas. To obtain similar results using a cost-increase approach, managers would need to increase costs to bears by more than 1,100 percent in urban areas and 400 percent in urban-interface areas. Given the modeling results and given how unpopular control strategies targeting wildlife are, researchers suggest allocating management resources to strategies that reduce foraging benefits to bears, such as reducing the availability of human food sources.
  Project Contact: Stewart Breck

Black bears can be a common sight in some communities. NWRC researchers are studying how humans influence the foraging behavior of bears in suburban and urban areas.
Photo by USDA, Sharon Baruch-Mordo

- **Rodent Control To Reduce Seed Predation of the Endangered Hawaiian Lobelia.** A rodent control effort was conducted on Oahu Island, HI, to protect endangered snails and plants at a 64-acre (26-hectare) site. To assess the effectiveness of this effort in protecting endangered Hawaiian lobelia plants *(Cyanea superba),* rodents' fruit consumption was monitored for 36 and 42 lobelia plants at 2 sites with and without rodent management. Over 47 percent of the fruit was eaten at the site without rodent control compared to only 4 percent at the managed site. To determine whether the rodents from the sites predated on or dispersed lobelia seeds, fruit was fed to captive black rats and house mice. Black rats consumed the entire fruit, killing all of the seeds, while mice did little damage to either the fruit or the seeds. Researchers conclude that large-scale rat trapping can benefit the reproduction of endangered plants and that controlling black rats at restoration sites appears integral to successfully restoring lobelia plants.
  Project Contact: Aaron Shiels

- **Benefits to Rare Plants and Highway Safety From Annual Deer Culling.** Browsing by overabundant white-tailed deer is one of the most serious threats to woodland plant communities in the Chicago area. The deer also pose hazards to human safety when they collide with vehicles. NWRC researchers and WS Operations specialists examined the benefits of culling deer at a Chicago-area woodland preserve by comparing browsing rates for four endangered plant species before and after deer were culled. Researchers also looked at deer-vehicle collisions and traffic flow rates on area roads during the same time period to assess whether reducing the deer population increased road safety. All four of the endangered plant species (three orchid species and sweet fern) had lower browsing rates in years when deer were culled, although the decreased browsing rates were statistically significant for only two species: grass pink orchid and sweet fern. After first verifying that traffic flow rates were similar for all the years examined, researchers analyzed Illinois Department of Transportation data on each deer-vehicle collision that caused more than $500 in damages. The data showed that deer-vehicle collisions were reduced by one-third in the years deer were culled. An economic analysis showed cost savings during the cull years of $600,000 for reduced browsing on the four monitored plant species and fewer deer-vehicle collisions.
  Project Contact: Richard Engeman

Wildlife Population Monitoring Methods and Evaluations

- **Pentosidine-Based Age Prediction Models for Cormorants.** The double-crested cormorant is a fish-eating waterbird whose population in some areas of North America has doubled every 5 years for the past 3 decades. These increases have resulted in both perceived and documented negative impacts to recreational fisheries, sensitive vegetation, other colonial-nesting birds, and channel catfish aquaculture. Determining the age demographics of animal populations such as the cormorant's helps resource managers predict population growth rates and responses to various management actions. NWRC scientists and collaborators at West Virginia University have identified a biomarker in the skin of double-crested cormorants, called pentosidine, which predicts their age. To improve models that predict cormorant population demographics, researchers developed and evaluated eight models using pentosidine data from cormorants with known ages and bird banding data. All of the models were able to produce estimated ages within 3 to 4 years of the birds' actual age for most samples. However, only the model for predicting the age of young cormorants was able to estimate the birds' age within 1 year of their actual age. Researchers discovered a high degree of variability in the amount of pentosidine that accumulated in the tissue of older birds, apparently reflecting different environmental and physiological factors. Because of this variability, researchers recommend the use of two different models: one for birds with pentosidine concentrations of eight picomoles per milligram of collagen or less (typically found in

NWRC scientists and collaborators at West Virginia University have identified a biomarker in the skin, called pentosidine, which is a predictor of age in double-crested cormorants.

Photo by USDA, Crissa Cooey

young birds) and one for all other samples. Researchers acknowledge there is still room for improving the models as more becomes known about pentosidine accumulation in birds. Knowing which age classes have the highest reproductive success, and knowing which percentage of the breeding colony consists of those age classes, will give managers a better idea of appropriate management actions to regulate regional populations.
Project Contact: Brian Dorr

- **Cumulative Effects of Cormorant Management.** Because management programs to reduce wildlife damage are often conducted at local levels, questions arise about the cumulative effects of these programs on the overall species populations. Double-crested cormorants are managed in many States and Canada to reduce their impact on sport fish and aquaculture, competition with other colonial waterbirds, and damage to vegetation. Techniques may include harassment at roosting or breeding sites, culls of breeding or wintering cormorants, egg oiling (to prevent hatching and re-laying), and nest destruction or removal. Using more than three decades of management and cormorant population data from the Great Lakes ecosystem, NWRC, Mississippi State University, and U.S. Fish and Wildlife Service experts investigated the cumulative impacts of management and other factors at differing spatial and temporal scales on the size and growth rates of cormorant colonies and populations. Models showed that colony-level density-dependent factors, such as clutch size and proximity of active neighboring colonies, as well as local control efforts, had the greatest influence on population growth. Management had a cumulative effect on growth rates when different control activities were combined and occurred over subsequent years. Results also suggest that catastrophic events (for example, predation, flooding, illegal harassment) and culls of breeding adults that occurred at least 2 years earlier could actually fuel subsequent recruitment or natural immigration from nearby colonies. Future cormorant management efforts will provide opportunities to refine the models and allow for a better understanding of density-dependence, breeding versus nonbreeding season management, and dispersal.
Project Contact: Brian Dorr

- **Monitoring Feral Swine.** An NWRC expert and international collaborators in the United Kingdom, Australia, and France have published a practical guide for wildlife managers, researchers, and others interested in monitoring feral swine and wild pig populations. The guide describes the advantages and disadvantages of proven and potential methods used for monitoring swine populations. Prospective users can consider and identify which options best suit their needs, circumstances, and resources. Although indices are not estimates of actual population numbers, they can make relative comparisons between populations or monitor trends within a population if properly designed and implemented. Included among the methods described are: track plots, dung surveys, animal marking and capture-

Passive tracking is one of several methods NWRC experts and international collaborators discuss in a practical guide for wildlife managers and others interested in monitoring feral swine and wild pig populations.
Photo by USDA, Bernice Constantin

mark-recapture, night vision and thermal imaging, aerial surveys, line transect surveys, spotlight surveys, take rates, camera traps, and DNA methods.
Project Contact: Richard Engeman

Registration Updates

- **Immunocontraceptive Vaccine Registered for Feral Horses and Burros.** In January 2013, APHIS was granted an EPA registration for the use of the GonaCon Immunocontraceptive Vaccine to manage fertility in wild and feral horses and burros. WS continues to conduct research to expand the vaccine's registration to other species.
Project Contact: John Eisemann

Technology Transfer

- **Large Reptile Trap.** In 2013, USDA was issued a patent for a live snake trap that uses two trip pans to capture large, heavy snakes such as the invasive Burmese python. It is the first trap to require that two trip pans be depressed at the same time to close the trap door. The pans are spaced so that nontarget animals such as small native snakes, raccoons, and opossums are unlikely to trigger the trap.
Project Contact: John Eisemann

- **New Cooperative Research and Development Agreements.** NWRC scientists signed three new Cooperative Research and Development Agreements (CRADAs) during fiscal year 2013 with private companies and foreign governments for conducting joint research to develop and commercialize inventions. Research activities under these agreements include testing new rabies vaccine delivery systems, pesticides, and fertility-control agents. In addition, NWRC researchers are collaborating with a private company to develop a prototype species-specific image and acoustic recognition system. This recognition system would allow the delivery of disease vaccines, contraceptives, or toxicants only to the species of interest. Currently, NWRC is participating in 12 CRADA projects.
Project Contact: John Eisemann

Awards

- **2012 NWRC Publication Awards.** NWRC scientists Matthew Hopken, Gary Witmer, Antoinette Piaggio, Brian Dorr, Brad Blackwell, Travis DeVault, and Thomas Seamans were honored with the 2012 NWRC Publication Awards. These awards are given annually at NWRC to recognize quality research published in the previous year.

  In the article "Genetic evaluation of an attempted *Rattus rattus* eradication on Congo Cay, U.S. Virgin Islands, identifies importance of eradication units" *(Biological Invasions),* Hopken, Witmer, Piaggio, and their collaborators used rapidly evolving genetic markers to understand the origins of an invasive rat population at Congo Cay. Unique to this study is the use of techniques to detect the source of rat populations based solely on post-eradication DNA samples. The relatedness of DNA from rats on Congo Cay and nearby cays was evaluated. The authors found a recent reduction of the rat population on Congo Cay and evidence of either a population bottleneck (survivors from a failed eradication effort) or a founder event (immigration of new individuals from other islands). This study is unusual because the authors took additional steps to determine if the cause was from a bottleneck or a founder event—a distinction many studies are unable to make. The findings suggest that the rat population on Congo Cay is at least in part a result of rat immigration from Lovango after the eradication attempts. The authors conclude with recommendations for future eradication attempts that could be applied to other biological invasions. This publication was recognized for its rigorous approach to an important management question, its publication in a high-quality scientific journal,

and the authors' ability to apply their findings to broader issues faced in eradication programs of invasive species.

In "Towards optimized population control efficiency in space and time: A modeling framework adapted to a colonial waterbird" *(Ecological Modeling),* Dorr and his colleagues developed simulation tools to gain insights into the efficiencies that can be expected from better planned management activities in both space and time. The data set the authors used included multiscale location data for the double-crested cormorant, a native North American waterbird that damages natural resources and aquaculture in the United States and Canada. This paper represents the first time a spatially explicit, stage-structured metapopulation model has been parameterized for the cormorant. Different spatio-temporal configurations of management activities generally yielded different metapopulation trajectories; however, the modeling framework is flexible enough to allow more complex scenarios to be investigated in the future. This approach can also be used for other ubiquitous species that are managed at large spatial scales. This publication was recognized for its creative and rigorous approach to important management questions, its strong collaborative effort among State and Federal institutions, its high technical and literary quality, and its publication in a widely respected scientific journal.

NWRC scientists Blackwell, DeVault, and Seamans collaborated with university experts in "Exploiting avian vision with aircraft lighting to reduce bird strikes" *(Journal of Applied Ecology).* They addressed the problem of bird-aircraft collision from a new perspective: how do birds perceive their environment and the approach of potential threats? They contend that we cannot view these situations from the human perspective but need to understand the visual capabilities of birds. The study used radio-controlled aircraft modified in various ways to test variables. The behavior of wing-clipped Canada geese when the aircraft approached them was documented and analyzed in an insightful and original manner. This study showed that birds quickly perceived lights in the ultraviolet/violet range of wavelengths as a threat. Consequently, aircraft lighting may be modified to reduce bird-aircraft strikes, with a concurrent reduction in aircraft damage and threats to human safety. This study was a good example of a collaboration between NWRC and university researchers, and evidence of how basic science can be used to develop practical management tools to solve important problems. The article was published in a high-quality scientific journal.

- **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 center's mission. The winners this year are:

  - Michael Avery, Research Grade Scientist, Avian and Invasive Species Population Management Project, Gainesville, FL

  - Kerri Pedersen, Support Scientist, National Wildlife Disease Program, Fort Collins, CO

  - Shelagh Tupper, Technician, Methods Development and Population Biology of Blackbirds and Starlings in Conflict With Agriculture, Concentrated Animal Feeding Operations, and Urban Environments, Fort Collins, CO

  - June Weisbeck, Administration, Administrative Support Unit, Bismarck, ND

- **Kerry-Manheimer Award.** In 2013, NWRC Director Larry Clark was honored with the prestigious Kerry-Manheimer Award, which recognizes the career contributions of outstanding researchers in the chemosensory sciences. The award was presented at a ceremony in Philadelphia, PA, and was attended by Monell Chemical Senses Center scientists and other guests. Clark began his career as a post-doctoral fellow and faculty member at Monell and joined APHIS in 1991. In the past 22 years, he has been instrumental in establishing and expanding NWRC's wildlife disease research capabilities. His extensive experience studying how animals perceive environmental chemicals has proved useful in developing lures and repellents, as well as understanding foraging ecology. Clark also has expertise in the use of biopharmaceuticals in wildlife molecular modeling to identify repellents, physiological and behavioral temperature regulation and biophysical modeling, and wildlife diseases and pathogens. Clark is the author or coauthor of over 140 scientific publications and 4 licensed patents.

- **Leader in Aviation Strike Hazards Research.** Earlier this year, NWRC research wildlife biologist and project leader Travis DeVault was recognized with Airport Business Magazine's "Top 40 Under 40" award for work related to aviation safety. DeVault oversees a team of research scientists and biologists at NWRC's Ohio Field Station that conducts research and develops methods to reduce wildlife strikes with aircraft. The team's research forms the basis for Federal Aviation Administration regulations regarding wildlife conflicts with civil aviation. DeVault's work in aviation began in 2000 during his dissertation research, when he studied the flight behavior of vultures for inclusion in computer models of bird avoidance for aircraft. Since that time, his research on wildlife-aircraft collisions has expanded into many areas, including the possibility of using airport land for renewable energy and agricultural projects instead of planting turf grass. This promising research area could trigger a paradigm shift in airport land cover from relying too much on turf grass to more productive and "greener" land uses (such as biofuel production and solar energy production) that reduce wildlife hazards. DeVault has published more than 75 scientific journal articles and book chapters, and served as lead editor for the book *Wildlife in Airport Environments: Preventing Animal-Aircraft Collisions Through Science-Based Management.* This book provides the first thorough overview of the science behind wildlife management at airports.

2013 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. Names highlighted in bold are current or former NWRC employees. (Note: 2012 publications that were not included in the 2012 NWRC accomplishments report are listed here.)

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Appendix 1

List of 2013 NWRC Research Projects

Avian and Invasive Species Population Management
Project Leader: Michael Avery

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

Defining Impacts and Developing Strategies To Reduce Mammalian Damage in Forested and Riparian Ecosystems
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 Oral Contraceptive Technologies and Their Assessment for Wildlife Populations and Disease Management
Project Leader: Douglas Eckery

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

Development of Methods To Control Rodent Populations and Damage With an Emphasis on Invasive House Mice and Native Voles
Project Leader: Gary Witmer

Ecology of Emerging Viral and Bacterial Diseases in Wildlife
Project Leader: Alan Franklin

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

Feral Swine Damage Control Strategies
Project Leader: Fred Cunningham

Investigating the Ecology, Control, and Prevention of Terrestrial Rabies in Free-Ranging Wildlife
Project Leader: Kurt VerCauteren

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: William Pitt

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

Use of Chemistry, Biochemistry, Computational Modeling, and Chemosensory Research To Develop Wildlife Damage Management Tools
Project Leader: Bruce Kimball

More information about these projects can be found on the NWRC Web page at:
www.aphis.usda.gov/wildlifedamage/nwrc

Appendix 2

NWRC Research Contacts

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Avery, Michael	(352) 375-2229 ext. 12 *Michael.L.Avery@aphis.usda.gov*	Project Leader: invasive species, birds
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Berentsen, Are	(970) 266-6221 *Are.R.Berentsen@aphis.usda.gov*	Rabies
Bevins, Sarah	(970) 266-6211 *Sarah.N.Bevins@aphis.usda.gov*	NWDP: wildlife disease
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Cunningham, Fred	(662) 325-8215 *Fred.L.Cunningham@aphis.usda.gov*	Project Leader: aquaculture, cormorants, feral swine
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Kimball, Bruce	(267) 519-4930 *Bruce.A.Kimball@aphis.usda.gov*	Chemistry Unit Leader/Project Leader: chemical ecology, foraging behavior, repellents, attractants, analytical chemistry
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Appendix 3

Acronyms and Abbreviations

AI	Avian influenza
AC	Alpha-chloralose
APHIS	Animal and Plant Health Inspection Service
BHI	Bird hazard index
bTB	Bovine tuberculosis
CDV	Canine distemper virus
CPV	Canine parvovirus
CRADA	Cooperative Research and Development Agreement
DDE	Dichlorodiphenyldichloroethylene
DMA	Denver Metro Area
DNA	Deoxyribonucleic acid
EPA	U.S. Environmental Protection Agency
FAA	Federal Aviation Administration
FDA	U.S. Food and Drug Administration
FID	Flight initiation distance
GonaCon	GonaCon Immunocontraceptive Vaccine
MCT	Multiple capture trap
NWDP	National Wildlife Disease Program
NWRC	National Wildlife Research Center
ORV	Oral rabies vaccination
PCB	Polychlorinated biphenyl
PIT	Passive integrated transponder
TMC	N,N,N trimethylated chitosan
USDA	U.S. Department of Agriculture
UV	Ultraviolet
WS	Wildlife Services

Issued June 2014