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

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

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Cover Photo: NWRC scientists recently compiled the results of more than 40 years of research on blackbird damage to sunflowers. Studies ranged from basic blackbird ecology and behavior to the development of repellents, scare devices, and habitat modification techniques to reduce bird damage. *Photo by USDA Agricultural Research Service*

Message From the Director

Larry Clark, NWRC Director
Photo by USDA, Gail Keirn

The many demands on our time often leave us caught up in the day-to-day business at hand, forgetting to take time to reflect upon where we fit into the bigger picture. The annual NWRC Accomplishments Report gives us an opportunity to reflect and take stock of where we are, how we are doing, and where we are going.

Some of the most pressing issues facing us now and into the foreseeable future relate to how we accommodate the world's growing population and mitigate the resulting negative impacts to the environment as resources become more and more limited. It is estimated that the world's population will be 9 billion people by the year 2050. Producing enough food to meet demands, distributing the food, creating an economically sustainable production capacity, and minimizing the associated environmental impacts are complex, global challenges. Australia, Canada, the United States, and Europe are projected to carry out most of the food production that will supply the impoverished areas of the world. This means efficient and intensified agricultural practices, which will increasingly place demands on our natural resources. The dilemma in any intensified agroecosystem is to balance the pressing need for production without devaluing natural resources.

Such challenges require a "One Health" approach, whereby experts from multiple disciplines collaborate to attain optimal health for people, animals, and

NWRC plays a key role in One Health initiatives by conducting research on issues that impact animal, human, and environmental health.

the environment. The National Wildlife Research Center has an important role in One Health because of its expertise on issues occurring at the agriculture-human-wildlife interface. Our experts provide information and methods to policymakers and managers to help them resolve such issues. This is an awesome responsibility, and the staff of NWRC should take pride in their efforts and contributions toward increasing agricultural production in a socially responsible manner.

This past year, five NWRC projects have completed their 5-year project cycle. This is a period in which the NWRC takes stock of its contributions and accomplishments. We highlight three of these efforts in this report. There is no doubt that productivity was impressive. However, the true measure of success will be incorporating our information and methods into new management practices, the transfer of technologies, and improved economies for agroecosystem sustainability. The fact that NWRC technologies are being pursued for licensing by the private sector and our information is being used by academics and managers is a testament to our impact.

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

Larry Clark, Director
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Research Spotlights

The National Wildlife Research Center (NWRC) is the research arm of Wildlife Services (WS), a program within the U.S. Department of Agriculture's (USDA) Animal and Plant Health Inspection Service (APHIS). NWRC's researchers are dedicated to finding biologically sound, practical, and effective solutions to resolving wildlife damage management issues. They seek these solutions using a multiyear, multidisciplinary project management system.

NWRC identifies and prioritizes projects based on feedback from WS program leaders, managers, and stakeholders concerning their most pressing wildlife damage management needs. Projects are 3 to 5 years in duration, have clearly stated goals and objectives, and identify milestones and expected outputs that require annual and final project reviews. NWRC uses the process not only to achieve specific research objectives within broader administrative directives, but also to develop new research projects to address important, emerging human-wildlife conflict issues.

During 2014, five research projects reached the end of their 5-year life cycle. At the final project reviews, project leaders and their staff presented and discussed each project's accomplishments, challenges, and findings. The following sections spotlight three of the completed projects.

Spotlight: Addressing Bird Damage to Agriculture, Feedlots, Dairies, and Urban Environments

NWRC's field station in Bismarck, ND, and its associated scientists support the research project "Methods Development and Population Biology of Blackbirds and Starlings in Conflict with Agriculture, Concentrated Animal Feeding Operations and Urban Environments." These experts routinely work with producers; commodity groups; research boards; universities; and local, State, and Federal agencies to reduce bird damage to crops, feedlots and dairies, and property. Traditionally, research has focused on developing scare devices, repellents, and habitat

It is estimated that more than 27 million red-winged blackbirds, 13 million common grackles, and 12 million yellow-headed blackbirds migrate through the Great Plains Region of the United States each year. These birds can cause considerable damage to agricultural crops, such as sunflower and rice.

Photo by USDA, Jeff Homan

NWRC research helps to reduce the damage suffered by agricultural and livestock producers from the more than 200 million invasive European starlings in North America.

modification techniques to reduce damage on seeded and ripening sunflower, corn, rice, and fruit crops and to improve profitability for growers. More recently, research has focused on disease issues and livestock feed consumption related to birds at feedlots and dairies, as well as impacts of large flocks of birds in urban environments. To develop new methods and tools, scientists conduct multifaceted studies involving the use of both captive and free-ranging birds.

Over the past 5 years, NWRC researchers focused their efforts on developing methods to reduce damage caused by blackbirds and invasive European starlings and obtain a better understanding of the effects local and regional management actions have on the biology and ecology of these birds. Additionally, researchers focused on nonlethal methods, such as bird repellents for food crops. Below are a few of the project's major accomplishments from the past 5 years.

40 Years of Blackbird-Sunflower Research

Sunflower is a globally important oilseed crop that is grown on approximately 59 million acres (24 million hectares) worldwide. Because of its high energy content, numerous bird species—from doves and parakeets to crows and cockatoos—feed on the crop. In the United States, blackbirds cause most of the bird damage to sunflowers, which are grown primarily in North Dakota and South Dakota. Annually, red-winged blackbirds, common grackles, and yellow-headed blackbirds combined eat about 19,000 metric tons of sunflower in these States ($7 million, at $0.37/kilograms; 2010 data from the National Sunflower Association), a figure based on bioenergetics estimates.

For nearly 40 years, NWRC researchers and their collaborators have worked to reduce blackbird damage to sunflowers by studying the life history and ecology of blackbirds and by testing a variety of chemical and physical frightening agents, aversive repellents, bird-resistant sunflowers, decoy crops, habitat management, population management, and cultural modifications in cropping.

"Managing bird damage to crops like sunflower falls into three main categories—frightening, evading, and population control," says George Linz, NWRC's North Dakota field station leader and project leader of the blackbird project. "From our decades of research and experience, we believe methods that focus on evasion have the best chance of long-term success. Evasion methods such as decoy crops, habitat management, and alternative harvesting regimes focus on manipulating the environment versus the birds."

As part of the research project's 5-year cycle, Linz and colleagues published a formal review in *BioScience* on (1) the efficacy and economic viability of current bird-damage management strategies for sunflower, (2) methods previously tested in the field and later abandoned for lack of efficacy or safety, and (3) future directions of bird-damage research. In summary,

researchers believe the following are the most effective, economically viable, and practical strategies for reducing blackbird damage to sunflower crops: habitat management of roosting sites, plant desiccants to accelerate harvest time, and decoy crops.

In the next decade, researchers anticipate an effective bird repellent will be registered for use on ripening sunflowers (and other grain crops) and a perennial sunflower variety will be developed that could be used as part of a decoy crop regime and alternative food source for birds. Alternative sources of foods, possibly in combination with repellents, should help make significant advances in the management of blackbird damage to sunflower crops.

Bird Repellents

California is the largest agricultural producer in the United States. In 2012, California's 80,500 farms and ranches produced a record $44.7 billion in produce, dairy, and meats. With more than 400 crop varieties grown in the State, California produces nearly half of all fruits, nuts, and vegetables grown in our country.

To help safeguard these vital resources, the California Department of Food and Agriculture (CDFA) partners with NWRC to address wildlife damage issues and develop repellents to protect crops from birds.

Birds cause substantial damage by feeding on newly planted or ripening crops. For example, horned larks damage lettuce, spinach, carrots, beets, turnips, and peas; American crows damage almonds; great-tailed grackles eat a variety of citrus crops; and wild turkeys consume an assortment of crops, from corn and wheat to strawberries, peanuts, and ginseng. In a recent study, NWRC economists estimated that bird damage to California's wine grape, blueberry, and cherry crops alone accounted for $64 million in losses each year.

From 2010 to 2013, NWRC experts and colleagues at the University of Mississippi and Arkion Life Sciences, LLC, conducted a series of CDFA-funded studies to test the effectiveness of an anthraquinone-based bird repellent to protect almonds, lettuce, melons, and ginseng from bird damage. Some anthraquinones, which occur naturally in plants, cause repellency in some animals. In addition, anthraquinone absorbs near-ultraviolet (UV) light, a portion of the light spectrum that is not visible to humans but is visible to birds. NWRC studies have shown this visual cue facilitates a compound's repellency effect in birds.

Horned larks were among several bird species used in NWRC studies to evaluate the effectiveness of an anthraquinone-based bird repellent for food crops.
Photo by USDA, Scott Werner

From previous feeding experiments, NWRC researchers learned that blackbirds shift preferences for both familiar and unfamiliar flavors based on their feeding experiences, and they rely on visual cues to avoid food previously associated with negative consequences. As NWRC research wildlife biologist Scott Werner explains, "Blackbirds avoided the color and flavor of food previously paired with a post-ingestive repellent. In contrast, birds avoided only the color, not the flavor, of food previously paired with a pre-ingestive irritant. These fundamental relationships are helping us develop effective bird repellents for agricultural production."

In studies with captive horned larks, American crows, great-tailed grackles, and wild turkeys, scientists identified the minimum amount of an anthraquinone-based repellent needed to reduce bird consumption of repellent-treated crops by at least 75 percent. One study also showed that wild turkeys who 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 repellents and even reduce the need for repellent applications since, once birds gain experience, they will avoid crops that are UV-treated. These studies aid in the development and registration of economically feasible, safe, and effective bird repellents for use on food crops.

Take Estimation Model for Toxicant DRC-1339

During the fall and winter, millions of invasive European starlings, common grackles, red-winged blackbirds, and brown-headed cowbirds descend upon feedlots and dairies to take advantage of easily accessible livestock feed and water sources. Producers often ask for assistance from WS in reducing damage caused by these birds.

DRC-1339 is a slow-acting toxicant used at feedlots, dairies, and bird roosting sites to reduce local populations of invasive European starlings, blackbirds, and other birds. The use of DRC-1339 is restricted to WS professionals, and take (i.e., number of animals lethally removed) is limited to that allowed under the U.S. Migratory Bird Depredation Permit. It is difficult to estimate the number of birds killed with DRC-1339 because it is a slow-acting toxicant and birds frequently leave the area before dying. Thus, carcass searches and other types of onsite counts are inaccurate for estimating mortality.

In an effort to improve mortality estimates and ensure local management activities do not jeopardize the long-term health of native blackbird populations, NWRC researchers developed a model based on the total amount of toxicant bait consumed at each site, birds' bioenergetics requirements under different environmental conditions, and the known toxicity of DRC-1339 to different species of birds. Because the model takes into account the effects of meteorological and environmental conditions such as temperature, wind speed, and cloud cover—all factors that influence bird feeding rates—scientists are better able to estimate the average amount of food consumed by each bird and subsequent mortality at specific sites.

Take estimates obtained with the new model are more scientifically rigorous than models previously used. Having more accurate estimates of mortality helps ensure that management actions do not negatively impact the long-term health of native bird populations. WS experts are required to use the new model to estimate bird take for all DRC-1339 operations.

Bird Damage to Dairies and Feedlots

More than 200 million invasive European starlings live in North America. When gathering in large flocks, these birds exact a heavy toll on feedlots and dairies by eating cattle feed and potentially spreading disease by contaminating feed and water troughs. A recent NWRC economic assessment of starling damage to dairy farms in Pennsylvania estimated that losses exceed $10 million annually due to bird consumption of feed and related increases in feed spoilage and veterinary expenses. Specifically, results showed that Pennsylvania dairies lose about 178 million pounds of feed to starlings each year and that dairies with large starling populations had higher occurrences of Johne's disease and Salmonella in their herds.

Invasive European starlings can descend on cattle feeding operations, consuming feed intended for livestock, defecating in feed bunks and water troughs, and spreading disease. NWRC scientists are studying the role these birds may play in the spread of disease. *Photo by USDA*

Characterizing and mitigating diseases introduced by starlings to these areas can reduce the spread of micro-organisms throughout the environment while increasing agricultural productivity. To better understand the disease risks associated with starlings at feedlots and dairies, NWRC scientists assessed the role the birds play in the spread of bovine coccidiosis, *Salmonella enterica*, and antimicrobial-resistant bacteria. Of the pathogens studied, scientists found that *S. enterica* contamination of cattle feed and water troughs increased as more starlings entered feed troughs, indicating that starlings are a source of *S. enterica* contamination. Similarly, *S. enterica* disappeared from feed troughs and substantially declined within water troughs after starling control operations at a large livestock facility in Texas. Subsequent genetic analyses of the *S. enterica* samples collected from cattle and starlings were indistinguishable based on pulsed-field gel electrophoresis, meaning both cattle and starlings were infected with the same strain of bacteria. The researchers concluded that reducing starling populations with lethal control methods, habitat management, exclusionary devices, and bird repellants may reduce the amplification and spread of this disease within livestock production systems.

Next Steps—NWRC blackbird and European starling research will continue to focus on the development of repellents for use in pre-plant seed treatments, as well as sprouting and ripening applications of these crops. Researchers will also continue efforts to combine bird repellents with rodenticide bait to avoid bait consumption by birds, evaluate and expand perennial crop plantings as decoy crops for managing bird damage, and quantify impacts of birds on milk and beef production. New areas of research with

NWRC's research related to chronic wasting disease and bovine tuberculosis focuses on practical tools for detecting and preventing these destructive diseases.

university collaborators will involve evaluating the use of unmanned aerial systems to deter bird use of grain fields and fruit orchards. Researchers will also seek to improve bird predator effigies and distress calls by assessing birds' physiological response to predation stress.

Spotlight: Managing Disease and Damage Associated With Deer and Elk

As increased urbanization and development lead to a loss of traditional wildlife habitat, the potential for conflicts between people and wildlife increases. Such conflicts can take many forms, including damage to agriculture and transmission of diseases among wildlife, livestock, and humans. Two diseases in particular—chronic wasting disease (CWD) and bovine tuberculosis (bTB)—can be found in wild and captive deer and elk and are a concern to wildlife managers, captive deer farmers, and livestock producers.

NWRC research has shown that scavengers, such as American crows and coyotes, can pass CWD-positive tissues through their digestive systems and infect new areas. *Photo by Belwin Outdoor Science, trail camera*

CWD is caused by modified rogue proteins called prions that affect the central nervous system and result in lesions in the brain. It infects elk, white-tailed deer, mule deer, and moose, but is not known to naturally infect other species of wildlife, livestock, or people. There is no treatment for CWD, and it is typically fatal in deer and elk. The threat of CWD has significant implications for Federal and State wildlife-management agencies, domestic deer and elk farmers, hunters, and businesses and economies reliant on deer and elk. In addition, these groups need additional and improved tools and management techniques to reduce the transmission, prevalence, and persistence of CWD in wild and captive animals.

Tuberculosis is a contagious, bacterial disease of both animals and humans; bTB can be transmitted from infected animals to humans and other animals. The significance of the disease is reflected in APHIS' efforts to eradicate bTB from the United States. The bTB eradication program, which started in 1917, has made significant progress over the years. By the mid-1990s, only a few known infected cattle herds remained, suggesting that eradication of the disease in the United States was imminent. However, deer and elk in Michigan, and occasionally other States, remain infected. Between 1975 and 1998, bTB was documented in Michigan's white-tailed deer with increasing prevalence, and scientific evidence revealed that infected deer transmitted the disease to some of Michigan's cattle.

NWRC studies found that mineral licks with high concentrations of sodium and manganese attracted high numbers of elk and deer in Rocky Mountain National Park and may increase the risk for environmental transmission of infectious pathogens, such as CWD.
Photo by USDA, Michael Lavelle

NWRC's "Management of Ungulate Disease and Damage" research project is dedicated to gaining a better understanding of CWD, bTB, and other diseases in wild and captive deer and elk, as well as the development of tools and strategies to manage and control agricultural damage and disease spread among wildlife and livestock. Below are several recent project accomplishments highlighting the breadth and depth of studies undertaken by NWRC scientists in these areas.

Role of Scavengers and the Environment in Spreading CWD

Since it was first detected in Colorado in 1967, CWD has spread to 18 States in our country. Much of the spread has been attributed to the movement of captive deer and elk, but there are some CWD-infected areas where no captive animal facilities are present. NWRC researchers studied whether scavengers such as American crows and coyotes may be able to pass CWD-positive tissue through their digestive systems and infect new areas.

In laboratory studies, captive mice were fed fecal extracts from American crows that were force-fed prion-positive material. All of the mice subsequently showed severe neurological dysfunction. Results suggest that prions can survive the crow's digestive system, and a crow that scavenges on a CWD-positive carcass can potentially transport infective prions a long distance and deposit them via their feces in new locations. A similar study with captive coyotes showed these animals can also pass infectious prions via their feces for at least 3 days after ingestion. Therefore, these common North American scavengers may also play a role in the geographic spread of CWD and other prion diseases.

Determining all potential CWD transmission routes in wild animals is important in controlling and preventing the disease. Much time and effort has been spent studying how prions are spread and maintained in the environment. For instance, scientists recently investigated whether inhaling CWD prions located in soil and dust can cause disease. NWRC researchers inoculated the nasal passages of captive white-tailed deer with a mixture of montmorillonite clay dust (a common soil component in the American West) and either CWD-positive or CWD-negative brain homogenate. The deer were euthanized, and samples were collected at necropsy for immunohistochemistry analysis. Results show that montmorillonite clay dust is an efficient carrier of CWD. CWD-positive tissues were observed in deer as early as 98 days after the last inoculation. This verifies that the intranasal route is a viable route of infection and that dust, a natural route of exposure, is capable of delivering the infected material through breathing.

In another study, NWRC scientists examined the role mineral licks may play in the spread of CWD. Free-ranging deer and elk acquire most of their essential minerals through their forage, although they occasionally seek other sources to account for seasonal

NWRC researchers erected a polypropylene mesh fence along the wooded edge of a field in conjunction with extensions (or "wings") at either end, placed perpendicular from the fence line. This more cost-effective fence design reduced deer damage to crops within the fence, without having to enclose the area entirely. *Photo by USDA, Michael Lavelle*

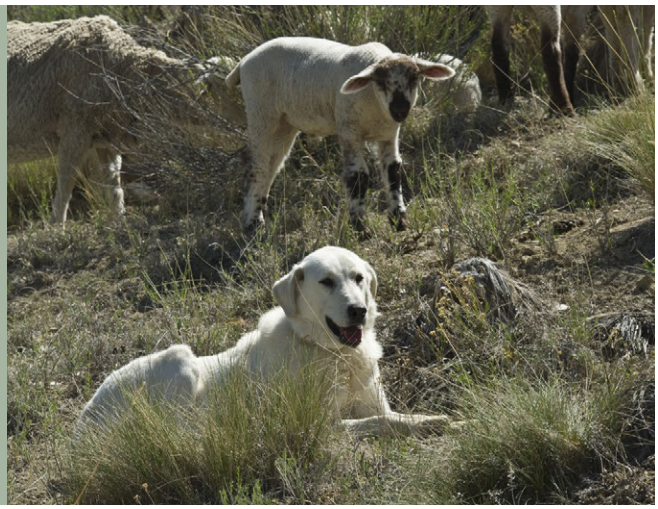
mineral deficiencies. Mineral sources occur as natural geological deposits (i.e., licks) or as anthropogenic mineral supplements. In both scenarios, these sources are commonly visited by a variety of animals. NWRC researchers monitored 11 licks in Rocky Mountain National Park, CO, using trail cameras to quantify daily visitation and soil consumption for elk and mule deer. The researchers also collected soil samples and compared mineral concentrations.

Results showed that visitation and soil consumption were greatest at two wet, low-elevation licks exhibiting relatively high concentrations of manganese and sodium. Because deer and elk are known to seek sodium from soils, researchers believe their observed association of manganese is likely a consequence of deer and elk seeking supplemental dietary sodium. Researchers note that mineral licks provide an area of high deer and elk visitation and interaction. This increases the risk for environmental transmission of infectious pathogens such as CWD, which can be shed in the saliva, urine, and feces of infected animals. Once in the environment, CWD prions are difficult to destroy and can remain there until consumed or inhaled.

"Gaining a better understanding of how prions spread through the environment and become available to animals adds yet another piece to this challenging disease puzzle," says Kurt VerCauteren, leader of the "Management of Ungulate Disease and Damage" research project. "Our next steps as scientists will be to figure out how best to prevent this spread."

Physical Barriers and Scare Devices To Prevent Disease and Damage

Whether it's a reliable watering hole, lush pasture, or pile of winter hay, wildlife and livestock often use the same resources. Such sharing and potential



Although livestock protection dogs have traditionally been used to prevent predation, NWRC studies have shown that these dogs can also prevent deer and other wildlife from accessing pastures and stored feed and are useful in separating cattle from deer and elk that may be disease reservoirs. *Photo by USDA, Anson Eaglin*

interactions may result in damage to crops or livestock feed and allow the spread of diseases such as bTB. As NWRC research wildlife biologist Kurt VerCauteren says, "Many infectious diseases are spread among animals by contaminated food, water, and soil or by direct contact between individual animals. The best way to control the spread of disease between livestock and wildlife is through effective biosecurity, husbandry, and pasture management."

As part of an international collaboration with the Instituto de Investigacion en Recursos Cinegeticos of Spain, NWRC researchers evaluated the effectiveness of exclusion devices, such as cattle-operated bump gates and fencing, for reducing bTB transmission between domestic cattle and wild ungulates at watering holes in Spain. 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 were designated "wildlife-only" sites. Cattle-only sites were surrounded with a wildlife-proof, 8-foot fence and a cattle-specific gate. Many cows learned to operate the cattle-specific gates quickly, with other cows learning from them. Within 2 weeks, approximately 70 percent of the cows routinely entered and exited through the cattle-specific gates. Wildlife-only sites were surrounded by a 4-foot fence that red deer and other wildlife could jump into or enter through small openings but cattle could not do so. Throughout the study, cows were unable to access the wildlife-only sites. The study demonstrates how simple, low-cost fencing strategies can serve as effective biosecurity measures for reducing contact and disease transmission between cattle and wildlife.

NWRC researchers have also studied various fencing strategies and designs in the United States to reduce deer and elk damage, as well as disease spread between livestock and wildlife. In one study, NWRC experts used a poly-mesh fence with side extensions, or "wings," to separate good deer cover from agricultural fields where crop damage by deer occurred primarily along the edge. The design used a 7-foot-high polypropylene mesh fence erected along the wooded edge of a field with either 164-foot or 492-foot wings extending perpendicular from the fence line and wooded habitat. Fences reduced deer damage in cornfields by 13.5 percent, which equals a net gain of approximately $265 per hectare. Researchers found no difference in damage between fences with 164-foot and 492-foot wings and concluded that poly-mesh fences with 164-foot wings were cost-effective at reducing damage by deer to corn without having to enclose the area entirely. Researchers are continuing to study the effectiveness of other fencing materials such as high-tensile and poly-tape fences with wings.

In a similar effort, NWRC and University of Minnesota scientists conducted an experiment in northwestern Minnesota to identify an effective way to prevent deer from eating and contaminating stored livestock feed during winter months. Typically, permanent woven-wire fences, approximately 8- to 10-feet high,

Ensuring the long-term health and biodiversity of island ecosystems is one goal of NWRC's invasive species research in the Pacific.

are used to prevent deer from accessing stored feed. In the study, researchers examined 4-foot tall electric fences made up of four strands of bipolar tape. Bipolar fences have an advantage over other electric fences because the offending animal does not have to be grounded to receive a shock, which can be a problem in areas prone to deep snowfall. Deer activity was monitored by camera at 21 artificial feeding sites. Scientists found that the bipolar fences effectively deterred deer more than 80 percent of the time. They caution, however, that even though the bipolar fence's level of efficiency is high, in areas where bTB is high, the bipolar fence should be used only temporarily until a more effective and permanent strategy such as woven-wire fences can be implemented. The scientists also note that the fence could be used to reduce deer access to gardens, small orchards, or seasonal resources. Future studies will focus on the use of the bipolar fence in conjunction with other preventative methods such as guard dogs or frightening devices.

In addition to fencing and other barriers to prevent damage and disease, NWRC experts have studied and encouraged the use of livestock protection dogs to protect an array of resources from wildlife. Although livestock protection dogs have traditionally been used to prevent predation, NWRC studies have shown that the dogs can also prevent deer and other wildlife from accessing pastures and stored feed and are useful in separating cattle from deer and elk that may be reservoirs of disease.

"We want to develop tools and techniques that are inexpensive and easy to use, such as fencing and dogs, so that private landowners and producers help themselves and play a larger role in protecting their property and livestock," concludes VerCauteren.

Next Steps—Future NWRC research on deer, elk, and other ungulates will focus on the development of a live test for CWD, methods for detecting bTB and other diseases using volatile organic compounds, strategies for oral delivery of pharmaceuticals, and the development of nonlethal tools to reduce disease and damage.

Spotlight: Invasive Species Impacts to Islands

Oceanic islands like the Hawaiian archipelago are more susceptible to the impacts of invasive species than mainland areas because they have evolved in ecological isolation and have few defenses against predators or competitors. These islands also have a lot of air and sea traffic and typically provide a favorable habitat and climate for many introduced species to thrive. Furthermore, native species on the islands evolved in the absence of many introduced threats and usually respond poorly to invasive animals or disease.

Invasive species are among the greatest threats to Hawaii's agricultural economy, natural environment, and the health and lifestyle of the Hawaiian people. Invasive vertebrate species cause millions of dollars in crop losses, the extinction of native species, the

destruction of native forests, the spread of disease, and threats to the health and safety of residents. Scientists at the NWRC Hawaii field station are investigating a variety of methods to reduce damage caused by invasive rodents, coqui frogs, brown treesnakes, birds, mongooses, and feral ungulates in Hawaii, as well as throughout Pacific islands linked to Hawaii via transport and trade.

The ghost crab is one of several land crab species found on the Palmyra Atoll, a remote island in the Pacific Ocean. NWRC experts evaluated the effectiveness of a rodent eradication effort on the island and its impacts to native plants and animals. *Photo by USDA, Are Berensten*

Experts at NWRC's field station in Hilo, HI, focus primarily on invasive species ecology and management to protect agricultural crops and native ecosystems on islands. The following summaries highlight recent accomplishments of the field station's research project titled "Methods and Strategies to Manage Invasive Species Impacts to Agriculture, Natural Resources, and Human Health and Safety."

Ensuring Safe Rodent Eradication Efforts

Rodenticides are commonly used throughout the world to eradicate or reduce invasive rodent populations from islands. Because of their expertise in rodent ecology, toxicology, and pesticide registration and use, NWRC and other WS experts have assisted with and/or evaluated the effectiveness of several of these efforts in the Pacific and Caribbean islands.

For example, in 2011, the Palmyra Atoll Rainforest Restoration Project (composed of the U.S. Fish and Wildlife Service, The Nature Conservancy of Hawaii, and Island Conservation) attempted to eradicate rats from Palmyra Atoll—a remote island in the Pacific Ocean, approximately 1,000 miles south of Hawaii—in an effort to enhance the biodiversity of seabirds, native plants, and terrestrial invertebrates. The eradication was carried out through aerial and ground application of the rodenticide bait Brodifacoum 25W Conservation.

In a comprehensive evaluation effort, NWRC scientists not only measured the application rate and bait distribution following aerial application and documented the fate of the bait, but also collected potential nontarget mortalities and soil, water, insects, geckos, fish, and crabs to determine environmental residue levels.

"Our goal was to document and evaluate any secondary hazards associated with the eradication effort," says NWRC wildlife biologist Are Berensten. "We also wanted to know whether the baits were affected by the high humidity and temperatures and if competition for baits by nontarget animals, such as land crabs, impacted the overall success of the effort."

Researchers found the overall rodenticide application rate on the atoll to be within the limits specified by the U.S. Environmental Protection Agency's (EPA) approved supplemental label. However, they also documented bait in the aquatic environment and considerable variation in the amount applied over small, localized areas. Following aerial bait applications, NWRC researchers monitored the condition of bait in four terrestrial environments and in the canopy foliage of coconut palms. One terrestrial site showed nearly 100 percent bait persistence after both applications, likely due to low localized rat and land crab densities. Most pellets disappeared in 1 to 2 days in terrestrial sites and 2 to 4 days in canopy sites. Frequent rainfall likely contributed to the rapid degradation of bait pellets in coconut palm fronds.

For future eradication efforts on similar islands, NWRC researchers recommend the following: (1) have an understanding of the land crab population, or other competitors for bait on an island, to aid in establishing application rates; (2) ensure baits persist and remain attractive to rats—bait degradation due to heavy and frequent rains can have a profound impact on bait longevity and availability to rats; and (3) have an understanding of local rat behavior and ecology to assist in determining whether direct hand-baiting in canopies is warranted, given the potentially high rate of bait disintegration due to pooled rainwater and rodent foraging on the ground.

Although efforts were made to reduce secondary hazards to native wildlife, some impacts did occur. NWRC researchers found rodenticide residues in ants, cockroaches, geckoes, hermit crabs, fiddler crabs, and black-spot sergeant fish. Fifty-one animal samples representing 15 species of birds, fish, reptiles, and invertebrates were found dead; they were collected for residue analysis during systematic searches or collected opportunistically as potential nontarget mortalities during regular activities throughout the atoll. NWRC researchers detected rodenticide residues in 12 of 15 birds that were found dead on or around the atoll after the bait application. Nontarget exposure to the rodenticide likely resulted from direct consumption of bait and secondary exposure through scavenging of poisoned carcasses.

The Palmyra Atoll Rainforest Restoration Project has deemed the overall eradication effort a success. Rats have not been detected on the atoll since 2012. Researchers monitoring the site also report a 130-percent increase in native tree seedlings and a 367-percent increase in native insects, spiders, and crabs. This type of collaboration, evaluation, and monitoring is critical to the success of such efforts and serves as a guide for future invasive vertebrate eradication projects.

Aerial Bait Drops Aim To Reduce Invasive Brown Treesnakes on Guam

One of the most notable invasive species in the Pacific—the brown treesnake—was accidentally introduced to the island of Guam soon after World War II, probably as a stowaway in ship cargo. With the absence of natural predators and other population controls, the brown treesnake population on Guam has grown to an estimated 1 to 2 million. The snake is responsible not only for the extinction of most native bird, bat, and lizard species on the island, but also for approximately $1 million to $4 million in damages and lost productivity to the island's economy and electrical grid each year.

Since the early 1990s, the NWRC has been actively involved in collaborative efforts with the U.S. Territory of Guam and the U.S. Department of Defense to reduce the number of brown treesnakes on the island and prevent the snake's spread. NWRC scientists have developed and/or evaluated a wide range of tools and methods including snake traps, chemical

To reach invasive brown treesnakes in the more remote and rugged areas of Guam, NWRC researchers are testing a new aerial bait delivery system that consists of a biodegradable streamer that snags onto tree branches where the snakes feed. *Photo by USDA*

repellents, fumigants for cargo containers, and acetaminophen—the only EPA-registered snake toxicant. These and other tools are used by WS field specialists and local partners on a daily basis. More than 150,000 snakes have been removed from the transportation system in Guam, and no live brown treesnakes have been detected at Hawaiian ports of entry in almost 20 years due to a cooperative interdiction and education program. The unintentional movement of snakes as a result of shipping or travel is a very real danger to all islands in the western Pacific basin and sections of the U.S. mainland. The economic costs of potential brown treesnake colonization to the Hawaiian Islands alone are estimated to be as high as $2 billion annually.

In 2013, the NWRC's Hawaii field station, in cooperation with the Guam Department of Agriculture, WS Operations, and the U.S. Departments of Defense and Interior, deployed an aerial baiting technique with the goal of significantly reducing the number of brown treesnakes in targeted areas of northern Guam. The successful aerial delivery of bait is a critical next step toward developing an effective method for large-area control of the snakes, particularly in remote and inaccessible parts of the island. The technique uses dead mice as baits, each inserted with 80-milligram tablets of acetaminophen. Earlier NWRC research and environmental assessments showed the method to be safe, that brown treesnakes readily accept dead mice as bait, and that acetaminophen is fatal to the snakes typically within 24 hours. The bait is fitted to a biodegradable streamer-like device designed to snag onto branches in the dense tree canopy where the snakes feed. The impact of the bait on other species is minimal, particularly since the snakes have eliminated most of the species that might have been most at risk.

"We hope to answer some basic questions about how often baits need to be dropped to have the biggest impact on the snake population," says NWRC's Aaron Shiels. "When dealing with such a large area, aerial deployment of bait appears to be a more efficient method than ground-based baiting. It is hard to know how many snakes are out there and whether some areas need to receive higher bait application rates than others. Also, we'd like to know if and how quickly snake populations recover after baiting in order to design appropriate and effective baiting strategies."

In the future, Shiels and others expect aerial bait drops will be more efficient once work is completed on a new automated bait broadcast device. The device, which was developed in collaboration with Applied Design Corporation, will allow for the aerial delivery of hundreds of mouse baits in a much shorter period than any other technique that has been previously developed. Another cost-saving effort underway, but still several years off, is the development of an artificial bait that is attractive to the snakes and lasts longer in the tropical environment than the current mouse bait.

"Though the mouse baits work well at attracting snakes, they decompose quickly in Guam's hot and humid climate and, therefore, only remain attractive to snakes for a few days after deployment," notes Shiels. "An artificial bait that lasts longer could help us reach more snakes."

NWRC scientists and partners are hopeful these new techniques will reduce snake numbers enough not only to aid current interdiction efforts and reduce the costly economic damages associated with the snake, but also to allow for the eventual reintroduction of native birds and the restoration of Guam's ecosystems.

Endangered Species Protection

Scientists estimate that Hawaii is home to thousands of native plant, animal, and insect species found nowhere else in the world. Unfortunately, invasive species can threaten the long-term health and existence of this unique ecosystem. Experts at the NWRC Hawaii field station develop and evaluate new management methods to reduce the impacts of invasive species on native plants and animals, including endangered species.

The 'ope'ape'a, or Hawaiian hoary bat, is the only native land mammal in Hawaii. The solitary bat species roosts in trees and gets its name from its heavy fur coat and white-tipped ears that give it a frosted look. The Hawaiian hoary bat was listed as an endangered species in 1970, and its population continues to be impacted by loss of habitat, predation, and pesticide use. NWRC researchers conducted field and laboratory experiments to assess nontarget impacts on bats of spray applications of citric acid, a registered minimum-risk pesticide used to control invasive coqui frog populations on Hawaii Island.

"Hoary bats are an important part of Hawaii's ecosystem," says NWRC researcher Aaron Shiels. "We want to ensure that management efforts to control invasive species on the islands are safe for the bat and other native species."

Researchers studied the effects of citric acid on surrogate big brown bats. Results showed citric acid was toxic to the bats when 0.10 milliliters or more solution was ingested. However, bats sprayed with 5 milliliters of citric acid solution did not show signs of intoxication from licking, grooming, or direct skin absorption. Based on observations, researchers believe Hawaiian hoary bats are at very low risk from harmful exposure of citric acid during frog control operations.

NWRC researchers also evaluated the effectiveness of control efforts to reduce rodent consumption of endangered Hawaiian lobeliod plants (*Cyanea superba*). At a 64-acre (26-hectare) site on Oahu Island, invasive black rat consumption of lobeliod fruit was monitored at 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 destroyed or dispersed the seeds of this endangered plant, 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 the fruit and seeds. NWRC 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 the successful restoration of particular native plants such as *Cyanea superba.*

NWRC researchers studied the impacts of invasive house mice and black rats on endangered Hawaiian lobeliod plants. Results have shown black rats to negatively impact the reproductive success of the plants by consuming the entire fruit and killing the seeds.
Photo by WikiCommons, David Eickhoff

Next Steps—NWRC will continue efforts to develop safe and effective strategies to reduce invasive species impacts to agriculture, natural resources, and human health and safety in island ecosystems. In particular, experts will focus on the development and evaluation of control methods such as the use of toxicants, traps, and barriers. Examples include the use of aerially broadcast bait on Guam to control brown treesnakes, laboratory trials to determine the most effective bait for invasive mongoose, and large-scale invasive rodent trapping in conservation areas on the islands of Hawaii, Maui, and Oahu. Basic research on the biology and ecology of invasive animals will aid in developing and enhancing control methods. Future studies will likely focus on the effects of habitat alterations and enhancements on invasive species, wildlife disease, and dietary assessments to determine invasive species impacts to native species and agriculture.

2014 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 2014 not previously mentioned in this year's report.

Devices

- **The Evolution of Flow Devices Used To Reduce Flooding by Beavers.** Following centuries of over-harvest, the American beaver has made a comeback and now occupies much of its historical range in North America. But with this successful recovery comes a variety of challenges for managing beaver damage due to flooding from beaver dams and plugged culverts. Resolving beaver flooding conflicts requires an integrated approach that includes both lethal and nonlethal techniques.

  In a recent review, NWRC researchers highlighted the evolution of modern nonlethal approaches to control water levels at beaver dams. Traditional nonlethal methods for dealing with beaver flooding involve either exclusion or deception. Fence systems exclude beavers from certain areas, while pipe systems attempt to modify beaver behavior by reducing water sound and movement. Although there is no scientific evidence to back it up, some believe that beavers are attracted to the sound and movement of water, which cues their damming behavior. Not until the 1980s–1990s were exclusion and deception combined to create flow devices such as the Clemson pond leveler, or flexible pipe and fence systems that allow managers to maintain desired water levels and reduce flooding. In some instances, flow devices may be an effective nonlethal tool for maintaining beaver ponds. However, in many instances, they were not effective; researchers noted that most device failures were due to beavers moving their activities up- or downstream and managers not properly maintaining devices.
  Contact: Jimmy Taylor

Nonlethal flow devices are used to maintain desired water levels in beaver ponds while reducing flooding caused by beavers. *Photo by USDA, Russell Singelton*

- **Cameras Record Selectivity of M-44s.** The accidental take of nontarget wildlife during wildlife damage management activities is a concern for WS professionals, natural resource managers, and

conservationists alike. To ensure the incidence of this is low, experts work to make tools as selective and effective as possible. The M-44, or sodium cyanide ejector, is one such tool that researchers continue to study and refine. Used to lethally remove coyotes and other canids for the protection of livestock or other resources, the spring-loaded device is designed to be staked into the ground. When the top of the device is baited with an attractant, it prompts a bite-and-pull response. Once activated, the device sprays the toxicant into the animal's mouth.

NWRC researchers used motion-activated cameras to record the number of target and nontarget animals triggering M-44s, as well as those that were attracted to and investigated the devices. Nineteen different species were observed at M-44 sites on 1,697 occasions. Coyotes were photographed within 1 meter of the device on 34 occasions and smelling, licking, or biting the device on 11 occasions. Sheep, cows, and deer were the most frequent visitors to the sites; respectively, they visited on 925, 378, and 114 occasions. Of all the species, only cows were more likely than coyotes to smell, lick, or bite the device. However, of all the species investigating the device, only canids were able to trigger it. M-44s were triggered 39 times: 36 times by coyotes, 2 times by feral dogs, and 1 time by a red fox. No non-canid species triggered the devices, suggesting a very high selectivity toward canids. Researchers note the development of coyote-specific lures would further improve the selectivity of M-44s.
Contact: Julie Young

- **Improved Satellite Transmitter Harness for Birds.** Satellite telemetry technology has revolutionized the ability of scientists to conduct long-term studies on bird movement and behavior. For large birds such as vultures and birds of prey, transmitters are attached using a backpack-style harness. The harness is secured by sewing, gluing, or crimping brass ferrules, which can sometimes be stressful to the bird. NWRC researchers have developed a simpler method for ensuring proper harness fit and longevity using nylon snap rivets. Researchers tested the new method using captive and wild black vultures. The improved modified device reduced handling time during the attachment process, simplified adjustments to ensure the harness fit properly, and secured the attachment so the harness would not loosen and subsequently interfere with the bird's natural movements.
Contact: John Humphrey

To accurately detect and measure contact between two or more deer, NWRC researchers built a deer-borne contact detection system that includes cameras and proximity loggers on GPS collars. Such a system was able to document that proximity loggers provide the best contact estimates of the three techniques. *Photo by USDA, Michael Lavelle*

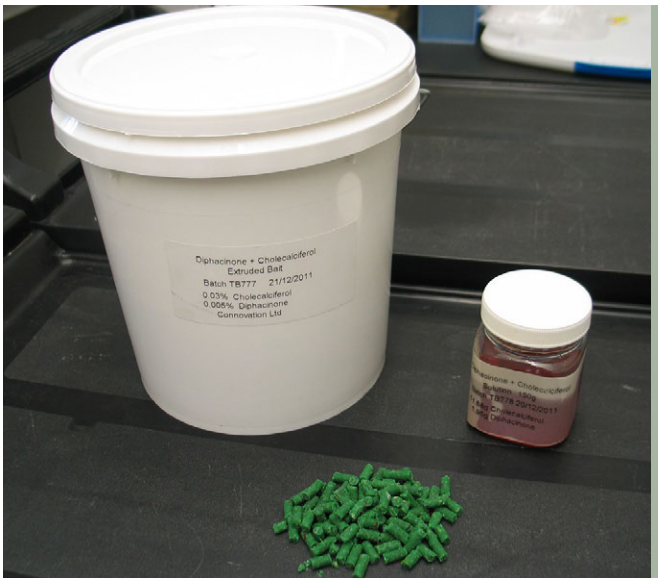
- **Contact Detection Systems Aid in Assessing Disease Risks.** A first step in developing management programs for disease control is to better understand disease transmission risks. Toward this end, accurately detecting contact rates among animals is critical. NWRC researchers simultaneously compared three methods of detecting contacts: motion-activated cameras (for video evidence of contacts), proximity loggers (which detect when

other proximity loggers are within 16 feet), and global positioning system (GPS) collars (from which contacts are defined as when locations of two or more animals are within 16 feet of each other). The researchers mounted the cameras and loggers on the GPS collars and then tested the system on 26 adult male deer, recording their locations and proximity to other deer and capturing video of deer interactions.

From 17 of the 26 collars, researchers documented 33 contacts with cameras, 61 contacts with proximity loggers, and 16 contacts with GPS. Though GPS is the most common technique currently used to assess contacts, researchers demonstrated that it underrepresented contact rates. The cameras also underrepresented contacts among deer, but their video showing the nature of contacts was valuable for assessing and modeling risk of disease transmission. The results underscore the importance of accurate detection and contact rates when modeling disease transmission risks and indicate that proximity loggers provide the most robust contact estimates.
Contact: Michael Lavelle

Pesticides

- **Improving Rodenticide Safety and Efficacy.** Rodents cause substantial damage and foodstuff losses around the world. While various methods are used to reduce these impacts, rodenticides remain the most important tool in the toolbox. The future use of rodenticides will be impacted by manufacturing and registration costs, concerns about toxicity levels for nontarget animals, potential hazards to children, reduced effectiveness of some formulations, and humaneness to the targeted rodents. While there have been very few new developments in rodenticides over the last several decades, NWRC researchers are beginning to address this issue.



Rodenticides continue to be an important tool for managing rodent damage. NWRC researchers are investigating new materials and formulations such as combining an acute toxicant with an anticoagulant. By combining two ingredients, researchers are able to increase the efficacy of the rodenticide while reducing concentrations of the active ingredients and their associated risks. *Photo by USDA, Gary Witmer*

Recent studies on new materials and formulations, including sodium nitrite, lower concentrations of zinc phosphide, and two-active-ingredient formulations (cholecalciferol plus diphacinone), demonstrate that they show promise for controlling a number of rodent species. For instance, by changing bait formulations, NWRC scientists achieved similar efficacy to existing formulations but with lower rodenticide zinc phosphide concentration (0.5 percent versus 2 percent). In other studies, sodium nitrite and zinc phosphide have been successfully encapsulated to avoid low palatability and bait shyness issues, leading to more efficient exposure to toxicants. Such modifications to active ingredients help improve the safety and efficacy of rodenticides.
Contact: Gary Witmer

Captive European starlings were used to test the effectiveness of an anthraquinone-based repellent and SucraShield to protect sweet corn from bird damage.
Photo by USDA, Jim Carlson

Repellents

- **European Starling Feeding Activity on Repellent-Treated Crops and Pellets.** Besides their natural diets, invasive European starlings eat agricultural crops and livestock feed. Damage and losses can be extensive when starlings congregate in large flocks. NWRC researchers evaluated the effectiveness of two product lines marketed as bird repellents: an anthraquinone-based repellent (Arkion Life Sciences; New Castle, DE) and SucraShield (Natural Forces; Davidson, NC) for protecting specialty crops and grains. Neither repellent formulation was effective at protecting blueberries or corn. However, results also indicated that fruit sugar content may influence repellency. For dry products such as CU bird carrier pellets (Purina Mills; Gray Summit, MO), anthraquinone was an effective repellent when applied at low concentrations (6,275 parts per million). SucraShield was not an effective repellent in similar tests. These findings will aid in developing improved repellents for use on livestock feed to prevent bird damage and consumption.
  Contact: Scott Werner

- **Ultraviolet Cues Improve Effectiveness of Bird Repellent.** Red-winged blackbirds, common grackles, yellow-headed blackbirds, and brown-headed cowbirds cause millions of dollars in damage to agricultural crops each year. Application of chemical repellents such as anthraquinone can be effective in reducing crop damage and loss, but it can also be expensive to maintain adequate repellent concentrations over long periods of time. NWRC researchers previously found that birds can effectively associate inert visual cues with the effects of repellents. The most recent experiments yielded two significant findings. First, there was a synergistic effect of combining anthraquinone with a spectrally matched ultraviolet (UV) pigment (i.e., it took less repellent to yield a specified avoidance). Second, once birds experienced the repellent-UV pairing, they avoided seeds treated with the UV pigment alone, and the response was more robust than for nonspectrally matched pigments. Researchers hope to use these findings to improve the development of cost-effective, repellent-based strategies for reducing bird damage to crops.
  Contact: Scott Werner

Other Chemical and Biological Methods

- **Use of a GnRH Vaccine for Preventing and Treating Adrenocortical Disease in Domestic Ferrets.** Ferrets are the third most popular domestic mammalian pet in the United States. Adrenocortical disease (ACD) is a common problem in surgically sterilized, middle-aged and older ferrets. Affected animals develop abnormal adrenal tissue including malignant tumors. Symptoms include hair loss, swollen vulva in female ferrets, muscle atrophy, limb weakness, cysts, and increased aggression. ACD is thought to be linked to continuous and increased luteinizing hormone secretion. NWRC researchers and partners investigated whether GonaCon Immunocontraceptive Vaccine (GonaCon), a

gonadotropin-releasing hormone (GnRH) vaccine developed by NWRC to reduce the fertility of wildlife species and the spread of disease, could prevent or delay the onset of ACD and treat hair loss in pet ferrets with existing ACD.

Results showed that GonaCon provided relief from ACD by causing production of antibodies to GnRH, probably suppressing the production and/or release of luteinizing hormone. GonaCon also caused many ACD symptoms to disappear, allowing the ferrets to return to a normal life. In addition, the study found that the probability of developing ACD was significantly reduced in ferrets treated with GonaCon when young (1–3 years old) compared to untreated animals. This is an example of an incidental or "spin-off" use of an NWRC product originally developed for wildlife management.
Contact: Doug Eckery

- **Effects of Immunocontraceptive Vaccine on Fox Squirrels.** The eastern fox squirrel was introduced into the Western United States in the last century and is abundant in many urban and suburban areas of California. Fox squirrels are often considered pests—raiding bird feeders, gardens, and orchards and gnawing on trees, electrical wiring, and wooden and plastic structures. Contraception may offer a nonlethal alternative for managing fox squirrel populations in urban areas where hunting and trapping are limited. GonaCon is an NWRC-developed immunocontraceptive vaccine registered for use in white-tailed deer and feral horses and burros.

  As part of a collaborative study with the University of California-Davis, NWRC researchers tested the effectiveness of the vaccine in male and female eastern fox squirrels. The vaccine completely suppressed reproductive activity in both sexes, compared to 12 of the 15 nontreated females that produced litters. Treated and nontreated animals did not differ in body weight, but vaccinated squirrels had poorer body condition and exhibited severe injection site abscesses. Scientists note the need for additional research to resolve concerns about injection site reactions.
  Contact: Doug Eckery

A GnRH immunocontraceptive vaccine developed by NWRC scientists is showing promise as a nonlethal alternative for controlling fox squirrels and reducing their damage in urban areas. *Photo by USDA, Laurie Paulik*

- **Testing a Molasses-Based Bait for Bovine Tuberculosis Vaccination of White-Tailed Deer.** *Mycobacterium bovis* (*M. bovis*) is a bacterium that causes bovine tuberculosis (bTB). In northeastern Michigan, white-tailed deer have been implicated as the source of *M. bovis* infection in over 57 cattle herds from 1988 through spring 2013. Eradication of bTB in cattle cannot succeed unless *M. bovis* is eliminated from wildlife or transmission from wildlife to cattle is prevented. NWRC scientists and partners at USDA's Agricultural Research Service evaluated the palatability and stability of a molasses-based bait for delivering a bTB oral vaccine to free-ranging white-tailed deer. In studies with captive deer, the bait was readily eaten; however, researchers caution the bait should

An NWRC study showed that pronghorn fawn survival increased by 242 percent in areas where coyotes were sterilized. Researchers believe that a coyote's need to kill larger prey items reduces when its energetic demands, such as those associated with provisioning pups, is reduced. *Photo by USDA, Wildlife Services*

also be tested with free-ranging deer to ensure its attractiveness and palatability. The physical stability test demonstrated that the bait matrix is stable in dry conditions but unstable when in contact with ice and water, indicating that bait stability is acceptable during winter with constant temperatures below freezing. However, if ambient temperatures result in melting snow and ice, bait stability will be compromised. Researchers recommend using a device to shield baits from ice and water.
Contact: Kurt VerCauteren

- **Changing Predation Rates of Coyotes Using Sterilization.** Current research shows that coyotes are more likely to kill larger prey (e.g., lambs and sheep) when their energy demands are greater, such as when they are provisioning pups. Additionally, NWRC research has shown that surgical sterilization of coyotes reduces their predation rates on domestic sheep. To see if a similar change in coyote predation occurs with pronghorn antelope, NWRC and Utah State University researchers radio-collared 71 pronghorn fawns found in 17 coyote-pack territories in Colorado. Fifteen coyotes from 10 packs were surgically sterilized, while 9 coyotes in 7 packs were given sham sterilizations (i.e., remained reproductively intact). The researchers also estimated the availability of alternative prey and coyote densities and estimated pronghorn fawn survival rates.

  Sterilization of coyotes resulted in reduced predation on pronghorn fawns. Fawn survival increased by 242 percent in areas where coyotes were sterilized versus areas where coyotes received sham treatments. No differences were found in the abundance of rabbits and rodents; coyote densities; or fawn sex, birth weight, and age across the 17 coyote-pack territories. Although costs associated with coyote sterilization were 12-percent higher than for trapping and killing coyotes, the method lasts for many years and may offer a less expensive long-term solution for managing coyotes in an area. A more formal analysis on factors contributing to

costs and efficacy is needed. However, for wildlife managers seeking an alternative to lethal removal of coyotes, sterilization may be a viable management action.
Contact: Eric Gese

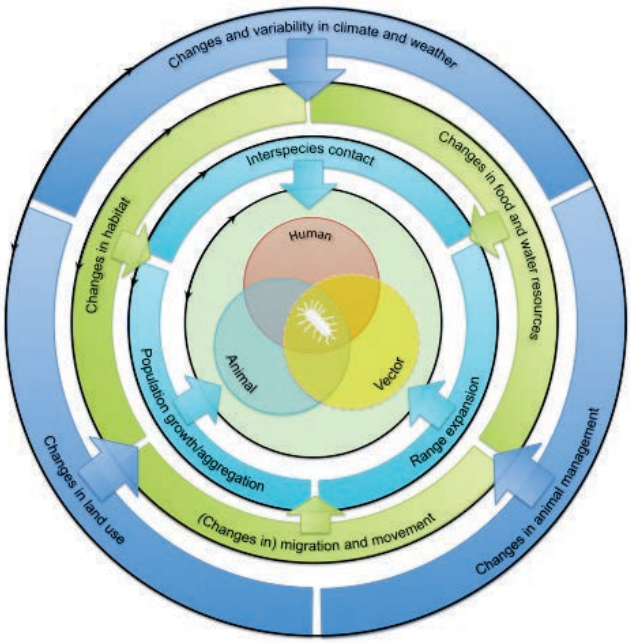
Disease Diagnostics, Surveillance, Risk Assessment, and Management

- **Using Breath Analysis To Differentiate Healthy Cattle From Cattle Experimentally Infected With *M. Bovis*.** Breath can contain volatile organic compounds (VOCs) that often emit unique odors and emission patterns. Because of these unique characteristics, VOCs have been identified as potential tools in disease surveillance. NWRC scientists and partners collected breath from healthy cattle and cattle experimentally infected with *M. bovis* (the pathogen that causes bovine tuberculosis [bTB], a disease that impacts approximately 10–14 percent of cattle in developing countries) and analyzed it using gas-chromatography/mass-spectrometry technology. Results demonstrated that it is possible to distinguish between healthy and infected cattle based on changes in their breath VOC profiles. These results suggest that VOC analysis may allow diagnosis of disease in cattle. This new technique could form the basis for a real-time cattle monitoring system that allows efficient and non-invasive screening for new bTB infections at dairy farms.
Contact: Kurt VerCauteren

Volatile organic compounds found in breath have been identified as potential tools in disease surveillance. NWRC and APHIS Veterinary Services researchers are exploring the use of these compounds to screen for bTB in cattle.
Photo by USDA

- **White-Tailed Deer Visits to Cattle Farms and Effects on Disease Transmission.** Bovine tuberculosis (bTB) is found in free-ranging white-tailed deer in Michigan. A better understanding of deer visits to cattle farms and the extent to which deer and cattle may share forage resources may aid in reducing bTB transmission risks among deer and cattle. NWRC researchers followed the movements of 25 white-tailed deer fitted with global positioning system collars on farms near the bTB-infected zone in Michigan's Lower Peninsula for 1 year. A minority of deer (19–43 percent) were responsible for the majority (80–88 percent) of visits to farms, yards, and cattle-use areas, with visits increasing through spring and peaking during the fawning season. Visits declined rapidly after June 1. Deer use of farms occurred mostly during the day and, while there, deer tended to visit areas related to cattle feeding, such as pastures, concentrated feeding areas, and water sources.

  Results suggest that when implementing mitigation and control efforts to guard against potential bTB transmission, producers should take into account the season as well as the time of day deer visitation occurs. Furthermore, specific livestock management practices, such as unfenced concentrated feeding or food storage areas, may contribute to farm visitation by deer. Deer visiting multiple farms may contribute to bTB spread in a local area.
  Contact: Are Berentsen



As part of a group of international scientists from 10 countries, an NWRC researcher developed a conceptual framework to aid in risk assessments and managing disease emergence and spread. *Graphic by USDA Wildlife Services*

- **Linking Bovine Tuberculosis on Cattle Farms to White-Tailed Deer and Environmental Variables.** Bovine tuberculosis (bTB) is a bacterial disease caused by *Mycobacterium bovis* (*M. bovis*) in livestock and wildlife with hosts that include white-tailed deer. To better understand the long-term survival and viability of *M. bovis* on farms and surrounding habitats, 762 cattle farms in Michigan were evaluated based on a multitude of environmental factors. Cattle farms test positive for *M. bovis* annually in the study area, despite efforts to eliminate the disease each year; this suggests that an environmental source, either on farms or in the surrounding landscape, may be contributing to new or re-infections with *M. bovis*.

  Results showed that deer prevalence and the amount of sandy soil in the sampling area were most strongly tied to the presence of *M. bovis*. Analysis of cattle farms tested for *M. bovis* identified that every 1-percent increase in sandy soil resulted in a 4-percent increase in odds of infection. Additionally, the impacts of potentially infected deer were still a concern even after considerable efforts to prevent cattle interactions with white-tailed deer through on-farm mitigation and reduction in the deer population. This research provides an initial assessment of environmental factors that should be considered when modeling *M. bovis* prevalence and risk.
  Contact: Kurt VerCauteren

- **Conceptual Framework for Pathogen Emergence.** The number of pathogens known to infect humans is increasing. On average, three to four new pathogen species are detected in humans every year. Whether this is due to increased surveillance or the actual emergence of new pathogens is unclear. A species barrier is defined as the natural mechanisms (e.g., animal immune systems, ecological roles) that prevent a disease from spreading from one species to another. As part of a group of international scientists from 10 countries, an NWRC scientist developed a conceptual framework for identifying factors that impact the interspecies barrier among humans, animals, and disease vectors. The framework classifies factors into a limited number of categories, including local influences such as habitat suitability, water and food availability, and migrations/movements, as well as more regional or global influences such as climate change, land use, and animal management. The framework can help improve risk assessments and optimize efforts to manage disease emergence and spread.
  Contact: Kurt VerCauteren

- **Forecasting the Spread of Raccoon Rabies.** In the United States, wildlife accounts for 92 percent of all reported rabies cases. The raccoon rabies virus variant is responsible for significant spillover infection into dogs and cats, as well as other wildlife.

A recent assessment and modeling effort by NWRC economists and researchers showed that, without an ORV zone in place, raccoon rabies could spread West and stretch from central Iowa to the Texas-Louisiana border by 2035. Such an expansion could greatly impact people, pets, livestock, and other wildlife.
Photo by U.S. Fish and Wildlife Service, Dave Menke

Following the relocation of raccoons from Florida to Virginia during the 1970s, 80s, and 90s, raccoon rabies has spread and is now prevalent throughout the Eastern United States. Although the spread of raccoon rabies beyond the Eastern United States was slowed in part by geographical features (e.g., the Appalachian Mountains, the Great Lakes, large rivers), an extensive collaborative oral rabies vaccination (ORV) program led by WS has further helped to prevent its westward spread.

The benefits of maintaining the ORV zone are significant for several public health, agricultural, and wildlife management reasons. Specific benefits include reductions in human post-exposure prophylaxis, reduced livestock and pet losses, and protection of wildlife resources. To better quantify the benefits of the ORV program, NWRC researchers and partners modeled the spread of raccoon rabies over 20 years in the absence of current ORV activities. The forecast models incorporated three different rates of spread—low (15 kilometers [km]/year), medium (30 km/year), and high (60 km/year)—based on historical rates of raccoon rabies spread in the Eastern United States. Over the 20-year horizon, spread would extend as far west as the Texas border and western Iowa. Over a longer period, the spread would likely continue to the Rocky Mountains, where harsh winters and unsuitable habitat might stop its spread. Such forecasting information aids managers in determining the costs and benefits associated with ORV programs.
Contact: Aaron Anderson

- **Modeling Climate Change Impacts on Fox Rabies in Alaska.** Scientists predict that the northern and southern reaches of the earth, such as the Arctic, will be more susceptible to climate change. The Arctic fox variant of rabies virus circulates in Arctic foxes, with significant spillover into red foxes in Alaska, and most reported domestic and wildlife cases occur in northern and western coastal areas. The number of rabid fox cases peaks in winter and spring. NWRC researchers and partners modeled

NWRC researchers and partners modeled the impacts of warming climates on the prevalence and spread of fox rabies in Alaska. As temperatures increased, models predicted a stronger seasonal effect on Arctic fox rabies at higher latitudes. *Photo by U.S. Fish and Wildlife Service*

Cottontail rabbits inoculated with low pathogenic avian influenza virus shed large quantities of the virus in laboratory studies. Given that this species often lives near people and agricultural production facilities, it may play a role in spreading the virus to domestic poultry.
Photo by USDA, Laurie Paulik

the impacts of warming climates on the prevalence and spread of fox rabies in Alaska. As temperatures increased, models predicted a stronger seasonal effect on Arctic fox rabies at higher latitudes. However, as temperatures continued to rise, the primary reservoir of rabies in Alaska shifted from Arctic fox to red fox. Researchers conclude that more information on fox and lemming populations, in addition to finer scale surveillance of fox rabies, will be critical to understanding the future spread of the Arctic fox rabies variant in North America.
Contact: Amy Gilbert

- **Low Pathogenic Avian Influenza Virus Shedding in Striped Skunks and Cottontails.** Striped skunks and cottontail rabbits can be infected with some avian influenza viruses and are frequent visitors to livestock production areas. To determine whether these species pose a disease transmission risk, NWRC researchers experimentally infected skunks and cottontails with a low pathogenic H4N6 avian influenza virus and monitored the animals for viral shedding for at least 20 days. NWRC researchers collected and analyzed nasal, oral, and fecal samples. All treated skunks and cottontails shed large quantities of viral ribonucleic acid (RNA). Given that these species often live near people and human-made structures, their presence on poultry and waterfowl operations could influence the spread of avian influenza virus. For example, skunks and cottontails could introduce avian influenza virus to naïve poultry flocks or act as a trafficking mechanism of avian influenza virus to and from an infected flock to previously unexposed flocks or wild birds. Researchers recommend biosecurity measures at poultry facilities to prevent access by these species.
Contact: Jeff Root

- **Tools for Guiding Responses to Avian Influenza Outbreaks in Poultry.** The emergence of avian influenza viruses (AIVs) in poultry remains a global problem that can cost hundreds of millions of dollars in damages. To help decisionmakers better prepare for and respond to AIV outbreaks in commercial poultry, NWRC researchers summarized the current state of knowledge about AIV in wild birds and poultry and identified research priorities to build on existing emergency response tools. In particular, researchers recommend modeling studies to: (1) quantify how quickly AIV can spread between wild hosts and poultry based on different population sizes and AIV prevalence, (2) understand how the structure and function of different poultry industry processes may impact AIV transmission within and between flocks, and (3) validate existing policy-decision tools with data.

  Researchers note that much of the data needed for these efforts are currently available, though limited. One recommendation for enhancing data resources is to standardize data collection techniques and methods during disease outbreaks.

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With the appropriate collaboration among scientists, response personnel, and policymakers, the development of such an outbreak-data collection policy could be achieved in a way that minimizes contamination risk during response, maximizes cost-effectiveness and operational efficiency, and includes data that are essential for improving quantitative tools. Such a policy could generate high-value data resources that would facilitate the development of accurate, response-oriented quantitative preparedness tools.
Contact: Kim Pepin

- **Brucellosis in Feral Swine.** Feral swine populations have spread across the United States through natural expansion, intentional translocation, and accidental release. The increasing number of feral swine not only damages public and private property, but also poses disease threats to native ecosystems, livestock, and people. Brucellosis is one of the many diseases that can be carried and transmitted by feral swine to people, livestock, pets, and wildlife. In 2014, NWRC staff from the National Wildlife Disease Program collected and analyzed samples from 183 feral swine in areas with high brucellosis prevalence. Twenty-two samples tested positive for brucellosis. Interestingly, only 52 percent of samples that tested positive via cultured tests also tested positive via antibody tests, indicating that standardized serum tests do not effectively capture all brucellosis-positive animals. The researchers noted that improved serologic tests are needed to more accurately determine feral swine exposure to *Brucella* spp. and to monitor disease trends in feral swine populations.
Contact: Sarah Bevins

Brucellosis is one of the many diseases that can be carried and transmitted by feral swine to people, livestock, pets, and wildlife. WS' National Wildlife Disease Program routinely monitors for brucellosis in feral swine to identify potential risks to commercial swine and livestock. *Photo by USDA, Justin Stevenson*

- **First Reports of Pseudorabies and Winter Ticks in Emerging Feral Swine Populations in New Hampshire.** The expansion of feral swine populations into new areas is a concern not only because of the increased damage to agriculture and natural resources, but also because feral swine carry diseases and parasites that pose a threat to people, livestock, and wildlife. Thirty-four blood samples from feral swine in New Hampshire were submitted to the National Wildlife Disease Program for disease surveillance testing. One was positive for pseudorabies virus, making it the first documented infection of feral swine in New Hampshire. Infestations of winter tick (*Dermacentor albipictus*) were also found on two of the feral swine. Previously, this tick had only been reported on feral swine in Texas. Feral swine may serve not only as a host for damaging pathogens such as pseudorabies, but may also increase host diversity for parasites such as the winter tick, a species that impacts moose survival rates. These findings warrant further investigation of feral swine populations as pathogen hosts in New Hampshire and support continued effort to reduce numbers or regionally eradicate feral swine.
  Contact: Tom Gidlewski

- **Infectious Diseases in Invasive Mute Swans.** Since their introduction to the United States in the late 19th century, mute swans (*Cygnus olor*) have become a nuisance species by damaging aquatic habitats, acting aggressively toward people, competing with native waterfowl, and potentially transmitting or serving as a reservoir of diseases that are infectious to humans and poultry. In an effort to investigate mute swans' potential role as a disease reservoir and establish baselines for bird pathogens that threaten agricultural species or human health, National Wildlife Disease Program (NWDP) biologists collected samples from 858 mute swans and tested them for avian paramyxovirus serotype 1 (APMV-1), avian influenza virus (AIV), and Salmonella species.

  Results indicate that exposure to APMV-1 and AIV is common in mute swans (60 percent and 45 percent, respectively), but researchers detected limited amounts of active viral shedding (8.7 percent and 0.8 percent, respectively). Salmonella was found in only three of these mute swans. Experts recommend biosecurity measures at poultry facilities to prevent contact between mute swans and domestic animals.
  Contact: Tom Gidlewski

Wildlife Damage Assessments

- **Feral Swine Disturbance to Sensitive Plant Communities.** Invasive feral swine are known to eat and destroy vegetation, especially grasses, sedges, forbs, and some shrubs and trees, and reduce the sites they forage to bare, overturned, and excavated soil. Furthermore, this rooting may also increase the ability for invasive weeds to take hold and reduce native plant species diversity in sensitive areas. To assist land managers in evaluating and determining the impacts of feral swine damage to native ecosystems, NWRC researchers developed an approach for obtaining swine damage measurements over time.

  Using hand-held global positioning systems, NWRC researchers measured feral swine rooting damage within 1,450 acres (587 hectares) of ecologically sensitive wetlands at Avon Park Air Force Range in south-central Florida and documented recurring damage at most sites. The age of damage was calculated and assigned to a severity index. By assessing the impacts of swine rooting over multiple sampling events and various seasons, researchers were able to determine how seasonal climate change may influence swine behavior. Tracking rooting over space and time enables managers to identify damage "hot spots" that may include sensitive plant communities in need of protection.
  Contact: Richard Engeman

Invasive feral swine cause more than $1 billion in damages to natural resources and agriculture each year. NWRC researchers reviewed previous management and control efforts for feral swine and found that a combination of approaches over a long and sustained period can be effective at reducing feral swine populations and damage. *Photo by USDA, Scott Woodruff*

- **Consequences Associated With the Recent Range Expansion of Feral Swine.** Aided by both an adaptable biology and deliberate introductions by people, the range of invasive feral swine in the United States has expanded from 17 to at least 39 States over the past 30 years. Swine's generalist diet, combined with high population densities, complicate efforts to conserve threatened and endangered species, and losses from crop damage and livestock predation in the United States alone are estimated to be more than $1 billion. In addition, feral swine can be a reservoir for multiple pathogens, some of which can be transmitted to people, livestock, and pets.

  NWRC researchers reviewed previous management and control efforts for feral swine and found that a combination of lethal and nonlethal approaches over a long and sustained period can be effective at reducing feral swine populations and damage. However, researchers note that the range of stakeholders interested in feral swine issues—including those that value feral swine for subsistence and sport hunting—can make management efforts divisive and difficult even when eradication is not the ultimate goal.
  Contact: Sarah Bevins

- **Impacts of Control Operations on Feral Swine.** Avon Park Air Force Range (APAFR) in Florida contains rare wetlands, plants, and plant communities, some of which are only found in peninsular Florida. Rooting by invasive feral swine damages some of these ecologically sensitive habitats. Moreover, APAFR encompasses dozens of archeological sites eligible for inclusion in the National Register of Historic Places, with 42 percent having had some level of feral swine disturbance. Considerable recreational hunting takes place on the base and is popular with the public, but feral swine damage to the APAFR plant communities and historical sites prompted further efforts to reduce the feral swine population by carrying out a lethal control program.

  NWRC researchers conducted a multiyear monitoring effort to evaluate the control program's impacts on the feral swine population at the base. Even though feral swine on the APAFR had been recreationally hunted for many years, researchers recorded substantial declines in feral swine detection rates (as much as 75 percent from pre-control levels in some areas) after control operations, with indices leveling for the final 2 study years. Researchers note that military missions and recreational hunting seasons impacted the time and scope of control operations, thereby limiting further impacts of the control effort.
  Contact: Richard Engeman

- **Use of Urban Areas by Black Bears.** Rapidly expanding urbanization is increasing opportunities for wildlife to forage and become dependent on human-related resources. For American black bears, little is known about the degree of bear urbanization (i.e., when and why bears enter urban areas) and the best ways to manage human-bear conflicts. Using 6 years of location and activity data from bears in Aspen, CO, NWRC researchers and partners evaluated the degree to which bears use urban areas and the factors that explain variations in use. Bear locations, movements, activity patterns, survival, and reproduction were modeled with bear characteristics and natural food availability.

Little is known about the degree of black bear urbanization, when and why black bears enter urban areas, and the best ways to manage human-bear conflicts. Using 6 years of location and activity data from black bears in Aspen, CO, NWRC researchers and partners evaluated the degree to which bears use urban areas and the factors that explain variations in use.
Photo by USDA, Sharon Baruch-Mordo

Results showed that bear locations and activity patterns were dependent on the availability of natural foods: bears became more nocturnal and used areas of higher urbanization in poor food years, but switched back to natural areas in subsequent good food years. Even though the number of bears born was similar across years, survival was lower in poor food years when bears used urban areas to a greater extent. The findings suggest that bear use of urban areas is reversible and fluctuates with the availability of natural food resources and that removal of urban bears in times of food failures has the potential to negatively affect bear populations. Given that current predictions estimate urbanization will increase by 11 percent across American black bear range by the year 2050 and that natural food failure years are expected to increase due to global climate change, alternative methods of reducing urban human-bear conflicts are required in order to sustain local bear populations.
Contact: Stewart Breck

- **Mammal Strikes at U.S. Airports.** Wildlife collisions with U.S. civil aircraft cost more than $900 million each year, with mammals five times more likely to cause damage than other wildlife. NWRC researchers surveyed two general aviation airports (primarily serve private planes and small charter operations) and six Federal Aviation Administration (FAA)-certified airports (primarily serve commercial airlines) to assess the effectiveness of their management efforts to reduce mammal hazards to aircraft. NWRC gathered information on mammalian species present on airport grounds, types and estimated effectiveness of management techniques used, and the amount of effort spent on wildlife management. Researchers evaluated the management techniques relative to species hazard scores calculated by body mass and the number of aircraft-wildlife collisions listed in the FAA's National Wildlife Strike Database.

Certified airports expended five times more effort and used twice as many techniques as general aviation airports. Species considered most hazardous by all airports included white-tailed deer (hazard score = 94) and coyotes (hazard score = 62). Generally, all airports surveyed are managing effectively for mammals; however, researchers

The impacts of wild turkeys on ginseng production in Wisconsin were part of a survey and study by the Ginseng Board of Wisconsin, Inc., and the NWRC. Results showed a decrease in the amount of money spent to reduce turkey damage from 2006 to 2012, likely due to the effective use of vertical fencing to protect crops from the birds.
Photo by NBII, Randolph Femmer

recommend that airports with deer present install additional exclusion devices. By prioritizing species to manage, and targeting management to these species, airports can reduce mammalian risks to U.S. civil aircraft.
Contact: Travis DeVault

- **Wild Turkey Impacts to Ginseng.** Eastern wild turkeys were reintroduced into Wisconsin for hunting purposes starting in 1976. Today, approximately 50,000 wild turkeys are harvested in Wisconsin each year. Unfortunately, the State's healthy turkey population has led to increased damage to specialty crops such as American ginseng. Wisconsin accounts for 95 percent of the U.S. production of ginseng, generating up to $20 million in gross income in Wisconsin each year. Ginseng is a high-value root crop grown under natural or simulated forest understory conditions. The Ginseng Board of Wisconsin, Inc., conducted surveys of Wisconsin ginseng producers in 2006 and 2012 to estimate turkey damage and methods used to reduce turkey damage; NWRC researchers analyzed the survey results.

  Most respondents reported that wild turkeys were present and caused moderate damage at their ginseng facilities every year. The majority of respondents in 2006 reported that annual losses were $2,000–$5,000, while most respondents in 2012 reported losses of less than $2,000. Most producers reported spending less than $2,000 annually for turkey damage management. Vertical fencing was reported as the most used and most effective damage management technique. The reported use and long-term efficacy of vertical

fencing increased substantially from 2006 to 2012, which may be related to the general downtrend in annual monetary losses due to wild turkeys in that time period. These survey results will be used to further identify, investigate, and manage the impacts of wild turkeys on Wisconsin ginseng production.
Contact: Scott Werner

Wildlife Management Methods and Evaluations

- **Effects of Lethal Management on Australian Dingoes.** Researchers with the University of Queensland, the University of Canberra, the Robert Wicks Pest Animal Research Centre, and NWRC investigated how the removal of dingoes in Australia affects the movement and behavior of surviving dingoes. Understanding the direct and indirect effects of lethal control on remaining animals allows managers to determine the overall ecological impacts of such actions. Seven dingoes equipped with global positioning system tracking collars that survived a lethal baiting program provided movement data before, during, and after baiting.

  Results showed that surviving adult dingoes did not alter their movements or home ranges in response to baiting. There were no significant changes in daily travel distances, speed of travel, or road and trail usage. The only noticeable shift in dingo behavior between pre- and post-baiting periods was a slight change from being more active at dawn to being more active at night. Researchers note that surviving dingoes may respond differently to lethal control programs that achieve greater population reductions, are conducted in places where extant dingoes have not previously been exposed to lethal control, or are conducted under different environmental conditions. Information gained from this study may be useful to understanding the impacts of similar wildlife damage management activities in other countries.
  Contact: Richard Engeman

- **Effectiveness of Rodenticides for Managing Rodents in Orchards.** Invasive roof rats (*Rattus rattus*) and native deer mice (*Peromyscus maniculatus*) occasionally cause damage to nut and fruit orchards in California and many other parts of the United States. In general, the most practical and cost-effective tools for controlling rodents in agricultural settings are rodenticides (toxic baits), but little information exists on the efficacy of current rodenticides in controlling roof rats and deer mice in orchards. Therefore, NWRC and University of California researchers developed an index of rodent activity to monitor and test the efficacy of three California Department of Food and Agriculture rodenticide baits (0.005 percent chlorophacinone-treated oats, 0.005 percent diphacinone-treated oats, and 0.005 percent diphacinone wax blocks) to control these species in orchards. Of the baits tested, the 0.005 percent diphacinone-treated oats was most effective for roof rats and deer mice, with 90 and 99 percent efficacy rates, respectively. The chlorophacinone grain was completely ineffective against roof rats. Researchers also note that the use of elevated bait stations was effective at providing bait to target species while limiting access to rodenticides by many nontarget species.
  Contact: Richard Engeman

- **Influence of Egg Oiling on Gull Colony Activities.** Egg oiling is often used to limit bird population growth and dispersal during breeding seasons. The technique involves coating eggs with mineral or corn oil and averts hatching by preventing gas exchange across the shell. Unlike other nest disturbance techniques, egg oiling reportedly does not cause birds to abandon nests and disperse to other areas. To determine the effects of egg oiling on a

During a recent cold spell in Florida, NWRC researchers obtained information on the ability of invasive Burmese pythons to tolerate and cope with cold temperatures. Instead of seeking refuge to counter lower temperatures, pythons attempted to bask, thus putting them more at risk. Empirical evidence from the cold spell demonstrated that current model predictions on the potential Burmese python range in the United States may be inaccurate.

Photo by National Park Service, Lori Oberhoder

ring-billed gull colony in Vermont, NWRC scientists radio-marked 58 gulls and subsequently oiled eggs in all gull nests in the colony, except for half of the nests belonging to the radio-marked gulls. Radio-marked gulls were monitored throughout the breeding season to determine any effects of treatment, sex, length of pre- and post-hatching periods, and presence at the colony site.

Researchers found no evidence that egg oiling influenced colony presence of ring-billed gulls within the breeding season. Managers interested in long-term local stabilization of ring-billed gull populations should consider egg oiling as a potential method. Researchers recommend minimizing colony disturbance during egg-oiling operations, especially if eggs are likely to be preyed on when incubating gulls are flushed from nests, as potential for re-nesting increases during this time.
Contact: Travis DeVault

Wildlife Population Monitoring Methods and Evaluations

- **Assessing Potential Range Limits of Invasive Burmese Pythons.** When prioritizing management actions taken against an invasive species, managers often want to know how likely it is that an invasive species will expand its range and how quickly that may happen. Understanding the potential for range expansion by invasive reptiles such as the Burmese python can be challenging. Experts are usually forced to rely on predictive models that are often hindered in their development by a lack of basic knowledge about the animal's physiological and behavioral limits in its new environment and untested with empirical data. However, a January 2010 cold spell in Florida provided an opportunity to test the limits of Burmese pythons' cold tolerance.

Impacts of the 2010 cold spell on wild and captive pythons involved in ongoing studies by researchers with multiple universities and State and Federal agencies, including the NWRC, indicated very high mortality rates for pythons in cold ambient conditions, even if the snakes had access to heated refuges. The tropical Burmese pythons did not display physiological capabilities for survival, nor a survival instinct for avoiding lethally cold temperatures. The January 2010 cold spell offered the first rigorous independent test of bioclimatic models predicting the potential range of Burmese pythons. The most conservative model, which predicts the Burmese python range is limited to the extreme southern part of Florida, corresponded best to the empirical observations. Researchers emphasize that modeling is an iterative process, whereby model assumptions and predictions are tested using empirical data and revised and improved accordingly.
Contact: Richard Engeman

- **Differences in Two Double-Crested Cormorant Populations.** Due to rapid population expansion of double-crested cormorants, conflicts between these birds and people have increased, particularly at fish farms in the Lower Mississippi River Valley. Although key demographic information on U.S. interior cormorant populations is sparse, management plans for population reduction are already in place across their breeding range in the north-central United States and Canada. NWRC researchers studied the population dynamics of two geographically distinct interior cormorant breeding areas—one west of the Great Lakes in Lake of the Woods (LOW) and one in eastern Lake Ontario (ELO) located on either side of the migration divide in Ontario, Canada. From 2000 to 2008, researchers gathered data on age, sex, survival rates, reproductive rates, and breeding site fidelity from 9,498 color-banded cormorants.

NWRC researchers observed regional differences in double-crested cormorant breeding populations. This may have important implications for future cormorant management efforts. *Photo by USDA, Jen Chastant*

Adult survival estimates (83–84 percent) did not differ between LOW and ELO; however, population growth models indicated a stable population in LOW and a slightly declining population in ELO. Although ELO produced almost 50 percent more female offspring each year, only 20 percent of those offspring survived their first year. LOW produced only a fraction of the amount of female offspring, but 45 percent of those offspring survived their first year. The potential interacting influences of survival and the number of fledglings may explain the slight differences in growth rates between the two populations. Considering these regional demographic differences, NWRC researchers recommend that future management efforts be based on migratory flyways within the interior population.
Contact: Tommy King

- **Influence of Habitat Factors on Swift Fox Survival and Density.** Swift foxes are a small, native predator of North American prairies. To better understand the influence of vegetation structure on swift fox survival and density in southeastern Colorado, NWRC and Utah State University researchers

monitored 109 foxes on 6 sites exposed to 3 different disturbance regimes, including military training, livestock grazing, and unused. On each site, researchers recorded vegetation height and type, shrub density, basal cover (i.e., percent of ground surface covered by vegetation), percent litter, and abundance of prey.

Results showed that fox survival rates ranged from 0.50 to 0.92 for adults and 0.27 to 0.78 for juveniles. Among sites, population estimates ranged from one to seven foxes per 10-kilometer (6.2-mile) transect. Neither fox density nor survival was related to prey abundance. Instead, models indicated that shrub density and percent basal cover were the best predictors of fox population size. As shrub density increased, so did adult fox survival rates; however, as mean grass height increased, population estimates decreased. Results support the idea that swift foxes are shortgrass prairie specialists who benefit from disturbance regimes leading to mixed prairie habitat. For conservation and restoration purposes, managers may effectively use disturbance regimes to create or maintain habitat for the swift fox.
Contact: Eric Gese

- **Western Gray Wolf and Western Coyote Hybrids.** Using artificial insemination, NWRC researchers and partners attempted to produce hybrids between captive, male, western gray wolves (*Canis lupus*) and female western coyotes (*Canis latrans*) to determine whether coyotes can produce and nurture viable offspring. The results contribute new information to an ongoing debate over whether the eastern wolf (*Canis lycaon*) is a unique species that could be subject to the U.S. Endangered Species Act (ESA) or is instead a coyote-wolf hybrid. The presence of self-sustaining hybrids can complicate the debates and rulings related to species designation for listing under ESA.

To determine whether coyotes can produce and nurture viable offspring as a result of mating with wolves, NWRC researchers and partners deposited wolf semen into nine coyotes, yielding three pregnancies and a total of six hybrid pups. The results contribute new information to an ongoing debate over whether the eastern wolf is a unique species that could be subject to protection under the U.S. Endangered Species Act. *Photo by USDA, Wildlife Services*

Researchers deposited wolf semen into nine coyotes over two breeding seasons, yielding three coyote pregnancies. One coyote ate her pups, another produced a resorbed fetus and a dead fetus by emergency C-section, and the third produced seven hybrids, six of which survived. These results show that, although it might be unlikely for male western wolves to successfully produce offspring with female western coyotes under natural conditions, western gray wolf sperm are compatible with western coyote ova, and at least one coyote could produce and nurture hybrid offspring. This finding, in turn, demonstrates that gamete incompatibility would not have prevented western gray wolves from inseminating western coyotes and thus producing hybrids with coyotes, countering the view that the eastern wolf is a separate species. However, some of the difficulties experienced by the other inseminated coyotes temper that finding.
Contact: Julie Young

- **Coyote Preferences for Habitats Mixed With Human and Natural Structures.** Coyotes have adapted and even thrived in cities and towns across the United States, and their presence can sometimes lead to conflicts with people and their pets. Although coyotes may use urban areas, they tend to prefer natural areas integrated into or surrounding urban development. Understanding the factors that influence a coyote's preference for one habitat type over another would be beneficial in managing human-coyote conflicts in urban areas. NWRC and Utah State University researchers used captive coyotes to determine whether sex, behavioral profile (shy versus bold), time of year, and food availability affected coyote preferences for habitats consisting of natural structures (e.g., shrubs, trees); urban structures (e.g., trash cans, pallets, lights); or a mixture of both.

  Prior to the study, researchers hypothesized that bold coyotes would use urban patches more than shy coyotes, and that food availability would affect coyote habitat preferences. Results showed coyotes generally preferred the controlled, homogeneous structure representing their natural habitat, regardless of behavioral profile and other attributes. The next most preferred habitat, especially by females and bold coyotes, was a mixture of urban and natural structures. This preference was more strongly expressed during the nonbreeding season. Food had no effect on preferences, as coyotes appeared to be motivated primarily by the structure of the habitat rather than by the amount of food. These results suggest that urban areas with large amounts of both natural and anthropogenic structures are more likely to be used by coyotes and thus could have the potential for human-coyote conflicts.
  Contact: Eric Gese

- **Genetic Diversity Supports Multiple Origins for Invasive Feral Swine.** Domestic pigs were first brought to North America during the 1500s by European settlers. Feral populations of these animals subsequently spread to many locations, with some persisting and others perishing. An estimated 5 million invasive feral swine now inhabit the United States. To identify and evaluate the genetic diversity of feral swine here, NWRC researchers and partners analyzed tissue samples from 81 pigs in 30 States and amplified a region of mitochondrial DNA.

  Results identified 15 haplotypes, or groups of genes, for introduced pigs; these represented wild and domestic animals from more than 30 countries. The widespread distribution of these haplotypes in North America suggests that recent feral swine expansion is due to the movement of swine from historical populations as well as introductions from new genetic sources (e.g., people introducing feral swine to new areas, escaped domestic pigs). The movement of feral swine by people and the ongoing exchange of animals between domestic and wild environs have implications for disease transmission as well as genetic variation. The latter is significant because genetic diversity can potentially improve the survival rates of individual animals and, therefore, exacerbate difficulties in controlling feral swine populations.
  Contact: Brandon Schmit

Registration Updates

- **DRC-1339 Concentrate Feedlots Label Amended.** DRC-1339 is a slow-acting toxicant used at feedlots, dairies, and bird roosting sites to reduce local populations of invasive European starlings, blackbirds, and other birds. Of the five APHIS DRC-1339 labels, the APHIS DRC-1339 pesticide product to control pest birds at feedlots is the most

widely used. The ability to mix the product on a variety of baits allows for tailored applications to meet unique site characteristics. The ingenuity of WS personnel has led to expanded-use sites, baits, and target birds, which have been accommodated through the development of Special Local Need (SLN) registrations. The NWRC Registration Unit consolidated most of these uses into the existing Federal label for feedlots. The U.S. Environmental Protection Agency (EPA) approved the label amendment in February 2014. The result is a DRC-1339 Concentrate–Feedlots label, providing greater utility and reducing the time and cost of maintaining SLN labels.
Contact: Jeanette O'Hare

- **EPA Registration Review of APHIS Pesticide Products.** The EPA re-evaluates pesticides every 15 years to determine a chemical's eligibility for continued registration. Through this process, EPA strives to ensure that pesticides pose little risk to humans or the environment and may call for the registrant to provide additional data. Six APHIS pesticide chemicals are currently in various stages of EPA registration review. They are sodium nitrate (an active ingredient in a gas cartridge), methiocarb, sodium cyanide, compound 1080, DRC-1339, and acetaminophen. NWRC's Registration Unit works to ensure these products remain available for use by WS.
Contact: Jeanette O'Hare

- **EPA Registration Review of DRC-1339.** As part of the current registration review of DRC-1339, EPA determined that additional data addressing the environmental fate of the product and the potential risk to aquatic animals were needed. These requirements were largely tied to the use of the DRC-1339 Concentrate–Staging Areas product in and around rice fields and would cost approximately $2 million. The NWRC Registration Unit summarized multiple years of DRC-1339 use by WS, provided additional data, and described WS use patterns, which were submitted to EPA through WS' Pesticide Coordination Committee (PCC). This effort reduced data requirements and saved $1 million in associated costs. Additional discussions with EPA by members of the PCC, and input from rice growers, have resulted in EPA's concurrence on modifications to label language, thus further reducing data costs from an estimated $2 million to approximately $250,000. This total savings of $1.75 million allows for the continued registration of all five APHIS DRC-1339 products—Compound DRC-1339 Concentrate for (1) feedlots; (2) gulls; (3) pigeons; (4) staging areas; and (5) livestock, nest, and fodder—for WS use to control pest birds.
Contact: Jeanette O'Hare

Technology Transfer

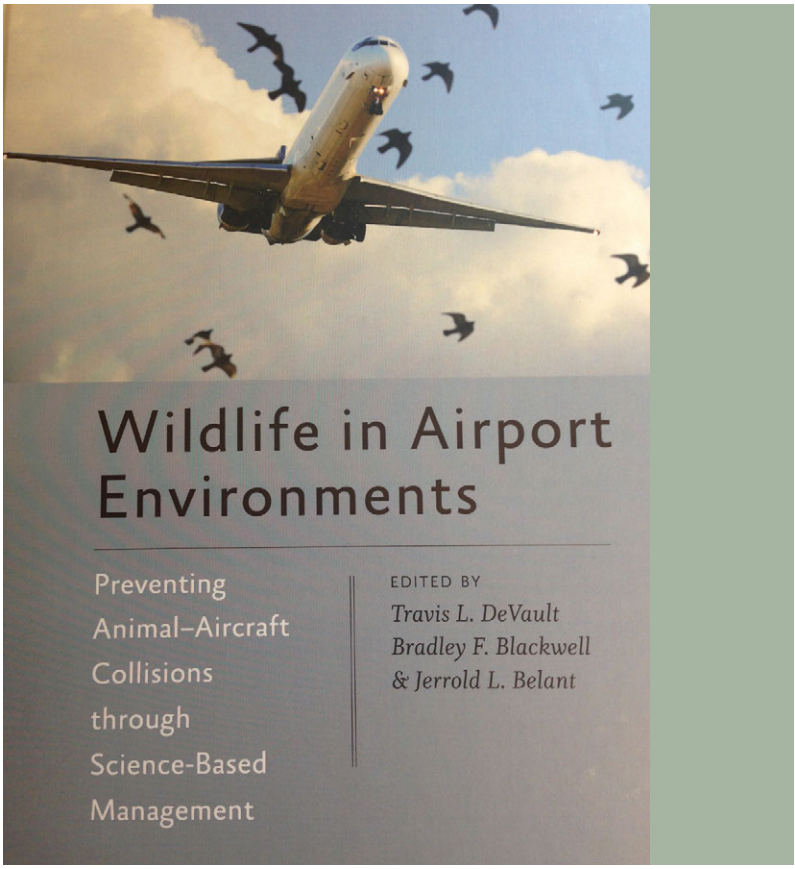
- **New Vaccine for the Prevention of Adrenal Cortical Disease in Domestic Ferrets.** GonaCon Immunocontraceptive Vaccine (GonaCon) was originally developed and patented by NWRC scientists to control fertility in wild and feral animals. Ongoing collaborative research with the University of Pittsburg has shown that GonaCon can also be used to prevent adrenal cortical disease (ACD) in domestic ferrets. ACD is the leading cause of death in domestic ferrets, and there is no preventative therapy currently available. Consequently, GonaCon would be a welcome addition to a veterinarian's toolbox. This technology was patented through the U.S. Patent and Trademark Office in 2014. USDA is now seeking licensing partners for this new and exciting technology.
Contact: John Eisemann

- **Mechanized Production and Delivery System for Brown Treesnake Baits.** NWRC scientists and engineers from the private design firm Applied Designs Corp. (Boulder, CO) have developed a mechanized system for the production and aerial delivery of bait to control invasive brown treesnakes on Guam and prevent their translocation to other islands or the U.S. mainland. The technology is easily adapted for delivery of other payloads and could have significant benefits in rodent control and eradication efforts, delivery of oral vaccines, and other applications. Multiple patents are being sought for this technology.
  Contact: Aaron Shiels

- **Cooperative Research and Development Agreement for Rodent Contraceptive.** In 2014, NWRC scientists entered into a Cooperative Research and Development Agreement with SenesTech Inc. (Flagstaff, AZ) to develop and evaluate a new rodent contraceptive that can be administered via water. This novel product is effective in both male and female rats. NWRC scientists have found the product to be highly effective in breeding trials with wild-caught Norway rats. Efforts are underway to develop a drinking water delivery system that ensures maximum exposure to rats and minimizes risks to nontarget species.
  Contact: Gary Witmer

Awards

- **2013 NWRC Publication Awards.** Each year, the NWRC Publication Awards Committee, composed of NWRC scientists, takes time to review over 120 publications generated by their NWRC colleagues. The resulting peer-recognized award honors outstanding contributions to science and wildlife damage management. In 2013, the annual award for outstanding NWRC research publication was awarded to Travis DeVault and Bradley Blackwell for the book, *Wildlife in Airport Environments: Preventing Animal-Aircraft Collisions through Science-Based Management.*



In 2013, the annual award for outstanding NWRC research publication was given to Travis DeVault and Bradley Blackwell for their book, *Wildlife in Airport Environments: Preventing Animal-Aircraft Collisions through Science-Based Management*.
Photo by USDA, Gail Keirn

Published by The Johns Hopkins University Press (Baltimore, MD), in association with The Wildlife Society, this book pulls together the multifaceted body of research associated with wildlife-aircraft collisions. Travis DeVault, Bradley Blackwell, and Mississippi State University colleague Jerrold Belant not only edited the volume, but contributed to more than half of the chapters. The volume collates and analyzes the current science on preventing wildlife encounters and provides best management practices for airport managers and wildlife professionals.

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

  - Scott Werner, Research Grade Scientist; Methods Development and Population Biology of Blackbirds and Starlings in Conflict with Agriculture, Concentrated Animal Feeding Operations and Urban Environments Project; Fort Collins, CO

  - John Humphrey, Support Scientist; Methods Development and Population Management of Vultures and Invasive Wildlife Project; Gainesville, FL

  - Niki Shelton, Technician; NWRC Animal Care Unit; Fort Collins, CO

  - Steven Greiner, Safety and Health Specialist; Administrative Support Unit; Fort Collins, CO

2014 Publications

The transfer of scientific information is an important part of the research process. NWRC scientists publish in a variety of peer-reviewed journals that cover a wide range of disciplines, including wildlife management, genetics, analytical chemistry, ornithology, and ecology. (Note: 2013 publications that were not included in the 2013 NWRC accomplishments report are listed here.)

Allen, B.L.; Lundie-Jenkins, G.; Burrows, N.D.; Engeman, R.M.; Fleming, P.J.S.; Leung, L.K-P. 2014. Does lethal control of top-predators release mesopredators? A re-evaluation of three Australian case studies. *Ecological Management & Restoration* 15(3): 191–195. doi: 10.1111/emr.12118.

Allen, B.L.; Allen, L.R.; Engeman, R.M.; Leung, L.K-P. 2014. Sympatric prey responses to lethal top-predator control: predator manipulation experiments. *Frontiers in Zoology* 11: 56. Online. www.frontiersinzoology.com/content/11/1/56.

Allen, B.L.; Engeman, R.M.; Leung, L.K-P. 2014. The short-term effects of a routine poisoning campaign on the movements and detectability of a social top-predator. *Environmental Science and Pollution Research* 21(3): 2178–2190.

Allen, L.R.; Engeman, R.M. 2014. Evaluating and validating abundance monitoring methods in the absence of populations of known size: review and application to a passive tracking index. *Environmental Science and Pollution Research*. Online. doi: 10.1007/s11356-014-3567-3.

Anderson, A.; Shwiff, S.A.; Chipman, R.B.; Atwood, T.; Cozzens, T.; Fillo, F.; Hale, R.; Hatch, B.; Maki, J.; Rhodes, O.E.; Rees, E.E.; Rupprecht, C.E.; Tinline, R.; VerCauteren, K.C.; Slate, D. 2014. Forecasting the spread of raccoon rabies using a purpose-specific group decisionmaking process. *Human-Wildlife Interactions* 8(1): 130–138.

Anderson, A.; Shwiff, S.; Gebhardt, K.; Ramírez, A.J.; Shwiff, S.; Kohler, D.; Lecuona, L. 2014. Economic evaluation of vampire bat (*Desmodus rotundus*) rabies prevention in Mexico. *Transboundary and Emerging Diseases* 61(2): 140–146.

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Baldwin, R.A.; Quinn, N.; Davis, D.H.; Engeman, R.M. 2014. Effectiveness of rodenticides for managing invasive roof rats and native deer mice in orchards. *Environmental Science and Pollution Research* 21: 5795–5802. doi: 10.1007/s11356-014-2525-4.

Baruch-Mordo, S.; Wilson, K.R.; Lewis, D.L.; Broderick, J.; Mao, J.S.; Breck, S.W. 2014. Stochasticity in natural forage production affects use of urban areas by black bears: implications to management of human-bear conflicts. *PLOS ONE* 9(1): e85122. doi: 10.1371/journal.pone.0085122.

Berentsen, A.R.; Bender, S.; Bender, P.; Bergman, D.; Hausig, K.; VerCauteren, K.C. 2014. Preference among seven bait flavors delivered to domestic dogs in Arizona: implications for oral rabies vaccination on the Navajo Nation. 2014. *Journal of Veterinary Behavior* 9(4): 169–171. doi: 10.1016/j.jveb.2014.03.001.

Berentsen, A.R.; Brummer, S.P.; Young, J.K.; VerCauteren, K.C. 2014. Evaluation of six ONRAB® Ultralite bait flavor matrices delivered to coyotes (*Canis latrans*): implications for oral rabies vaccination. *Journal of Veterinary Behavior: Clinical Applications and Research* 9(5): 258–261. http://dx.doi.org/10.1016/j.jveb.2014.05.004.

Berentsen, A.R.; Johnson, S.R.; VerCauteren, K.C. 2014. Bait matrix flavor preference by mongoose (*Herpestes auropunctatus*) in Puerto Rico: implications for oral rabies vaccination. *Caribbean Journal of Science* 48(1): 52–58.

Berentsen, A.R.; Miller, R.S; Misiewicz, R.; Malmberg, J.L.; Dunbar, M.R. 2013. Characteristics of white-tailed deer visits to cattle farms: implications for disease transmission at the wildlife-livestock interface. *European Journal of Wildlife Research* 60(2): 161–170. doi: 10.1007/s10344-013-0760-5.

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Appendix 1

List of 2014 NWRC Research Projects

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

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

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

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

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

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

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

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

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

Defining Economic Impacts and Developing Control Strategies for Reducing Feral Swine Damage
Project Leader: Fred Cunningham

Methods and Strategies for Controlling Rabies
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: Aaron Shiels

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

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

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

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Appendix 3

Acronyms and Abbreviations

ACD	Adrenocortical disease
AIV	Avian influenza virus
APHIS	Animal and Plant Health Inspection Service
APAFR	Avon Park Air Force Range
APMV-1	Avian paramyxovirus serotype 1
bTB	Bovine tuberculosis
CDFA	California Department of Food and Agriculture
CWD	Chronic wasting disease
DNA	Deoxyribonucleic acid
ELO	Eastern Lake Ontario
EPA	U.S. Environmental Protection Agency
ESA	Endangered Species Act
FAA	Federal Aviation Administration
GnRH	Gonadotropin-releasing hormone
GonaCon	GonaCon Immunocontraceptive Vaccine
GPS	Global positioning system
LOW	Lake of the Woods
NWDP	National Wildlife Disease Program
NWRC	National Wildlife Research Center
ORV	Oral rabies vaccination
PCC	Pesticide Coordination Committee
RNA	Ribonucleic acid
SLN	Special Local Need
USDA	U.S. Department of Agriculture
UV	Ultraviolet
VOC	Volatile organic compound
WS	Wildlife Services

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