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Innovative Solutions to Human–Wildlife Conflicts

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

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

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Cover Photo: Researchers studied interactions among bobcats, coyotes, and foxes at artificial water sites in the arid Southwest.

Photo by U.S. Department of the Interior/Fish and Wildlife Service, Gary Kramer

Message from the Director

Larry Clark, NWRC Director
Photo by USDA, Gail Keirn

The U.S. Department of Agriculture is building a modern and efficient service organization that is closely in tune with the long-term vitality of rural America and the success of American agriculture. At the same time, the Department is taking a realistic view of the needs of American agriculture in a challenging budget climate, and looking closely at the way we do business. Ultimately, NWRC scientists and support staff will maintain our sense of mission and accomplishment, and we will continue to modernize and accelerate our services while improving the customer experience. This year's accomplishments report demonstrates this commitment, and I feel privileged to lead such a dedicated and highly functioning workforce.

As we continue to deliver services within our budgets, scientists have been asked to find more productive ways to leverage their resources. As a result, collaboration is becoming the operative word among NWRC scientists. Over 67 percent of all study protocols conducted at the NWRC are collaborative in nature. The collaborations come in many forms: across NWRC projects; with our Wildlife Services operational counterparts; with universities (61) and Federal (16), State (21), and local (9) governments; with nongovernmental organizations (23) and the private sector (27); and with foreign organizations (19). Through these efforts, our scientists have been able to tackle the hardest problems facing the field of wildlife damage management to date. One example of this is our research into the sensory systems of animals and applying that research to a real-world problem—preventing collisions between aircraft and birds.

Like our research, our reporting has become more comprehensive and synergistic. This year, as part of our annual report's new "spotlights" section, we highlight a few of these key endeavors in more depth. We explain the nature and extent of the problems wildlife damage managers face, our approaches and collaborative efforts toward addressing these problems, and the significance and impact of the findings and methods developed—all of which puts our research in a broader perspective. I am hopeful that readers will find these descriptions of our research engaging, informative, and useful.

If there is one thing that I have become more appreciative of as NWRC's Director, it is the power of social networks in disseminating the results of our research. Traditionally, science organizations have relied heavily on publishing in scientific literature. While NWRC does a good job at this, with more than 120 publications last year alone, finding out how our research is being received has been more of a challenge. But today, thanks to various Web-based tools, our ability to track this kind of information—who is reading our work, which topics are popular, and most importantly, who is using the results of our research—is increasing.

We now know that NWRC scientific information (manuals, journal publications, and factsheets) has been downloaded over 120,000 times from the University of Nebraska's Digital Commons Web site since 2004. We also know that the most-often visited pages on the NWRC Web site focus on reproductive inhibition, aviation research, predator research, and registration. From an administrator's point of view, all of this information is helpful in gauging how well our work is being accepted and used. By all indications, we are doing well in each measure.

I am very proud that NWRC serves as a leader, both nationally and internationally, in advancing the science of wildlife damage management and developing practical solutions to meet today's challenges. As we continue to progress, the level of engagement NWRC has with fellow scientists, wildlife managers, and the public—as well as the strong demand for and interest in our work—will continue to be key indicators of our success as an organization.

With this in mind, I am pleased to present NWRC's accomplishments for 2011.

Larry Clark, Director
National Wildlife Research Center
Wildlife Services
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Research Spotlights

The National Wildlife Research Center (NWRC) is the research arm of Wildlife Services, a program within the U.S. Department of Agriculture (USDA), Animal and Plant Health Inspection Service (APHIS). NWRC's researchers are dedicated to finding biologically sound, practical, and effective solutions to resolving wildlife damage management issues. The following four spotlights for 2011 show the depth and breadth of NWRC's research expertise and its holistic approach to address today's wildlife-related challenges.

Spotlight: Understanding Wildlife Impacts

The NWRC uses a science-based, multidisciplinary approach to addressing wildlife damage management problems. This philosophy is seen in the Center's efforts to reduce the impacts of invasive wildlife species, such as **European starlings** and **feral swine,** on agriculture, human health, and natural resources. The two case studies below exemplify how NWRC researchers work across disciplines to find practical solutions to complex ecological problems.

Starlings Linked to Disease at Feedlots and Dairies

More than 200 million invasive European starlings live in North America. When gathering in large flocks—numbering in the thousands—these birds exact a large toll on agriculture. Not only do they eat grain and fruit crops, but they also eat cattle feed and can potentially spread diseases at dairies, feedlots, and other areas.

To understand the complex issues surrounding starling damage, NWRC researchers with diverse expertise in animal behavior, ecology, disease, and economics work together to quantify the impacts these birds have on the Nation's dairy farms and feedlots.

"Cattle feedlots contain abundant and nutritious food sources that attract European starlings. Unfortunately, starlings are known carriers of pathogens such as *Salmonella*," notes NWRC research wildlife biologist Alan Franklin. "Identifying and managing this invasive species not only reduces production losses but also helps to prevent the contamination of human food products."

Invasive European starlings take advantage of food and water at cattle feedlots.
Photo by USDA, James Carlson

“European starling impacts to agriculture are diverse. Finding practical solutions for reducing damage requires a multidisciplinary approach.”

Salmonella is the second most common disease-causing foodborne pathogen in the United States. *Salmonella* in cattle is a source for an estimated 1.3 million human cases of salmonellosis, resulting in 15,600 hospitalizations and 550 human deaths each year.

In 2011, NWRC researchers discovered that as the number of starlings increased at cattle feeding operations, so too did the prevalence of *Salmonella enterica* contamination in cattle feed and water within 10 Texas feedlots where the study was conducted. The NWRC researchers found *Salmonella* in 2.5 percent of starlings, 8.4 percent of cattle feed, 13.6 percent of cattle water, and 6.5 percent of cattle fecal samples.

However, direct contamination by starling feces may not be the most important factor in the contamination process. Instead, researchers hypothesized that starlings may move contaminated cattle feces on their feet, legs, and feathers from cattle pens to other locations in feedlots, such as feed and water troughs.

To better understand how far and how often starlings move among feedlots, NWRC researchers captured and radio-tagged 102 wintering starlings at cattle feeding operations in central Kansas. The birds’ use of and movement among local area feedlots was tracked in an effort to learn more about the potential role these birds play in the movement of pathogens among feedlots. The researchers found that approximately 12 percent of radio-tagged starlings visited feedlots other than their capture site, suggesting strong site fidelity by wintering populations of starlings. Currently, it is unknown if this level of alternate feedlot use results in the spread of cattle pathogens between facilities, but data suggest it is a possibility that deserves closer examination.

In efforts to further understand how starlings may affect the spread of pathogens, NWRC researchers and Wildlife Services field operations personnel in Texas investigated whether removal of starlings reduces *Salmonella* at cattle feedlots. Two comparable cattle feeding operations were sampled for *Salmonella* before and after the removal of starlings. The treated facility incorporated Wildlife Services bird control into its operations, while the reference facility did not control birds. On the treated facility, *Salmonella* disappeared from feed bunks and declined significantly in water troughs, while cattle fecal shedding stayed at pre-treatment levels following starling control. On the reference facility, *Salmonella* contamination increased within feed bunks, water troughs, and cattle fecal samples during the same period of time. Researchers believe the removal of starlings on the treated facility reduced feed and water contamination and may have prevented new infections within the herd.

“Many factors may be influencing *Salmonella* infections in cattle,” states NWRC biologist James Carlson. “For instance, herd size, age of cattle, stocking densities, manure management, feed rations, feed storage, and large flocks of invasive

> **"NWRC is leading the way in feral swine research—focusing on nonlethal and lethal ways to reduce damage."**

starlings may affect *Salmonella* levels. Starling control shows promise as a method to help livestock operations manage disease at their facilities, but we don't believe it should be the only tool. It should be part of a comprehensive disease management plan designed to improve farm-side biosecurity."

To better quantify the damage from starling-livestock interactions such as these, NWRC economists looked at starling-related costs associated with the consumption of cattle feed, increased feed spoilage, and higher veterinary expenses.

"The economic costs associated with starling damage at farms is significant," states NWRC economist Stephanie Shwiff. "In an analysis of dairy farms in Pennsylvania, we discovered starling damage at dairies costs the State more than $10 million annually in lost productivity."

Results also showed that Pennsylvania dairies lose approximately 6 percent (or 178 million pounds) of cattle feed to starlings each year, costing farms thousands of dollars in additional feed. Dairies with large starling populations were associated with higher occurrences of Johne's disease (up to a 148-percent increase) and *Salmonella* (up to a 900-percent increase) in their herds, resulting in increased veterinary costs compared to farms with lower starling numbers.

By encouraging multidisciplinary efforts and collaboration among its scientists, the NWRC is able to address complex wildlife damage management issues like those associated with European starlings. These efforts aid in the development of effective, practical, and cost-effective management strategies.

NEXT STEPS—Future NWRC research will work to identify efficient and economical management strategies for dealing with starling damage while also continuing to explore the effects starlings and other wildlife have on pathogen transmission, food safety, and economics. For example, preliminary work is underway to determine if starlings deplete the nutritional value of cattle feed by selecting the more nutritious pellets from feed mix. This information could lead to more efficient feeding strategies that minimize starling-related feed losses.

Feral Swine Impacts Reach Far and Wide

Feral swine, sometimes called the "rototillers" of nature because of their ability to root up crops, native plants, and suburban landscapes, now occur in at least 35 States, and their expanding populations show few signs of slowing. Experts estimate feral swine numbers in the United States at over 5 million, with the largest populations located in California, Florida, Oklahoma, and Texas. These large populations cause extensive damage to public property and native ecosystems and potentially increase transmission of pathogens to livestock and humans.

"We're trying to address feral swine issues on multiple fronts," explains NWRC research wildlife biologist Tyler Campbell. "We have researchers investigating new toxicants, attractants, bait delivery systems, vaccines, and fencing, as well as basic questions related to disease transmission, reproductive biology, ecology, population demographics, and economic impacts."

Experts estimate that feral swine in the United States cause more than $1 billion in damages and control costs each year. For example, rooting and wallowing activities cause property damage and erosion to river banks. Feral swine eat and destroy field crops, such as corn, milo, rice, watermelon, spinach, peanuts, hay, turf, and wheat. They are also efficient predators and, when given the opportunity, prey upon young livestock and small animals, such as ground-nesting birds.

In addition to degrading natural habitats and farm lands, feral swine were recently implicated in the damage of archeological sites at Avon Park Air Force Range in Florida. The 106,082-acre range comprises military training areas, as well as natural habitats containing numerous archeological sites that are more than 10,000 years old. In recent surveys, NWRC researchers also discovered feral swine damage at 14 out of 36 (or 39 percent) of the eligible sites for the National Register of Historic Places.

"Swine damage to agriculture and natural habitats may eventually be repaired, but the historical information lost through the disturbance of an archeological site cannot be regained," states Richard Engeman, a research biometrician with NWRC who is investigating feral swine damage to these and other sensitive areas. "Thus, swine damage to these sites is especially disheartening and makes finding methods to control populations even more critical."

Though it is difficult to place a price tag on the loss of national treasures, NWRC economists can and have assessed the general economic impact that could occur if feral swine were to introduce a foreign animal disease such as classical swine fever or foot-and-mouth disease to domestic livestock. Once prevalent in wild populations, these kinds of diseases would be difficult to eradicate. In one particular scenario, NWRC economists studied the potential damages associated with a foot-and-mouth disease outbreak in feral swine in Missouri. Such an outbreak was estimated to last approximately 45 days, result in 18,658 head of livestock being destroyed, and cost the State a minimum of $7.5 million. Risk assessments like this one not only help managers, biosecurity experts, and others plan for potential disease impacts to the livestock industry, but also help NWRC managers prioritize and invest in high-impact research.

Feral swine can carry over 30 pathogens that affect livestock, people, and pets. Current NWRC research involves developing oral toxicants and other tools to prevent the spread of some of these pathogens. Researchers are also evaluating a swine-specific

Feral swine lifting BOS™ feeder to access bait
Photos by USDA/NWRC

toxicant-bait delivery system that excludes nontarget native species, such as black bears, peccaries, and raccoons, from eating treated bait.

NWRC and Wildlife Services field operations are testing two delivery systems, both of which take advantage of the swine's rooting behavior. To access the bait, a pig must lift upward on a heavy metal cone (Boar-Operated System™/BOS) or metal trap door (HOG-HOPPER®) with its snout; these designs prevent smaller or weaker animals from accessing the bait. In Texas, NWRC researchers evaluated and monitored the use of 10 BOS units using motion-activated cameras and bait containing the biomarker tetracycline hydrochloride (TH). Results showed the BOS largely prevented bait removal by nontarget wildlife. Of the 81 feral swine and 23 raccoons captured in the study area, 90 percent and 13 percent, respectively, had TH-marked teeth, indicating that they had eaten bait from a BOS unit. Raccoons likely feed upon bait spilled from the BOS where swine had fed, as none of the surveillance photos showed raccoons lifting the feeder. These results show that, with minor modifications, the BOS could be a valuable tool for use in managing feral swine in certain areas.

Currently, NWRC and Wildlife Services field operations personnel in Alabama, Florida, Mississippi, Missouri, Oklahoma, and Texas are modifying and testing the HOG-HOPPER® in a variety of habitats to determine if it might also be a useful delivery tool. Information from the trials will be included in a data package seeking permission from the U.S. Environmental Protection Agency (EPA) to perform lethal trials with HOG-GONE®, a sodium nitrite toxicant bait developed in Australia.

The diversity of challenges posed by feral swine highlights the need for coordinated and strategic research among a variety of experts. Wildlife Services' researchers based at the NWRC and its operations personnel are uniquely positioned to offer this type of strategic support to those dealing with feral swine and other wildlife damage management issues.

NEXT STEPS—Future NWRC research plans include continuing investigation on feral swine impacts to historical sites, sensitive and rare plant communities, and agriculture; conducting benefit-cost analyses for feral swine management; determining the prevalence of specific pathogens in feral swine populations and resulting threats to domestic swine; and evaluating various fencing materials, capture devices, and vaccines for disease prevention. NWRC is also continuing tests on sodium nitrite delivery systems to ensure target specificity.

Spotlight: Improving Disease Surveillance

Considerable concern exists around the world about emerging infectious diseases—75 percent of which are zoonotic, meaning the pathogens causing the disease can be transmitted between animals and humans. Understanding and anticipating the transmission of pathogens from wildlife can help reduce infections among wildlife, domestic pets, livestock, and humans. NWRC is at the forefront of research and surveillance for many of these pathogens, including rabies and avian influenza viruses. NWRC researchers are combining data on animal behavior, ecology, genetics, movement, habitat features, and disease ecology with methods that incorporate spatial ecology. This allows them to examine biological and environmental interactions throughout space and time that affect the risk of disease spread and may impede mitigation efforts to prevent disease in domestic animals and humans. Below are two case studies highlighting NWRC efforts to improve surveillance for **rabies** and **avian influenza** viruses.

Optimizing Rabies Surveillance and Control

Rabies is an acute, fatal viral disease that can infect people as well as animals. Impacts to society from this disease can be great, especially in underdeveloped countries. The cost of detection, prevention, and control of rabies in the United States alone exceeds $300 million annually. Recent economic evaluations have shown that the return on investment for oral rabies vaccination (ORV) programs in wildlife can be as high as $13 dollars for every dollar spent.

In the United States, terrestrial rabies is found in many wild animals, including raccoons, skunks, gray foxes, arctic foxes, bobcats, and coyotes. In an effort to halt the spread of and eventually eliminate terrestrial rabies in the United States, NWRC scientists work with APHIS Wildlife Services' National Rabies Management Program (NRMP) to study the behavior, ecology, movement, and population structure of raccoons and other wildlife hosts. They also evaluate methods and techniques used in ORV programs to mitigate and control rabies.

Another particularly promising area of rabies research at NWRC is the incorporation of spatial ecology—the study of spatial patterns as they relate to ecological environments—to better understand patterns of rabies virus transmission within and among species and to optimize ORV baiting strategies. By targeting high-use areas and maximizing bait encounters, wildlife managers can increase the number of animals vaccinated with fewer baits, potentially saving thousands of dollars.

"In the arid West, water is often a limiting factor for many wildlife populations. The development of water features for livestock, such as stock tanks and artificial catchments, increases the risk of interactions among wildlife, and between wildlife and livestock, as animals utilize and share these critical resources," states Todd Atwood, a research wildlife biologist at NWRC. "Since rabies can infect multiple species and has a high potential for cross-species transmission, it is critical that we understand the role water availability may play in facilitating disease transmission. With that, we can develop better strategies for disrupting transmission."

In a recent study, NWRC researchers collected data on interactions among coyotes, bobcats, and gray foxes at 31 artificial water features in Texas. Results indicated that gray foxes behaved as subordinate competitors for these water sources, having both the shortest time intervals at the sites and using them almost exclusively (greater than 97 percent of visits) at night. In contrast, only 41 percent of coyote and 61 percent of bobcat visits to water sources occurred at night. Bobcats also spent more time at the sites, on average, than coyotes or gray foxes. The use of water sources by both coyotes and bobcats was directly related to the days since the last rainfall, with animals using artificial water sources more frequently as the time since last rainfall increased. Gray fox use

Researchers studied interactions among bobcats, coyotes, and foxes at artificial water sites in the arid Southwest.
Photo by DOI/FWS, Gary Kramer

> **“Combining genetics, movement, and behavioral data with a knowledge of disease ecology arms wildlife managers with critical information for controlling the spread of rabies.”**

of artificial water sources, on the other hand, was positively related to the availability of rugged escape terrain and inversely related to activity of the larger carnivores.

These data suggest that while artificial water in arid environments of the southwestern United States may result in increased interactions and potential disease transmission among coyotes and bobcats, this may not be the case for gray foxes. Researchers also observed that 60 percent of the interspecies interactions recorded were between carnivores and cattle. These data indicate that the incidence of encounters at water features may be higher between carnivores and cattle than between carnivores and other carnivores, which suggests that these sites can lead to a higher probability of rabies virus transmission from wildlife to livestock.

In related work, NWRC researchers are using genetic analyses to better understand the gene flow in populations of raccoons and gray foxes as it relates to landscape features and how this, in turn, affects the spread of rabies. Genetic tools, such as Bayesian clustering analyses and assignment tests, are used by NWRC population geneticists to infer population structure and historical patterns of dispersal (gene flow). These cutting-edge tools provide NWRC researchers with the ability to assess the risks of rabies virus transmission across various geographic distances based on the genetic history of the population.

NWRC field ecologists and geneticists have studied raccoon ecology in Alabama, Pennsylvania, and most recently, Ohio. Thus far, all studies have concluded that local, rather than long-distance, movements are most common for this species in the study landscapes. These results suggest that, if detected and managed early, rabies outbreaks can be locally contained.

“Through our genetics work, we’ve found that landscape features, such as mountain or hill ridges, influence gene flow only to a limited extent,” states NWRC research wildlife biologist Kurt VerCauteren. “This result suggests that these landscape features may not serve as substantial long-term barriers to the spread of rabies. We’re now applying that information to models that will help predict the spread and transmission risk of rabies in the Eastern United States.”

Similar ongoing NWRC work for gray foxes has resulted in the collection of over 500 gray fox tissue samples, including rabies virus samples, for genetic analyses from western Texas and New Mexico. These samples are being used by NWRC researchers and collaborators at New Mexico State University to develop similar models to predict the spread of the fox rabies variant in the desert Southwest.

Tracking radio-collared raccoons
Photo by USDA, Michael Dunbar

Spatial tools are also integral to the optimization and refinement of raccoon abundance estimates, which, in turn, are used to determine ORV baiting densities. NWRC researchers, in collaboration with the NRMP and Purdue University, are evaluating and refining methods used to estimate raccoon abundance. Using telemetry data for 50 raccoons in the agricultural ecosystems of northern Indiana, researchers constructed spatially explicit resource selection function models for predicting habitat use by raccoons within the landscape. Researchers then used the models to estimate raccoon abundance at specific sites in northern Indiana and compared the estimates with those from two other techniques: (1) the raccoon abundance index currently used by the NRMP and (2) the "gold standard" mark-recapture method. The results indicated that the NRMP raccoon abundance index consistently underestimated raccoon numbers as compared to the mark-recapture models. However, the more cost-effective, spatially informed trap placement method for conducting raccoon abundance indices also provided a distinct improvement over the current NRMP abundance index. Such information aids ORV program managers and stakeholders who continually work to improve the effectiveness of their baiting efforts.

NEXT STEPS—Future NWRC research will continue to leverage spatial ecology and genetics to help optimize ORV programs. NWRC researchers are using spatially explicit resource selection function models to evaluate the potential impacts of modifying baiting strategies to account for habitat use by raccoons. Researchers are also comparing the success and efficiency of current baiting protocols, which disperse ORV bait uniformly across a landscape, to a more spatially informed baiting strategy that accounts for differences in habitat use. NWRC economists also plan to analyze the benefits and costs associated with rabies containment programs and the impacts of barrier breaches.

Discovering Transmission Pathways for Avian Influenza in Wildlife and Poultry

Avian influenza virus (AIV) is found naturally in waterfowl and other wild bird species. There are 144 known subtypes of AIV, but few of these subtypes cause serious diseases in wild birds. However, mutation of these viruses can cause disease in domestic livestock, poultry, and humans. Such mutations can result in AIV strains that are highly pathogenic. For example, the highly pathogenic strain of H5N1 first seen in 2006 originated from a low pathogenic strain of AIV in wild waterfowl that mutated into a highly pathogenic strain in Asia. This strain subsequently spread from Asia across the Eastern Hemisphere and continues to cause considerable economic loss and mortality in domestic poultry, as well as human deaths. Thus, understanding the ecology of low pathogenic strains of AIV circulating in the wild is critical to prevent future influenza epidemics and global pandemics that affect both livestock and humans.

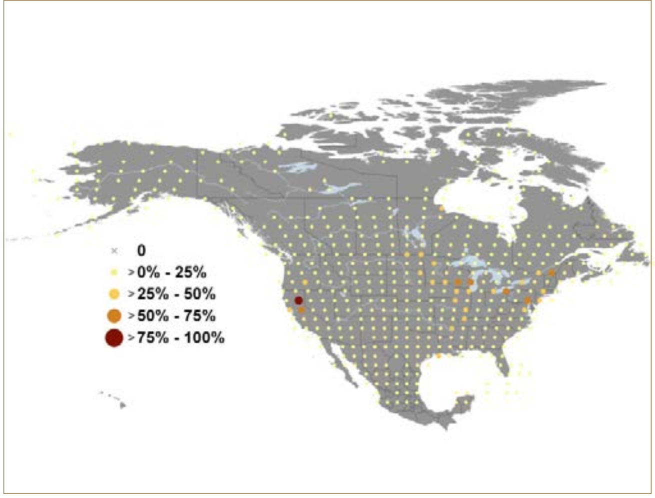
> **“Knowing where to look is the first step in successful disease detection and eradication.”**

NWRC researchers assist surveillance and mitigation efforts for AIV, both nationally and internationally. Research efforts focus on a wide variety of issues, such as determining how different wildlife species shed AIV infections into the environment, which can subsequently infect domestic poultry and humans; understanding the transmission dynamics of key wildlife species; developing spatially explicit quantitative tools to enhance AIV surveillance; and other strategies to mitigate AIV transmission from wildlife and the environment to agricultural facilities.

Waterfowl Connectivity

Map showing the overall connectivity of waterfowl in North America based on analysis of banding and recovery records of all harvested waterfowl from 2002 through 2006. The larger, darker colored circles indicate areas that are potentially important in the spread of avian influenza viruses.

Map by USDA



“Our goal is to optimize surveillance and detection strategies for avian influenza virus so that, if a highly pathogenic strain of the virus is detected in the United States, emergency responders can act quickly and effectively to contain and eliminate the spread of the virus, particularly to our domestic poultry farms,” notes Alan Franklin, a research biologist at the NWRC. “By identifying the weakest links—those areas where we can most easily enhance biosecurity or eliminate disease threats—we can disrupt or eliminate the pathways of virus transmission among waterfowl, wildlife, and domestic poultry.”

The use of spatially explicit methodologies, in combination with data related to waterfowl migration patterns, poultry operation locations, and the epidemiology and structure of AIV strains, brings numerous benefits. This approach allows NWRC researchers to examine the biological and environmental interactions that affect the spread of AIV from waterfowl to domestic poultry, influence the success of surveillance and early detection of AIV strains in wildlife species that could impact agriculture and human health, and improve efforts to mitigate the introduction and spread of AIV on a continental scale.

Many experts believe the migration of waterfowl may aid in the introduction and spread of new AIV strains in North America. Therefore, understanding the distribution and frequency of waterfowl movements within and among geographic locations is critical to overall AIV surveillance efforts.

Using data from the North American Bird Banding Program, NWRC researchers and their collaborators have employed network analyses (i.e., techniques that reveal connectedness among populations and geographic areas) to clarify spatial and temporal trends in the movement of select waterfowl species across North America. More than 200,000 bird banding and band recovery records from 2002 to 2006 were used to create these "networks." Based on the results, researchers were able to identify specific locations in North America of high waterfowl use and connectedness and, thus, identify high-priority areas for AIV surveillance.

NEXT STEPS—NWRC researchers and collaborators recently extended their use of these bird banding networks to evaluate AIV risks for poultry operations in the United States. AIV research also involves integrating data from previous studies into quantitative risk assessment models. Studies are looking at the role peridomestic mammals (those living in and around human structures such as barns and poultry facilities) may play in the spread of AIV. These models will aid in the development of biosecurity strategies to protect agricultural operations and humans.

In addition, NWRC researchers are employing spatially explicit methods to explore the transmission dynamics of other pathogens, such as bovine tuberculosis (bTB), in agricultural landscapes. Recent data from Michigan indicate that North American opossums can serve as reservoirs for bTB and infected animals are occurring in the core of that State's bTB zone. Concern exists that opossums using stored feed and hay in barns and storage facilities used by livestock can transmit the disease to livestock and other wildlife, such as white-tailed deer. NWRC researchers are using global positioning system (GPS) technologies to reveal how and when opossums utilize farms and farm structures in the core bTB zone of Michigan to better understand what role this species may plan in the transmission of this disease to cattle and other wildlife species.

Scientists are evaluating avian influenza risks to backyard and commercial poultry operations.
Photo by USDA, Anson Eaglin

Spotlight: Developing Safer Rodenticides

Rodenticides are an important component of many integrated pest management programs to protect human health and safety and to safeguard agricultural crops, natural resources, and property from overabundant and/or invasive wildlife. However, these chemical approaches can pose hazards to nontarget animals and the environment. NWRC scientists work to reduce or eliminate these hazards, as well as develop and register effective, alternative approaches for managing wildlife damage. Examples of current research include **preventing rodenticide consumption by nontarget wildlife, modeling physiological impacts** of toxicants, and **reducing risks** associated with rodenticide baiting operations.

"Reducing rodenticide hazards to nontarget wildlife is a valuable part of NWRC research."

Reducing Rodenticide Consumption by Nontarget Wildlife

Rodenticides, such as zinc phosphide, are often used to control rodent populations that cause damage in cropland and rangeland environments. Zinc phosphide breaks down rapidly after ingestion and poses little risk to predators and scavengers that might consume poisoned rodents; however, birds that directly consume the rodenticide bait may be at risk.

In an effort to reduce nontarget hazards to birds during rodent control efforts, NWRC researchers evaluated whether the addition of the registered goose repellent anthraquinone to rodenticide baits would prevent consumption of the baits by certain birds.

Anthraquinone, which occurs naturally in some plants, produces a laxative effect when eaten. In addition, anthraquinone absorbs near-ultraviolet light (a portion of the light spectrum not visible to the human eye) that is visible to most birds. This color cue may facilitate the repellency effect in birds.

"Anthraquinone exhibits both a visual cue and a laxative effect. These unique characteristics make it an effective repellent for wild birds," states NWRC research wildlife biologist Scott Werner. "By adding it to a rodenticide bait, such as zinc phosphide, we hope to minimize the number of baits consumed by birds."

In captive studies, NWRC researchers treated 2-percent zinc phosphide baits typically used in rodenticide applications with 2 to 2.5 percent anthraquinone (Arkion® Life Sciences). No mortality or signs of zinc phosphide toxicosis were observed among the 20 Canada geese, 24 horned larks, and 47 ring-necked pheasants that were offered the repellent-treated zinc phosphide baits. Although some geese and pheasants initially sampled treated baits, all birds survived and subsequently avoided treated baits throughout the remainder of the study. The findings could aid in the development of new bait formulations that reduce the ingestion of rodenticides by these and other nontarget wildlife species.

In addition to modifying the composition of the bait itself, NWRC researchers are redesigning bait stations to reduce nontarget species access and exposure to

In an effort to reduce nontarget hazards to birds, researchers evaluated whether adding the bird repellent anthraquinone to rodenticide bait would prevent consumption of the bait by horned larks.

Photo by USDA, Scott Werner

rodenticides. On islands like Hawaii, rodent feeding or bait delivery stations are often used to prevent nontarget bait "take" by other wild animals, livestock, or pets. Opportunistic feeders such as birds, reptiles, amphibians, terrestrial crabs, feral swine, and goats sometimes access these stations; this leads not only to toxic bait exposure, but also to loss of bait, which reduces the overall efficiency of the control program.

In captive rodent studies with invasive Polynesian rats, Norway rats, roof rats, and house mice, NWRC researchers examined the physical and behavioral capabilities of these species in relation to the design—entry opening and height above ground—of bait stations. The maximum jumping height achieved by the three rat species was 40 centimeters (cm), whereas house mice jumped a maximum of 25 cm. The minimum diameter of the hole through which these species could pass was 40 millimeters (mm) for Norway rats, 35 mm for roof rats, 30 mm for Polynesian rats, and 13 mm for house mice. These findings establish threshold differences for rodent species related to their ability to enter openings or jump to platforms to obtain food. This information could be used in designing bait stations that help prevent accidental poisoning of endangered birds or other animals from rodenticide bait.

NEXT STEPS—Additional studies are underway to evaluate the efficacy of the new anthraquinone-zinc phosphide bait for target rodent species. NWRC researchers also plan to investigate possible uses of anthraquinone to reduce nontarget hazards associated with other pesticides.

Modeling Rodenticide Toxicity

Anticoagulant rodenticides are important and widely used tools for managing rats, ground squirrels, voles, and other rodents that damage agriculture, impact native flora and fauna, transmit diseases, or otherwise conflict with human interests. However, concerns about nontarget hazards to wildlife and other adverse environmental effects could limit the use of these rodenticides in the United States.

An absence of toxicity data for many species makes it difficult to evaluate potential secondary hazards associated with these rodenticides. In the absence of such data, the EPA usually takes a conservative approach and extrapolates from data obtained from the most sensitive, closely related species. Additionally, since the concentration of the rodenticide in the various organs of a poisoned rodent is usually unknown, EPA generally assumes that the diet of any potentially exposed predator or scavenger consists entirely of the liver, the organ that typically has the highest rodenticide residues.

"It is understandable for the EPA to be very conservative when it comes to rodenticides and their impacts to nontarget animals," notes NWRC pharmacologist Katherine Horak. "However, such an approach may still lead to underestimating or overestimating the true risks to many species. NWRC hopes to provide the EPA and others with more accurate and reliable data by modeling rodenticide residues in various tissues and providing a means to estimate the sensitivity of nontarget species to these residues."

NWRC scientists are using physiologically based pharmacokinetic/pharmacodynamics models to more accurately estimate the toxicity of rodenticides. By measuring rodenticide residues in various tissues of target and nontarget species, NWRC scientists then use model-generated estimates to calculate the exposure, sensitivity, and risk of anticoagulant rodenticide baiting to these and closely related species.

For example, collaborative studies by NWRC and U.S. Geological Survey (USGS) scientists with northern bobwhite (commonly used for regulatory toxicity studies) and American kestrels indicated that the rodenticide diphacinone was 20 times more toxic to American kestrels than to northern bobwhite—meaning some raptors are considerably more sensitive to diphacinone, and their protection may require more substantial safety margins than other bird species.

More recently, NWRC scientists evaluated diphacinone toxicity in screech owls and observed that most birds that were administered a single large dose regurgitated about half of the diphacinone. Thus, researchers administered lower doses over a period of 7 days rather than a single acute dose. Screech owls dosed at 0.34, 1.25, and 2.46 milligrams (mg) of diphacinone per week showed clear signs of toxicity. The dietary lowest observed effect level (LOEL) of diphacinone for screech owls was estimated to be 0.24 mg/kg/day or approximately 1 to 2 diphacinone-treated whole mice per day.

Results from toxicity studies showed that raptors, such as the American kestrel, are more sensitive to rodenticides than other species are.

Photo by USGS, Barnett Rattner

The species- and organ-specific toxicity data and pharmacokinetic/pharmacodynamics models being developed by NWRC scientists permit more realistic and accurate estimates of target and nontarget species risks from anticoagulant rodenticides.

NEXT STEPS—NWRC researchers are exploring methods to increase the efficacy of rodenticides while also reducing the toxicity levels found in bait. For example, by fortifying baits with pomegranate or grapefruit juice, researchers can reduce the amount of anticoagulant metabolized by the rodent, which decreases the quantity of toxicant the rodent must consume. Methods such as this could allow for lower toxicant concentrations in baits while maintaining the same level of rodent control, ultimately decreasing the amount of toxicants placed out in the environment. Researchers are also working to determine the active ingredient in these natural substances.

Assessing Hazards to Nontarget Wildlife

Island biodiversity around the world is threatened by the effects of introduced rodents and other invasive species. As a result, there have been dramatic increases in the registration and use of rodenticides to eradicate rodents on islands. However, concern still exists over the potential impact of rodenticides on nontarget birds and reptiles that live on islands. To aid national and international eradication efforts, NWRC scientists are evaluating the potential impacts of rodenticide baiting operations on several islands in the Pacific Ocean.

One recent study assessed nontarget risks to the endangered Micronesian megapode on the Kayangel Atoll at the northern end of the Republic of Palau archipelago. The Micronesian megapode is a pigeon-sized, ground-dwelling bird that eats a variety of plant and animal foods on the forest floor, including seeds, beetles, ants and other insects, and plant matter. The Kayangel megapode population is being

"NWRC research identifies potential risks to native plants and animals associated with rodent eradication efforts on islands."

impacted by invasive rats, and efforts are underway to eradicate these rodents. In a field study on the atoll, NWRC scientists used infrared cameras to assess bait acceptance of a broadcast application of two formulations of pelletized placebo bait (i.e., bait without any toxicant). Rats consumed the bait soon after it was distributed. Micronesian megapodes and feral chickens also consumed the bait, indicating that these nontarget species might be at risk of poisoning from bait made available on the atoll.

In a similar study, NWRC scientists investigated responses of captive reptiles to small, acute doses of two anticoagulant rodenticides. This study helped to fill a much-needed area of research for wildlife management; although reptiles are common on many islands, few studies have assessed their vulnerability to rodenticide poisoning.

"Because reptiles are cold-blooded and their blood chemistry is different from mammals and birds, we expect their reaction to anticoagulants to also differ," notes NWRC research wildlife biologist Gary Witmer.

The effects of two anticoagulants commonly used in rodent eradication programs, diphacinone and brodifacoum, were evaluated using captive Central American wood turtles and boa constrictors. Animals in one treatment group were dosed at a level potentially found in the environment during a typical rodent eradication program. The second treatment group was given a dose 10 times greater. No mortalities, abnormal bruising, or overt signs of poisoning were observed in either group, although low levels of the rodenticides were detected in the animals' tissues and livers. These results indicate that the risks to most reptiles from nontarget or secondary poisoning by anticoagulant rodenticides are low.

NEXT STEPS—NWRC studies on the effects of anticoagulants on nontarget reptiles continue with work on Ameiva lizards and iguanas. Researchers are also developing new methods for detecting nontarget hazards associated with diphacinone and brodifacoum in soil, fresh water, and salt water. The methods are unique in that they quantify both diphacinone and brodifacoum simultaneously, thus reducing the number of samples needed.

NWRC researchers are developing new methods to detect rodenticide residues in water.

Photo by USDA, Are Berentsen

> “Encouraging a bird to respond to an airplane like it would a predator requires a basic knowledge of bird biology and behavior.”

Spotlight: Exploring Animal Sensory Systems

What do disease detection, repellents, baits, lures, and aircraft-bird collisions have in common? They each require an understanding of how animals perceive their surroundings. Scientists at the NWRC have a long tradition of studying the sensory systems of wildlife—how animals see, smell, taste, and touch. By understanding these mechanisms, researchers are able to design effective and selective wildlife damage management tools.

Helping Birds Detect and Avoid Aircraft

Since 1989, scientists at the NWRC Sandusky, OH, field station have been working to reduce wildlife risks to aircraft. Early studies involved the development and testing of a low-powered, “red-light” laser system that subsequently was commercialized and now is being used successfully to disperse crows, cormorants, vultures, and Canada geese.

Currently, NWRC scientists and partners are investigating the visual capabilities of birds from a visual sensory and behavioral perspective. By knowing how birds detect approaching objects, the researchers hope to develop lighting systems that make objects more detectable to birds.

“Escaping from an impending threat is critical for animal survival,” states NWRC research wildlife biologist Bradley Blackwell. “Unfortunately, animals do not always perceive man-made objects, such as cars and airplanes, as a threat until it is too late.”

Certain lighting systems that exploit the visual sensory capabilities and antipredator behavior in birds can allow birds to react more quickly to avoid an approaching object, such as a vehicle. NWRC scientists and their collaborators at Purdue University and Indiana State University have confirmed that specific light wavelengths and pulse frequencies can alert and evoke an earlier escape response in birds. Earlier research by the NWRC scientists, in collaboration with Precise Flight, Inc. (a manufacturer of aviation oxygen, lighting, and electromechanical technologies), set the stage for developing new aircraft lighting systems intended to enhance bird detection of approaching aircraft and, subsequently, escape behaviors. The impact of such tools could be significant given that more than 7,400 bird strikes are reported annually in the United States, costing the civil aviation industry at least $625 million in downtime and damages.

One species known to cause considerable damage to airplanes because of its large size and tendency to fly in flocks is the Canada goose. In an effort to build upon past NWRC research in how lighting systems might be used to promote escape behavior in birds, NWRC scientists took a step back and asked, “What are the fundamental sensory and behavioral limits to visual detection and processing in birds?” To this end, NWRC and their colleagues at Purdue and

Indiana State universities studied the distribution of ganglion cells[1] and photoreceptors in the retinas of captive Canada geese, as well as their eye movements and scanning behavior.

Overall, researchers found that the visual system of the Canada goose is designed to detect objects such as predators and other geese in open terrain. Furthermore, their ganglion cells are arranged in an oblique formation across the retina, which allows the birds to scan the ground and the sky simultaneously when their heads are up and approximately parallel to the ground. The researchers hypothesize that this cell distribution, along with the birds' large eye size, may reduce the need for the birds to move their heads extensively while scanning their surroundings in open environments, whether in flight or on the ground. Thus, Canada geese likely have a higher probability than other birds of detecting a light stimulus from an aircraft, particularly from a light that is designed relative to the species' visual capabilities.

NEXT STEPS—NWRC researchers and partners continue to explore the use of lighting systems to prevent wildlife collisions with aircraft and automobiles, focusing particularly on the range of light wavelengths and pulse frequencies that maximize detection. Researchers are also studying the flight initiation distances of several bird species when approached by vehicles of varying size and speed to better understand how birds perceive and react to approaching objects. This type of information is useful in the design of lighting systems that maximize the chances a bird will detect aircraft and other approaching objects and initiate an appropriate escape response.

Sniffing Out Disease

As early as 2003, dogs were trained to sniff out cancer in humans. Scientists noticed that diseased cells create a scent not present in healthy cells and

Researchers are studying the visual systems of Canada geese to learn how they perceive approaching objects, such as airplanes.
Photo by USDA, Laurie Paulik

that dogs have the ability to detect the scent. NWRC researchers and their partners at Monell Chemical Senses Center (Monell) are building upon this knowledge to create new diagnostic tools that use odor as a means to detect disease.

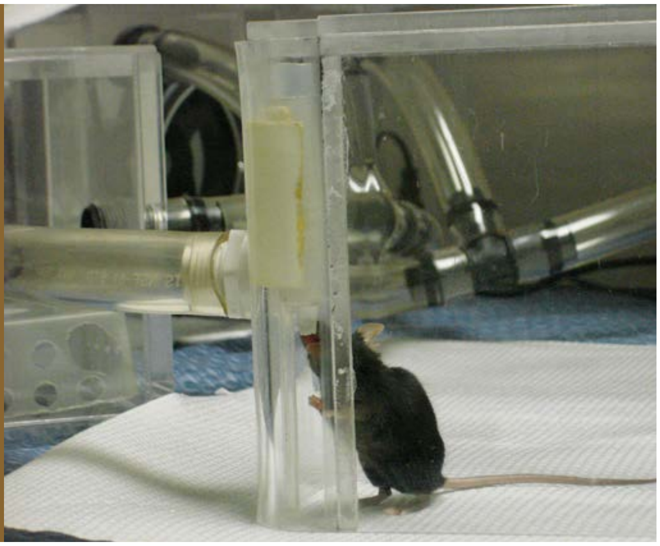
Odors from animals have several origins. Some are metabolic byproducts of diet, others come from species-specific scent glands, and still others arise from the natural metabolites and chemical composition of the animal's response to pathogens. These latter odors are largely determined by the genetic makeup of the animal.

Monell scientists have shown that mice can discriminate odor differences among other mice even if the genetic difference is minor. These experiments demonstrate the highly sensitive nature of odor detection and discrimination in mice. NWRC research chemist Bruce Kimball, in collaboration with Monell colleagues, has adapted this animal model to see if mice can be trained to detect the odor of other mice that have been exposed to pathogens.

[1] Ganglion cells receive and compile visual information from photoreceptors in the eye and transmit it to the brain.

“Taking advantage of how animals see, smell, or taste allows NWRC researchers to design selective and effective damage management tools.”

“We were first able to train mice to use odor to identify feces collected from ducks infected with low pathogenic avian influenza,” explains Kimball. “The mice distinguished between infected and uninfected feces more than 90 percent of the time. These results indicate that a yet-to-be-identified volatile compound or compounds may be an indicator of infection. Through further experiments, we found that mice can also tell if other mice have been treated with a vaccine. However, it is still not clear if they can discriminate between the odors of different pathogens. We are also applying sophisticated chemical and statistical analyses to perform the same discrimination task using laboratory equipment instead of mice.”



Scientists have learned that mice, using their sense of smell, can distinguish between vaccinated and unvaccinated mice.
Photo by Monell Chemical Senses Center, Maryanne Opiekun

The first finding is promising, and the latter has led to new research with an aim toward determining whether the correct set of odorants has been identified. The results suggest that animals can be trained or tools can be developed for identifying infected animals or populations. The same technique for training mice as sensor animals could be used to train dogs for environmental screening, while the same odorants and associated pathogens identified by the mice could be monitored by advanced analytical chemistry techniques to help detect and prevent disease outbreaks.

NEXT STEPS—NWRC researchers are modeling the immune responses of vaccinated mice with the goal of learning more about the specificity of immune responses in animals. In particular, researchers are comparing odor changes caused by vaccination with odor changes produced by inflammation to see if these changes have diagnostic potential. They are also investigating the longevity of these odor responses. Additional experiments will determine if odor changes have the potential to produce behavioral changes in natural systems. For instance, a number of studies by other groups have demonstrated avoidance of parasitized animals by conspecifics. Researchers will determine if vaccination may also produce avoidance behaviors, which may have implications regarding large-scale vaccination programs in wildlife.

Taking Advantage of Sensory Cues

NWRC has a long history of developing baits, lures, and chemical repellents for the protection of agricultural crops, natural resources, property, and human health and safety. Starting in the 1940s, NWRC's predecessor organizations—the Denver Wildlife Research Center and the Food Habits Laboratory—focused primarily on developing lures and baits and making products palatable to wildlife. The challenge of finding new and effective wildlife damage management tools continues with the development of aversive conditioning techniques, repellents, and new toxicants.

Taste, smell, sight, and tactile cues help mammals and birds identify and discriminate among foods, but these senses play somewhat different roles in food preferences and food selection. In studies with captive red-winged blackbirds, NWRC researchers have learned that blackbirds use chemosensory and feeding experiences to determine flavor preferences and use color or visual cues to select or avoid certain foods.

"In our feeding experiments, we saw that captive red-winged blackbirds were able to associate the color of food with a particular feeding experience, and then apply their experiences with the color and flavor of foods to select nutrients and avoid toxins," states NWRC research wildlife biologist Scott Werner. "For example, blackbirds avoided the color and flavor of food previously paired with post-ingestive illness. In contrast, the birds avoided only the color (not flavor) of food previously paired with a pre-ingestive irritant. These fundamental relationships are helping us develop effective bird repellents for agricultural production."

Anthraquinone is a natural substance that not only has a laxative effect but also absorbs near-ultraviolet light, which is visible to most birds. NWRC researchers hypothesize that applying a repellent such as anthraquinone to crops, followed by subsequent application of a color or flavor cue similar to the repellent (such as a near-ultraviolet color cue), might help protect newly planted and ripening crops from blackbird depredations.

As discussed in the previous spotlight "Developing Safer Rodenticides," NWRC scientists are exploring other uses for anthraquinone. Working with Arkion Life Sciences, a private rodenticide manufacturing company, researchers are reducing the accidental consumption of zinc phosphide rodenticide bait by birds. Preliminary results show that incorporating anthraquinone into baits discourages consumption by birds. NWRC's work with anthraquinone is one example of how researchers take advantage of various animal sensory systems.

New chemical tools, such as anthraquinone, that are developed for use in wildlife damage management must be registered with the EPA. The NWRC's Registration Unit maintains APHIS registrations with the EPA for rodenticides, predacides, avicides, repellents, snake toxicants, and an avian repellent. The unit frequently provides consultation and other technical assistance to APHIS Wildlife Services program staff, Federal and State agricultural and conservation agencies, academic institutions, nongovernmental groups, and private industry. Recently, NWRC researchers and registration specialists met with representatives of the fruit industry and academia to evaluate the possibility of registering anthraquinone or other existing pesticide products for use as bird repellents on ripening fruit crops like cherries and blueberries.

Bird damage has plagued orchardists since the earliest times of cultivation. In a matter of minutes, a flock of birds can destroy an entire crop either by stripping trees of all harvestable fruit or by damaging the appearance of hanging fruit, making it unmarketable. Current crop protection techniques are limited to hazing (scarecrows, propane cannons, flagging) and physical exclusion (netting) that can be difficult to install and maintain. A recent evaluation by NWRC's Registration Unit estimated the cost of developing the data to register a new active ingredient for food crops like soft fruit with the EPA at $7.8 million, whereas data development for registering an existing bird repellent, such as anthraquinone, for application on food-use crops would cost approximately $750,000. Such information is useful to decisionmakers looking for the most cost-effective approach for developing new wildlife management tools.

Bird damage to ripening fruit crops, such as cherries, remains a difficult problem for producers.
Photo by USDA/NWRC

NEXT STEPS—Discussions with the fruit industry have since led to the development of a multiyear, interdisciplinary collaboration between the NWRC, Michigan State University, Cornell University, Trinity Western University, Washington State University, and Oregon State University. Research studies will focus on quantifying economic impacts of bird damage for producers, consumers, and regional economies; determining how bird damage varies within and across orchards, landscapes, and regions; identifying amounts of damage attributable to specific bird species across crops and regions; investigating consumer responses to management strategies and the potential effects on marketing; and evaluating various management strategies to reduce damage.

2011 Accomplishments in Brief

The NWRC employs approximately 150 scientists, technicians, and support staff who are devoted to 16 research projects (see Appendix 1). Below are brief summaries of select findings and accomplishments from 2011 not previously mentioned in this year's report.

Agriculture and Natural Resource Protection

- **Relocation and Survival of White-Tailed Deer.** Translocation of white-tailed deer has become popular in Texas, but little is known about the survival, movements, and body condition of moved animals. Fifty-one deer were monitored by NWRC researchers after being moved to either a partially fenced or an unfenced property. Survival of white-tailed deer relocated to the partially fenced property was lower (59 percent) than those relocated to the unfenced property (74 percent). In both cases, young translocated males had lower average antler gain, body condition scores, and rump fat measurements than native males. These data will be useful for managers evaluating the benefits and costs of translocation as a management tool.
  Project Contact: Tyler Campbell

Researchers study the survival, movements, and overall health of translocated white-tailed deer.
Photo by USDA, Tyler Campbell

Research on calf mortality showed calves selected by predators were, on average, 25 days younger than surviving calves.
Photo by USDA

NWRC researchers are studying how snowmobile trails may impact coyote movements and subsequent interactions with lynx.
Photo by USDA, Eric Gese

- **Calf Mortality and Producer Detection Rates.** To investigate factors influencing calf mortality and producer detection rates, researchers monitored 930 radio-tagged domestic calves at two sites in New Mexico and Arizona. Study areas differed in grazing practices, density of predators (mountain lions, black bears, coyotes, and Mexican wolves), and the amount of effort spent monitoring cattle. Calves selected by predators were, on average, 25 days younger than surviving calves. The results indicate that year-round calving, especially in areas with high predator densities, is subject to higher losses primarily because calves are exposed to mortality agents for longer periods of time rather than having higher natural rates of mortality. Researchers also found a significant difference in producer detection rates likely due to differences in the intensity of monitoring cattle. These findings support changing husbandry practices to limit calving to a seasonal endeavor and indicate that paying producers to maintain sustainable predator populations may be a better compensation strategy than paying producers based on verified losses.
Project Contact: Julie Young

- **Snowmobile Trails as Corridors for Coyote Movement.** Increased snowmobile use and subsequent snow compaction in Canada lynx recovery areas are a concern for agencies responsible for recovery efforts. Researchers observed that coyotes used compacted snow trails as transit routes for approximately 35 percent of their travel distance. Coyotes also traveled closer to snow-compacted trails than expected. By facilitating coyote access to winter lynx habitats, snowmobile use may inadvertently allow for increased competition between the two species. These results support the need for wildlife management agencies to consider winter recreational use patterns that may influence the distribution of coyotes in lynx reintroduction areas.
Project Contact: Julie Young

In a captive study, house mice damage to tree seedlings resulted in the mortality of more than half of the seedlings.
Photo by USDA, Gary Witmer

Rodenticide bait is loaded into an aerial spreader as part of an effort to eradicate invasive rodents on Lehua Island, HI.
Photo by USDA, Justin Fisher

- **Assessing Seedling Damage by Mice.** Research has shown that house mice and deer mice may cause substantial damage to tree seedlings. In captive studies at NWRC, deer mice and house mice were placed in metal stock tanks with planted ponderosa pine and narrow-leaf cottonwood seedlings. Both rodent species damaged leaves and stems of cottonwood seedlings, with house mice damage resulting in the mortality of more than half of the cottonwood seedlings. Only slight damage was done by either species to the pine seedlings, and neither species damaged the roots of seedlings, despite extensive burrowing by house mice. Researchers concluded that management actions to reduce mouse damage at regeneration sites or in plant nurseries may be warranted.
  Project Contact: Gary Witmer

- **Effects of Deer and Elk Browse on Reforestation.** In intensively managed conifer tree farms in western Washington, NWRC researchers monitored stand use and level of browse by deer and elk. Seedling survival was similar between plots that were accessible and those that were inaccessible to deer and elk. However, seedlings inside fences were taller and had a greater basal diameter than did seedlings outside the fences. Terminal leader damage by deer and elk ranged from approximately 33 to 60 percent after 1 year of growth. Despite trees surviving, these effects led to deformed growth in seedlings. The results of this study will aid foresters in modifying management strategies and tree growth and yield models.
  Project Contact: Jimmy Taylor

- **Sources of Island Rats.** Rodent control on islands to protect nesting seabirds and other threatened wildlife is an important conservation activity. When rats reappear after eradication efforts, it is important to know whether eradication was incomplete or whether the island was recolonized. Using genetic analyses, researchers showed that in the case of Lehua Island, HI, the reemergence of rats was due to an incomplete eradication effort and not to new colonizations. This finding has led to reevaluations of rat eradication strategies and efforts.
  Project Contact: William Pitt

Researchers investigated whether landscape features could be used to predict predation risks to endangered black-footed ferrets.
Photo by DOI/FWS, Ryan Hagerty

- **Effects of Cormorant Management on Co-Nesting Birds.** Researchers evaluated the effects of disturbance due to egg oiling and lethal removal of double-crested cormorants on co-nesting herring gulls and Caspian terns. Overall, cormorant management activities did not affect the success of herring gull nests or flushing from nests for both herring gulls and Caspian terns. However, researchers documented severe weather that may have led to the complete abandonment of the Caspian tern colony in the second year of the study. Researchers note that numerous other factors besides management (i.e., research disturbance, unauthorized disturbance, aggressive interactions among and within species, and environmental conditions) can potentially affect nesting success. Wildlife managers should be cautious when determining the ultimate cause or causes of disturbance to co-nesting species.
  Project Contact: Fred Cunningham

- **Predation on Endangered Black-Footed Ferrets.** Researchers investigated whether landscape features could be used to predict predation risk from coyotes and great horned owls on endangered black-footed ferrets. Exposure to areas near likely owl perches reduced ferret survival, but landscape features potentially associated with coyote movements had no appreciable effect on survival. These results suggest that future decisions concerning the location of re-introduction sites should consider the location and distribution of landscape features potentially used by great horned owls.
  Project Contact: Julie Young

- **Monitoring Endangered Seabirds.** Researchers developed monitoring protocols and collected baseline data for two endangered endemic seabirds—the Hawaiian petrel and Newell's shearwater—in Kohala Mountain on Hawaii Island. Both species are nocturnal, colonize remote regions, and nest underground, making them difficult to study and manage, as well as protect from invasive species (i.e., mongooses, rats, and pigs). Ornithological radar and visual and auditory surveys confirmed the presence of both species in the region, detected a 76-percent decline since 2001 for one flyway population, and determined locations of potential Hawaiian petrel colonies. Further studies that combine the use of these indirect methods will improve the means for locating colonies and monitoring seabird populations for conservation managers who implement invasive species control regimens.
  Project Contact: William Pitt

Wildlife Diseases

- **Bioindicators for Avian Influenza Viruses.** NWRC researchers showed that avian influenza viruses (AIV) can accumulate in snails and mollusks. These species may be useful in the detection of AIVs in natural water bodies and, if used properly, could aid in bringing down costs for AIV surveillance. Furthermore, NWRC researchers showed that house mice and Norway rats can become infected with AIVs and may be an important farm-side risk factor for transmission of the virus to poultry. These results suggest that enhanced rodent control efforts to protect farm biosecurity are warranted during disease outbreaks.
  Project Contact: Alan Franklin

- **AIV Transmission Routes in Wild Mammals.** Researchers investigated three alternative routes (water, eggs, and scavenged waterfowl carcasses) of AIV transmission that may explain how raccoons in the wild are exposed to AIV. Some raccoons exposed to the high-dose water treatment yielded apparent nasal shedding; however, none of the animals associated with the egg and mallard carcass treatments yielded evidence of nasal shedding. These results indicate that virus-laden water could provide a natural exposure route of certain AIV subtypes for raccoons and possibly for other mammals associated with aquatic environments.
  Project Contact: Alan Franklin

- **Co-Circulating Strains of AIV.** Researchers investigated the effects of multiple subtype co-infections and sequential infections with different AIV subtypes on viral population growth curves in mallards. Growth curves for single infections and co-infections were similar, while viral growth was significantly suppressed by sequential infections with different subtypes. Moreover, differences in the mallard hosts influenced the growth models, highlighting that the assumption of homogenous host populations—which underlies many epidemiological models—is a simplification that could lead to extremely biased estimates of subtype fitness and disease risk.
  Project Contact: Alan Franklin

- **AIV Genetics.** In 2006 and 2007, approximately 75,000 bird fecal samples were collected from across the United States by Wildlife Services disease biologists as part of an interagency avian influenza surveillance effort. Researchers isolated and amplified 160 hemagglutin (HA) DNA sequences from these samples. These sequences represented a broad diversity of HA subtypes with 13 of the possible 16 subtypes represented. NWRC used this and other data from around the world to generate information about relationships among and between HA subtypes of AIV. The researchers detected evidence of intercontinental exchange within some subtypes and a lack of exchange in

Exotic nilgai antelope were tested for cattle fever protozoan parasites near the Mexico-Texas border.
Photo by USDA/NWRC

others. Unique lineages of some HA subtypes were detected in the United States, and some subtypes were detected in areas where they had not been previously documented. Such information is useful to managers and decisionmakers because it identifies areas of high AIV diversity, and these areas may be more likely to produce new outbreaks of high or low pathogenic AIV.
Project Contact: Alan Franklin

- **Coyotes as a Biosurveillance Tool for Bovine Tuberculosis.** Bovine tuberculosis (bTB) has been documented in a variety of wildlife species, including coyotes. Localized prevalence of bTB in coyotes can be as high as 30 percent, versus 1.8 percent in deer. Thus, sampling coyotes may be an efficient method for detecting bTB in an area. To explore this concept, researchers collected biological samples from 171 coyotes in northeastern Michigan. Seventeen coyotes were positive for *Mycobacterium bovis,* the causative agent of bTB. Sixteen of the coyotes were from known bTB-infected counties, and one was found in a county with no previous documentation of bTB. The use of coyotes as sentinels may allow wildlife managers to detect the spread of bTB into uninfected counties before it reaches prevalence levels sufficient to be detected in deer. With earlier detection, managers may be able to take proactive surveillance and management measures to reduce the potential risk to domestic livestock and captive deer herds.
Project Contact: Kurt VerCauteren

- **Deer Visitation at Medicated Bait Sites Used To Reduce Ticks.** Cattle fever ticks *(Boophilus microplus* and *B. annulatus)* are commonly found on white-tailed deer and can pose a serious risk to livestock in areas where deer and livestock coexist.

Direct and indirect contact through fences at elk farms may play a role in the transmission of chronic wasting disease and bovine tuberculosis.

Photo by USDA, Keith Weller

Researchers assessed patterns of deer visitation at medicated bait stations used to treat deer for ticks. Sixty percent of marked, adult male deer visited bait sites compared to 12 percent of adult females and 25 percent of fawns. Bait site visitation did not vary seasonally for females, but males visited bait sites less frequently during the summer. The results of this study suggest that treating fawn and female white-tailed deer will be difficult and may require higher bait-site density to overcome social interactions that presumably caused these patterns of bait site use.
Project Contact: Tyler Campbell

- **Nilgai Antelope and Cattle Fever.** Nilgai antelope are an exotic species introduced into Texas in the 1940s. Researchers investigated the role of nilgai in the spread of cattle fever (also known as bovine babesiosis). Of the 20 blood samples collected from nilgai near the United States-Mexico border, 6 were positive for cattle fever protozoan parasites. Researchers note that nilgai may serve as a potential reservoir of cattle fever. Important modifications to cattle fever eradication strategies may need to be implemented if nilgai antelope are capable of disseminating cattle fever ticks and therefore maintaining the disease.
Project Contact: Tyler Campbell

- **Elk and Fence-Line Disease Transmission.** Direct and indirect contact through fences at captive elk farms may play a role in the transmission of diseases such as chronic wasting disease (CWD) and bTB. Researchers examined the effectiveness of a baited electric fence, as an addition to an existing single woven-wire fence (2.4 meters high), for altering behavior and reducing fence-line contact between elk. Researchers documented

426 contacts between elk (direct transmission risk) or the woven-wire fence (indirect transmission risk) during trials without the electric fence. When the electric fence was installed, there were no contacts between adult elk or the woven-wire fence. Researchers note that this approach targets behavior modification of farmed elk routinely exposed to the electric fence, not wild elk that may occasionally approach from the outside. The results of this study suggest that adding a baited electric fence inside an existing woven-wire-fenced enclosure has the potential to provide a cost-effective means of minimizing contacts between farmed and wild elk.
Project Contact: Kurt VerCauteren

Human Health and Safety

- **Vulture Flight Times and Military Aircraft Safety.** Using solar-powered global positioning system (GPS) satellite transmitters on vultures, researchers documented the flight patterns (time of day, altitudes) of black and turkey vultures during a 2-year study at the Marine Corps Air Station in Beaufort, SC. Results revealed that greater than 60 percent of vulture flight activity occurred from 4 to 9 hours after sunrise at altitudes below 656 feet/200 meters. These data can be used to develop directed hazing programs and options for optimal military flight training schedules to reduce the risk of bird-aircraft collisions.
Project Contact: Michael Avery

- **Relative Hazards of Wildlife to Aircraft.** Researchers used Federal Aviation Administration National Wildlife Strike Database records from 1990 to 2009 to rank the relative hazard of wildlife to aircraft. The three most hazardous species to aircraft overall were mule deer, white-tailed deer, and domestic dogs. The most hazardous bird species included snow geese, Canada geese, and turkey vultures. The majority of the most hazardous bird species or species groups were strongly associated with water. Researchers recommend the use of fencing for managing large mammals and habitat modification (e.g., reductions in standing water) accompanied by hazing for reducing bird use of airports.
Project Contact: Travis DeVault

Vultures are fitted with satellite transmitters to study their movements and activity patterns.
Photo by USDA, Michael Avery

- **Diphacinone Residue in Feral Swine.** Researchers examined feral pig tissues to determine whether the potential hazard of consuming meat from pigs previously exposed to diphacinone rodenticide baits was reduced by cooking. Cooking had little effect on residual diphacinone concentrations, the highest concentration of which was found in the liver tissue. Accordingly, researchers caution that the consumption of pig meat obtained from areas with active rodent control programs should be avoided.
  Project Contact: William Pitt

Hunting feral swine for food is common in many States; however, researchers caution against the consumption of pig meat obtained in areas with active rodent control programs.
Photo by USDA, Laurie Paulik

Economics

- **Value of Cormorant Management to Regional Economies.** Researchers have documented the economic impact of increasing populations of double-crested cormorants on sport fisheries and associated economies in central New York. The total economic impact of cormorants for the Finger Lakes region ranged from $132 million to $532 million in damages, plus 1,000 to 5,000 lost jobs for the period of 1990 through 2006. The benefits of cormorant control programs ranged from $20 million to $50 million in avoided damages and 100 to 300 regional jobs saved.
  Project Contact: Stephanie Shwiff

- **Value of Raccoon Trapping.** In Wyoming, trapping raccoons is often used to enhance ring-necked pheasant hunting opportunities, but agriculture may also benefit from reduced raccoon numbers. An analysis by NWRC economists showed that corn growers' revenue increased in fields adjacent to trapping. In these fields, raccoon-caused damage to corn was reduced by 65 to 90 percent, increasing revenue by $1 to $16 per acre.
  Project Contact: Stephanie Shwiff

Damage by double-crested cormorants on sport fisheries and associated economies in central New York ranged from $132 to $532 million in one NWRC economic study.
Photo by USDA/NWRC

- **Venison Donation Programs.** Deer meat donation programs exist in most States to provide much-needed resources to food pantries and other charitable organizations. NWRC researchers evaluated the effectiveness of the Nebraska Deer Exchange, which matches hunters with organizations in need of donated meat. Sixty-six percent of hunters indicated that they harvested an additional deer under license because of the existence of this program. *Project Contact: Kurt VerCauteren*

Technology Development and Chemical Methods

- **Scare Device for Woodpeckers.** Researchers evaluated the Sonic Dissuader®, a new scare device designed to detect drumming and pecking by woodpeckers. Once pecking is detected, the device emits woodpecker and avian territorial and/or alarm calls to scare birds away. Researchers did not detect any differences in the amount of time pileated woodpeckers spent pecking on poles with and without the Sonic Dissuader, but they did notice the birds spent more time on a pole immediately following the activation of the Sonic Dissuader. This finding supports field observations that pileated woodpeckers freeze when confronted with a predator. To increase the efficacy of the device, researchers recommended that the Sonic Dissuader broadcast a call whenever pecking is detected rather than once within each 15-minute period as was initially programmed. In followup studies, researchers evaluated pileated woodpecker distress calls as a possible deterrent and recommended their use in combination with the detection technology. *Project Contact: George Linz*

New detection devices show promise for use in preventing pileated woodpecker damage to utility poles and other structures.
Photo by USDA/Forest Service, Mike Ostry

- **Passive Integrated Transponders (PIT)[2] in Darts.** Methods to individually mark and identify free-ranging wildlife without the added expense of initial trapping and handling of animals would be useful to wildlife managers. Researchers successfully injected PIT into captive elk using dart guns. The PIT remained functional during recaptures for at least 4 months. The long-term use of PIT can increase the efficiency of monitoring efforts. *Project Contact: Kurt VerCauteren*

[2] A PIT is a tag that is injected under the skin or into the muscle of an animal. It contains a series of numbers and letters used to identify individual animals, and the numbers can be recalled by passing a “PIT Tag Reader” over the implanted tag.

- **Foraging Behavior of Deer.** To determine how black-tailed deer *(Odocoileus hemionus columbianus)* respond to the flavor, color, texture, and smell of plants while browsing, researchers offered captive and free-ranging deer rooted cuttings and seedlings of western redcedar with varying monoterpene content. (Monoterpenes are chemicals found in conifer plants that have a repellent effect on foraging mammals.) Experiments demonstrated that browse preference for individual western redcedar plants was a function of the amount of monoterpene in the leaves of the plants. Researchers note that deer's sense of smell may play a significant role in both fine- and coarse-scale browse behaviors of deer as they employ a risk-averse foraging strategy.
Project Contact: Bruce Kimball

- **Preliminary Evaluation of Sodium Nitrite as a Rodenticide.** Researchers evaluated sodium nitrite (a compound commonly used as a color fixative and preservative in meats and fish) as a potential rodenticide. The preliminary trials involved black-tailed prairie dogs and Norway rats and used food and liquid bait containing encapsulated sodium nitrite. The results determined that lethal dose (LD-50) for both species was less than 200 mg/kg, which indicates that sodium nitrite has the potential to be an effective rodenticide.
Project Contact: Gary Witmer

- **GonaCon™ Use in Black-Tailed Prairie Dogs.** Researchers evaluated the immune response and health effects of captive black-tailed prairie dogs injected with the GonaCon immunocontraceptive vaccine. No adverse effects of GonaCon were noted on the animals' weight or blood chemistry. Given the antibody titers recorded in the animals, researchers note that GonaCon will likely be able to contracept prairie dogs for at least 1 year in the field.
Project Contact: Lowell Miller

- **Snake Irritants.** Researchers investigated methods for flushing invasive brown treesnakes from within cargo shipping containers on Guam. Vapors of three essential oils (cinnamon, eucalyptus, and wintergreen) and two chemicals (chloroform and tetrachloroethylene) were tested to see whether snakes would travel and exit the length of a darkened tube. Vapors of all agents were repellent to snakes, but only chloroform reliably caused snakes to completely exit the tube. These potential new fumigants could improve efforts to prevent the accidental movement of invasive brown treesnakes from the island of Guam.
Project Contact: William Pitt

The GonaCon™ immunocontraceptive vaccine was successfully tested in black-tailed prairie dogs.
Photo by USDA, Gail Keirn

- **Toxicants for Invasive Reptiles.** In Florida, using wild-caught, nonnative black spiny-tailed iguanas, researchers screened acetaminophen and zinc phosphide to determine their suitability as toxicants for this prolific invasive species. Of the animals that received acetaminophen, none died except at the highest test dose (240 mg per lizard), which is not practical for field use. Zinc phosphide produced 100-percent mortality at dose levels as little as 25 mg per lizard; this is equivalent to about 0.5 percent in bait, which is lower than currently used in commercial baits for commensal rodent control. Researchers conclude that zinc phosphide has potential as a useful reptile toxicant provided that target-selective delivery methods are developed.
  Project Contact: Michael Avery

Research has shown that zinc phosphide may be an effective toxicant for use on invasive black spiny-tailed iguanas.
Photo by USDA, Richard Engeman

- **Sampling Wolves and Coyotes.** Monitoring wolves and coyotes in the wild is challenging because they are notoriously wary of humans and novel items in their environment. To identify potential alternatives for sampling these animals, researchers tested whether lures and rubbing posts could be used to monitor coyote and wolf populations. The rub stations successfully gathered enough hair samples to extract DNA. The researchers note that rub stations can be strategically placed in the environment in accordance with specific sampling designs and provide an inexpensive way to monitor populations, estimate abundance, and explore genetic diversity.
  Project Contact: Julie Young

Rub stations provide an inexpensive way to monitor wolf and coyote populations.
Photo by USDA, Julie Young

- **NWRC Launches Chemical Effects Database.** NWRC launched a searchable, Web-based database containing bioassay records and data for chemicals analyzed and evaluated for repellency, toxicity, reproductive inhibition, and immobilization. The data included were from studies conducted between 1943 and 1987 by the NWRC and its predecessors and by USGS' Patuxent Wildlife Research Center (formerly part of the U.S. Fish and Wildlife Service); additional data may be added in the future. The database is useful to researchers worldwide who are involved in environmental risk assessments and the development of new wildlife damage management tools. The database is accessible through the NWRC Web site at www.aphis.usda.gov/wildlife_damage/nwrc.
  Project Contact: John Eisemann

Registration Updates

- **Sodium Nitrite (Feral Swine Toxicant).** NWRC has consulted with the EPA regarding data submission in support of an APHIS registration for a feral swine toxicant based on sodium nitrite. NWRC believes all necessary chemical data, based on Australian research, are available for registration. The remaining issue is developing a target-specific bait delivery system for the protection of native wildlife. Field trials of several bait delivery systems are underway. NWRC will withhold registration submission until the nontarget safety issues are resolved.
Project Contact: John Eisemann

- **Caffeine-Theobromine (Predator Toxicant).** Coyotes cause approximately 80 percent of all predatory losses of livestock that are attributed to canids (e.g., wolves, dogs, coyotes). Researchers have conducted studies to evaluate whether a mixture of the natural substances caffeine and theobromine could be used as a toxicant for canids, particularly for coyotes that prey upon livestock. Although initial studies have been promising, NWRC is withholding a registration package for this new tool until product efficacy can be increased. NWRC studies to improve efficacy are ongoing.
Project Contact: Julie Young

Technology Transfer

- **Oral Rabies Vaccine.** NWRC and Merial, a private animal health company, filed for a provisional patent application in April 2011 for a joint patent on the use of trimethylated chitosan to enhance efficacy of the Raboral V-RG® vaccine used in oral rabies vaccination programs for wildlife.
Project Contact: Kathleen Fagerstone

- **GonaCon™ Immunocontraceptive Vaccine.** NWRC is negotiating licensing with several private companies to produce GonaCon for wildlife and domestic animal reproductive control. GonaCon is the first single-shot, multiyear immunocontraceptive vaccine for use in mammals.
Project Contact: Kathleen Fagerstone

- **Large Snake Trap.** In October 2011, NWRC filed a patent application for a live snake trap to capture Burmese pythons and other large invasive snakes in the Florida Everglades. The trap capitalizes on the larger size and weight of invasive snakes, thus helping to minimize the accidental capture of smaller native species.
Project Contact: Kathleen Fagerstone

- **New Cooperative Research and Development Agreements.** NWRC scientists signed five new Cooperative Research and Development Agreements (CRADAs) during fiscal year (FY) 2011 with private companies for conducting joint research to develop and commercialize inventions. Research activities under these agreements include the development of a new trap for large invasive snake species, avian repellents, and hazing systems. In addition, GonaCon is being investigated for its effectiveness and safety in cattle. NWRC researchers are also assisting in the development of a contraceptive vaccine for farmed Norway salmon and cod in order to improve fish growth and prevent potential negative impacts to wild fish populations if farmed-raised fish were to escape; in particular, this research agreement seeks to develop a practical way to sterilize farmed salmon and other fish species such as cod.
Project Contact: Kathleen Fagerstone

Awards

- **2011 Lindbergh Grant.** NWRC research wildlife biologist Bradley Blackwell and a colleague from Purdue University received the prestigious 2011 Lindbergh Grant from the Charles A. and Anne Morrow Lindbergh Foundation. The grant supports the researchers' continued investigations of how aircraft lighting might be used to enhance bird detection and avoidance of aircraft, as well as the design of new aircraft lighting systems that will serve this purpose under different environmental conditions (i.e., sunny versus cloudy days).

- **2010 NWRC Publication Awards.** NWRC scientists Todd Atwood, Eric Gese, and Michael Avery were honored with the 2010 NWRC Publication Awards. These awards are given annually at NWRC to recognize quality research published within the previous year.

NWRC researcher Bradley Blackwell *(left)* and Purdue University researcher Esteban Fernandez-Juricic were awarded the 2011 Lindbergh Grant for their studies related to aircraft lighting and bird detection and avoidance of aircraft.

Photo by USDA, Gail Keirn

In the article "Importance of Resource Selection and Social Behavior to Partitioning of Hostile Space by Sympatric Canids" *(Journal of Mammalogy),* Atwood and Gese determined spatial overlap of coyotes and wolves in southwestern Montana using radio-collared coyotes and snow-track indices. Resource selection models were constructed using habitat and spatial variables. The researchers concluded that coyotes did not avoid areas with wolves but rather traded risk for scavenging benefits.

In "Genetic Evidence for High Propagule Pressure and Long-distance Dispersal in Monk Parakeet *(Myiopsitta monchus)* Invasive Populations" *(Journal of Molecular Ecology),* Michael Avery and collaborators demonstrated that individual birds invading a new location can vary in many attributes from those of the native, source population. This flexibility in population attributes implies that wildlife managers should not assume that certain characteristics of a source population prevent individuals within that population from establishing in other locations. This paper suggests that multiple releases, as might result from pet industry sources, are more likely to result in established populations, whereas single releases are more likely to fail.

- **Award for Professional Excellence.** The University of Maine's Department of Wildlife Ecology honored NWRC research wildlife biologist Bradley Blackwell with an Award for Professional Excellence in May 2011. The award recognizes former students for their years of service to the wildlife profession.

- **NWRC Employee of the Year Awards.** The winners of this award are nominated by their peers as employees who have clearly exceeded expectations in their contributions toward the Center's mission in 2011. The winners this year are listed below.

  - Kurt C. VerCauteren, Research Grade Scientist, Management of Ungulate Disease and Damage Project, Fort Collins, CO

  - David B. Long, Support Scientist, Feral Swine Damage Control Strategies Project, Kingsville, TX

  - Robert T. Sugihara, Technician, Methods and Strategies to Manage Invasive Species Impacts to Agriculture, Natural Resources and Human Health and Safety Project, Hilo, HI

  - Elizabeth J. Poggialli, Administration, Administrative Support Unit, Sandusky, OH

2011 Publications

The transfer of scientific information is an important part of the research process. NWRC scientists publish in a variety of peer-reviewed journals that cover a wide range of disciplines, including wildlife management, genetics, analytical chemistry, ornithology, and ecology. Names highlighted in bold are NWRC employees. (Note: 2010 publications that were not included in the 2010 NWRC accomplishments report are listed here.)

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Allen, B.L.; **Engeman, R.M.;** Allen, L.R. 2011. Wild dogma II: the role and implications of wild dogma for wild dog management in Australia. *Current Zoology* 57(6): 737–740.

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Appendix 1

More information about these projects can be found on the NWRC Web site at **www.aphis.usda.gov/wildlife_damage/nwrc.**

List of 2011 NWRC Research Projects

Avian and Invasive Species Population Management
Project Leader: Michael Avery

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

Defining Impacts and Developing Strategies To Reduce Mammalian Damage in Forested and Riparian Ecosystems
Project Leader: Jimmy Taylor

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

Development of Injectable and Oral Contraceptive Technologies and Their Assessment for Wildlife Populations and Disease Management
Project Leader: Lowell Miller

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

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

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

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

Feral Swine Damage Control Strategies
Project Leader: Tyler Campbell

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

Management of Ungulate Disease and Damage
Project Leader: Kurt VerCauteren

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

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

NWRC Registration Unit: Providing Tools for Wildlife Services
Project Leader: John Eisemann

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

Appendix 2

NWRC Research Contacts

Name	Contact Information	Areas of Expertise
Atwood, Todd	(970) 266-6054 *Todd.C.Atwood@aphis.usda.gov*	Carnivores, landscape modeling
Avery, Michael	(352) 375-2229 ext. 12 *Michael.L.Avery@aphis.usda.gov*	Project Leader: invasive species, birds
Blackwell, Bradley	(419) 625-0242 ext. 15 *Bradley.F.Blackwell@aphis.usda.gov*	Aviation hazards, lighting systems
Breck, Stewart	(970) 266-6092 *Stewart.W.Breck@aphis.usda.gov*	Carnivores
Campbell, Tyler	(352) 375-2229 *Tyler.A.Campbell@aphis.usda.gov*	Project Leader: feral swine, pseudorabies
Cunningham, Fred	(662) 325-8215 *Fred.L.Cunningham@aphis.usda.gov*	Project Leader: aquaculture, cormorants
DeVault, Travis	(419) 625-0242 ext. 11 *Travis.L.DeVault@aphis.usda.gov*	Project Leader: aviation hazards
Dorr, Brian	(662) 325-8216 *Brian.S.Dorr@aphis.usda.gov*	Aquaculture, cormorants
Dwyer, Diana	(970) 266-6015 *Diana.L.Dwyer@aphis.usda.gov*	Information Services Unit Leader: library, Web, archives
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Appendix 3

Acronyms and Abbreviations

AIV	Avian influenza virus
APHIS	Animal and Plant Health Inspection Service
BOS	Boar-operated system
bTB	Bovine tuberculosis
CRADA	Cooperative Research and Development Agreement
CWD	Chronic wasting disease
EPA	U.S. Environmental Protection Agency
FY	Fiscal year
GonaCon	GonaCon™ immunocontraceptive vaccine
GPS	Global positioning system
LD-50	Lethal dose for 50 percent of sample population
LOEL	Lowest observed effect level
Monell	Monell Chemical Senses Center
NRMP	National Rabies Management Program
NWRC	National Wildlife Research Center
ORV	Oral Rabies Vaccination
PIT	Passive integrated transponder
TH	Tetracycline hydrochloride
USDA	U.S. Department of Agriculture
USGS	U.S. Geological Survey

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