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Innovative Solutions to Human–Wildlife Conflicts

National Wildlife Research Center Accomplishments, 2010

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Wildlife Services

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Cover Photo: Black vultures tear and sometimes consume rubber, vinyl, or leather upholstery from cars and trucks. *Photo by USDA, Michael Avery*

April 2011

Message from the Director

Dr. Larry Clark, NWRC Director
Photo by USDA, Gail Keirn

I was recently invited to speak at the Farm Foundation on the challenges facing research organizations at the human, agriculture, and wildlife interface. Attending were leaders from the agricultural industry, public health, veterinary community, academia, government agencies, and international organizations. During discussions with these diverse groups, two underlying themes emerged as obstacles to effective problem-solving: funding and "silos." One strategy when faced with limited resources is to become more defensive and protect a narrow range of interests. This strategy often fails over the long term, as it doesn't consider the full scope of priorities needing attention. In my view, a more successful strategy toward delivering highly effective and impactful solutions is to reach out, leveraging the limited resources at hand—in effect, building bridges rather than erecting silos.

Since becoming NWRC Director 2 years ago, I have encouraged the use of this strategy when allocating resources or developing external partnerships. The NWRC staff has fully embraced this approach as an effective business model. In the past year, NWRC scientists collaborated with 45 U.S. universities, 9 foreign universities, 29 other Federal Departments, agencies, and programs, 23 State and local governments, 9 nongovernmental organizations, and 21 private sector companies. This is a remarkable level of activity and engagement for a program with a staff of only 170 people. In addition, NWRC staff completed 80 studies and produced over 109 scientific publications, an indication of a high level of efficiency in communicating the results of their research efforts. NWRC staff also reached out to stakeholder groups by presenting the Center's research findings at 236 scientific and stakeholder meetings.

Providing quality research for the formulation of scientifically sound wildlife management practices is a central function of the NWRC. But its contributions are rooted even more broadly: another important role for the NWRC is to develop new products for use in wildlife management. Toward this end, NWRC has developed an immunocontraceptive vaccine, GonaCon™, and obtained U.S. Environmental Protection Agency registration for adult female white-tailed deer. This product will be a useful part of the tool kit available to wildlife managers as they struggle with difficult urban deer management issues. Its uses may eventually expand further than originally foreseen—NWRC is discussing licensing and technology transfer oppor-

tunities with the private sector for the use of GonaCon in companion animals and the pet trade, as well as its use in rabies vaccinate-and-release programs for feral dogs. This effort is just one of many highlighted in this report and is an excellent example of the NWRC's collaborative work with its many partners.

In an era of fiscal constraints, research is under increased scrutiny, with questions of impact and return on investment being raised more frequently and vigorously. Ultimately, the overall impact of research is determined by a number of different, and sometimes subjective, factors. In terms of technology transfer, impact is measured by the ability to translate research findings into practical and marketable products. From a management perspective, impact is measured by the ability to translate research into useful plans and methods, as well as its specific influence on policy matters. And within the scientific community, impact is measured in part by the prestige of the publication venue, the number of times an article is cited, and whether the research influences the direction of subsequent research efforts by others.

By all of these measures, NWRC research is demonstrating increased levels of impact. Examples of successful product development such as GonaCon are becoming more frequent. NWRC scientists have been working actively to place their research findings in higher impact scientific journals; the average journal impact factor* for NWRC publications has improved by 5 percent in the past 5 years. The NWRC also continues to place greater emphasis on the economic value of research and APHIS Wildlife Services operations through studies conducted by the NWRC Economics unit. The results of these studies are increasingly used to demonstrate the return on Government investment in wildlife management research and work.

The NWRC remains committed to providing the best value for the taxpayer's dollar. This year's highlights report exemplifies the NWRC's dedication to leveraging resources in scientific collaborations; improving the impact of our communications efforts; producing products of high value to other researchers, managers, policymakers, and the private sector; and demonstrating the economic value of our research and development efforts to the public and private sectors.

It is my privilege to introduce the NWRC's accomplishments for 2010.

Larry Clark, Director
National Wildlife Research Center
Wildlife Services
APHIS-USDA
Fort Collins, CO

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* Impact Factor: A measure of the frequency with which articles from a scientific journal have been cited.

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Introduction

NWRC economist and orchard manager examine rodent damage to almonds.

Photo by USDA, Katie Kirkpatrick

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.

National Wildlife Research Center

As the research arm of Wildlife Services, a program within the U.S. Department of Agriculture's (USDA) Animal and Plant Health Inspection Service (APHIS), NWRC develops methods and information to address human-wildlife conflicts related to:

- agriculture,
- human health and safety,
- property damage,
- invasive species, and
- threatened and endangered species.

The NWRC is the only Federal research facility in the United States devoted entirely to the development of methods for effective wildlife damage management. The Center employs more than 170 scientists, technicians, and support staff to develop and evaluate new wildlife conflict management tools and strategies that are biologically sound, environmentally safe, and socially acceptable. NWRC's research authority comes from the Animal Damage Control Act of 1931.

The NWRC's research priorities are based on nationwide research needs assessments, congressional directives, APHIS Wildlife Services program needs, and stakeholder input. The Center is committed to helping resolve the ever-expanding and changing issues associated with human-wildlife conflict management and remains well positioned to address new issues through proactive efforts and strategic planning activities.

NWRC research falls under four principal areas that reflect APHIS' commitment to "protecting agricultural and natural resources from agricultural animal and plant health threats, zoonotic diseases, invasive species, and wildlife conflicts and diseases"*:

- **Agriculture and Resource Protection—**Focuses on reducing wildlife damage to crops, aquaculture, timber resources, livestock, property, and natural resources; examines the ecology, behavior, and management of birds and mammals; and develops methods to mitigate wildlife-aviation strike hazards.

- **Invasive Species—**Develops methods for reducing damage by invasive vertebrate species to crops, aquaculture, timber resources, livestock, property, natural resources, native wildlife, and ecosystems.

- **Technology Development—**Promotes technological development related to pesticide registration, formulation chemistry, chemical analysis, benefit-cost analysis, and wildlife contraceptives.

- **Wildlife Disease—**Explores ways to reduce the spread and transmission of diseases from wildlife to humans and domestic animals; develops disease diagnostic methods, as well as methods and strategies to monitor wildlife pathogens; assesses risks to agriculture and human health and safety; and assists Wildlife Services' field operations with surveillance and monitoring.

In addition to the four main research areas, the NWRC maintains support functions related to animal care, administration, information transfer, archives,

* From *APHIS Strategic Plan (2007-2012)*

Assistant Director

In 2010, Dr. Olin (Gene) Rhodes joined NWRC as one of two Assistant Directors. Dr. Rhodes comes to NWRC from Purdue University, where he has served as a Professor in the Department of Forestry and Natural Resources. He received his undergraduate biology degree from Furman University, a master's degree in wildlife biology from Clemson University; and a doctoral degree in wildlife science from Texas Tech University. In addition, he worked as a research ecologist at the University of Georgia's Savannah River Ecology Laboratory.

Dr. Rhodes is an accomplished scientist with a broad skill set that spans many basic and applied disciplines, including wildlife biology, wildlife genetics, population biology, ecology, and disease ecology. He has worked extensively in the area of applied wildlife management, including working with Wildlife Services on issues relating to animal damage management. He has over 140 scientific publications, has been honored by chapters of The Wildlife Society, and is recognized as a Faculty Scholar by Purdue University. Dr. Rhodes has served in a variety of roles throughout the university, including efforts to establish standards of performance and accountability for students and staff. He has also worked extensively with students, universities, State and Federal agencies, and nongovernmental organizations.

Dr. Gene Rhodes, NWRC Assistant Director
Photo by USDA, Gail Keirn

In these endeavors, Dr. Rhodes has demonstrated an ability to serve as a mentor and role model, effectively negotiate solutions among diverse stakeholder groups, build coalitions, leverage resources, and secure extramural support. His commitment to these efforts will serve the NWRC and Wildlife Services well as they position themselves for the new challenges and opportunities posed by the ever-changing landscape of wildlife damage management.

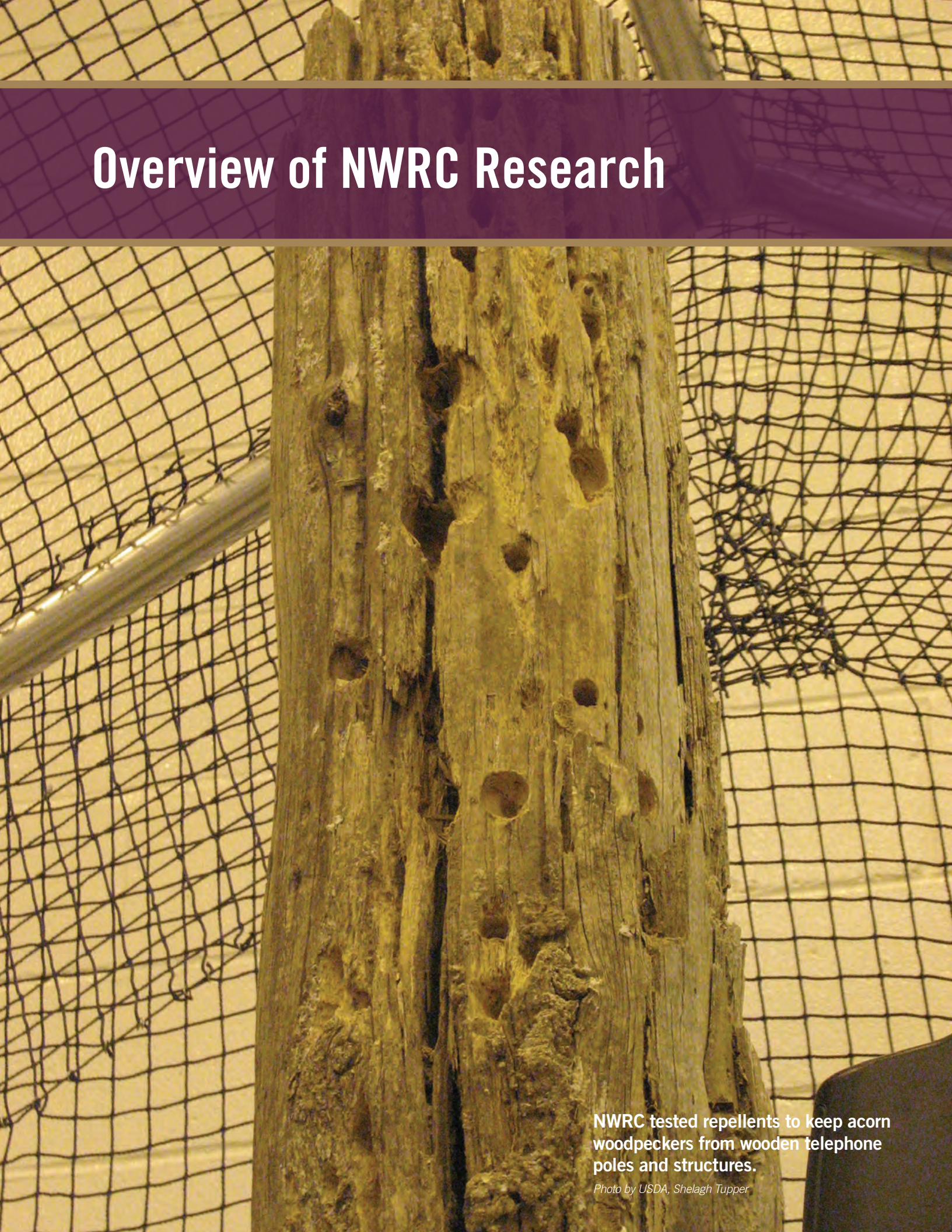
quality assurance, facility development, and legislative and public affairs.

Facilities Update

NWRC's 43-acre headquarters campus is located on the Foothills Research Campus of Colorado State University (CSU) in Fort Collins, CO. During the early part of fiscal year (FY) 2010, planning and design activities continued toward the development of a Biosafety Level-3 Agriculture (BSL-3 Ag) wildlife disease research building at NWRC's headquarters campus. However, due to constraints in the Federal budget, the construction of the building has been placed on hold indefinitely.

Another construction-related development in 2010 was NWRC's purchase of its Hilo, HI, field station site from the Hawaiian Agricultural Research Corporation. Renovations are underway to bring the facility up to Federal code.

Overview of NWRC Research



NWRC tested repellents to keep acorn woodpeckers from wooden telephone poles and structures.

Photo by USDA, Shelagh Tupper

The majority of research projects undertaken by NWRC involve multi-year studies. This chapter includes studies for which NWRC completed data analysis or had other noteworthy results to report in 2010.

Agriculture and Resource Protection

This research area focuses on reducing wildlife damage to crops, aquaculture, timber resources, livestock and property, and natural resources. The examination of bird and mammal ecology, behavior, and management and the development of methods for mitigating wildlife-aviation strike hazards are also key topics within this research area.

Aviation Safety

NWRC scientists conduct research to develop methods and provide guidance to the Federal Aviation Administration (FAA), airport operators, and the American public regarding the mitigation of bird-aircraft strike hazards. NWRC research is focused on understanding the nature of wildlife hazards at airports, developing management tools to reduce those hazards, and providing Wildlife Services' biologists, airport personnel, and FAA officials with information on the latest strategies for controlling wildlife hazards.

Foraging Preferences of Canada Geese for Turfgrasses—Wildlife strikes to the civil aviation industry in the United States are both costly and deadly. In order to minimize and help prevent such threats, it is important to have management techniques available that reduce bird use of habitats on and around airports.

From 2005 to 2007, NWRC scientists conducted a study to determine if Canada geese (*Branta canadensis*) exhibit a feeding preference among various commercially available turfgrasses. Behavioral responses of captive geese to nine turfgrasses, bare ground, and litter were observed over six, 4-week trials during July through September each year. The scientists evaluated a different turfgrass each year: Kentucky bluegrass (*Poa pratensis*), tall fescue (*Festuca arundinacea*), common Bermudagrass (*Cynodon dactylon*), and zoysiagrass (*Zoysia japonica*) in 2005; creeping bentgrass (*Agrostis stolonifera*), buffalograss (*Buchloe dactyloides*), and zoysiagrass in 2006; and a fine fescue mixture (*Festuca* spp.), centipede grass (*Eremochloa ophiuroides* 'Common'), St. Augustine grass (*Stenotaphrum secundatum* 'Palmetto'), and zoysiagrass in 2007.

Scientists at the NWRC Sandusky, OH, field station assess responses of Canada geese to nine varieties of turfgrass.
Photo by USDA, Tom Seamans

During 2005, Canada geese exhibited a strong preference for Kentucky bluegrass when loafing, resting, or foraging. Geese also spent time and foraged in the common Bermudagrass and tall fescue plots, but avoided foraging on zoysiagrass. During 2006, geese strongly preferred creeping bentgrass when foraging.

Geese also spent time and foraged in the buffalograss plots, whereas they spent the least amount of time and avoided foraging in the zoysiagrass, bare ground, and litter plots. During 2007, captive geese preferred to loaf, preen, rest, and forage in fine fescue plots compared to centipede grass, St. Augustine grass, and zoysiagrass. Variation in nutritional and chemical characteristics (e.g., moisture content, crude protein, and crude fat) might explain the foraging preferences Canada geese exhibited during this study.

These findings suggest that zoysiagrass, centipede grass, and St. Augustine grass might be favorable turfgrasses to use in reseeding and vegetation renovation projects on airfields and other areas in the central and southern United States where Canada geese are unwanted. The study's findings also suggest that endophyte-free tall fescue varieties should not be included in tall fescue mixtures.

Additional NWRC studies have shown that Canada geese do not consume endophyte-infected tall fescue. Grasses containing endophytic fungi have several benefits, such as resistance to both grazing and insect herbivory, tolerance to heat and drought stress, and increased vigor. Over 160 varieties of turf-type tall fescue are currently available from the turfgrass industry for potential use in airfield revegetation projects. The NWRC is currently conducting research at nine civil airports and military airbases to examine the establishment of several varieties of tall fescue grass, each containing endophytic fungus. Information gained from this study will help identify varieties of tall fescue that will grow successfully given the environmental conditions found on these airfields while providing a feeding deterrent to Canada geese.

Project Contacts: Travis DeVault, Brian Washburn, Tom Seamans

Monitoring Vulture Movements With Satellite Telemetry and Avian Radar—Many wildlife management efforts require researchers to monitor the location and movements of animals in situations where it is difficult to detect and monitor individuals visually. Radar and satellite Global Positioning System-Platform Transmitter Terminal (GPS-PTT) transmitters may be useful in these situations, as they provide complementary information on the movements and behaviors of individual animals. The newest GPS-PTT technology can report altitude, speed, and heading in addition to position (latitude and longitude). By updating the data at hourly intervals, a researcher can sample an animal's behavior and location. Digital avian radars, on the other hand, can detect and track birds on a more continuous basis (e.g., every 2.5 seconds, depending on the antenna rotation speed). However, the technology has limitations; radar cannot be used to identify birds by species, let alone distinguish individual birds from one another. Scientists must use other sources to identify this information.

NWRC scientists use satellite telemetry to track movements of vultures.
Photo by USDA/NWRC

NWRC researchers integrated data from both radar and GPS-PTT to continuously monitor the behavior and movements of tagged vultures. Radar detected 40 percent of the locations of vultures carrying GPS-PTT tags that were within 5 kilometers of the radar. Approximately 75 percent of the undetected locations were calculated to be above or below the radar's

antenna beam. Speed and direction values recorded by the GPS-PTT tags and the radar were poorly correlated because the vultures were soaring and circling, which produced rapid changes in their azimuth (angular measurement/direction) and ground speed. Nevertheless, findings show that combining these two techniques allows for the monitoring of species when it is otherwise difficult to follow individual birds.

Project Contacts: Michael Avery, John Humphrey

Deterring Birds From Ponds and Waterways Near Airports—Deterring birds from water on or near airports is an important part of many bird strike reduction programs. Overhead wires made with various materials and in a variety of patterns can reduce bird use of such areas, although the costs of such efforts can be substantial. As part of a study to determine whether increasing the spacing of grid wires reduces material and initial labor costs while still deterring birds, NWRC researchers placed lines 50 feet apart over wastewater ponds in South Carolina and monitored bird usage. The total number of waterfowl using the ponds increased. Canada goose numbers declined, while mallard, ring-necked, and ruddy duck numbers increased. During a similar NWRC study in Illinois, lines 15 feet apart over narrow streams in the State also showed no significant difference in total bird use before and after line installation. Mallards, great blue herons, and great egrets all used the protected areas. Waterfowl using the protected areas might have perceived the overhead lines as protection from avian predators. These findings show that an integrated approach is necessary to haze birds effectively at protected locations.

Project Contacts: Travis DeVault, Tom Seamans, Bradley Blackwell

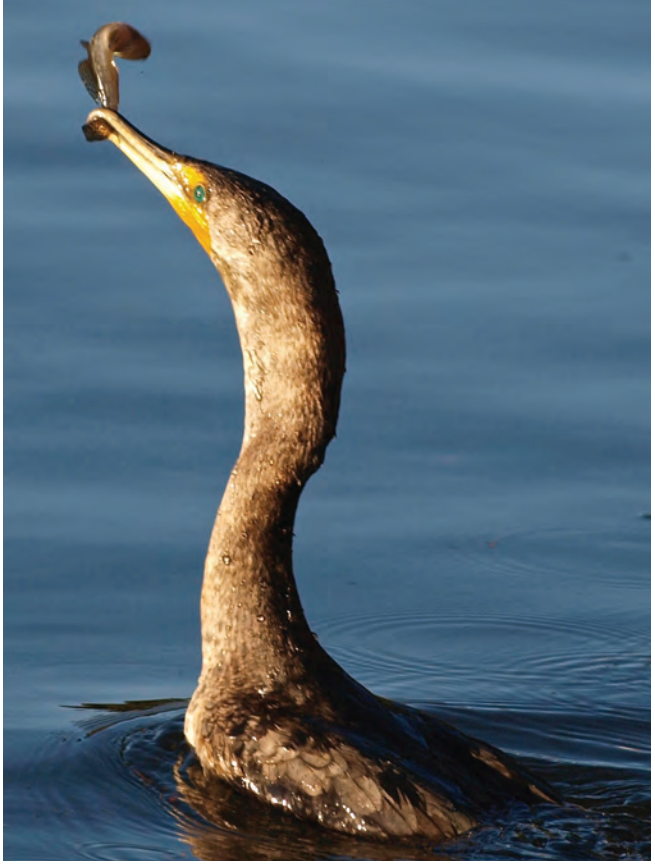
Differences in Reporting Rates of Patagial Tags—Banding or marking birds is an inexpensive yet viable means to determine local and long-range bird movements. However, in addition to its potential negative effects on birds (e.g., discomfort, weight loss, or behavior changes), this technique can produce misleading results in studies that incorrectly assume all tags are equally visible to observers. As part of a study in Chicago, IL, NWRC researchers marked 725 ring-billed gulls (*Larus delawarensis*) with poly-vinyl, chloride-coated patagial (wing) tags in royal blue, green, yellow, or orange. Re-sighting reports gathered over 2 years indicated a more than 3:1 bias towards the yellow or orange tags. When further investigation showed that the observed bias was not related to color visibility or differential mortality between color-tagged breeding birds, the researchers hypothesized that the bias is related to behavioral effects associated with the darker colored tags. Both blue and green tags had higher reflectance than yellow or orange tags in the ultra-violet (UV) range. Because gulls can see in the UV range, this slight spectral difference might have influenced a subtle behavioral cue. These findings demonstrate that marking studies should consider the potential behavioral effects of tag color on individual birds.

Ring-billed gulls with blue patagial tags
Photo by John Haire, Winston-Salem, NC

Project Contacts: Travis DeVault, Tom Seamans, Bradley Blackwell

Aquaculture

In the past 30 years, populations of fish-eating birds have increased dramatically, causing substantial economic impacts to aquaculture production. Aquaculture industry costs associated with bird damage and damage prevention are estimated to exceed $25 million annually. The goal of NWRC's research is to determine the impact of fish-eating birds on aquaculture production and natural resources and to develop methods to reduce depredation of southeastern catfish, baitfish, and crawfish industries. Current research is aimed at gaining information about the abundance, distribution, and foraging behavior of fish-eating birds, the economic impacts associated with their foraging activities, and the diseases they transmit at aquaculture facilities. This information will help to develop new techniques for reducing damage.



Cormorants are a significant predator of sportfish in the Great Lakes region.
Photo by Flickr Commons, Ingrid Taylar

Evaluation of Cormorant Harassment To Limit Depredation on Sport Fish—The interior population of double-crested cormorants *(Phalacrocorax auritus)* has shown a substantial resurgence over the past 35 years, from approximately 32,000 breeding pairs in the mid-1970s to more than 226,000 breeding pairs (including the Great Lakes States and Canadian provinces) by the mid-1990s. Diverse management techniques are used to mitigate conflicts between humans and cormorants, including harassment (e.g., pyrotechnics) supplemented by lethal removal.

In this study, NWRC scientists evaluated impacts of cormorant harassment programs on the walleye *(Sander vitreus)* fishery in Brevoort Lake, MI, and the yellow perch *(Perca flavescens)* and walleye fisheries at Drummond Island, MI. Cormorant foraging declined significantly at both locations after scientists initiated harassment programs in the spring. Overall harassment deterred 90 percent of cormorant foraging attempts, with less than 6 percent of the cormorants taken lethally on average at each site. Yellow perch were a predominant prey item in number and biomass at both locations. Walleye made up a small proportion of the diet at both locations. However, both walleye and yellow perch abundance increased significantly at Drummond Island following cormorant harassment. The estimated cormorant consumption of age-1 walleye in the absence of management at Brevoort Lake during 2005 accounted for 55 percent of the 2006 age-1 walleye population. Walleye abundance increased to record levels in 2008 following 3 years of cormorant management at Brevoort Lake.

These results support the hypothesis that cormorant predation on spawning aggregations of sportfish was a significant mortality factor, and that cormorant management could reduce sportfish mortality and increase abundance at both locations. Continuation of cormorant harassment programs and fishery assessments at Brevoort Lake and other locations will determine whether improvement of targeted sport fisheries is sustainable.

Project Contacts: Fred Cunningham, Brian Dorr, Jimmy Taylor

Adult and immature American white pelicans captured on aquaculture ponds
Photo by USDA, Tommy King

Sex and Age Bias in American White Pelicans Captured on Wintering Grounds—American white pelican (*Pelecanus erythrorhynchos*) use of aquaculture facilities in the southeastern United States has increased during the last 20 years. While capturing loafing pelicans with foot-hold traps and rocket nets for studies evaluating impacts of foraging pelicans on the aquaculture industry, NWRC scientists noticed an apparent age and sex bias among the captured and collected pelicans, which suggests segregation of age and sex classes among pelicans.

In a study to examine this issue further, scientists analyzed data from 284 pelicans captured or collected near aquaculture ponds in Alabama, Arkansas, Louisiana, and Mississippi from 1998 to 2009. Immature male pelicans (73 percent of those captured) appeared more vulnerable to capture than female and adult male pelicans. This vulnerability may be due to immature birds being more naive than older birds and less wary of humans or disturbances at a loafing site. The scientists also found a preponderance of males (38 percent adult male, 47 percent immature male, 15 percent female) among pelicans removed from catfish farms and loafing sites. Female American white pelicans appear to be less available for capture or collection at loafing sites in the southeastern United States because female and male pelicans segregate at loafing sites, or males and females spend the winter in different geographic areas. Based on these findings, the scientists recommended additional research to determine if sex ratios of pelicans are male-biased at birth and/or fledging and to confirm whether pelicans of known age and sex are spatially segregated on their wintering grounds.

Project Contacts: Fred Cunningham, Tommy King

Feeding Behavior and Diet of Black-Crowned Night Herons—Little is known about the effects of black-crowned night herons *(Nycticorax nycticorax)* on catfish production in the southeastern United States. Because these fish-eating birds inhabit important catfish production areas and opportunistically exploit abundant food resources, NWRC researchers monitored the movements of free-ranging night herons during 2004 to 2006 and documented their nocturnal use of catfish ponds in Mississippi to assess their potential impacts on catfish aquaculture facilities. The researchers also collected 75 night herons for stomach content analysis.

During the summer and early fall each year, the researchers observed approximately 85 night herons per biweekly survey. In 2005 and 2006, on randomly selected ponds, few birds were present, indicating selective or clumped use of the study area. Night herons left the study area beginning in November and were gone by January of each year. The birds returned in late spring or summer, with peak abundance occurring in September of each year. Seventy-two percent of the stomachs analyzed contained catfish fingerlings, with 0 to 26 fingerlings per stomach. The fingerlings' mean length and weight was 9.8 centimeters and 11 grams, respectively. More research is needed to document the birds' economic impact and to assess the issue of compensatory mortality.

Project Contact: Jimmy Taylor

NWRC biologists evaluated the impact of black-crowned night herons on aquaculture ponds.
Photo by USGS/NBII, John J. Mosesso

Blackbirds and grackles cause significant damage to sunflower crops in the United States.
Photo by ARS/k5752-10

Agriculture and Property

Wildlife cause significant damage to agricultural resources and property in the United States. A survey conducted by USDA's National Agricultural Statistics Service (NASS) reported wildlife damage to U.S. agriculture at $944 million during 2001 (the most recent year of this data available). Field crop losses to wildlife totaled $619 million, and losses of vegetables, fruits, and nuts totaled $146 million. Blackbirds, starlings, geese, and other birds are a primary cause of damage to grain and fruit crops. Starlings and blackbirds also consume livestock feed and potentially transmit diseases in urban areas and feedlots. NWRC scientists are studying ways to refine current damage abatement methods and to develop new methods for reducing bird depredation on seeded and ripening sunflower, corn, and rice.

Bird Damage to Corn and Sunflower in North Dakota—North Dakota is the top sunflower producer in the United States, harvesting about 1 million acres annually. Red-winged blackbirds, common grackles and yellow-headed blackbirds cause significant damage to this crop. The last comprehensive field survey of bird damage to sunflowers in the State, conducted in 1979 and 1980, indicated that bird depredations resulted in average annual economic losses of almost $5 million to North Dakota sunflower growers. The losses are probably even greater today, as sunflower prices have increased appreciably since this survey was conducted. There has also been an increase in complaints about bird depredations from corn growers, as acreages of this crop have increased in North Dakota during recent years. However, quantitative surveys of blackbird damage to corn have never been conducted in the State. A current survey of bird damage to both sunflowers and corn (many growers plant both crops) could be useful for allocating resources to manage depredating blackbird populations and plan perennial sunflower planting locations.

In 2008, NWRC researchers surveyed blackbird damage to sunflower and corn crops in the Prairie Pothole Region, the principal corn and sunflower growing area in North Dakota. Despite a reduction in planted sunflower acres from approximately 2 or 3 million acres in 1979 and 1980 to about 1 million in 2008, the percentage of loss due to bird damage in sunflower crops was nearly identical between the 2008 survey and the 1979/1980 surveys. In 1979 to 1980, damage averaged 1.4 percent (range = 0.0 to 26.4 percent) over approximately 2.8 million acres, whereas the 2008 damage averaged 1.2 percent over approximately 1 million acres. The researchers found that birds

damaged approximately 0.7 percent (range = 0.0 to 9.5 percent) of the 2 million acre corn crop in 2008. Based on these findings, the researchers speculated that corn—which was not commonly available to the blackbirds 30 years ago in North Dakota—served as an alternative food source for the birds. Additionally, growers might have benefited from APHIS Wildlife Services' cattail management program, which was implemented in the early 1990s to thin cattail stands and thereby disperse blackbird roosts away from sunflower fields.

Project Contact: George Linz

Anthraquinone-Based Bird Repellent for Sunflower Crops—NWRC scientists continue to explore nonlethal alternatives for managing bird damage to confectionary and oilseed sunflower crops. Ring-necked pheasants (*Phasianus colchicus*) and blackbird species are of particular concern due to the extensive localized damage they cause to newly planted and ripening sunflower crops. NWRC scientists conducted several laboratory and field studies to determine whether an anthraquinone-based repellent can decrease bird depredations to seeded and ripening sunflowers.

Prior to testing the repellency of Avipel® repellent (50 percent 9,10-anthraquinone), NWRC scientists determined that the product did not hinder germination rates of confectionary and oilseed sunflower seeds. In preference tests with captive birds, pheasants avoided seedlings derived from anthraquinone-treated seeds. Grackles (*Quiscalus quiscula*) avoided anthraquinone-treated sunflower seeds in cage trials and in penned enclosure trials. In cage trials, grackles avoided treated seeds in a dose-dependent manner. These trials showed an 80-percent repellency rate for confectionary sunflower seeds at a concentration application rate of 9,200 parts per million (ppm) anthraquinone (Avipel). Penned enclosure trials confirmed the utility of Avipel as a repellent for grackles. Enclosures containing ripening confectionary sunflower treated with Avipel sustained 18-percent damage compared to 64-percent damage for the enclosure containing untreated crops. The biomass of seeds harvested from treated enclosures averaged 2.54 kilograms (dry weight) compared to 1.24 kilograms among untreated enclosures. These tests suggest that anthraquinone-based repellents may be effective in preventing blackbird damage to sunflowers and result in increased yields for Avipel-treated crops.

Project Contacts: George Linz, Scott Werner

Use of Anthraquinone To Alleviate Non-Target Take From Rodenticides—Rodenticides are a key component for crop protection, and reducing non-target exposure to rodenticides is an important consideration in the maintenance of existing pesticide labels and the development of new products. In an effort to reduce the non-target risk associated with rodenticides, NWRC scientists explored the possibility of adapting a currently registered bird repellent (anthraquinone) for incorporation into these materials.

The results of this study showed that adding an anthraquinone repellent prevents the consumption of rodenticide baits by Canada geese (*Branta canadensis*) and ring-necked pheasants (*Phasianus colchicus*). Captive geese avoided baits treated with 2-percent zinc phosphide (typical concentration level used in rodenticide applications) and 2- to 2.5-percent anthraquinone (Arkion® Life Sciences). Although some geese and pheasants initially sampled treated baits, all birds subsequently avoided treated baits. No mortality or signs of zinc phosphide poisoning were observed among 10 geese and 40 pheasants that were offered the repellent-treated zinc phosphide baits.

Additional NWRC 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 this new bait in reducing non-target hazards with other pesticides, to compare costs relative to expected damage at unmanaged sites, and to assess the bait's environmental impacts.

Project Contacts: George Linz, Scott Werner

Woodpecker Deterrent for Utility Pole Crossarms— Woodpeckers cause millions of dollars in damage to wooden utility pole structures around the world by pecking or drumming at the structures when searching for insects, announcing their territory, or excavating nesting or roosting cavities. The resulting damage presents a safety hazard to utility workers, promotes decay (due to water entrapped in the holes), necessitates premature replacement, and can lead to collapse under adverse conditions. In the United States, pileated woodpeckers *(Dryocopus pileatus)* cause some of the most severe damage to poles.

During studies of captive pileated woodpeckers, NWRC researchers evaluated the effectiveness of a polyurea elastomer coating material (applied in a process developed by Brooks Manufacturing Company in Bellingham, WA) for eliminating or reducing woodpecker damage. The company supplied coated, Douglas-fir crossarms that measured 8.5 x 11 centimeters wide and 243 centimeters long. In the study, researchers presented 18 pileated woodpeckers (which were captured and later returned to national forests in Missouri and Arkansas) with coated and uncoated crossarms for 10 days. Researchers recorded daily the dried weight of wood chips removed; the length, depth, and area of damage; and the condition of the coating on the crossarms. Woodpeckers removed an average of 29.5 grams of wood chips from non-coated crossarms, but caused no measurable damage to the fully coated crossarms.

NWRC scientists evaluated repellents to deter acorn woodpeckers from damaging utility poles.
Photo by USDA, Shelagh Tupper

The cost of an uncoated wood crossarm is approximately $22 to $35, compared to approximately $65 to $120 for a fiberglass composite crossarm. The cost of a wooden crossarm with protective polyurea elastomer ranges from $52 to $80, which is less or comparable to the cost of crossarms made of fiberglass composites or other resistant materials on the market. However, additional research is needed to determine whether coated wood crossarms are more cost effective than other materials over the lifetime of the utility structure.

Project Contacts: George Linz, Shelagh Tupper

Forestry

Wildlife impacts on forest resources can be extensive. Cutting and gnawing on seedlings by deer, elk, mice, mountain beavers, pocket gophers, rabbits, and voles during the first 5 years of tree growth greatly hinder reforestation efforts following harvests and wildfires. Other mammals such as bears and porcupines damage mature trees. North American beavers and nutria alter riparian vegetation, which limits streamside restoration efforts, erodes roads and railways, and can endanger human health and safety. NWRC scientists are developing nonlethal tools and methods (e.g., repellents and habitat and behavior modification) to manage wildlife damage to forest resources.

White-Tailed Deer Browsing and Rubbing Preferences for Trees and Shrubs—Non-timber forest products (e.g., foods, herbal medicines,

White-tailed deer browse damage to seedling
Photo by Southern Forest Insect Work Conference Archive, Bugwood.org

In autumn, male white-tailed deer cause damage when they rub against the stems of trees and shrubs to remove the velvet from their antlers.
Photo by USDA/Forest Service, North Central Research Station Archive

woody florals, and handicraft products) are important sources of income for some landowners. However, white-tailed deer (*Odocoileus virginianus*) can reduce the quality, quantity, and profitability of forest products by browsing twigs and rubbing stems, resulting in direct and indirect losses. NWRC researchers collaborated with colleagues from the University of Nebraska in a study to (1) evaluate deer damage—in particular, the frequency and intensity of browsing and rubbing—sustained by 26 species of trees and shrubs; (2) relate morphological features of trees and shrubs to damage levels; and (3) estimate the economic impacts of deer damage on the production of non-timber forest products.

Results from the study showed levels of browsing to be quite high in most species of trees and shrubs, with the highest intensity occurring in Chinese chestnut (*Castanea* spp.) and dogwoods (*Cornus* spp.) and the lowest in ginkgo (*Ginkgo biloba*), curly willow (*Salix matsudana*), scarlet curls willow (*S. matsudana* var. *'Scarlet Curls'*), smooth sumac (*Rhus glabra*), and pussy willow (*S. caprea*.). Sparse trees or shrubs with one or a few exposed stout stems unprotected by dense branching (e.g., American elderberry *[Sambucus canadensis]*, smooth sumac, and curly willow) sustained the most damage from deer rubbing. Trees and shrubs with many small diameter stems or with dense tangled branching (e.g., yellow-twig dogwood [*C. sericea* var. 'yellow-twig'], forsythia [*Forsythia suspense*], flame willow [*S. alba* var. *'Flame'*], and streamco willow [*S. purpurea*]) were least damaged by rubbing. The economic costs of deer damage to producers of non-timber forest products ranged from

$9 per acre for pussy willow to $1,428 per acre for curly willow.

These results provide resource managers with useful information on which trees and shrubs sustain the most damage and the economic costs of deer damage to local land users.

Project Contact: Kurt VerCauteren

Repellents To Prevent Ungulate Browsing—Chemical repellents are frequently used to deter deer browsing on trees and shrubs. Repellents promote an avoidance behavior using one or a combination of several mechanisms—neophobia (tendency of an animal to avoid/retreat from an unfamiliar object or situation), irritation, conditioned aversion, and/or flavor modification. The relative effectiveness of repellents often depends on the individual animal's motivation to consume the protected resource. For example, when alternative foods are available, shiny ribbons (a visual repellent with no consequence) may provide significant protection to plants in localized areas; however, when alternative foods are scarce, visual repellents may no longer be effective.

In captive deer studies, NWRC scientists evaluated how feeding motivation may impact repellent efficacy. The incentive to consume test diets was manipulated by allowing captive deer to learn about two test diets that differed in energy content. Scientists then conducted a series of experiments to compare the different mechanisms of deer repellency and evaluate repellent effectiveness when the incentive to consume the treated diet was varied. They tested four repellents representing different modes of action (neophobia, irritation, conditioned aversion, and flavor modification). When the high-energy diet was treated with repellents, only blood (flavor modification) and capsaicin (irritation) proved highly effective. Rapid habituation to the odor of meat and bone meal (neophobia) presented in a sachet limited its effectiveness as a repellent under conditions with a high feeding motivation. Thiram, a stimulus used to condition aversions, was not strongly avoided in these trials.

These data support previous studies indicating that habituation to odor limits the effectiveness of repellents that are not applied directly to food, while topically-applied irritants and animal-based products produce significant avoidance behavior in deer.

Project Contacts: Bruce Kimball, Jimmy Taylor

Mountain Beaver Genetics—Mountain beaver (*Aplodontia rufa rufa)* are endemic to the Pacific Coast of North America and can be found in California, Nevada, Oregon, Washington, and British Columbia, Canada. There are seven subspecies of mountain beaver. The U.S. Department of the Interior's (DOI) Fish and Wildlife Service (FWS) has classified one of these subspecies, *A. r. nigra*, as endangered and several other mountain beaver subspecies as populations of concern under the Endangered Species Act. However, in some portions of its range, mountain beaver cause significant damage to forestry interests and are managed as a pest species. Studies of mountain beaver populations are critical for understanding their status and informing wildlife damage management practices. Molecular genetics techniques are particularly useful for explaining population demographics.

To aid research efforts related to mountain beavers, NWRC scientists developed and characterized 10 microsatellite markers from the *A. r. rufa* genome. The addition of these 10 markers to previously published ones provides a powerful tool for studying *A. r. rufa* populations. For instance, NWRC researchers are using deoxyribonucleic acid (DNA) analyses to test whether mountain beaver populations are closed systems or if individuals move across forested landscapes to new areas. Researchers are also studying the relatedness and connectivity among the last two remaining populations of the endangered *A. r. nigra.*

Project Contacts: Jimmy Taylor, Antoinette Piaggio

NWRC researchers analyzed the composition of beaver colonies at 89 sites with chronic damage in the southeastern United States.
Photo by iStock/000011557709

Composition of Beaver Colonies—Natural resource managers faced with resolving beaver damage often make decisions based on classic scientific literature that suggests three basic factors: (1) beavers are monogamous breeders that live in colonies; (2) colonies are composed of a breeding pair of adults, their offspring, and occasionally, the offspring from the previous year; and (3) beavers typically breed during the winter and have their offspring in the spring. However, these assumptions are not always correct. NWRC scientists recently analyzed the composition of beaver colonies at 89 chronic damage sites in 7 southeastern States and found several deviations from this conventional knowledge.

In this study, colony size ranged from 2 to 18 beavers. Eleven colonies contained one male and one female only, and only five of these were breeding pairs. Colonies contained anywhere from 1 to 11 males, while the number of females among colonies ranged from 0 to 8. The mean age of beavers across all States in which the study was conducted was 3, with an overall age range of 1 to 20 years. Thirty percent of all beavers captured were in the 1-year age class. In addition, at least one breeding female was found in 78 percent of all colonies. Breeding females were also found in every age class older than 1 year, and more than one breeding female occurred in 17 percent of all colonies sampled. The youngest age of reproductively active females was 2, and the oldest was 18 years of age. Lactating and/or pregnant females were captured in every month except September, October, and November, suggesting a flexible or extended breeding season in southeastern colonies.

These data show that the dynamics of beaver colonies are more complex than previously thought. Issues such as female site fidelity, the reproductive potential of beavers, generally larger colony sizes, and the tendencies of juveniles to disperse to less optimal habitats or remain in their natal colonies indicate that beaver colonies in the southeastern United States—if left unmanaged—could prove detrimental to resources being protected in high-density areas. For instance, managers working in areas of long-term damage may underestimate the number of beavers that need to be removed in order to protect an area's resources. In this regard, the results of the study have serious implications for wildlife managers when determining whether to use lethal or nonlethal approaches to control beaver populations.

Project Contacts: Jimmy Taylor, Russell Singleton

Den Sharing Among Lactating Beavers—During a radio-tracking study of North American beavers *(Castor canadensis)* near Phoenix, AZ, APHIS Wildlife Services field operations specialists and NWRC researchers discovered three adult, lactating beavers using the same bank den at the same time (seven occasions during 68 days). Two adult females 5.2 kilometers downstream also used the same den at the same time (three occasions during 45 days). For North American beavers, the conventional family unit comprises a single adult breeding pair, young of the current year, and yearlings born the previous year. However, the social organization of beaver colonies in this study area appeared to consist of multiple reproductive females with an extended family unit.

To test the hypothesis that these communal females were closely related, researchers sampled and com-

pared eight, autosomal DNA microsatellites. Except for a pair of females in the first den, all communal females who shared dens were unrelated to each other. The observed communal denning of adult, reproductively active females in the area may be due to the limited amount of available habitat (i.e., suitable sites for foraging and denning) in southwestern Phoenix. The scarcity of available dens and proximate high-quality food in the area could be delaying and, in some instances, eliminating the dispersal of sub-adults and adults. These results suggest that relocating beavers as part of an integrated management strategy will likely not harm the beaver population in this area.

Project Contacts: Jimmy Taylor, Antoinette Piaggio, Justin Fischer

Predation

The development of new predator management tools to reduce livestock losses and protect public safety is a high priority for APHIS Wildlife Services, as well as wildlife managers and livestock producers. Livestock predation costs producers approximately $93 million each year. Concerns also exist for public safety and animal welfare when predators cause conflicts and management is implemented. NWRC uses a multidisciplinary approach to study interactions among predators and the impact of predators and predator removal on ecosystems and wildlife populations. Results from these studies are fundamental to selective and socially responsible predator management. In addition, NWRC researchers are developing improved methods for capturing predators; monitoring their behaviors and movements; developing more selective predacides; and finding alternative, nonlethal tools and techniques to prevent predatory behavior.

Evaluation of Cable Foot-Restraints—Negative public perceptions regarding the use of foot-hold traps have led to restrictions or all-out bans on these traps in several States. However, traps can be selective and effective tools for wildlife managers. To compensate

The nutritional status of coyote pups may effect their reproductive fitness as adults.
Photo by NPS, Wilford L. Miller

Effects of Maternal Nutrition on Whelping Rates in Coyotes—To determine if nutritional status during the postnatal period affected reproductive fitness in coyotes, scientists at the NWRC field station in Logan, UT, hand-reared 24 pups from 10 days to 6 months of age on either an unrestricted or reduced nutrient diet. Scientists assessed the pups' weight, stature, blood and hormone values, and reproductive performance during the first reproductive season. Pups on the unrestricted nutrient diet weighed more than those raised on the reduced nutrient diet. Of the 21 blood parameters analyzed, 19 differed in concentrations as the pups matured. The study results did not show relationships between diet and leptin or social rank and testosterone. Eighty-three percent of the females became pregnant, with 80 percent known to have produced viable young. Animals on the reduced nutrient diet produced nearly three times more pups than those on the unrestricted nutrient diet did. Scientists also noted a strong similarity in placental implantation rates among sibling sisters, which suggests that maternal effects may influence reproductive performance in juvenile coyotes.

These findings are useful in understanding time lags in coyote reproduction, which in turn influence depredation rates on domestic livestock.

Project Contacts: Julie Young, Eric Gese

for the loss of this tool, wildlife managers in some areas use cable foot-restraints to capture coyotes. In a continued effort to improve the selectivity of traps and the welfare of trapped animals, NWRC researchers evaluated animal injuries associated with three types of cable foot-restraints:

- standard cable restraint—53.34 centimeters of 0.32-centimeter-diameter, 7 x 19-strand cable with a cam-lock;
- sleeved cable restraint—same as standard, but with a 4.45-centimeter-long, 0.476-centimeter-diameter, clear plastic tube fitted over the cable; and
- chain cable restraint—same as standard, but with 3.02 centimeters of a 0.2-centimeter-diameter, twist-link chain that attaches the lock to the cable.

During 2004 to 2006, NWRC researchers captured and examined 21, 14, and 17 coyotes using the standard, sleeved, and chain cables, respectively.

Coyote Sterilization To Reduce Predation on Pronghorns—Coyote predation accounts for the majority of neonatal pronghorn mortality in many areas and may influence local population declines. Current techniques used to manage coyote predation on wildlife species often focus on lethal control methods, especially where nonlethal methods are not effective. However, coyote sterilization has been shown to be effective in reducing sheep predation in certain situations. Sterilization reduces the energetic need for parents to provision coyote pups, which may decrease predation on fawns by sterile coyotes.

In a recent study, NWRC and Utah State University researchers further examined the potential value of this management method. The researchers used tubal ligation and vasectomy to sterilize 15 coyotes while maintaining pair bonds and territoriality. Seven additional coyotes were captured and sham sterilized. They also monitored 71 pronghorn fawns by radio telemetry for 1 year pre-treatment and coyotes and pronghorn fawns for 1 year post-treatment. In addition, the researchers examined the effects of sterilization on coyote territorial maintenance and survival. The results showed that the survival of fawns was higher in home ranges of sterile coyotes than fawns in home ranges of non-sterilized coyotes.

Coyote predation accounts for the majority of mortality in newborn pronghorn antelope fawns.
Photo by NPS, T. Pittenger

The results also supported the hypothesis that sterilization, while keeping hormonal systems intact, did not change coyote territorial behaviors. Packs of sterile coyotes were the same size as packs of non-sterilized coyotes, and sterile and non-sterile coyote packs maintained similar home range sizes in all seasons tested. Residency rates were also similar for all coyote packs.

Based on this research, coyote sterilization may prove useful as a possible tool to boost pronghorn fawn survival in areas where fawn survival is a critical factor in pronghorn population persistence and where lethal control is not a viable management option.

Project Contacts: Julie Young, Eric Gese

The researchers used International Organization for Standardization (ISO) injury scores to evaluate the cables. There were no significant differences in injury scores between the standard restraint and the other two cable restraints. However, injury scores for coyotes captured in sleeved restraints were higher than those for coyotes captured in chain restraints. The sleeve may have prevented the cable from tightening snugly on the coyote's foot, allowing the leg to move against the lock and causing more lacerations, abrasions, and other injuries. The chain restraint had the lowest injury score. Researchers believe this could be the result of (1) the links within the chain providing a greater, rounded surface area, thus distributing the pressure of the device's grip; or (2) the lengths of chain acting similar to teeth or buttons on some jawed devices, which are thought to reduce movement and therefore reduce injury. All three restraints tested had lower injury scores than unpadded steel-jaw traps, but only the chain cable restraint had a lower mean injury score (though only slightly) than the padded steel-jaw trap. Scientists note that the padded foot-hold trap may cause less injury to captured coyotes than either the standard or chain cable restraints, thereby serving as a more humane method for capturing coyotes.

The results of this study provide valuable information to aid wildlife managers in choosing the most selective, effective, and humane type of cable foot-restraint when they must capture coyotes and traps are not available or legal to use for this purpose.

Project Contacts: Julie Young, Patrick Darrow

Human-Black Bear Conflicts in Colorado—Human-wildlife conflict in urban environments is increasing throughout the United States, impacting species conservation, jeopardizing human livelihood and safety, and requiring increased resources from wildlife managers. An ongoing NWRC research project is studying black bear (*Ursus americanus*) ecology and management in urban areas of Colorado to discover

Human-bear conflicts are a common problem throughout the United States.
Photo by USDA, Sharon Baruch-Mordo

patterns of bear conflict, how conflict is influenced by the availability of both human food sources and natural food sources, and management strategies to reduce conflict. The goal of the study is to provide citizens and managers with a better understanding of why bears enter towns and offer tools for reducing conflict with the animals.

Because availability of garbage has been identified as a key driver in human-bear conflict, a novel aspect of this research is focusing efforts on reducing garbage availability by altering human behavior. Research devoted to solving human-wildlife conflicts often focuses on managing wildlife, but there is a growing recognition that this approach typically provides only a temporary solution. Particularly in urban environments, changing human behavior would likely provide long-term solutions to growing problems with bears. Thus, part of this study is evaluating the effectiveness of education and law enforcement for altering human behavior.

Since the study's inception in 2005, production of natural foods available for bears has fluctuated dramatically each year. A key discovery of this research is that bears that may have used town environments

in poor production years will keep away from town during good food years, dispelling the commonly held notion that "once a garbage bear, always a garbage bear." Other results indicate that education and law enforcement as implemented in the study do very little to change human behavior. This important finding has led toward more focus on understanding the impact of urban areas on the local bear population (potentially positive or negative) and determining the impact of removal (translocation or lethal control).

Most importantly, this study illustrates the importance of understanding the ecological context of human-wildlife conflict, which can be critical for understanding the effectiveness of any management tool. Furthermore, the study shows that, without an experimental approach, conclusions about management success could be confounded. NWRC encourages the use of similar experiments when assessing the effectiveness of any management tool, be it focused on changing human behavior or bear behavior.

Project Contacts: Julie Young, Stewart Breck

Select Foraging of Black Bears in Yosemite National Park—Black bears are one of the most adaptable large carnivores and readily raid human sources of food, such as trash cans, bird feeders, and campgrounds. However, it is unknown if bears forage selectively for these resources or just take advantage of random opportunities. NWRC scientists and collaborators at Yosemite National Park conducted a study on black bears over several years to determine whether they forage selectively for human food sources, particularly those found in cars.

From 2001 to 2007, bears broke into 908 vehicles at Yosemite National Park. Use of minivans was more than four times higher than expected (29 percent versus the 7 percent expected) based on the availability of different vehicle models. Researchers hypothesize that black bears selected minivans over other car models to maximize caloric gain and minimize costs by targeting vehicles with higher probabilities of payoff. In addition, minivans may be more likely to emit food odors—regardless of whether they contain food—because these vehicles are designed to hold large groups of people and children, which may increase the likelihood of them containing spilled food and drinks. Another potential reason bears selected minivans is that minivan owners may be more prone to leave large caches of food in their vehicles because they have the space to do so. Minivans also may be easier to break into than other vehicles. Lastly, scientists note the data could reflect the foraging decisions of a few individual animals that have developed a learned behavior for breaking into minivans.

The information gathered from this study will help managers develop strategies that include greater education efforts focused on vehicles carrying large groups of people and children, increased enforcement efforts for vehicles violating food storage regulations, and management of select problem bears in Yosemite National Park.

Project Contacts: Julie Young, Stewart Breck

Snowshoe Hare Distribution and Abundance: Management Implications for Canada Lynx—Snowshoe hares (*Lepus americanus*) are an important prey species for Canada lynx (*Lynx canadensis*) and are considered critical for the persistence of lynx populations. To support effective lynx conservation efforts, land management agencies need to determine snowshoe hare distribution and abundance. One accepted approach for estimating snowshoe hare abundance is the use of fecal pellet plot counts. In a recent study, NWRC and Utah State University researchers examined correlations between snowshoe hare density, as determined by mark-recapture estimates, and pellet plot counts on both uncleared plots and annually cleared plots in the Bridger-Teton National Forest in western Wyoming.

Snowshoe hares are an important prey for lynx.
Photo by USDA, Eric Gese

Endangered leatherback sea turtle nests are vulnerable to predation by raccoons and armadillos.
Photo by NPS, Canaveral National Seashore

The results of the study show significant correlations between snowshoe hare density estimates and fecal pellet counts for both uncleared and annually cleared plots; however, the relationship was stronger when using pellet counts from annually cleared plots. In addition, researchers found that omitting hard habitat edges (not used by hares) around trapping grids improved correlations between snowshoe hare density and fecal pellet counts for both uncleared plots and annually cleared plots. Though precision is sacrificed when using uncleared plots, researchers note that such plots are useful as a coarse index of habitat use by snowshoe hares. These results may be useful for identifying important foraging habitat for Canada lynx in western Wyoming, as well as for monitoring changes in hare populations among habitats and during prescribed management actions.

Project Contacts: Julie Young, Eric Gese

Endangered Species

APHIS Wildlife Services conducts research and management activities to protect threatened and endangered wildlife species. These activities focus on protecting listed species from predation and competition with other wildlife, enhancing recovery programs, and increasing the public's ability to live with introduced and expanding populations of listed species.

Sea Turtle Nesting Success and Predator Control— Predators can have a severe impact on rare and endangered species through predation and competition. One of the primary threats to endangered sea turtle reproduction in Florida is nest predation by raccoons (*Procyon lotor*) and armadillos *(Dasypus novemcinctus).* In a recent study, an NWRC scientist worked with representatives from APHIS Wildlife Services' Florida State Office; Ecological Associates, Inc.; and the Hobe Sound National Wildlife Refuge to examine the impacts of effective predator management during an exceptional nesting year at a sea turtle nesting beach in Florida.

Historically, without predator management up to 95 percent of turtle nests were lost to predation each year at this location, primarily by raccoons and, more recently, by armadillos. Although the refuge managers previously identified predator control as potentially the most important tool for increasing sea turtle reproduction, other staff duties at the refuge usually took higher precedence, and predator management was typically an ancillary duty. As a result, predation

levels were held to only around 50 percent. However, recent predator control efforts, optimized by predator monitoring, have reduced predation to much lower levels (less than 20 percent). For example, in 2008, loggerhead turtle (*Caretta caretta*) nesting was above average, and both green (*Chelonia mydas*) and leatherback (*Dermochelys coriacea*) turtles had record numbers of nests at twice or more the median number of nests usually deposited. Overall predation was held to 14.7 percent of nests.

As a result of this low predation level, an estimated 128,000 additional hatchlings emerged as compared to estimates associated with no predator management and historical predation rates (i.e., "no control" scenario). These efforts also resulted in an estimated 56,000 additional hatchlings over what researchers would have expected had predator management activities been conducted as ancillary duties rather than by experts who could focus solely on predator management (i.e., "control as ancillary duty" scenario). In addition, the study showed that the costs of effective predator management could be relatively low. The total investment for predator management by experts in this study was $12,000, which equates to a cost of only $0.09 per additional hatchling produced for the "no control" scenario and only $0.21 for the "control as ancillary duty" scenario.

In a similar study, NWRC and the Florida Department of Environmental Protection examined the biological and bioeconomic results of predator management relative to sea turtles and shorebirds on two adjacent barrier islands (Cayo Costa and North Captiva) along Florida's west coast. Both islands suffered severe nesting losses due to predation and disturbance by raccoons, while Cayo Costa also was impacted by a large population of feral swine. Prior to predator management, no least tern production occurred on either island, and sea turtle nest predation was 74 and 60 percent, respectively, for Cayo Costa and North Captiva. In 2007, predator management occurred on Cayo Costa, while North Captiva served as an untreated reference island. Cayo Costa produced 31 least terns, and sea turtle nest predation decreased to 15 percent. In contrast, North Captiva again had no least tern production, and sea turtle nest predation was 84 percent. In 2008, both islands received predator management. Cayo Costa and North Captiva produced 20 and 55 least terns and had 16- and 0-percent sea turtle nest predation, respectively. The entire cost for predator management by experts over the course of the study was $39,636, and the returns in additional production of least tern young and hatchling sea turtles were valued at over $1.1 million—resulting in a benefit-cost ratio of 27.8 for dollar expended.

Project Contacts: Michael Avery, Richard Engeman

Rodent-Proof Nest Box for Endangered Birds in Hawaii—The puaiohi, or small Kauai thrush (*Myadestes palmeri*), is an endangered bird endemic to the island of Kauai, HI. The sole population of about 500 birds is currently restricted to remote, higher elevation areas of the Alakai Plateau. Puaiohi nest primarily on steep stream-side cliffs, and their distribution and abundance are limited partly by the availability of suitable nest sites. Black rats (*Rattus rattus*) cause nest failure and mortality of nesting females, and ground-based rodent control has not been effective at reducing nest predation.

In 2007, researchers at the NWRC Hilo, HI, field station investigated whether artificial nest structures might be a viable alternative to rodent control by testing nest box designs to find one that is resistant to rats. In laboratory trials, the researchers evaluated three designs that were currently being deployed as artificial nest boxes for puaiohi and found that these structures are not rat resistant. From these initial results, researchers developed and tested an improved nest box design. Captive rats were unable to enter the new nest box, which was made from a 35-centimeter length of 15-centimeter-diameter plastic pipe with an overhanging entrance cut at a 49-degree angle (distance between the top and bottom lips of the pipe was

too large for rats to reach while standing on top of the pipe). The overhang and size of the pipe prevented rats from climbing into the entrance. Field tests of the new nest box design are currently underway to determine whether wild birds can use the boxes successfully as protection against rats.

Project Contact: William Pitt

Monitoring Ethiopian Wolf Populations—The endangered Ethiopian wolf is considered to be the rarest canid in Africa. The species faces many threats and is particularly vulnerable to diseases such as rabies. A simple, low-technology means of monitoring Ethiopian wolf populations would greatly facilitate conservation efforts, as it could detect early population changes and behavior and signal a need for intervention.

To help address this issue, NWRC scientists partnered with Colorado State University and the Ethiopian Wolf Conservation Programme to test a passive tracking index methodology for use with Ethiopian wolves. The method uses counts of track intrusions into plots placed in the animals' routes of travel as the basis for calculating an index. While this approach has been successful when used for other species, researchers found that this approach did not work well for Ethiopian wolves, as the method did not intersect the wolves' activity patterns adequately. The low vegetation associated with Afro-alpine habitats offered little benefit for the wolves to travel roads. However, in a second trial of this approach among colonies of mole rats—a focus of wolf foraging activity—placing plots on mole-rat mounds was an efficient way to collect Ethiopian wolf plot intrusions for index calculations.

This plot placement method, coupled with passive tracking index calculations, might offer resource managers a cost-efficient tool that requires minimal equipment to monitor Ethiopian wolf populations on the Sanetti Plateau and other Afro-alpine habitats. Plot placement on roads in other Ethiopian wolf habitats where cross-country travel is more difficult might still be a viable means to collect track data as well, but requires further testing.

Project Contacts: Michael Avery, Richard Engeman

Economics

NWRC economic research seeks to quantify the benefits and costs of new and traditional wildlife management activities. The Center's current studies are aimed at determining the potential benefits (resource savings) and costs involved in reducing the impacts of introduced invasive species; emerging wildlife-transmitted diseases; traditional wildlife-caused damages to agriculture, property, and natural resources; and wildlife-posed risks to public health and safety.

Economic Assessment of Beaver Damage in Mississippi—It has become essential for groups involved with wildlife policy formulation and decision-making to examine the economic benefits and costs derived from the management of nuisance wildlife species. Beavers (*Castor canadensis*) in Mississippi have seen significant population fluctuations over the last 150 years, as their status has changed from a game species to protected species to nuisance species. To determine the overall value of APHIS Wildlife Service's Mississippi beaver control assistance pro-

Beaver damage to timber, structures, and roads
Photo by USDA, Ricky Walker

gram (BCAP), NWRC economists assessed beaver-caused economic impacts to Mississippi's timber industry and estimated the damages avoided due to BCAP activities from 2005 to 2009.

The total BCAP costs averaged $1.1 million annually over the study period. An analysis of six combinations of possible timber savings showed a range of $25 million to $57 million on average for annual direct program benefits. To estimate the potential secondary impact to the regional economy from these timber losses, the economists utilized an input-output model. The additional loss in annual economic activity in the region ranged from $19 million to $42 million.

Using these estimated values of potential beaver damage, all calculated benefit-cost ratios indicated that BCAP was an economically efficient expenditure of resources during the study period.

Project Contacts: Stephanie Shwiff, Katy Kirkpatrick

Economic Impacts of Brown Treesnakes to Hawaii—Hawaii and other islands tend to be susceptible to invasion by introduced plant and animal species because these locations often have few predators or competitors, experience a high volume of air and sea traffic, and typically provide a favorable habitat and climate for the introduced species. A prime example of this problem is the invasion of the brown treesnake (BTS) on the Pacific island of Guam. The snake arrived on Guam shortly after World War II, probably as a stowaway on U.S. military cargo ships from another island. Without any natural predators on Guam, and with an abundant prey base, the snakes dramatically increased in number and have caused numerous snake bite incidents and power outages, as well as the extirpation of 10 of 13 endemic forest bird species. Although there has been extensive research on BTS and efforts to control its spread in Guam, few studies have measured its economic damages, and none have evaluated the potential economic damages if the snake was introduced to Hawaii. Like Guam, Hawaii has no endemic terrestrial snakes, and despite intensive cargo-screening measures to prevent the snake from leaving Guam, eight BTS have hitch-hiked on aircraft from Guam to Oahu since 1981.

NWRC conducted an economic analysis on the potential introduction of BTS to Hawaii. The analysis collected information on medical incidents and power outages on Guam and used it to guide estimates of potential damage to Hawaii. Data on the potential impacts to Hawaii tourism were collected through a survey conducted on Oahu in January 2008. The results showed that the total estimated damage from medical incidents, power outages, and decreases in tourism to Hawaii would range from approximately $593 million to $2.14 billion annually. The results also showed a loss of between approximately 1,400 to 13,000 jobs within the regional economy related to decreased tourist spending. This study revealed that a BTS invasion and establishment on Hawaii could have potentially permanent and costly economic consequences.

NWRC researchers assessed the potential economic impact of brown treesnake introduction into Hawaii.
Photo by USGS, Gordon H. Rodda

Project Contacts: Stephanie Shwiff, Katy Kirkpatrick

NWRC economists evaluated the benefits of a red fox oral rabies vaccination program in Ontario, Canada.
Photo by USGS/NBII, John Mosesso

Economic Analysis of Ontario Red Fox Oral Rabies Vaccination Program—Ontario has had a red fox *(Vulpes vulpes)* oral rabies vaccination (ORV) program in place since 1989. To determine if the program is cost effective, economists from the NWRC, Ontario Ministry of Natural Resources, and Texas A&M University conducted a benefit-cost analysis. Between 1979 and 1989, prior to ORV baiting, there were annual averages of 2,248 human post-exposure treatments; 1,861 positive red fox rabies diagnostic tests; and $246,809 in indemnity payments for livestock lost to rabies. After baiting, from 1990 to 2000, there were 35-, 66-, and 41-percent decreases in post-exposure treatments, animal rabies tests, and indemnity payments, respectively. Researchers viewed these reductions as benefits of the ORV program, whereas total costs were those associated with ORV baiting. Using several statistical techniques, researchers quantified a range of total estimated benefits from approximately $35 to $98 million. The annual mean ORV program cost was approximately $6 million, with total program costs of $77 million. The average benefit-cost ratios over the analysis period were 0.49, 1.06, 1.27, and 1.36, indicating overall program efficiency in three of the four conservative scenarios.

Project Contacts: Stephanie Shwiff, Katy Kirkpatrick

Wildlife Diseases

Increasingly, wildlife are implicated in the transmission of diseases such as avian influenza, West Nile virus, rabies, and chronic wasting disease to people, pets, and livestock. Managing wildlife vectors must be an integral part of any efforts to control the spread of such diseases. Current NWRC research focuses on developing methods to reduce or eliminate the transmission of diseases among wildlife, domestic animals, and humans.

Rabies

Rabies is an acute, fatal viral disease most often transmitted through the bite of a rabid mammal. It can infect people as well as animals and has far-reaching impacts on society. In the United States, terrestrial rabies occurs in many wild animals, including raccoons, skunks, gray foxes, arctic foxes, and coyotes. In an effort to halt the spread of and eventually eliminate terrestrial rabies in the United States, NWRC scientists conduct research on the behavior, ecology, movements, and population structures of raccoons and gray foxes. These scientists also evaluate methods and techniques to vaccinate free-roaming wildlife against rabies to decrease the risks of transmitting and maintaining the disease in the wild.

Landscape Genetics of Raccoons: Implications for ORV Programs—In the United States, raccoons (*Procyon lotor*) are reservoirs for the raccoon rabies virus variant, which can infect humans and other wildlife species. To combat this threat, APHIS Wildlife Services conducts an ORV program in many eastern States. In a recent study, NWRC, Wildlife Services' Pennsylvania State Office, and the Centers for Disease Control and Prevention (CDC) determined the genetic structure of raccoons in Pennsylvania and the geographic features (e.g., ridges and valleys), if any, that may hinder or enhance raccoon gene flow (i.e., movement) and the transportation of the rabies virus by this mammal.

As part of this study, researchers collected a total of 185 raccoon DNA samples from one ridge site and two adjacent valleys in southwestern Pennsylvania.

Raccoons are considered a public health threat for zoonotic diseases, such as rabies, larval migrans, and potentially avian and human influenza A viruses.
Photo by Bugwood.org, Johnny N. Dell

Raccoon genetic structure within and among the sites was characterized at nine microsatellite loci. Results indicated that there was little genetic difference among the raccoons sampled, and that random mating was occurring within the population over a reasonably broad geographic area (e.g., sites up to 36 kilometers apart). However, distance was found to impact some of the genetic difference, which suggests that adequate widths of ORV zones are critical for success. The researchers concluded that geographic features within this landscape influence gene flow in raccoons only to a limited extent, and geographic features such as ridges are not long-term barriers to the spread of rabies virus. These results may be of value to inform future ORV efforts in Pennsylvania and other eastern States with similar landscapes.

Project Contacts: Kurt VerCauteren, Jeff Root

Field Evaluation of Infrared Thermography for Screening Rabid Animals—NWRC researchers are exploring the use of infrared thermography (IRT) as a field tool to detect rabies in trapped raccoons. NWRC and APHIS Wildlife Services' field operations personnel evaluated IRT on 311 animals captured during trap, vaccinate, and release efforts in Ohio in 2009. Of these captures, 292 were raccoons, some of which were caught more than once. Thirty-two of the trapped animals that showed possible signs of being rabid were euthanized, and their brains were tested to confirm whether they had rabies. Although four of the animals were classified as positive for rabies based on the IRT screening, all laboratory tests were negative for rabies. The ability of the IRT to correctly identify negative raccoons ranged from 85 to 98 percent (depending upon the operator).

The researchers continued this study through 2010 in an area of higher rabies prevalence to identify field conditions that may influence evaluations and conduct IRT field evaluations on rabies-positive animals.

Project Contacts: Kurt VerCauteren, Shylo Johnson

Raccoon Movements and Dispersal in Urban Environments—In 2004, raccoon-variant rabies moved westward from Pennsylvania into Ohio. In an effort to prevent further spread of the disease across Ohio, APHIS expanded the ORV boundary west toward Cleveland that year. NWRC researchers recently conducted a study to gain a better understanding of how raccoon-vectored rabies might move through urban areas of Cleveland and to help develop a vaccination strategy to stop this spread.

In this study, researchers placed remote download GPS collars on 10 raccoons (*Procyon lotor*). These collars offer advantages over traditional very high frequency (VHF) telemetry and conventional "store on board" global positioning system (GPS) collars, particularly in urban environments, because they have a remote download capability that allows researchers to retrieve data without collecting the collar. To date, raccoons have restricted their space use to small green-spaces when available, but also occasionally

Tracking radio-collared raccoons as part of an urban raccoon rabies study
Photo by USDA, Michael Dunbar

inhabited nearby abandoned houses. Restricted movements by raccoons in urban areas suggest that rabies may move more slowly in these locations than in surrounding areas with higher levels of habitat connectivity. However, these results do not suggest that urban areas should be disregarded when conducting ORV baiting operations. Small, tree-covered habitat patches—particularly those that border urban housing areas—should be hand-baited in an effort to prevent rabies spread between raccoons and from raccoons to domestic animals and humans.

Project Contacts: Kurt VerCauteren, Are Berensten

Vitrification of Raboral V-RG® for Improved Vaccine Stability—In the United States, the canine variant of rabies has been eliminated, but wildlife reservoirs for other variants of rabies are a common source of infection for pets, livestock, and humans. Raboral V-RG, an oral rabies vaccine, is the vaccine currently used in the United States to immunize free-ranging wildlife for rabies. However, biological materials such as the Raboral V-RG require low temperatures for stability. The stability of live viruses in vaccines for field use is of crucial importance. The longer the vaccine remains viable, the better the odds are for a target animal to encounter the vaccine and become immunized.

NWRC scientists have been working on a method called vitrification that may help APHIS Wildlife Services' ORV program increase rabies vaccination rates for wild, free-ranging wildlife. Vitrification is the process of preparing materials in a matrix of compounds, usually sugars or polymers, in a manner that, upon drying, results in the formation of a glass rather than a crystallized product. Vitrification of Raboral V-RG provides protection from a loss of viability at elevated tempera-

tures. This protection extends through temperatures likely to be encountered in outdoor and non-refrigerated storage conditions. NWRC scientists observed that, even at temperatures of 50° C or higher for 24 hours, substantial amounts of viable vaccine virus remained in the samples. At 37° C, for the duration of the 3-week study, the vaccine virus was protected and essentially no loss was observed. This is in stark contrast to the standard liquid suspension presently being used where viability decreased measurably over time and no detectable viable vaccine virus remained after 3 weeks. These results suggest that the vaccine virus would remain stable for even longer periods of time in a vitrified format.

Project Contact: Kurt VerCauteren

Emerging Viral and Bacterial Diseases

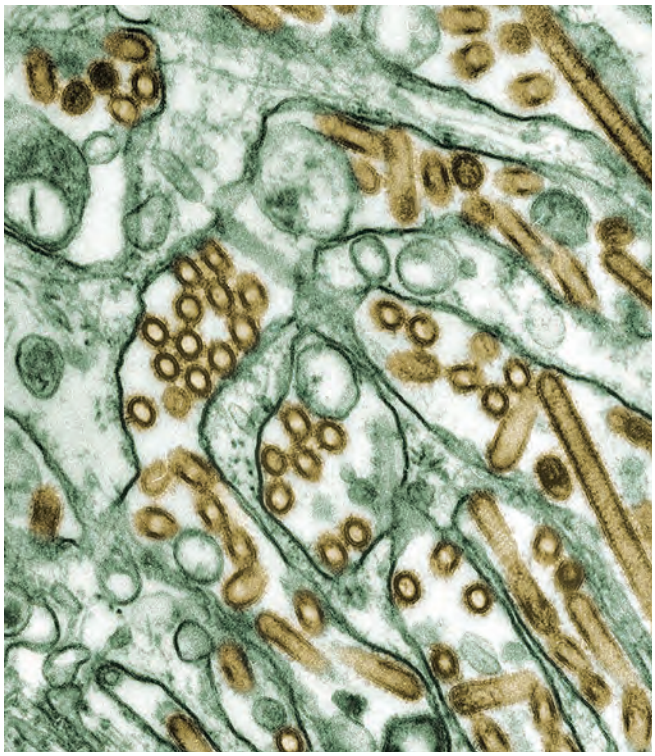
Considerable concern exists worldwide about recent emerging infectious diseases. Seventy-five percent of these emerging infectious diseases are zoonotic, meaning that they are naturally transmitted between wildlife species and humans. Some zoonotic diseases carried by wildlife can also be transmitted to economically important domestic animals, such as avian influenza virus to poultry and pathogenic bacteria to cattle. Therefore, wildlife populations often play a key role in many diseases that directly impact humans and agriculture. NWRC is at the forefront of monitoring, surveillance, and research for many of these diseases.

Raccoons and West Nile Virus—Raccoons *(Procyon lotor)* are considered a public health threat for a variety of zoonotic diseases. It is well established that raccoons are commonly exposed to West Nile virus (WNV) in several geographic regions of the United States, but little is known about their ability to serve as reservoirs for WNV and/or shed significant quantities of the virus. In a recent study, NWRC scientists experimentally infected eight raccoons with WNV to monitor morbidity and mortality rates, blood profiles, viral shedding, viral production in tissues, and pathology. The results of this study suggest that raccoons are not an important host in WNV mosquito transmission cycles. Only 75 percent of the test animals developed detectable levels of virus in their blood. WNV was not detected in tissues tested or in any opportunistically collected urine samples. WNV fecal shedding was observed in the majority of inoculated individuals and typically began several days after the virus was detected in the blood. On occasion, fecal swabs contained relatively high WNV titers, suggesting that whole feces may contain much higher viral loads. Observations of high survival with little or no obvious signs of the disease in raccoons are consistent with those reported for some other mammalian species. Although raccoons are well documented to be commonly exposed to WNV in nature, their role in WNV transmission, if any, may more likely be associated with fecal contamination of the environment rather than with mosquito-host transmission cycles. Researchers surmise that, although raccoons are commonly exposed to WNV, they probably do not have a major involvement in WNV cycles.

Project Contacts: Alan Franklin, Jeff Root

Antibody Responses of Raccoons Naturally Exposed to Influenza A Virus—NWRC and Iowa State University scientists investigated the concentration of naturally acquired antibodies to influenza A virus in raccoons *(Procyon lotor)* over time. Seven wild raccoons, some of which had been exposed to multiple subtypes of influenza A virus, were held in captivity for 279 days, and scientists collected serum samples on 10 occasions during this interval. They then tested the serum samples for the presence of antibodies to influenza A virus. Although titer declines were noted in most animals over time, all animals maintained detectable antibodies for at least 9 months.

These data indicate that naturally acquired antibodies to influenza A virus can remain detectable in raccoons for many months, with the actual duration presumably



Colorized transmission electron micrograph of avian influenza A H5N1 viruses (shown in gold) grown in Mallard duck cells (shown in green).
Photo by CDC, courtesy of Cynthia Goldsmith, Jacqueline Katz, Sherif R. Zaki

being much longer because all animals had been exposed to influenza A virus prior to the study. Surveillance programs using antibodies to detect recent influenza A virus activity should take into account that these antibodies may portray a historical perspective in mammalian wildlife and only occasionally represent recent exposures to influenza A virus. However, the longevity of these antibodies could be extremely useful to detect exposures months after outbreaks have occurred.

Project Contacts: Alan Franklin, Jeff Root

***Baylisascaris* Nematode in Raccoons**—*Baylisascaris procyonis* is an intestinal nematode commonly found in raccoons (*Procyon lotor*) that can cause fatal larva migrans. This disease is characterized by enlargement of the liver, fever, cough, and abnormally large amounts of globulins in the blood in birds and mammals, including humans. The *B. procyonis* parasite has been found in isolated regions in the Appalachian Mountains and, more recently, in Atlanta, GA. NWRC researchers collaborated with scientists from the Southeastern Cooperative Wildlife Disease Study (within the College of Veterinary Medicine at the University of Georgia) to investigate the distribution and prevalence of *B. procyonis* in selected populations of raccoons in Georgia.

The researchers examined intestinal tracts of 312 raccoons from 25 Georgia counties for *B. procyonis*. *B. procyonis* was detected in Clarke County where 12 of 116 (10.3 percent) raccoons were infected. In addition, *Toxascaris leonina*, a morphologically similar nematode, was found in three raccoons from Clarke County and Morgan County. The researchers also genetically compared worms from Georgia, Kentucky, and Texas; sequence analysis confirmed that the Georgia samples were *B. procyonis*. These data indicate that the distribution of *B. procyonis* within Georgia is increasing dramatically, and that only limited genetic variation is present in the rRNA and internal transcribed spacer (ITS) gene regions among *B. procyonis* from the southern United States.

Project Contact: Tyler Campbell

Ring-Billed Gull Movements in Response to Egg Oiling—Overabundant populations of ring-billed gulls in the Chicago, IL, lakefront area are a potential hazard to aviation and have led to numerous swim bans due to concerns over fecal pollution of the water. At the request of Chicago city officials, APHIS Wildlife Services implemented the Chicago Ring-Billed Gull Damage Management Project in 2006 to prevent increases in the local population of ring-billed gulls, reduce the severity of conflicts with gulls, and evaluate if the majority of gulls on Chicago lakefront are from local colonies.

In 2007, Wildlife Services field operations staff oiled 53 percent of the estimated number of nests at two local colonies and found that oiling eggs with food-

Low Pathogenic Avian Influenza in House Sparrows and European Starlings—Little is known about the role of songbirds (Order Passeriformes) in the ecology of the avian influenza (AI) virus. Many passerine species are abundant and widespread, and they commonly come into contact with free-ranging birds as well as captive game birds and poultry. In a recent study, NWRC scientists inoculated captive house sparrows (*Passer domesticus*) and European starlings (*Sturnus vulgaris*) with low pathogenic AI viruses to better understand the birds' responses to primary infection and their potential role in the transmission of this disease.

The results showed shedding of the virus for both starlings and sparrows; however, the shedding was low and short-lived with no transmission among cage mates. Antibodies were detected as early as 3 days post treatment, and 97 percent of inoculated birds developed antibodies within 28 days post treatment. Pre-existing immunity appeared to reduce shedding. Infectious low pathogenic AI virus was cultured from oral and cloacal samples, as well as from gastrointestinal and/or respiratory tissues from both species. These results suggest that passerines are not likely to be significant reservoirs of low pathogenic AI viruses in nature.

NWRC scientists evaluated the role of starlings in the spread of low pathogenic avian influenza.
Photo by USDA, Jeff Homan

Project Contacts: Alan Franklin, Paul Oesterle

grade oil was a successful method of preventing gull production. In 2008, Wildlife Services increased gull population management efforts and oiled 80 percent of the nests in the two Chicago nest colonies, totaling 57,590 gull eggs in 22,136 nests. Without this project, Wildlife Services estimates that the Chicago hatch-year gull population would have increased by an additional 22,000 to 44,000 gulls beginning in July 2008, based on a fledge rate of 1 to 2 birds per nest. Significantly fewer gulls were observed on most of Chicago's beaches in 2008, which likely contributed to a reduction in conflicts, including a 33-percent decrease in the frequency of swim bans on Chicago's beaches (without canine harassment) in comparison to 2006.

To observe gull movements in the region, NWRC scientists partnered with Wildlife Services field personnel to mark and observe 5,968 gulls in Chicago and 5,617 gulls in northwestern Indiana throughout the summer of 2008. The researchers did not observe any movement of marked after-hatch-year gulls between Chicago colonies; after-hatch-year gulls nesting in Chicago, IL, and East Chicago, IN, tended to use beaches nearest to their nest colony. Recognizing this and the fact that gull use of beaches remained relatively stable throughout the swim season, it appears that gulls nesting outside of Chicago do not move into the city in significant numbers to use beaches during the swim season, and thus are not likely to contribute significantly to the conflicts on Chicago's beaches

during the swim season. Oiling the eggs with food-grade oil proved to be an effective method of reducing Chicago's hatch-year gull numbers without resulting in the abandonment or relocation of nest colonies.

Project Contacts: Travis DeVault, Tom Seamans, Richard Engeman

Chronic Wasting Disease

The spread of chronic wasting disease (CWD) in wild and captive cervids is of great nationwide concern. More research is needed to fill information gaps about disease transmission at the interface between wild and domestic cervids. CWD infects elk, white-tailed deer, mule deer, and moose, but is not known to naturally infect other species of wildlife (including predators and scavengers), livestock, or humans. There is no treatment for CWD, and typically, the disease is fatal in cervids. Realized and perceived CWD threats have significant implications for Federal and State wildlife management agencies, domestic cervid farmers, hunters, and businesses and economies reliant on deer and elk. In addition, these groups need additional and improved tools and management techniques to reduce the transmission, prevalence, and persistence of CWD in wild and captive cervids.

Elk Age and Sex Influences on CWD Rectal Biopsies—Rectal lymphoid tissue can be used for detecting CWD in Rocky Mountain elk *(Cervus elaphus nelsoni).* In fact, this method is the only practical live test for CWD in elk at this time. During a study conducted between 2005 and 2008, NWRC researchers took 1,361 rectal biopsies from captive elk to determine if the number of rectal lymphoid follicles in animals decreases with respect to age and sex relative to the diagnosis of CWD. Rectal tissues were then stained with a monoclonal antibody that selectively stains the abnormal isoform of the prion protein associated with CWD.

The results of this study showed that the number of lymphoid follicles obtained from typical biopsy tissues decreased with the age of the animal. The acceptable number of lymphoid follicles for detection of CWD was not considered to be a problem for elk up to 8.5 years of age, but for elk over 8.5 years of age, the follicle count was considered to be low. The sex of the animal had no affect on the number of lymphoid follicles observed in each age group. Based on these results, the researchers concluded that the rectal biopsies were an accurate test to diagnose preclinical stages of CWD in elk, especially for elk less than 8.5 years of age.

NWRC and partners developed a technique to detect CWD in elk.
Photo by USDA, Kurt VerCauteren

Project Contact: Kurt VerCauteren

Predicting CWD Progression in Elk—In a recent study, NWRC researchers examined sections of brain stem, lymph node, and tonsil from approximately 300 free-ranging and 15,000 ranch-raised adult Rocky Mountain elk (*Cervus elaphus nelsoni*) for the presence of the abnormal isoform of the prion protein (PrP^{CWD}) that has been associated with CWD. A total of 321 (24 free-ranging and 297 ranch-raised) elk were found to be positive. The researchers then selected 60 of the positive ranch-raised elk and all of the 24 free-ranging elk to be the basis for the development of a detailed scoring technique of the obex (brain stem at the level where the fourth ventricle converges into

the central canal of the spinal cord). NWRC scientists assisted colleagues from Colorado State University (CSU), DOI's National Park Service (NPS), USDA's Agricultural Research Service (ARS), the U.S. Geological Survey (USGS), and the Canadian Food Inspection Agency to develop the technique, called the "obex score," to predict in elk which structure or regions of the brain, spinal cord, and extra neural tissues contain PrP^{CWD}.

It is expected that PrP^{CWD} spreads throughout the obex of the brain stem at a rate similar to the movement of PrP^{CWD} throughout the central nervous system and extra neural tissues. Results suggest that PrP^{CWD} and the severity of spongiform degeneration have a unique and consistent pattern of progression through a section of brain stem at the level of the obex in both naturally occurring and experimentally induced CWD. Therefore, the obex score has potential usefulness as a basis for evaluating the presence of PrP^{CWD} in peripheral tissues and brain. Current studies are evaluating approximately 100 peripheral tissues and 75 neuro-anatomical locations of the brain and spinal cord in 36 free-ranging and ranch-raised elk with naturally occurring CWD and known incubation times. These results will be compared with corresponding obex scores.

Concurrent work with live animals is relating the level of CWD infection with changes in behavior. Cumulative results could lead to strategies for detecting infected animals before they show clinical signs, which could be useful in the treatment of infected individuals and management of CWD.

Project Contacts: Kurt VerCauteren, Tracy Nichols

Avian Scavengers as Vectors of Prion Disease— Mechanisms for the spread of CWD in North American deer and other cervids are not completely understood. NWRC researchers hypothesize that avian scavengers may play a role in translocating CWD in

Distribution and Epizootiology of CWD in Nebraska Deer—Western Nebraska is considered part of the core endemic area of CWD, yet little is known about prevalence rates or the factors affecting the distribution of CWD in this area. NWRC researchers used data on the occurrence of CWD collected from 2000 to 2007 throughout Nebraska to calculate prevalence rates and investigate the role that key spatial, temporal, demographic, and environmental factors have on the distribution of this disease. Researchers conducted analyses at two spatial scales, including the Panhandle region of western Nebraska and Statewide.

Results show that the dynamics of CWD were similar between the different spatial scales. CWD was more prevalent in mule deer *(Odocoileus hemionus)* than in white-tailed deer *(Odocoileus virginianus)*, in male deer than in female deer, and in adult deer than in fawns. Overall prevalence has increased from 0.3 to 1.4 percent in the Panhandle and from 0.2 to 0.5 percent Statewide. The sex of the animal and the interaction of latitude and longitude had the most influence when predicting CWD occurrence in Nebraska at both spatial scales. Age, year collected, and soil texture were also predictors. These results concur with studies conducted in other areas of the CWD core endemic area, suggesting that CWD dynamics are governed by similar processes throughout the disease's range.

Project Contact: Kurt VerCauteren

NWRC scientists study the impact of flooding on habitat use, movement, and survival rates of white-tailed deer in Nebraska.
Photo by USDA, Anson Eaglin

the wild, potentially encountering CWD-infected carcasses, consuming infected tissue, and transporting it over long distances before depositing feces. In a recent study, researchers inoculated 100 mice with fecal extracts obtained from American crows (*Corvus brachyrhynchos*) that were force-fed material infected with mouse scrapie (PrP^{Sc}). These mice showed severe neurological dysfunction 196 to 231 days post inoculation and tested positive for PrP^{Sc}. These results demonstrate that a common, migratory North American scavenger can pass infective prions in feces and, therefore, could play a role in the geographic spread of CWD in the environment.

Project Contacts: Kurt VerCauteren, Gregory Philips, Justin Fischer

Impact of Flooding on Deer Movements—Few studies have examined the effects of flooding on the habitat use, movements, and survival of white-tailed deer (*Odocoileus virginianus*). In June 1996, the Missouri River overflowed its banks and inundated much of the floodplain in eastern Nebraska and western Iowa. The flood occurred 3 weeks after the peak of the fawning season and was concurrent with a study evaluating the home range activity and movements of female white-tailed deer in a suburban natural area. NWRC, University of Nebraska, and McNeese State University scientists monitored the locations of 22 radio-marked, female white-tailed deer inhabiting eastern Nebraska lowlands and determined mean size of use-areas, use-area overlap, and movements of deer 30 days before, during, and after the flood.

The results showed that over 75 percent of the deer abandoned their pre-flood use-areas and moved short (less than 400 meters) distances to elevated areas. The average distance moved from before-during the flood period was 0.69 kilometers and from during-after the flood period was 0.32 kilometers. The mean size of use-areas was similar from before (100 ha) to during (103 ha) the flood, but decreased by 50 percent to 54 ha after the flood. The overlap between before- and during-flood use-areas was 35 percent, while during- and after-flood use-areas overlapped 53 percent. However, these distances were biased by four deer that moved greater than 900 meters to avoid floodwaters, three of which never returned to their pre-flood use-areas. Once these were removed from the data set, mean movement distances were 0.37 kilometers (before-during) and 0.11 kilometers (during-after); mean use-area size was 106 ha (before), 56 ha (during), and 41 ha (after); use-area overlap was 43 percent (before-during) and 59 percent (during-after). Doe:fawn ratios in 1996 (1:0.4) were considerably lower after the flood than in 1995 (1:1.5). Female deer showed strong fidelity to pre-established use-areas. Flooding had little effect on adult deer survival. The combination of flood waters and loss of quality forage most likely explain the decline in fawn numbers. These data provide important information towards understanding the impact of severe weather and flooding on white-tailed deer populations and management strategies.

Project Contact: Kurt VerCauteren

Invasive Species

Invasive vertebrate species cause substantial damage to crops and livestock, property, and natural resources (including threatened and endangered species, biodiversity, and ecosystem health) and pose a disease hazard to humans and livestock. NWRC research seeks to improve methods and strategies to prevent invasive species introductions, detect and eradicate new introductions, and support sustained suppression of well-established invasive species where eradication is not feasible.

Amphibians and Reptiles

Although worldwide distributions of many amphibians and reptiles are declining, a handful of species are spreading rapidly and disrupting native ecosystems throughout tropical regions of the world. The most notable of these species includes coqui frogs, cane toads, bullfrogs, BTS, and Burmese pythons. NWRC

researchers are developing methods to detect incipient populations of invasive amphibians and reptiles and implement control methods.

Impacts of Invasive Coqui Frogs on Hawaiian Forests—In Hawaii, invasive plants and animals may alter food webs because invasive plants have traits that differ from native plant species and abundant invasive predators can selectively reduce prey populations. The relative importance of these two processes on the litter invertebrate community in Hawaii is important and could affect the large number of endemic and endangered invertebrates.

In a recent study, NWRC researchers and colleagues at Utah State University determined the relative importance of litter resources, represented by leaf litter of an invasive nitrogen-fixer, *Falcataria moluccana* and a native tree, *Metrosideros polymorpha,* and predation by the invasive coqui frog *(Eleutherodactylus coqui),* on the abundance and composition leaf litter invertebrate community. The researchers found that the litter of the invasive *F. moluccana* has an associated invertebrate community that differs greatly from that found in the native *M. polymorpha* litter. The invasive tree was also associated with a 400-percent increase in the abundance of non-native crustaceans (Orders Amphipoda and Isopoda) that fragment plant material during feeding and a 200-percent increase in the abundance of non-native predatory ants. The coqui frog had less effect on the litter invertebrate community, reducing microbivores by 40 percent in *F. moluccana* and non-native ants by 30 percent across litter types. Coqui frog stomach contents were similar in abundance and composition in both litter communities, despite dramatic differences in the invertebrate community.

NWRC biologist spraying bicarbonate dust on foliage to control coqui frogs in Hawaii
Photo by USDA, Will Pitt

These results suggest that invertebrate community differences between the litter types did not cascade to influence the growth or survivorship of coqui frogs. The researchers conclude that the invasive tree species has a greater influence on litter invertebrate community abundance and composition than the invasive coqui frog does.

Project Contact: William Pitt

Excluding Non-Target Species from BTS Bait Stations—Bait stations with toxic baits are a major tool in efforts to eradicate the invasive BTS (*Boiga irregularis*) on Guam. To reduce the hazard of non-target animals getting into the bait stations, NWRC researchers evaluated the efficacy of three bait station designs (horizontal pipe, pipe angled downward at 45 degrees, pipe angled downward at 60 degrees) placed on three commonly used station support structures (vegetation, chain-linked fence, rebar tripod) to exclude non-native rats (roof rat: *Rattus rattus*; Norway rat: *Rattus norvegecus*; Polynesian rat: *Rattus exulans*) and native coconut crabs (*Birgus latro*).

Because the BTS is primarily arboreal, bait stations are typically placed approximately 1.3 meters above the ground to facilitate access by snakes and limit access by terrestrial non-target species. In laboratory studies simulating bait station placement commonly used in the field (approximately 1 meter above ground

NWRC and NPS biologists holding a Burmese python captured in Florida
Photo by USDA, John Humphreys

Effects of Cold Weather on Burmese Pythons—The Burmese python *(Python molurus bivittatus)* has invaded and become established in Everglades National Park and neighboring areas in south Florida. Beyond its substantial ecological impacts to native fauna in south Florida, there have been concerns about its potential to occupy other parts of the United States, even areas as far north as Washington, DC. During a recent period of cold weather, seven of nine captive Burmese pythons held in outdoor pens at the NWRC field station in Gainesville, FL, died or would have died in the absence of intervention. This cold-induced mortality occurred despite the presence of refugia with heat sources. These findings cast doubt on the ability of free-ranging Burmese pythons to establish and persist beyond the subtropical environment of south Florida.

Project Contacts: Michael Avery, Richard Engeman, John Humphrey, Tom Mathies, Richard Mauldin

level), roof and Norway rats were equally able to enter bait stations placed on all three station support structures; Polynesian rats rarely entered any of the elevated stations. However, the ability to access only the entrances of stations (but not the interior of the stations, where the bait was placed) when on support structures was extremely high for roof rats and appreciable for the other rat species, including Polynesians. The horizontal pipe station design, when placed on a chain-link fence, had the highest probability of access by all rodent species. The two downward-angled station designs, when placed in simulated vegetation, had the lowest probabilities of access by rats. Coconut crabs accessed station entrances readily, but never entered the interiors where the bait was.

Based on these results, the researchers recommend the suspension of either of the downward-angled station designs from vegetation wherever possible in areas where non-target species are a concern.

Project Contacts: William Pitt, Tom Mathies

Birds

Invasive bird species cause thousands of dollars in damage to agriculture and property, and they compete with native birds for food and nesting space. NWRC is developing methods and tools to prevent or reduce damage caused by invasive bird species, such as European starlings, monk parakeets, and feral pigeons.

Movements and Site Use of Rural and Suburban European Starlings—NWRC researchers tracked the movements and habitat use of European starlings radio tagged in central New Jersey during December 2009. The study area was a mosaic of rural and suburban land features, including three study sites—a game bird facility and two dairies. The sites were separated by an average of 40 kilometers.

By late December, a majority of the radio-tagged birds at the game bird facility had either abandoned or severely limited use of the facility. The researchers speculate that the birds stopped coming to the site

NWRC biologists attaching transmitter to a European starling
Photo by USDA, Jeff Homan

after the facility switched from a meal-based food to whole kernel corn. Even though use of the study site declined, the cohort remained within 15 kilometers of the study site.

Of the two dairies, one was embedded within a suburban area, whereas the other was in a predominately rural area. The dairies were used differently by the starling cohorts. The rural dairy received more consistent and intensive use than the suburban-embedded dairy. The differences also extended to roosting behavior, with the rural dairy being a favorite roosting site of its cohort, whereas the suburban-embedded dairy was never used for roosting. Starlings in suburban areas typically roosted in the dense vegetation of evergreen stands or in low-lying areas with wetland emergents (e.g., *Phragmites* spp. and *Typha* spp.).

Compared to the rural group, turnover rates at suburban roosts were higher, resulting in less cohesive roosting congregations. The difference in behaviors between rural and suburban starlings was probably related to increased habitat diversity in the suburban environment, which decreased daily site fidelity and increased sporadic use of small satellite roosts lying near major roost sites. By contrast, starlings in the rural environment existed in a rather homogenous landscape that consisted of large portions of infrequently used habitats. The used habitats were isolated and island-like, perhaps promoting greater site fidelity to daytime sites and roosts. (Note: The researchers do not consider the observed dichotomous behavior to be an anomalous result of this study, as they have had results similar to these in five other radio telemetry studies in rural study areas [Texas, Kansas, and Ohio] and suburban-urban areas [Indianapolis, IN, and Omaha, NE]).

The results of this study provide useful information for those tasked with lethally managing populations of nuisance starlings in suburban-urban areas. Because DRC-1339 is a slow-acting avicide, birds usually fly away from the bait site and, in suburban environments, can die in a wide array of habitats where they are difficult to find. Therefore, prior to baiting with DRC-1339, managers should know the general directions of arriving and departing flight lines that may provide an approximate bearing to the roosting site where their carcasses can be recovered.

Project Contacts: George Linz, Jeff Homan

Small Mammals

Invasive mammals, such as rats and house mice, mongoose, and nutria, have had a damaging impact on native animal habitat, agriculture, threatened and endangered species, property, and human health and safety. NWRC researchers are developing and evaluating toxicants, barriers, and other tools to eliminate or reduce the damage caused by these invasive mammals.

Efficacy of Rodenticide Baits for Invasive Polynesian Rats, Roof Rats, and House Mice—For several centuries, invasive rodents have decimated native flora and fauna in Hawaii and other areas of the Pacific Basin, reduced agriculture production, and threatened human health. Although many rodenticides are commercially available nationally, few are available for use in Hawaii or have been tested with wild rodents commonly found in the Pacific. To help address this issue, researchers at the NWRC field station in Hilo,

Invasive rodents have decimated native flora and fauna in Hawaii and other areas of the Pacific Rim.
Photo by iStock/000002356431

HI, tested the efficacy and palatability of nine commercial rodenticide bait formulations (0.005 percent diphacinone; 0.0025 percent brodifacoum; 0.005 percent bromadialone; 0.005 percent chlorophacinone; 0.0025 percent difethialone; 0.01 percent bromethalin; 2 percent zinc phosphide in two different formulations; and 0.025 percent warfarin) on Polynesian rats (*Rattus exulans*), roof rats (*R. rattus*), and house mice (*Mus musculus*).

Efficacy varied by rodenticide tested and rodent species. Generally, rodenticides were more effective against mice than they were against either of the rat species, and mice tended to consume more rodenticide bait than the laboratory chow alternative food. Efficacy was generally highest for the second-generation anticoagulants tested; however, this result varied across products, and one first-generation rodenticide had a similar level of effectiveness. The only rodenticide formulation that had 80 percent or higher mortality for all three species was a difethialone-based rodenticide. Rodenticide baits containing either bromadialone or brodifacoum had 70 percent or higher mortality rates for all three rodent species.

Bait acceptance (palatability) also varied both by rodenticide and by rodent species. Acceptance was the lowest for the acute rodenticides. The chlorophacinone bait product was notable in having high acceptance by all three rodent species, although mortality percentages were below 80 percent for *R. rattus* and *M. musculus*. The warfarin bait, zinc phosphide pellets, zinc phosphide oats, and bromethlin-based product were generally not well accepted by the two rat species but were eaten by the mice. Bait acceptance appeared to substantially affect the efficacy of rodenticides; materials that were not well accepted produced lower mortality rates.

Rodenticide products currently registered for use in Hawaii performed less effectively in this study than other available products not yet registered. Although markets for rodent control products for use on islands are limited, the results of this study show that there are advantages to having additional products registered for island use in agriculture, conservation, and public health.

Project Contact: William Pitt

Molecular Genetics of Roof Rats in the U.S. Virgin Islands—NWRC scientists conducted a genetic analysis of tissues from ship rats (*Rattus rattus*) captured on Congo Cay in the U.S. Virgin Islands and three other nearby islands to determine if the rats had survived an eradication effort in 2006 or re-invaded the area from neighboring islands. Analysis suggests that there was a single invasion, or if there were multiple invasions, that the rats came from a single source with limited genetic diversity. Model simulations indicated that, with no immigration among islands, it would require 100 rats to give rise to the present level of genetic differentiation between the islands. With immigration, 500 generations would be required.

These results indicate that the rats had not invaded from neighboring islands, but rather had survived the eradication effort. This information is useful for wildlife managers, as it indicates that future rat eradication efforts should consider the islands as independent eradication units.

Project Contact: Gary Witmer

Behavior of Invasive House Mouse—House mice (*Mus musculus*) pose a threat to the native flora and fauna of islands and can cause significant damage wherever they have been introduced. Methods used to eradicate high-density invasive rodent populations such as house mice might not be appropriate for intercepting the rodents at lower densities. A better understanding of the behavior of house mice immediately after they are introduced to a novel environment would help wildlife managers develop effective biosecurity techniques to protect against new invasions.

NWRC researchers conducted a controlled laboratory experiment that simulated an invasion by wild house mice into a novel environment. The researchers quantified and compared the immediate (within 15 minutes) behaviors of house mice by testing various odors and other attractants (e.g., foods and other mice, shelter, water, and a control). Results showed that mice presented with novel stimuli most commonly sought shelter in a den box. Secondarily, the mice were interested in food scents, particularly cheese, bacon grease, almond extract, and peanut butter. Females investigated male urine and feces odors more often than males investigated female odors.

Based on these findings, the researchers surmised that a secure den box that includes certain food and mice odors might entice and hold mice in a restricted area for a short duration in a novel environment. If done properly, this arrangement could be utilized for early detection and response to newly invading house mice.

Project Contact: Gary Witmer

Feral Swine

Free-ranging populations of wild pigs (also called feral swine) exist in at least 39 U.S. States. Some experts estimate the number of wild pigs in the United States at over 4 million, with the largest populations located in California, Florida, Hawaii, and Texas. Wild pigs feast on field crops, are efficient predators of young livestock and other small animals, and transmit diseases to domestic livestock. Developing effective methods and tools for managing wild pig populations is essential to protect agriculture and livestock from the threats these animals pose.

Scientists evaluated the effectiveness of five different fences in excluding feral hogs from areas.
Photo by USDA, David B. Long

Evaluating Feral Swine Fencing for Use During Disease Outbreaks—Feral swine (*Sus scrofa*) are susceptible to many diseases that are transmissible to cattle (e.g., foot-and-mouth disease, bovine tuberculosis, brucellosis) and domestic swine (e.g., classical swine fever, African swine fever). Animal health officials and wildlife managers need ways to effectively and quickly contain feral swine during disease outbreaks.

In collaborations with researchers at the University of Nebraska, NWRC scientists evaluated five candidate fences and, based on efficacy, selected traditional 0.86-meter-high hog panels to test rigorously for containing feral swine with increasing levels of motivation. During 4-day trials, the fences proved 97 percent successful when feral swine were least motivated (relatively undisturbed by humans), 83 percent effective when motivated by humans with paintball

Evaluation of Boar-Operated Systems (BOS™) Feeder: Non-Target Hazards—Feral swine *(Sus scrofa)* pose a significant disease threat to livestock and humans. Emerging technologies to reduce risks associated with the transmission of diseases by feral swine include fertility control, vaccination, and toxicants. However, for these technologies to be appropriate for field application, a feral swine-specific oral delivery system is needed.

In a recent study, NWRC researchers tested the effectiveness of the BOS, an oral delivery system designed to provide bait access only to feral swine. The researchers evaluated and monitored 10 BOS units for wildlife visitation, bait removal, and ingestion using motion-activated photography and baits containing the bait marker tetracycline hydrochloride (TH). Three of five pre-baited BOS units were used exclusively by feral swine. Additionally, five BOS units that were not pre-baited were not used by either feral swine or non-target wildlife. BOS units reduced bait removal by 10 percent for feral swine and by 100 percent for all other wildlife. Of the 81 feral swine and 23 raccoons captured in the study area, 90 percent and 13 percent, respectively, had TH-marked teeth.

Raccoon attempting to remove bait from BOS feral hog feeder
Photo by USDA/NWRC

These results show that, with minor modifications, the BOS could be a valuable tool for use in managing feral swine diseases.

Project Contact: Tyler Campbell

projectors, and 100 percent successful when pursued by gunners in a helicopter. The researchers also conducted two longer, 14-day trials where only 1 of 12 feral swine escaped.

In addition to being effective in containing motivated feral swine, enclosures constructed of hog panels were easy to erect and inexpensive ($5.73 per meter, excluding labor) relative to other fencing options. Hog-panel fence structures therefore offer a valuable tool for managing feral hog populations.

Project Contacts: Kurt VerCauteren, Gregory Philips, Michael Lavelle, David Long

Activity Patterns of Feral Swine—Free-ranging feral swine (*Sus scrofa)* are increasing in abundance and geographic distribution throughout North America. Currently, there are established populations of feral swine in Arizona, California, Colorado, Kansas, Nevada, New Mexico, Oklahoma, and Texas. Information on their natural history, such as daily and seasonal activity patterns, is not available for much of the Southwest, and there is evidence that these patterns may vary by region.

In 2008, NWRC researchers studied feral swine activity patterns and the impact of temperature on those patterns in southern Texas. The researchers placed GPS collars on 25 feral swine. Feral swine displayed highly nocturnal activity patterns, and during the dormant and early growing season (January through March), activity increased with rising temperatures. However, data for summer (May through July) suggest no influence of temperature. These data are counter to observed reductions in the success of feral swine trapping during summer months. The researchers believe that reductions in summer trapping success

may be due to the availability of alternative forage associated with the growing season and, therefore, are not directly related to temperature.

These findings provide useful information for wildlife managers, as they can better focus their work depending on the season and environment. For example, during summer droughts, trapping success may increase by targeting trapping efforts near sources of water.

Project Contacts: Tyler Campbell, David Long

Feral Swine Toxicant—Feral swine populations are growing throughout the United States. This population growth also means an increase in their threats of spreading diseases and damaging property. To help control feral swine populations safely, wildlife managers need effective means of delivering toxicants to these animals without impacting non-target groups. NWRC scientists, in collaboration with a private company, conducted trials to develop a palatable placebo bait for feral swine.

In this study, the scientists offered two baits (developed at Genesis Laboratories, Inc.) to 10 feral swine for 3 days. One bait contained strawberry flavoring, and the other had no added flavoring. On average, the feral swine consumed 1.937 kilograms more of the bait without flavoring compared to that with flavoring. To determine the best toxicant to use in the chosen bait, scientists tested two active ingredients: warfarin (0.005 percent, 0.0125 percent, and 0.025 percent) and diphacinone (0.001 percent). Results showed that warfarin was more effective. The scientists then conducted field tests to determine potential non-target hazards when using a swine-specific, bait delivery system. They placed placebo baits into specially designed feeders. Various animals, including collared peccary (*Dicotyles tajacu*), Norway rat (*Rattus norvegicus*), raccoon (*Procyon lotor*), and coati (*Nasua nasua*), visited the feeders and sampled baits when the lid was open, but once the lid was closed, only collared peccary gained access to the bait.

These findings show that, to reduce non-target exposure to toxicants, wildlife managers should limit baiting to areas where collared peccary are not present. The researchers also recommend close collaboration and planning with State authorities to ensure human and wildlife safety if toxicants are to be used with feral swine.

Project Contact: Tyler Campbell

Technology Development

NWRC scientists are using new technologies to create innovative methods and tools for use in wildlife damage management. Research areas include genetics, geographic information systems (GIS), formulation chemistry, chemical analysis, and wildlife contraceptives.

Chemistry-Based Tools

To help meet the increasing need for new, federally approved chemical tools to manage wildlife damage, NWRC scientists design and test methodologies to identify, analyze, and develop new drugs, repellents, toxicants, DNA markers, and other chemistry-based wildlife damage management tools. These methodologies support U.S. Environmental Protection Agency (EPA) and U.S. Department of Health and Human Services, Food and Drug Administration (FDA) registration requirements. The NWRC chemistry unit also conducts research to develop improved techniques for modeling, tracking, monitoring, and censusing wildlife populations.

Rodenticide Toxicity to Non-Target Bird Species—Diphacinone is a first-generation anticoagulant rodenticide used to manage rats, mice, and other rodent pests. Non-target species, such as birds, are potentially exposed to anticoagulant rodenticides through a variety of pathways during field rodent control operations.

In laboratory studies, NWRC scientists and colleagues at the USGS Patuxent Wildlife Research

Biologists determined the sublethal responses and toxicity of kestrels as part of a toxicological model.
Photo by USGS, Barnett Rattner

Center investigated sublethal responses (blood clotting time) and lethality to diphacinone in northern bobwhite quail (*Colinus virginianus*), a species traditionally used in wildlife pesticide risk assessments, and American kestrels (*Falco sparverius*), a model for studying toxicology in predatory birds. The scientists adapted several precise and sensitive clotting assays for measuring prothrombin time, Russell's viper venom time (RVVT), and thrombin clotting time in these species. The oral administration of diphacinone over a range of doses (sublethal to low lethal dose) prolonged prothrombin time and RVVT within 24 to 48 hours after exposure. The oral toxicity of diphacinone was about 20 times greater to American kestrels *(Falco sparverius)* than to northern bobwhite quail *(Colinus virginianus).* Prolonged *in vitro* clotting times reflect impaired coagulation abilities; scientists detected these prolonged times before or at the onset of overt signs of toxicity and lethality in both bobwhite quail and American kestrels. They also tested tissues from these animals for diphacinone, enabling the scientists to correlate tissue residue levels of diphacinone to prolonged clotting times and overt signs of toxicity.

This information will aid in the development of a physiologically based, pharmacokinetic model to assess and predict rodenticide toxicity to a variety of non-target avian species.

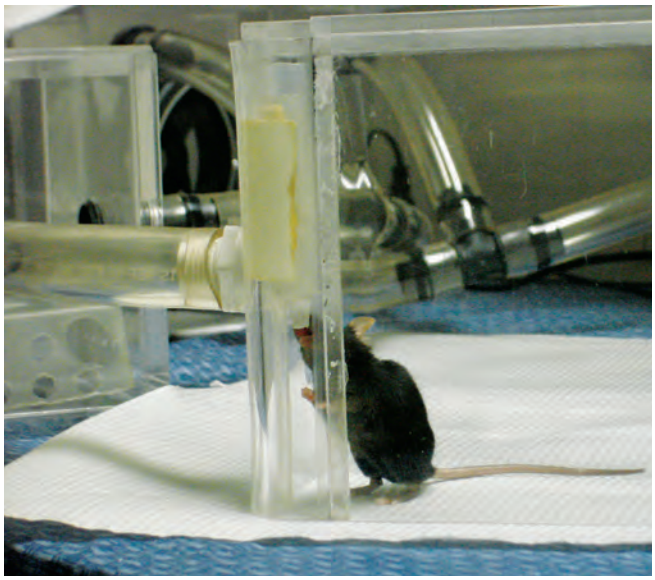
Project Contacts: Bruce Kimball, Katherine Horak

Detecting Disease Using Volatile Compounds— Wildlife can transmit various diseases (e.g., rabies, avian influenza, bovine tuberculosis, salmonella) to humans and livestock. Thus, early detection in wildlife can be important for controlling the spread of such diseases. There is evidence that animals can detect disease through odors and that trained animals might be used to identify the presence of AI in wild birds. NWRC partnered with the Monell Chemical Senses Center to develop diagnostic tools that use odor as a means to detect disease.

Researchers trained mice to identify odors in feces collected from ducks infected with low-pathogenic AI. Mice correctly distinguished between infected feces and uninfected feces more than 90 percent of the time. These results indicate that yet-to-be-identified volatile compound(s) are indicators of infection. Furthermore, the results suggest that animal and instrumental tools could be developed for identifying infected animals or populations. For example, the same behavioral system used for training mice as sensor animals could be used to train dogs for environmental screening, and the same odorants used by the mice for discrimination could be monitored by advanced analytical chemistry techniques.

Project Contact: Bruce Kimball

Taste Receptors and Implications for Oral Baits— Animals use taste, smell, and nervous system senses to identify beneficial nutrients, non-edible items, and toxins. For example, bitterness is thought to prompt an avoidance response in animals to toxic items. Recently, taste receptors were identified in the gastro-



B6 mouse in a Y-maze apparatus used in training mice to detect duck feces infected with avian influenza
Photo by Monell Chemical Senses Center, Maryanne Opiekun

intestinal (GI) mucosa of mammals. It is unclear, however, if chemosensory input from GI taste receptors can modify the taste response to a substance infused directly into the gut (i.e., stomach or small intestine).

In a series of experiments with mice, NWRC scientists and colleagues from the Monell Chemical Senses Center demonstrated that, despite the presence of taste receptors in the mammalian gut, information regarding food taste is not transmitted directly from the gut to the brain. However, tastes delivered directly to the gut can be detected in the oral cavity, likely via the circulatory system. These results suggest that microencapsulation of active ingredients in orally delivered baits may not prevent animals from tasting bitter toxicants. Although such coatings may prevent oral detection of bitter toxicants during ingestion, the circulatory system may be a source of taste information that could be involved in bait shyness.

Project Contact: Bruce Kimball

Evaluation of Natural Compounds as Snake Repellents—A repellent that could deter snakes from entering into areas of human activity would be a valuable wildlife management product for military, commercial, and private users. To help address this need, NWRC scientists collaborated with a private company to evaluate 10 natural compounds for use as snake repellents.

The scientists used Y-mazes to test responses of individual garter snakes *(Thamnophis sirtalis)* and rattlesnakes (*Crotalis atrox*) to formulations that included one or more of the following: butanethiol, butric acid, elemental sulfer, naphthalene, oleoresin of capsaicin, Colgin Liquid Smoke™, cassia oil, cornmint oil, cedar oil, and synthetic fermented egg (SFE). Each Y-maze consisted of a base arm into which a test snake was placed at the beginning of a trial, along with a right and left arm. An 8-inch-wide "strip" of test formulation was placed across the width of one arm near the Y-juncture, and a strip of control material was placed in the other arm. A trial was complete when the test snake crossed completely over either test strip. The test was repeated the following day using the same individual, but switching the placement of test and control formulations in maze arms.

Only one formulation (0.8 percent SFE, 0.2 percent butyric acid, 0.1 percent capsaicin, 0.9 percent cassia oil) yielded a statistically significant repellency (80 percent; 20 of 25 snakes chose control arm), but that result only occurred on the first day of testing. Three of the compounds tested (cassia oil, cedar oil, and cornmint oil) are listed as minimum-risk pesticide products exempted under section 25(b) of the Federal Insecticide, Fungicide and Rodenticide Act (FIFRA) and were previously shown to be highly repellent to snakes when sprayed directly on them. These results indicate that few to none of the agents currently under FIFRA are repellent to snakes when granularly formulated and broadcast.

Project Contacts: Will Pitt, Thomas Mathies, Richard Mauldin

Bioenergetics Model for European Starlings—DRC-1339 is an avicide registered for use with European starlings (*Sturnus vulgaris*) to protect agricultural crops, feedlots and dairies, and other resources. To better estimate starling mortality during DRC-1339 baiting operations, NWRC scientists developed a bioenergetics model. The model uses environmental variables and avian characteristics to estimate metabolic energy demands of individual starlings and then generates a mortality estimate based on the total number of treated baits eaten and DRC-1339 toxicity.

NWRC scientists developed a bioenergetics model to estimate starling mortality during baiting operations.
Photo by USDA, Anson Eaglin

To verify that the model makes realistic estimates of daily metabolic rates during varying environmental conditions, the scientists compared predictions from the model with actual energy requirements associated with the maintenance metabolism of caged starlings held outdoors during a 12-day feeding trial in Kansas. A broad range of temperatures (17 to 14° C), wind speeds (0 to 40 kilometers per hour), and percent cloud cover (0 to 100 percent) was encountered during the trial. Daily feeding rates of caged starlings indicated that metabolic rates ranged from 157 to 305 kilojoules per bird per day, compared to 208 to 274 kilojoules per bird per day predicted by the bioenergetics model. There was no significant difference between the bioenergetics model estimates of daily

Effects of Vitamin K-Rich Plants on Anticoagulants in Voles—Voles (*Microtus* spp.) can cause significant losses to vegetable production in California. To reduce vole populations and damage, growers typically rely on anticoagulant rodenticide baits. However, in recent years, the efficacy of those rodenticides has been decreasing. One hypothesis suggests that voles foraging on green leafy plants consume high levels of vitamin K, the antidote to anticoagulants. In a recent study, NWRC scientists tested this hypothesis by feeding voles diets that were high in vitamin K (in green leafy plants commonly grown in California) prior to exposing them to either a chlorophacinone rodenticide bait, a diphacinone rodenticide bait, or a control bait (rodent chow). Mortality was 100 percent in voles fed the chlorophacinone bait and 60 percent in those fed the diphacinone bait.

Voles can cause significant losses to vegetable production in California.
Photo by USDA/NWRC

These results indicate that plants rich in vitamin K may counteract the effects of diphacinone but not chlorophacinone in voles.

Project Contacts: Gary Witmer, Nathan Snow, Rachael Piergross

metabolic rate when compared against estimates generated in the feeding trial.

The bioenergetics model produced robust predictions under varying meteorological conditions typical of winters in the interior United States. Thus, the model can be used to estimate starling mortality under the wide variety of conditions where DRC-1339 is used to reduce populations of this species.

Project Contacts: George Linz, Jeff Homan, Randal Stahl

Capture, Frightening, and Containment Devices

Most wildlife managers prefer nonlethal solutions to wildlife damage problems when these approaches are economical and acceptable to both society and the agricultural industry. NWRC scientists develop and test new capture, frightening, and containment devices to more selectively and efficiently reduce wildlife damage in certain areas.

Evaluating Handheld Lasers To Disperse Roosting Blackbirds—Red-winged blackbirds, yellow-headed blackbirds, and common grackles cause an estimated $15 million worth of damage to sunflowers in North Dakota and South Dakota each year. Many blackbird populations roost in wetland areas near sunflower fields, and wildlife managers need a cost-effective, user-friendly method for dispersing birds from roosts in these areas. To help address this issue, NWRC researchers tested the effectiveness of moderately powered red and green lasers for dispersing blackbirds roosting in a cattail marsh. Preliminary results showed no significant differences among the control (non-laser), red laser (650 nanometers), and green laser (520 nanometers).

NWRC researchers tested the effectiveness of moderately powered red and green dot lasers for dispersing blackbirds roosting in a cattail marsh.
Photo by USDA, Jeff Homan

Project Contacts: George Linz, Jeff Homan

Evaluation of Large, Mobile Decoy Traps for Managing Blackbirds—Each year, an estimated 75 million blackbirds migrate through the sunflower-growing regions of the Great Plains and cause severe damage to ripening sunflowers and corn. It is important for wildlife managers to have effective options available to control blackbird populations and protect the region's crops from damage.

In a recent study, NWRC scientists evaluated large, mobile decoy traps for capturing blackbirds that were damaging or preparing to cause damage to sunflower fields in North Dakota. Over a period of 1 month, researchers captured 154 red-winged blackbirds (from an estimated population of 15,000) in two decoy traps. All of the birds were captured in the last 2 weeks of the study—after the sunflower crops had reached physiological maturity and become slightly less palatable or harder to open. In this regard, the traps did not reduce blackbird depredation on the sunflowers. Researchers concluded that large decoy traps are not cost effective because of the high labor and travel costs associated with maintaining decoy birds and the relatively few numbers of captured free-ranging blackbirds. The results of this study corroborate those obtained in the past by researchers in Canada and suggest that decoy traps would not be an effective component of an

Livestock Protection Dogs—Livestock producers worldwide, particularly those with smaller scale operations, are often confronted with the challenge of reducing livestock losses to predators and wildlife-transmitted diseases. In the Great Lakes Region of the United States, this conflict has increased in recent years, as gray wolf (*Canis lupus*) populations have recovered and burgeoning populations of white-tailed deer (*Odocoileus virginianus*) have served as a wildlife reservoir for bovine tuberculosis (*Mycobacterium bovis*; TB). One potentially valuable, nonlethal tool for protecting livestock against such threats is the use of livestock protection dogs (LPDs).

During 2007 and 2008, NWRC scientists and colleagues from Central Michigan University conducted field experiments to evaluate the effectiveness of LPDs for excluding wolves, coyotes (*C. latrans*), white-tailed deer, and medium-sized predators (e.g., raccoons, skunks, foxes) from livestock pastures. Scientists placed LPDs on six cattle farms (the treatment group) and monitored wildlife use on the farms along with three control farms, determining the amount of time deer spent in livestock pastures by direct observation. In the livestock pastures protected by LPDs, there was reduced use by all species of wildlife compared to control pastures not protected by LPDs. Most notably, white-tailed deer spent less time in livestock pastures protected by LPDs compared to control pastures not protected by LPDs.

Livestock protection dogs are a proactive tool that wildlife managers can use to protect livestock.
Photo by USDA, Kurt VerCauteren

This research supports the theory that LPDs can be an effective management tool for reducing livestock predation and disease. Based on these findings, NWRC supports the use of LPDs as a proactive management tool that producers can implement to minimize the threat of livestock depredations and the transmission of disease from wildlife to livestock. LPDs also may be useful as a more general conservation tool for protecting valuable wildlife, such as ground-nesting birds, that use livestock pastures and are impacted by predators using these pastures.

Project Contact: Kurt VerCauteren

integrated bird management plan to protect ripening sunflowers.

Project Contact: George Linz

Perch Deterrents and Area Repellents: Can Birds Learn To Avoid Them?—Understanding how birds perceive and react to deterrent methods is important for controlling property damage and protecting human health and safety, as well as preserving the aesthetic value of places shared by birds and people. In a recent study, NWRC researchers investigated the reaction of captive brown-headed cowbirds (*Molothrus ater*) and rock pigeons (*Columba livia*) to a perching deterrent that caused slight pain and the reaction of Canada geese (*Branta canadensis*) to an area deterrent designed to provoke a fear response. Objectives of the study were to determine (1) the efficacy of these two techniques, (2) the latency of each technique, (3) if members of a flock would communicate the apparent risk among themselves and to naive flock members, and (4) if the birds would habituate to the techniques.

The results of this study showed that both methods, when activated, were effective in displacing birds. With each method, each bird had to experience the technique, as video observations showed no evidence of communication among flock members or to naive birds that were introduced to the flock. When researchers deactivated each method after an initial period of activation, birds returned to the protected areas. No habituation to either technique was observed. These results indicate that the loss of comfort due to direct pain or the perception of risk due to chronic random stimulus remains a critical component in promoting bird avoidance behavior.

Project Contacts: Travis DeVault, Thomas Seamans, Bradley Blackwell

Population Modeling and Estimation

NWRC develops tools for estimating wildlife populations to aid in planning and assessing the impacts of various management actions.

Pentosidine Biomarker for Aging Birds—In a recent study, NWRC scientists and partners at the University of West Virginia identified a safe and effective method for removing and aging skin tissue samples from living birds. Scientists determined that a 6-millimeter-diameter piece of skin removed from the patagium (fold of skin between the wing and body of a bird) of living vultures and other similar-sized birds provides a sufficient amount of tissue for measuring the biomarker pentosidine. This small amount of tissue provides for reliable age estimation without impairing the birds' ability to fly. Studies that use bird banding often take a long time to acquire useable age structure data, whereas pentosidine has the potential to determine the age structure of a small population in a matter of months.

Researchers compared pentosidine concentrations in four skin-size samples (4-, 6-, 8-, and 20-millimeter-diameter biopsies) from the breast of black vulture *(Coragyps atratus)* carcasses. They also compared pentosidine levels from breast and patagium tissues of deceased vultures of unknown ages and monk parakeets (*Myiopsitta monachus*) of actual, minimal, and unknown ages to document potential differences among skin collection locations. Pentosidine concentrations were similar between the four sizes of vulture breast skin. Pentosidine concentrations for the breast and patagium of vultures were similar, but in parakeets, pentosidine was higher in the breast than the patagium. The researchers then made pentosidine-based age estimates for vultures and parakeets using a general wild-bird age curve. Vulture age estimates were also made using plumage characteristics and a double-crested cormorant (*Phalacrocorax auritus*) age curve. Vulture pentosidine-based age estimates appeared to correspond to plumage-based age estimates. Pentosidine-based age estimates for 88 percent of the known-aged parakeets were within 6 months of actual ages. Even though known ages were not available for all birds, scientists found a positive trend in pentosidine versus age for both species.

This information may lead to a reliable technique for determining the age of vultures and many other species of birds without the need for more costly and logistically difficult methods. The technique may also be applicable across a wide range of wildlife, potentially providing a valuable resource in the conservation and management of species of societal concern. NWRC is conducting similar research to develop a better understanding of cormorant demographics and impacts to catfish production in the southeastern United States.

Project Contacts: Michael Avery, Brian Dorr

Assessing Allowable Take of Migratory Birds—Black vulture populations are expanding throughout the eastern United States, causing an increase in associated problems involving livestock predation, property damage, and aviation strike hazards. Wildlife managers need a more reliable method to determine how many birds can be removed for damage management purposes without endangering the future sustainability of the population.

Biologists from NWRC, USGS, and FWS collaborated to develop an objective method for determining the number of black vultures that can be safely removed from populations where these birds cause damage.
Photo by USGS/NBII, Charles H. Warren

To help address this issue, NWRC scientists and biologists from USGS and FWS collaborated to develop a method for determining allowable take. Their analysis indicates that greater numbers of these birds could be culled than what is currently permitted without adversely affecting population levels. Called "Prescribed Take Level," the method developed in this study includes an estimate of the minimum size of the animal population, its maximum growth rate, and a variable determined by wildlife managers, based on the specific management objective and acceptable risk. Precisely estimating local vulture populations is difficult, due to uncertainties about the birds' lifespan and breeding habits. The researchers relied on annual bird-count data from the USGS North American Breeding Bird Survey and studies of radio-tagged vultures.

This method has great potential value for wildlife management efforts, as it can be adapted for use with other species and situations, such as the incidental take of depleted species, sport harvest, or nuisance control.

Project Contacts: Michael Avery, Bradley Blackwell

Estimating Coyote Numbers in Wyoming—
Determining carnivore population sizes is a daunting task for wildlife biologists and managers. Currently, there is no known accepted technique for conducting censuses of coyote populations over large areas; however, APHIS Wildlife Services and its State partners are often asked to justify management activities based on their impacts on a species' population.

NWRC and collaborators with Utah State University and APHIS Wildlife Services examined the use of two methods for estimating coyote density and population size in Wyoming. During 2008, researchers documented density, or used home-range size and pack size to determine density, from coyote studies conducted in Wyoming, surrounding States, and areas with similar habitat. They also estimated deposition of scats along transects across the 97,818 square-mile (223,840 square-kilometer) State for comparison.

Analysis indicated that density estimates from past literature had a poor correlation with the density estimates from the scat transects, probably because of differences in methods of estimating density, differences in sampling regimes and observers used to collect data, and the more than 30-year timespan between the periods being compared.

Using estimates from the scat transects, the researchers estimated a statewide population of 49,854 ± 22,718 (±95 percent confidence interval) coyotes. The wide confidence interval was a result of the large variance in scat deposition among transects. When researchers assumed a high survival rate (i.e., no or low natural and anthropogenic mortality), they calculated an estimate of 86,601 ± 22,718 coyotes for the State. While scientists initially attempted to sample at least 20 transects within each strata, they found that a minimum of 40 transects per strata was needed to reduce the variance and resulting confidence intervals.

This was the first attempt to estimate the size of a coyote population over a very large area. Future research

will continue to examine methods of estimating coyote population size, which will assist State wildlife managers and APHIS Wildlife Services in documenting the efficacy of removal activities on coyote populations.

Project Contact: Eric Gese

Reproductive Control

The severity of human-wildlife conflicts is often directly related to wildlife population density, and many problems are exacerbated as wildlife populations become larger. NWRC's wildlife contraceptive research aims to develop and field-test economical and effective agents to suppress reproductive fertility in local populations of selected species that cause conflicts. Wildlife contraceptives can be used in conjunction with other tools in an integrated program to manage local, overabundant wildlife species.

GonaCon™ Efficacy in Elk—Overabundant populations of elk *(Cervus elaphus)* are a significant concern in some areas of the western United States because of the potential ecologic damage they can cause and their risk of spreading brucellosis (*Brucella abortus*) to domestic livestock. Brucellosis is transmitted among elk through direct contact with aborted fetuses, placentas and associated fluids, or postpartum discharge of infected animals. Because the transmission of brucellosis is dependent on pregnancy, using contraception in cows (female elk) could help both to manage the disease and to manage elk populations.

NWRC scientists, in collaboration with other APHIS researchers and the Wyoming Game and Fish Department, evaluated the contraceptive efficacy of a gonadotropin-releasing hormone vaccine (GonaCon) in female elk. In 2004, cows were given a single immunization of either 1,000 milligrams or 2,000 milligrams of GonaCon and were then compared with a group of control elk. In 2004, 2005, and 2006, cows were grouped with bulls for the breeding season. Blood samples were taken each spring for pregnancy testing, progesterone assays, and antibody titers. For cows given 1,000 milligrams of GonaCon, 86, 90, and 100 percent were infertile during 2005, 2006, and 2007, respectively. For cows given 2,000 milligrams of GonaCon, 90, 100, and 100 percent were infertile. Rates of infertility for control cows were 23, 28, and 0 percent for the same periods.

Overabundant populations of elk are a significant concern in some areas of the United States because of the potential spread of brucellosis to domestic livestock.
Photo by USDA, Jim Gionfriddo

These results indicate that either dose of GonaCon prevented the pregnancy of elk cows for at least 3 years. The researchers conclude that GonaCon has potential as part of an integrated strategy to control brucellosis and manage elk populations.

Project Contacts: Lowell Miller, Gary Killian

Diazacon Use in Rose-Ringed Parakeets—Rose-ringed parakeets *(Psittacula krameri),* also known as ring-necked parakeets, are native to central Africa and Asia, but through accidental and deliberate release, populations are now established in Europe, Japan, and the United States. As an invasive, non-native species, the rose-ringed parakeet has raised conservation concerns, because its early breeding season and preference for established nest cavities places it in potential conflict with native cavity-nesting birds.

Cost Effectiveness of OvoControl-G® To Manage Nuisance Canada Geese—OvoControl-G is an oral contraceptive bait for Canada geese *(Branta canadensis)*. When fed to geese during their breeding season, the bait's active ingredient (nicarbazin) reduces the hatching success of eggs. When it is withdrawn from the diet, egg production and hatchability return to normal within a few days.

NWRC's economist modeled the cost effectiveness of using OvoControl-G versus egg addling, oiling, or other nest-destruction techniques to manage nuisance Canada geese at two locations in Oregon. Assuming that the biological effects of egg oiling, addling, and destroying nests are similar to those of OvoControl G, researchers used a cost-effectiveness analysis (CEA) to evaluate the costs associated with the different methods and determine which method minimizes those costs. The model also evaluated the effects of the presence of nontargets, alternative foods, and public support on cost efficacy. Results showed that at low goose densities (less than 35 pairs of geese), fixed labor was a significant portion of costs. As goose densities increase, OvoControl-G becomes more cost effective than other methods, such as egg oiling or addling.

The analysis provides useful information for wildlife managers, as they can use this model to determine whether OvoControl-G will provide a successful and cost-effective tool for controlling populations of Canada geese in specific management areas.

Project Contact: Stephanie Shwiff

NWRC economists developed a model to determine whether OvoControl-G can be a cost-effective treatment for controlling populations of Canada geese.
Photo by USDA, Anson Eaglin

Rose-ringed parakeets are an invasive species that has become established in Europe, Japan, and the United States.
Photo by iStock/000001042447

Potential economic impacts on agriculture, conservation concerns, and mixed public opinion regarding the species have highlighted the need to develop new management options.

The chemical 20,25-diazacholesterol dihydrochloride (diazacon) has previously been used to reduce reproductive output in avian species through reduction of blood cholesterol and cholesterol-dependent reproductive hormones. In a recent study, NWRC and researchers at the United Kingdom's Food and Environment Research Agency orally dosed captive rose-ringed parakeets with a solution of either 9 milligrams/kilograms (mg/kg) or 18 mg/kg of diazacon for up to 10 days. Researchers found that a dose of 18 mg/kg for 10 days temporarily reduced blood cholesterol levels with no adverse side effects. Further evaluation showed the 18 mg/kg-dose level reduced fertility in rose-ringed parakeets in a captive breeding population. Egg fertility rates were reduced by 54.2 percent for the first clutch and 66.5 percent for the second clutch, compared to control birds.

Based on these results, researchers conclude that diazacon has potential for fertility control in rose-ringed parakeets if a suitable formulation and delivery system is developed for free-living populations.

Project Contacts: Lowell Miller, Christi Yoder

Support Services

Animal care technician preparing food for animals in NWRC's Animal Research Facility

Photo by USDA/NWRC

NWRC support staff provide valuable assistance to researchers through animal care, quality assurance, registration, safety, and information services.

Responsibilities of NWRC animal care staff include daily care of animals and sanitizing cages.
Photo by USDA/NWRC

Animal Care

NWRC's Animal Care Unit provides for the care and well-being of animals at the Center's headquarters campus in Fort Collins, CO, and its eight field stations; meets the NWRC training and research needs involving the capture, maintenance, and use of animals; and assures compliance with Federal laws and regulations, as well as USDA policy and guidelines. The staff consists of an Attending Veterinarian, who oversees all animal care activities, and 12 animal care technicians. The NWRC Attending Veterinarian provides instruction and hands-on training for NWRC and APHIS Wildlife Services personnel during courses designed for certification or recertification for the possession and use of immobilization and euthanasia drugs. He is also a member of the NWRC Institutional Animal Care and Use Committee, the NWRC Biosafety Committee, and the APHIS Wildlife Services Immobilization and Euthanasia Committee.

In 2010, the NWRC Attending Veterinarian consulted with NWRC scientists on the care and use of animals for approximately 100 studies. Those protocols involving infectious organisms were further reviewed by the NWRC Biosafety Committee.

Animal Care Contact: Gordon Gathright

Quality Assurance

The NWRC Quality Assurance Unit offers resources, guidance, and training to NWRC scientists in the areas of research quality assurance and quality control. The unit provides support for all NWRC activities at all locations. The staff consists of the Quality Assurance Manager and a Quality Assurance Specialist, who also acts as the archivist for research records.

The principle responsibilities of the Quality Assurance Unit include:

- Overseeing the NWRC Project Database, which indexes all NWRC studies;
- Keeping a complete archive of all NWRC research records;
- Maintaining the NWRC Standard Operating Procedures (SOPs) and Analytical Chemistry Methods files, including all original documents and validation records;
- Reviewing and commenting on all research protocols and SOPs for compliance with all regulatory and NWRC policy requirements;
- Participating in local and national Society of Quality Assurance meetings and events;
- Providing training to NWRC researchers in Good Laboratory Practices (GLP) and data documentation and record archiving.

In 2010, the NWRC Quality Assurance Unit provided GLP training at two sites where studies were being conducted to evaluate and register wildlife reproductive inhibitors. In addition, the Unit reviewed and commented on 109 new research protocols and 20 new SOPs. Unit staff also took the lead in coordinating review of these documents by various other oversight committees, such as the NWRC Institutional Animal Care and Use Committee (IACUC) and the NWRC Biosafety Committee.

Regulatory Inspections

The NWRC Quality Assurance Unit performs independent inspections of studies conducted by the Center to register repellents, vaccines, pesticides, and other chemical tools use in wildlife management. The purpose of these inspections is to assure compliance with NWRC policies, procedures, and protocols, as well as GLP regulations and guidelines. The NWRC Quality Assurance Unit conducted inspections of 21 studies during 2010.

Research Record Archive

The NWRC maintains an archive of all NWRC research records at the Center's headquarters campus. At the completion of all NWRC studies, study directors submit research records to the Quality Assurance Unit, where the records are indexed and archived in acid-free folders and containers within the designated quality assurance archive. Each study archived includes the research protocol, all original records (raw data, correspondence, maps, videos, electronic data, etc.), and any final reports or manuscripts. These historical records are maintained under controlled environmental conditions with limited access, but are available to the public in accordance with NWRC procedures and policies. In 2010, 76 studies were accessioned into the archive, for a total of 1,111 NWRC-archived research studies.

Quality Assurance Contact: Catherine Bens

Registration

The NWRC Registration Unit works cooperatively with APHIS Policy and Program Development (including the Environmental Services staff) and Wildlife Services' field operations to ensure that the agency's registrations for chemical-based vertebrate management tools are in compliance with Federal and State regulations. APHIS maintains registrations with the U.S. Environmental Protection Agency (EPA) for rodenticides, predacides, avicides, repellents, snake toxicants, and an avian repellent. In addition, APHIS holds Investigational New Animal Drug (INAD) authorizations through the U.S. Department of Health and Human Services' Food and Drug Administration (FDA) for one contraceptive and two immobilizing agents used in wildlife damage management. The NWRC Registration Unit frequently provides consultation and other technical assistance to Wildlife Services program staff, Federal and State agricultural and conservation agencies, academic institutions, nongovernmental groups, and private industry. The NWRC Registration Unit also works closely with NWRC scientists to ensure that studies conducted for regulatory purposes meet EPA and FDA guidelines.

Single-Shot Contraceptive for White-Tailed Deer

In September 2009, NWRC obtained approval from the EPA for the registration of GonaCon™ as a single-shot contraceptive to control reproduction in female white-tailed deer. Since the early 1900s, wildlife conservation efforts in the United States have focused on restoring, protecting, and promoting the growth of populations of many wildlife species. Such efforts with white-tailed deer have been so successful that local populations have erupted throughout much of its range. Deer populations have increased from only about 500,000 deer across the United States in the early 1900s to over 15 million today.

Although this recovery is considered a wildlife management success story, deer are causing many problems, particularly in urban environments. Overabundant deer populations degrade natural habitats, decimate ornamental trees and shrubs in residential and commercial areas, and pose a serious threat to motorists due to numerous deer/vehicle collisions. It is estimated that there are over 700,000 deer-vehicle collisions each year that result in more than 200

human fatalities and 29,000 injuries. In addition to vehicle accidents, deer have been implicated in the distribution and transmission of Lyme disease. Annual estimates of deer damage are reported to exceed $2 billion nationwide, including $1 billion in car damages, over $100 million in agricultural crop damage, $750 million in damage to the timber industry, and over $250 million in damage to metropolitan households (landscape plantings, etc.).

Regulated hunting remains the most effective and efficient means of managing deer populations in most situations. However, deer are now overabundant in many areas where hunting and the discharge of firearms are legally prohibited. In addition, many urban and suburban residents prefer nonlethal wildlife control methods. Wildlife contraception—when used as part of an integrated approach with other methods—can potentially help manage locally overabundant deer populations.

Over the past 14 years, scientists from the NWRC developed a new wildlife immunocontraceptive (GonaCon™) vaccine to help reduce overabundant urban white-tailed deer and other overabundant wildlife populations. This multi-year, single-shot vaccine stimulates the production of antibodies that bind to gonadotropin-releasing hormone (GnRH), which is necessary for the production of estrogen, progesterone, and testosterone. By binding to GnRH, the antibodies reduce GnRH's ability to stimulate the release of these sex hormones. As long as a sufficient level of antibody activity is present in the bloodstream, sexual activity is decreased, and vaccinated animals remain infertile.

In recent NWRC field studies in New Jersey and Maryland using free-ranging deer in semi-enclosed urban settings, a single shot of GonaCon prevented pregnancy in 67 to 88 percent of the deer in the first year and in 47 to 48 percent the second year. In pen studies, a single shot of GonaCon successfully induced infertility in four out of five female deer for 5 years. A second shot given the same year or in subsequent years increased effectiveness, potentially rendering deer infertile for life. There is no known danger associated with humans or wildlife eating deer that have been vaccinated with GonaCon.

Expanded Use of DRC-1339 for Laughing Gulls

DRC-1339 is a selective toxicant registered for the control of local populations of blackbirds, starlings, pigeons, and several species of gulls. When originally approved, the USDA-APHIS DRC-1339 product label (Compound DRC-1339 Concentrate–Gulls) prohibited the product's use to control laughing gulls in Connecticut, Rhode Island, Massachusetts, New Hampshire, and Maine due to historically low numbers of the species at that time. However, laughing gulls have since become locally abundant throughout New England, posing a serious risk to endangered or threatened birds (such as terns and piping plovers) by preying on adults, chicks, and eggs; interfering with the establishment of nests; and disturbing adults that are foraging for food. At the request of APHIS Wildlife Services and with the support of the U.S. Department of the Interior's Fish and Wildlife Service (FWS), the NWRC Registration Unit prepared a label amendment for submission to the EPA seeking to remove the restriction that limits use of DRC-1339 with laughing gulls. In May 2010, the EPA approved this label amendment, allowing for expanded use of DRC-1339 to protect threatened and endangered species from laughing gull predation.

Consolidation of Section 24c Compound DRC-1339 Labels

DRC-1339 is an avicide used to control blackbirds, starlings, pigeons, crows, ravens, magpies, and gulls. The NWRC Registration Unit drafted an amendment to the product label for "Compound DRC-1339 Concentrate Feedlots" to consolidate eight special local need (SLN) registrations regulated under the Federal Insecticide, Fungicide and Rodenticide Act (FIFRA) authority. This consolidation will significantly reduce the number of SLN registrations and provide increased flexibility to end-users of the product.

White-Footed Mice Can Remain on the Zinc Phosphide Label

White-footed mice (*Peromyscus* spp.) are classified as a species of concern by FWS because these rodents can transmit hantavirus. Zinc phosphide is one of only two active ingredients currently registered for controlling populations of white-footed mice and is the only registered product for this use that does not lead to potential resistance in mice. EPA previously determined that there were insufficient efficacy data to support the continued registration of this product for white-footed mice. However, after discussion with the NWRC Registration Unit, the EPA recognized the serious public health consequences of eliminating one of the few management tools available in the event of a hantavirus outbreak and subsequently reversed their decision to remove *Peromyscus* uses on the USDA-APHIS Zinc Phosphide Concentrate for Rodent Control label.

Registration Contact: John Eisemann

Safety, Health, and Environmental Management

Employees at NWRC work with a variety of hazardous materials (e.g., chemicals, biological agents, and radioactive materials) and specialized equipment, as well as drive vehicles and use firearms, all of which require specific training and precautions. The NWRC Safety and Occupational Health Specialist is responsible for the overall safety, health, and environmental program within the NWRC. The program addresses chemical, biological, and radiological safety; industrial hygiene; chemical management and hazardous waste disposal; medical monitoring; shipment of dangerous goods; workers compensation; emergency response; and environmental management.

The Safety Specialist serves as the Chairperson of the NWRC's IACUC and Biological Safety Committee. In 2010, the IACUC reviewed over 66 new proposed research studies and more than 75 changes to existing studies involving the use of animals to ensure those activities are in compliance with the Animal Welfare Act and that animals intended for use in research facilities are provided humane care and treatment.

Also in 2010, the NWRC Safety and Occupational Health Specialist provided "Defensive Driver" training to 48 employees, "Use of Biological Safety Cabinets" training to 30 employees, and "Firearms Safety" training to 24 employees. In addition, 68 employees participated in the H1N1 flu vaccination program, many of whom are laboratory personnel who work with avian influenza viruses. The NWRC Safety and Occupational Health Specialist also conducted respirator fit testing for over 40 APHIS Wildlife Services biologists.

The safety specialist also serves as the Chairperson of the NWRC Green Team. In compliance with a Presidential Executive Order issued in 2009 to reduce the use of water, gas, and electricity, increase building efficiency, and promote recycling, the Green Team is responsible for the NWRC Environmental Management System. The NWRC achieved Silver Level status as a member of the Fort Collins ClimateWise program, which assists local companies by conducting building efficiency evaluations and promoting green initiatives. Materials collected and sent for recycling included 9,000 pounds of scrap metal, 2,500 pounds of computer equipment, 6 boxes of florescent tubes and 2 boxes of ballasts, 150 gallons of used motor oil, and 200 pounds of batteries, along with 2 truckloads of useable office furniture sent to Habitat for Humanity. The NWRC also sponsored a breakfast station for "Bike to Work Day" and had 85 people stop for snacks and drinks. In addition, all NWRC employees received online Environmental Management System awareness training in 2010, and the Center replaced several vehicles with alternative fuel vehicles, including one that uses E85 gas and one hybrid vehicle.

Safety, Health, and Environmental Management Contact: Steve Greiner

NWRC Director Larry Clark speaking with members of the business community during NWRC's 2010 August open house
Photo by USDA, Laurie Paulik

Information Services

The NWRC uses various media to be proactive in its communications with the general public, disseminating scientific and technical information to manage human-wildlife conflicts and working to build a better understanding of the Federal role in wildlife damage management. NWRC information and public affairs specialists distribute information to stakeholders, the public, the scientific community, and State and Federal agencies through tours, publications, oral presentations, news releases, reports, and the Internet.

Library, Web, and Archives

Access to current, accurate information and to historical internal documents is an important part of the research process. The NWRC Information Services Unit serves the information needs of the NWRC and the administrative and operational personnel of the APHIS Wildlife Services program by providing user-friendly access to scientific literature, electronic resources, and NWRC research documents.

In 2010, the Information Services staff increased public access to NWRC research information by adding pages listing research and professional staff information to the NWRC Web site and using analytical information to evaluate usage patterns. The staff also continued to collaborate with Colorado State University to develop an Agriculture Information Network Center (AgNIC) Web site on wildlife damage (http://lib.colostate.edu/research/agnic/).

The full text for all NWRC-authored publications in 2010 was added to both the Library Online Catalog and USDA's AgSpace Digital Repository. Information Services staff also located material from other

libraries and resource centers in response to information requests within the APHIS Wildlife Services program and responded to requests for NWRC information.

The mission of the NWRC Archives staff is to collect, preserve, and make available research records and materials that document NWRC's history. To this end, much of the staff's work in 2010 focused on continuing to organize and make accessible historical records. The Archives staff is also responsible for NWRC records management functions. With several staff reorganizations and employee retirements at the Center in 2010, Archives employees had a particularly busy year sorting through records. In addition, the unit spearheaded the creation and implementation of a comprehensive records disaster plan for the NWRC headquarters site and field stations. The Archives staff also created a main hallway display in the Wildlife Science Building that features NWRC's blackbird research over the years.

Information Services Contacts: Diana Dwyer, Laurie Paulik, Nancy Freeman

Outreach

In 2010, NWRC and APHIS Legislative and Public Affairs staff responded to approximately 50 media requests for information regarding NWRC research activities. NWRC also hosted 1,943 visiting scientists, students, stakeholders, and others at the NWRC headquarters office in Fort Collins, CO, and field stations across the country. In August, NWRC's headquarters office hosted an open house for more than 60 northern Colorado business leaders; Federal, State, and local agency representatives; and academia. The goal of the open house was to encourage new partnerships and technology transfer to the private sector.

The NWRC seminar program provides a valuable forum for the exchange of ideas among Center staff, visiting scientists, local partners/collaborators, and Wildlife Services staff. During 2010, NWRC hosted 15 seminars in Fort Collins, CO, including presentations by speakers from various universities, foreign wildlife organizations, and NWRC headquarters and field staff.

Legislative and Public Affairs Contact: Gail Keirn

Awards and Research Collaborations

Biologists vaccinating and tagging an elk cow in Rocky Mountain National Park as part of a GonaCon fertility study

Photo by USDA, Jim Gionfriddo

NWRC acknowledges its employees and their expertise through awards and collaborations with numerous agencies, universities, and private sector partners.

Awards

Shown below are NWRC employees who have been recognized for their outstanding achievements and significant contributions in supporting NWRC's mission.

2009 Outstanding Research Publication Awards

The NWRC Publication Award was created to recognize quality research conducted by NWRC scientists. Research is judged on a number of factors—its impact or importance to the field, scientific and technical quality, soundness of concept, originality and motivation, effectiveness of analysis, and the literary quality of the published article.

In 2010, NWRC presented the award for the following 2009 publication:

• Bradley F. Blackwell, Esteban Fernández-Juricic, Thomas W. Seamans, and Tracy Dolan. 2009. Avian visual system configuration and behavioural response to object approach. *Animal Behaviour* 77:673–684.

NWRC researchers Bradley Blackwell and Thomas Seamans collaborated with scientists from California State University, Long Beach, to investigate the role of avian visual systems in the responses of birds to humans. The investigators hypothesized that antipredator behavior theory provides a framework to understand the mechanisms behind human-wildlife interactions, and that a better understanding of the physiological and behavioral responses of birds to different lighting treatments might lead to better strategies for reducing collisions between birds and structures and vehicles. The study blended theoretical with applied science in using innovative methods to examine the influ-

NWRC Scientist Receives Indiana State University's GOLD Award

On February 12, 2010, Dr. Travis DeVault was one of four recent Indiana State University (ISU) graduates who received the Graduate of the Last Decade (GOLD) Award. Dr. DeVault is currently a Supervisory Research Wildlife Biologist and field station leader with the NWRC in Sandusky, OH. Dr. DeVault leads research efforts to reduce wildlife hazards at airports and to aircraft. The GOLD award recognizes graduates who are outstanding in their professions; have made significant contributions to their communities, States, or Nation; and have exhibited interest in the university and/or the ISU Alumni Association since leaving the campus.

Dr. Travis DeVault, NWRC Sandusky, OH, field station leader

Photo by USDA/NWRC

ence of vehicular movement and lighting systems on antipredator responses in mourning doves and brown-headed cowbirds. In particular, the researchers integrated physiological and behavioral approaches with a sophisticated experimental design.

The results of this research suggest that vehicle-mounted lighting can influence avian alert behavior depending upon (among other factors) the sensory system of the target species and ambient light conditions. These findings not only are relevant to existing theory, but also have practical applications, as they advance understanding of factors that can be used to manipulate the behavior of avian species and develop lighting systems to reduce bird collisions with aircraft, communication towers, wind turbines, and other vehicles.

NWRC Technician Receives Conservation Award

On March 15, 2010, Lisa Brohl, a biological science technician at the NWRC field station in Sandusky, OH, received the 2010 Wildlife Diversity Conservation Award from the Ohio Department of Natural Resources' (ODNR) Division of Wildlife. Brohl is the chairperson of the board of directors for the Lake Erie Islands chapter of the Black Swamp Conservancy, a conservation organization committed to preserving the integrity of the natural environment of the Lake Erie islands. She has volunteered thousands of hours over many years to coordinate land acquisition and easements on the islands, many of which are, or will be, dedicated as conservation areas for the public. As stated on the plaque awarded to Brohl, "She embodies a conservation ethic and sense of stewardship that serve to inspire all who care about Ohio's natural resources." Brohl is the ninth recipient of the award, which is given annually at ODNR's Wildlife Diversity Conference.

Lisa Brohl, NWRC Sandusky, OH, field station

Photo by USDA, Tom Seamans

NWRC Employee of the Year Awards

The winners of this NWRC award are nominated by their peers as employees who have clearly exceeded expectations in their contributions toward the Center's mission in 2010. The winners this year are listed below:

- **David Goldade, Analytical Chemistry Project, Fort Collins, CO.** Goldade played a large role in guiding the Analytical Chemistry Project as acting Project Leader in 2009. While taking on these additional responsibilities, he continued to complete his normal commitments without any delays. The project and NWRC will continue to benefit as a result of his commitment and integrity.

- **Kandy L. Keacher, Avian and Invasive Species Population Management Project, Gainesville, FL.** As an Animal Care Technician at the NWRC's field station in Florida, Keacher has been a consistent, reliable source of support and guidance for her colleagues and is very resourceful and knowledgeable in her care of a wide array of captive animals. She has also been responsible for recruiting, training, and mentoring volunteers and student interns, providing much-needed assistance to the field station and valuable experience for students. Her dedication and professional approach have been key to the success of the field station's research.

- **Linda Love, Administrative Support Unit, Fort Collins, CO.** As an Administrative Support Assistant, Love has made countless contribution to ensure the seamless transition of the NWRC's administrative services and consolidation of timekeeping and travel support services into a centralized office. Love recommended and established procedures for these functions and provided timely training and customer service to employees, spending many off-duty hours to ensure employees were compensated in a timely manner. Love's presence eased

what might have been otherwise a much more difficult time during this transition.

- **Jeffrey Root, Ecology of Emerging Viral and Bacterial Diseases in Wildlife Project, Fort Collins, CO.** Dr. Root has taken the lead as a Research Grade Scientist on various studies related to West Nile and avian influenza viruses, which have resulted in a number of published works. Due to his wildlife and disease expertise in rodent-borne viruses, mammalogy, and field biosafety, Dr. Root has frequently been requested to conduct research activities throughout the world, including Australia, Bangladesh, Brazil, China, Ghana, Kenya, Mexico, Micronesia, and Thailand. He is a recipient of 3 USDA Certificate of Merit awards, is a member of 4 professional organizations, and has authored or coauthored 16 peer-reviewed articles and a book chapter. He is also a faculty affiliate with Colorado State University and Texas A&M University-Kingsville.

Research Collaborations

NWRC collaborates with various government agencies, universities, private-sector industries, and others to develop new tools and techniques for resolving human-wildlife conflicts. During 2010, NWRC researchers collaborated with 24 State and local governments, 11 U.S. Department of Defense units, 8 Federal Government agencies, 20 nongovernmental organizations, 26 private sector companies, 45 U.S. universities, and 9 foreign universities.

These partners are listed below.

State and Local Governments		
California Department of Health Services	North Carolina Department of Transportation	Savannas Preserve State Park
California Vertebrate Pest Control Research and Advisory Committee	Nebraska Game and Parks Commission	Sebastian Inlet State Park
Cayo Costa State Park	New York Department of Environmental Conservation	State Museum of Pennsylvania
Hawaii Department of Agriculture	Ohio Division of Wildlife	Texas Department of Health Services
Hawaii Department of Natural Resources	Oneida Shores State Park	U.S. Virgin Islands
Indiana Department of Natural Resources	Port Authority of New York/New Jersey	Utah Division of Wildlife Resources
Louisville Zoo	Puerto Rican Department of Agriculture	Wisconsin Department of Natural Resources
Missouri Department of Conservation	New York Department of Health, Rabies Diagnostic Center	

U.S. Government Agencies		
USDA's Agricultural Research Service	Federal Aviation Administration	USDA's Forest Service
Centers for Disease Control and Prevention	National Aeronautics and Space Administration	DOI's Fish and Wildlife Service
Department of Defense	DOI's National Park Service	DOI's U.S. Geological Survey

Nongovernmental Organizations		
Air Line Pilots Association	Back to the Wild® Wildlife Rehabilitation Center	Danforth Plant Science Center
American Museum of Natural History	Berryman Institute	Deer and Elk Foundation
Animal Protection Institute	Caesar Kleberg Research Institute	Ecological Associates, Inc.

Nongovernmental Organizations (continued)		
Ethiopian Wolf Conservation Program	Minnesota Audubon	University of Minnesota Raptor Center
Houston Advanced Research Center	Monell Chemical Senses Center	Welder Wildlife Refuge
Heritage Foundation	Oneida Lake Association	Wildlife Conservation Society
Island Conservation	Pacific Rim Conservation	
Lelaneau Nature Conservancy	Turner Endangered Species Fund	

Private Sector		
AGEISS Environmental, Inc.	Hacco, Inc.	Monsanto
Avian Research Associates, LLC	Hawaii Tropical Fruit Growers Association	Needham-McCaffrey Associates
Barnes Nursery, Inc.	J.T. Eaton	Pandion Systems
BASF	Kalapana Tropical, Inc.	Pioneer
Delta System Products, LLC	King Ranch	Precise Flight, Inc.
EDM International, Inc.	Kauai Invasive Species Committee	Prion Tech
Electrobraid	Liphatech, Inc.	Syngenta
Forestry Solutions	MacGregor Ranch	White Buffalo, Inc.
Genesis Laboratories	Merial, Inc.	

U.S. Universities		
Auburn University	Nebraska State University	University of California, Santa Barbara
Central Michigan University	New Mexico State University	University of Hawaii, Hilo
Clemson University	North Carolina State University	University of Hawaii, Manoa
Colorado State University	North Dakota State University	University of Kentucky
Columbia University	Oglethorp University	University of Minnesota
Cornell University	Ohio State University	University of Nebraska
Florida Atlantic University	Pennsylvania State University	University of Northern Colorado
Gettysburg College	Purdue University	University of West Virginia
Indiana State University	Southeast Missouri State University	University of Wisconsin
Iowa State University	Southern Illinois University	University of Wyoming
Kansas State University	Stanford University	University of Alaska
Lake Superior State University	Syracuse University	University of Idaho
McNesse State University	Texas A&M University	University of Missouri
Michigan State University	University of California, Berkeley	Utah State University
Mississippi State University	University of California, Davis	West Virginia State University

Foreign Universities		
Agrocampus-Ouest Rennes, FR	University of Exeter, UK	University of Ryukyus, JP
Deakin University, AU	University of Guelph, CA	University of Sheffield, UK
Lincoln University, NZ	University of Montreal, CA	
University of Alberta, CA	University of Potsdam, GER	

Supporting Student Research

NWRC scientists conduct collaborative research, maintain formal affiliations and adjunct professorships, teach courses, and serve on graduate student committees at numerous colleges and universities throughout the country. These activities strengthen and expand the expertise and capabilities of both NWRC and collaborating academic institutions, expose students to the mission of APHIS Wildlife Services and the NWRC, and provide them with opportunities to work directly with professional Government scientists on wildlife research and management issues.

The following table shows the many partnerships NWRC scientists formed with student researchers in 2010, including the student's degree and expected date of completion, the title of the research project, the affiliated academic institution, and the name of the NWRC scientist overseeing the student's research.

Degree/Date	Title	Institution	NWRC Collaborating Scientist
Ph.D., 2010	Black bear-human conflicts in the Roaring Fork Valley, CO	Colorado State University	Breck
Ph.D., 2011	Continued improvement of the pentosidine aging method leading to the investigation of management effects on survival and fecundity of double-crested cormorants	West Virginia University	Cunningham
Ph.D., 2011	Using stable isotope analysis to determine migratory patterns of double-crested cormorants	Cornell University	Cunningham
Ph.D., 2010	Potential for piscivorous birds to serve as hosts of *Bolbophorus damnificus* trematodes	Mississippi State University	Cunningham
M.S., 2010	Bioenergetics of American white pelicans foraging on channel catfish and grass carp	Mississippi State University	Cunningham
M.S., 2011	Colony dynamics and disease surveillance of double-crested cormorants nesting in Ontario	Michigan State University	Cunningham
M.S., 2011	An overview of wildlife damage caused by selected species in the Southeast	Mississippi State University	Cunningham
Ph.D., 2011	Potential risks of dingoes to beef cattle production and wildlife in the arid zone of Australia	University of Queensland	Engeman
Ph.D., 2012	Feral swine damage to natural habitats and associated environmental economic analysis	University of Florida	Engeman
M.S., 2011	Simulations to optimize line intercept sampling and estimation methods	University of Colorado, Denver	Engeman
M.S., 2011	Avian blood parasites in barred and spotted owls	Colorado State University	Franklin
M.S., 2011	Application of research on northern spotted owls to the development of a community-based forestry program	Colorado State University	Franklin
M.S., 2010	Potential effects of nest structure and weather on microclimate of northern spotted owl nests	University of Minnesota	Franklin
Ph.D., 2012	Patterns of temporal and spatial variation in northern goshawk reproduction and prey resources	Colorado State University	Franklin

Degree/Date	Title	Institution	NWRC Collaborating Scientist
M.S., 2011	Out with the old and in with the new? Investigating competition between barred owls (*Strix varia*) and northern spotted owls (*Strix occidentalis caurina*) with a playback experiment	Colorado State University	Franklin
Ph.D., 2010	Avian conservation and ecology in northern Vietnam	Colorado State University	Franklin
M.S., 2010	Snowshoe hare and forest structure relationships in western Wyoming	Utah State University	Gese
M.S., 2011	Coyote movements and diet in relation to winter recreation in northwestern Wyoming	Utah State University	Gese
Ph.D., 2010	Cognitive inference and resulting behaviors in response to ambiguous threat in the coyote	Utah State University	Gese
M.S., 2011	The ecological role of the coyote on the Valles Caldera National Preserve, New Mexico	Utah State University	Gese
Ph.D., 2011	The relationship between artificial water sources and the ecology and behavior of kit foxes and coyotes on the U.S. Army Dugway Proving Ground, Utah	Utah State University	Gese
Ph.D., 2010	The effects of social status and nutrition on the reproductive fitness of coyotes	Utah State University	Gese
M.S., 2010	Surgical sterilization of coyotes to reduce predation on pronghorn fawns	Utah State University	Gese
Ph.D., 2012	Field efficacy of GonaCon immunocontraceptive vaccine for contraception of fox squirrels (*Sciurus niger)* in California	University of California-Davis	Gionfriddo
M.S., 2011	Development of occupancy models and census techniques for kit foxes	Utah State University	Jaeger
TBD	Influence of environmental factors on the evaluation of the cervical tests for bovine tuberculosis by infrared thermography on experimentally sensitized captive elk (*Cervus elaphus*)	Ecole Nationale Veterinaire de Toulouse	Johnson
M.S., 2011	Quantifying trap outcomes from camera-monitored traps (working title)	University of Connecticut	Johnson
M.S., 2010	Avian use of rice-baited trays attached to cages with live decoy blackbirds in central North Dakota	North Dakota State University	Linz
Ph.D., 2013	Landscape analysis of migratory routes, stop-over habitats, and winter roost sites of red-winged blackbirds and yellow-headed blackbirds nesting in North Dakota	North Dakota State University	Linz
M.S., 2011	Influence of landscape factors on bird damage to sunflower and corn in North Dakota	North Dakota State University	Linz

Degree/Date	Title	Institution	NWRC Collaborating Scientist
M.S., 2011	Evaluation of Christmas bird counts and landscape factors as indicators of local blackbird and European starling winter roosts	North Dakota State University	Linz
M.S., 2011	Genetic analyses of Yellowstone National Park conservation bison herd and investigation of genetic resistance to brucellosis	Colorado State University	Piaggio
M.S., 2011	Rodent-associated viruses in Kenya	Maseno University, Kisian, Kenya	Root
M.S., 2011	Helminth communities associated with rodents and arctic fox in Alaska	Colorado State University	Root
Ph.D., 2012	The role of invertebrates in the transmission of influenza A viruses	Colorado State University	Root
Ph.D., 2010	Integration of ecologically based approaches to re-eradicate cattle fever ticks from the United States	Texas A&M University	Taylor
M.S., 2009	Influenza surveillance of mammals from southern Texas and northern Mexico	Texas A&M University	Taylor
M.S., 2011	Efficacy and cost analysis of corral traps versus drop-nets for feral hog capture	Texas A&M University	Taylor
M.S., 2010	The effect of leptin on angiogenic hormones in luteal cells in gilts	Texas A&M University	Taylor
M.S., 2011	Survival, movements, and reproduction of translocated white-tailed deer	Texas A&M University	Taylor
Ph.D., 2012	Differences between urban and non-urban nutria populations, habitat and movement modeling, and environmental impacts	Portland State University	Taylor
Ph.D., 2011	Management of feral swine in eastern Texas	Texas A&M University	Taylor
M.S., 2009	Resource selection and disease spread by white-tailed deer, mule deer, and elk in Nebraska	University of Nebraska-Lincoln	VerCauteren
M.S., 2010	Home range, movements, and survival of male white-tailed deer in the middle Missouri River Valley	University of Nebraska-Lincoln	VerCauteren
Ph.D., 2009	Modeling population and disease dynamics of mule deer and white-tailed deer in Nebraska	University of Nebraska-Lincoln	VerCauteren
M.S., 2010	Scraping behavior of male white-tailed deer as a potential means of transmitting chronic wasting disease	University of Nebraska-Lincoln	VerCauteren
M.S., 2010	Impact of feeding regimes on the potential for direct disease transmission within and among maternal groups of white-tailed deer	University of Wisconsin-Madison	VerCauteren
Ph.D., 2012	Evaluation of environmental transmission of chronic wasting disease using mouse models	Colorado State University	VerCauteren
Ph.D., 2011	Efficacy of GonaCon for reducing reproduction in grey squirrels	Clemson University	Yoder

Publications

Starlings and grackles cause significant damage to corn in the United States.

Photo by USDA/NWRC

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.

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Appendix 1

List of 2010 NWRC Research Projects

Avian and Invasive Species Population Management

Defining Economic Impacts and Developing Strategies for Reducing Avian Predation in Aquaculture Systems

Defining Impacts and Developing Strategies To Reduce Mammalian Damage in Forested and Riparian Ecosystems

Developing Control Methods, Evaluating Impacts, and Applying Ecology, Behavior, Genetics, and Demographics To Manage Predators

Development of Injectable and Oral Contraceptive Technologies and Their Assessment for Wildlife Populations and Disease Management

Development of Management Strategies To Reduce Wildlife Hazards to Aircraft

Development of Methods To Control Rodent Populations and Damage With an Emphasis on Invasive House Mice and Native Voles

Ecology of Emerging Viral and Bacterial Diseases in Wildlife

Economic Research of Human-Wildlife Conflicts: Methods and Applications

Feral Swine Damage Control Strategies

Investigating the Ecology, Control, and Prevention of Terrestrial Rabies in Free-Ranging Wildlife

Management of Ungulate Disease and Damage

Methods and Strategies To Manage Invasive Species Impacts to Agriculture, Natural Resources, and Human Health and Safety

Methods Development and Population Biology of Blackbirds and Starlings in Conflict with Agriculture, Concentrated Animal Feeding Operations, and Urban Environments

NWRC Registration Unit: Providing Tools for Wildlife Services

Use of Chemistry, Biochemistry, Computational Modeling, and Chemosensory Research to Develop Wildlife Damage Management Tools

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

Appendix 2

Acronyms and Abbreviations

AgNIC	Agriculture Information Network Center
AI	Avian influenza
APHIS	Animal and Plant Health Inspection Service
ARS	Agricultural Research Service
BCAP	Beaver control assistance program
BOS	Boar-operated systems
BSL-3 Ag	Biosafety Level-3 Agriculture
BTS	Brown treesnake
CDC	Centers for Disease Control and Prevention
CEA	Cost-effectiveness analysis
CSU	Colorado State University
CWD	Chronic wasting disease
DNA	Deoxyribonucleic acid
DOI	U.S. Department of the Interior
EPA	Environmental Protection Agency
FAA	Federal Aviation Administration
FDA	Food and Drug Administration
FIFRA	Federal Insecticide, Fungicide and Rodenticide Act
FY	Fiscal year
FWS	Fish and Wildlife Service
GI	Gastrointestinal
GIS	Geographic information systems
GLP	Good Laboratory Practices
GnRH	Gonadotropin-releasing hormone
GOLD	Graduate of the Last Decade
GonaCon	Gonadotropin-releasing hormone vaccine
GPS	Global positioning system
GPS-PTT	Global Positioning System-Platform Transmitter Terminal
IACUC	Institutional Animal Care and Use Committee
INAD	Investigational New Animal Drug
IRT	Infrared thermography
ISO	International Organization for Standardization
ISU	Indiana State University
ITS	Internal transcribed spacer
LPD	Livestock protection dog
NASS	National Agricultural Statistics Service
NPS	National Park Service
NWRC	National Wildlife Research Center
ODNR	Ohio Department of Natural Resources
ORV	Oral rabies vaccination
ppm	Parts per million
PrP^{CWD}	Prion protein associated with CWD
PrP^{Sc}	Prion protein associated with scrapie
RVVT	Russell's vipor venom time
SFE	Synethetic fermented egg
SLN	Special local need
SOP	Standard Operating Procedure
TH	Tetracycline hydrochloride
USDA	U.S. Department of Agriculture
USGS	U.S. Geological Survey
UV	Ultra-violet
VHF	Very high frequency
WNV	West Nile virus

Appendix 3

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