Wildlife Services

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National Wildlife Research Center

FY 2012

Seeking Solutions Through Research

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Wildlife Services On-going Research & Development

Table of Contents

USDA APHIS
United States Department of Agriculture
Animal and Plant Health Inspection Service

National Wildlife Research Center & Field Sites
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FY 2012

Reducing Wildlife Hazards to Aircraft

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Major Cooperators:

- Airline Pilots Association
- Airports across the United States
- Auburn University
- Bird Strike Committee USA
- Federal Aviation Administration
- Indiana State University
- Mississippi State University
- National Association of State Aviation Officials
- National Center for Atmospheric Research
- North Carolina Division of Aviation
- North Carolina State University
- Port Authority of New York and New Jersey
- Purdue University
- University of Georgia
- U.S. Air Force
- U.S. Air Force Bird Air Strike Hazard (BASH) Team at Kirtland Air Force Base
- U.S. Army
- U.S. Fish and Wildlife Service
- U.S. Marine Corps
- U.S. Navy

Groups Affected by This Problem:

- Airline passengers, pilots, crews, owners and administrators
- Aircraft and engine manufacturers
- Insurance underwriters
- Military pilots and aircrews
- Residents near airports

National Wildlife Research Center Scientists Study Wildlife Hazards On and Near Airports

Wildlife Services' (WS) National Wildlife Research Center (NWRC) is the only Federal research organization devoted exclusively to resolving conflicts between people and wildlife through the development of effective, selective, and socially responsible methods, tools, and techniques. The NWRC field station in Sandusky, Ohio, is dedicated to providing a scientific foundation for WS and Federal Aviation Administration (FAA) programs that reduce wildlife collisions with aircraft. Consequently, the scientists work closely with WS airport programs throughout the nation, the FAA, and the U.S. Department of Defense.

To be certified for commercial passenger traffic by the FAA, many U.S. airports are required to develop and implement a wildlife hazard management plan. The FAA strongly discourages any management practice that might create a significant attractant to wildlife hazardous to aircraft in the vicinity of an airport. NWRC scientists conduct research to provide guidance to the FAA and WS regarding mitigation of wildlife-aircraft strike hazards. More specifically, NWRC research is focused on understanding the nature of wildlife hazards on and near airports; developing management methods and tools to reduce those hazards; and providing WS, airport personnel, and the FAA with information on the latest strategies for controlling wildlife hazards.

Applying Science and Expertise to Wildlife Challenges

Wildlife Habitat Management and Other Land-Use Studies—Habitat management is fundamental to reducing wildlife use of airfields. NWRC scientists have studied vegetation types and vegetation management practices to identify strategies for making areas on and near airports less attractive to wildlife. For example, previous NWRC research has shown that grazing Canada geese do not consume endophyte-infected tall fescue. Grasses containing endophytic fungi (i.e., a fungus that lives within a plant without causing harm) have several benefits, such as resistance to both grazing and insect herbivory, heat and drought stress tolerance, and increased vigor. Over 200 varieties of turf-type tall fescue are currently available from the turfgrass industry for use in airfield re-vegetation projects. NWRC scientists identified several commercially available tall fescue varieties, including Titan LTD, 2nd Millennium, and Crossfire II, which grow successfully in airport environments but are not a preferred food source for geese. NWRC scientists also are evaluating wildlife use of various agricultural crops to determine whether some may be safe for planting on and near airports.

Safe management of stormwater runoff on and near airports is another focus of research. NWRC scientists and WS biologists have developed models of bird use of stormwater-detention ponds and identified factors that discourage birds from using these facilities, particularly within airport approach/departure zones. Researchers suggest that stormwater ponds be located as far away as possible from other water resources, but recommend a minimum of one kilometer of separation between a planned stormwater facility and other water resources. Also, designs that minimize perimeter, surface area, and the ratio of emergent vegetation to open water help reduce bird use of stormwater ponds. This research aids in the design of new airport facilities.

NWRC researchers are evaluating the potential for alternative energy production at airports. Many airport properties are already managed to reduce wildlife abundance and habitat quality as part of efforts to avoid wildlife collisions with aircraft. Ongoing and future NWRC research will examine whether renewable energy practices that limit use by wildlife hazardous to aircraft and are compatible with safe airport operations. For example, NWRC researchers and collaborators are studying wildlife use of solar array facilities and adjacent airport grasslands in Arizona, Colorado, and Ohio. NWRC researchers and collaborators at Mississippi State University are evaluating wildlife use of experimental biofuel production

plots that contain switchgrass or a mixture of native warm-season grasses in Mississippi. Once biofuel crops that are suitable for airport use are identified, the conversion of grasslands to these alternative land uses could produce renewable energy and provide airports with an additional source of revenue.

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

Bird Movements On and Near Airports—NWRC researchers are developing new methods to quantify bird movements in relation to airport locations and aircraft flight patterns, allowing for a better understanding of wildlife strike risks. Using advanced satellite telemetry tracking technologies, NWRC scientists are studying the movements of raptors including bald eagles, osprey, and red-tailed hawks around commercial and military airports. These research efforts provide detailed information on daily and seasonal movements of birds, the timing of peaks in bird activities, and the specific altitudes at which these birds fly. Using three-dimensional models of the airspace used by both raptors and aircraft, researchers are able to quantify the risk these birds pose to civil and military flight operations.

Exploiting Wildlife Anti-Predation Behaviors and Visual Ecology to Reduce Hazards to Aviation—NWRC scientists and collaborators are investigating the visual ecology of birds and mammals from both physiological and behavioral perspectives. By better understanding how these animals detect and respond to approaching objects, the researchers hope to develop lighting systems that will enhance detection and avoidance responses to approaching aircraft and ground-based vehicles. Earlier research by NWRC scientists and aviation industry collaborators set the stage for developing new aircraft lighting systems intended to enhance bird detection of approaching aircraft and, subsequently, escape behaviors. More recently, NWRC scientists and their collaborators at Purdue University and Indiana State University have confirmed that specific light wavelengths and pulse frequencies can alert and evoke earlier escape responses in birds.

To gain a better understanding of avian visual physiology, NWRC scientists and their colleagues studied the distribution of ganglion cells and photoreceptors in the retinas of captive Canada geese, as well as their eye movements and scanning behavior. Overall, researchers found that the Canada goose's visual system is designed to detect objects such as predators and other geese in open terrain. Furthermore, ganglion cells of geese are arranged in an oblique (i.e., slanting) formation across the retina, which allows the birds to scan the ground and the sky simultaneously when their heads are up and approximately parallel to the ground. The researchers hypothesize that this cell distribution, along with the birds' large eye size, may reduce the need for the birds to move their heads extensively while scanning their surroundings in open environments, whether in flight or on the ground. Thus, Canada geese might have a higher probability than other birds of detecting a light stimulus from an aircraft, particularly from a light that is designed relative to the species' visual capabilities. Future research efforts will examine physiological response by birds to the combination of light wavelength and pulse frequencies (which aid in movement detection) to narrow specifications for candidate lighting systems. Subsequently, the candidate lighting systems will be tested in field experiments involving birds and approaching aircraft exhibiting the specific lighting treatments.In related research, NWRC researchers are studying flight initiation distances of several bird species when approached by vehicles of varying size and speed to better understand how birds perceive and react to approaching objects. This information is critical to understanding how visual stimuli associated with detection of an approaching object are processed by the animal to initiate an avoidance response. Findings from this research will be particularly useful in the design of lighting systems that maximize the chances a bird will detect aircraft and other approaching objects and initiate an appropriate escape response.

Selected Publications:

BIONDI, K. M., J. L. BELANT, J. A. MARTIN, T. L. DEVAULT, and G. WANG. 2011. White-tailed deer incidents with U.S. civil aircraft. Wildlife Society Bulletin 35:303-309.

BLACKWELL, B. F., T. W. SEAMANS, P. M. SCHMIDT, T. L. DEVAULT, J. L. BELANT, M. J. WHITTINGHAM, J. A. MARTIN, and E. FERNÁNDEZ-JURICIC. 2013. A framework for managing airport grasslands and birds amidst conflicting priorities. Ibis 155:189-193.

BLACKWELL, B. F., T. L. DEVAULT, T. W. SEAMANS, S. L. LIMA, P. BAUMHARDT, and E. FERNÁNDEZ-JURICIC. 2012. Exploiting avian vision with aircraft lighting to reduce bird strikes. Journal of Applied Ecology 49:758-766.

DEVAULT, T. L., J. L. BELANT, B. F. BLACKWELL, J. A. MARTIN, J. A. SCHMIDT, L. W. BURGER, Jr., and J. W. PATTERSON, Jr. 2012. Airports offer unrealized potential for alternative energy production. Environmental Management 49:517-522.

DEVAULT, T. L., J. L. BELANT, B. F. BLACKWELL, and T. W. SEAMANS. 2011. Interspecific variation in wildlife hazards to aircraft: implications for airport wildlife management. Wildlife Society Bulletin 35:394-402.

DEVAULT, T. L., B. F. BLACKWELL, and J. L. BELANT, eds. 2013. Wildlife in Airport Environments: Preventing animal-aircraft collisions through science-based management. Johns Hopkins University Press, Baltimore, MD, USA.

FERNÁNDEZ-JURICIC, E., J. GAFFNEY, B. F. BLACKWELL, and P. BAUMHARDT. 2011. Bird strikes and aircraft fuselage color: a correlational study. Human-Wildlife Interactions 5:224−234.

FERNÁNDEZ-JURICIC, E., B. MOORE, M. DOPPLER, J. FREEMAN, B. F. BLACKWELL, S. L. LIMA, and T. L., DEVAULT. 2011. Testing the terrain hypothesis: Canada geese see their world laterally and obliquely. Brain, Behavior & Evolution 77:147–158.

MARTIN, J. A., J. L. BELANT, T. L. DEVAULT, B. F. BLACKWELL, L. W. BURGER, Jr., S. K. RIFFELL, and G. WANG. 2011. Wildlife risk to aviation: a multi-scale issue requires a multi-scale solution. Human-Wildlife Interactions 5:198-203.

MOORE, B. A., P. BAUMHARDT, M. DOPPLER, J. RANDOLET, B. F. BLACKWELL, T. L. DEVAULT, E. R. LOEW, and E. FERNÁNDEZ-JURICIC. 2012. Oblique color vision in an open-habitat bird: spectral sensitivity, photoreceptor distribution, and behavioral implications. Journal of Experimental Biology 215:3442-3452.

WASHBURN, B. E. and M. J. BEGIER. 2011. Wildlife Responses to long-term application of biosolids to grasslands in North Carolina. Rangeland Ecology and Management 63:131–138.

WASHBURN, B. E. 2012. Avian use of solid waste transfer stations. Landscape and Urban Planning 104:388-394.

WASHBURN, B. E., and T. W. SEAMANS. 2012. Foraging preferences of Canada geese among turfgrasses: implications for reducing human-goose conflicts. Journal of Wildlife Management 76:600-607.

Major Research Accomplishments:

- WS experts published a comprehensive book on wildlife-aviation issues titled “Wildlife in Airport Environments: Preventing Animal-Aircraft Collisions through Science-based Management” (2013, Johns Hopkins University Press).
- WS identified several commercially available tall fescue varieties, including Titan LTD, 2nd Millennium, and Crossfire II, which grow successfully in airport environments but are not a preferred food source for geese.
- WS used advanced satellite tracking technologies and an operational risk-management process to quantify the risk that breeding and migrating ospreys pose to military flight operations along the Eastern seaboard. The U.S. Department of Defense is incorporating this information into natural resource management plans and mission planning systems to mitigate the risk of collisions between ospreys and military aircraft.
- WS and collaborators have confirmed that specific light wavelengths and pulse frequencies can alert and evoke an earlier escape response in some birds. The discovery will aid in the development of new aircraft lighting systems intended to enhance bird detection of approaching aircraft and, subsequently, escape behaviors.

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Reducing Avian Predation in Aquaculture Systems

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Major Cooperators:

- Canadian Wildlife Service
- Catfish Farmers of America
- Cornell University
- Delta Research and Extension Center, Thad Cochran National Warmwater Aquaculture Center
- Michigan Department of Natural Resources
- Mississippi Agricultural and Forestry Experiment Station
- Mississippi State University, College of Veterinary Medicine
- Mississippi State University, Department of Wildlife, Fisheries, and Aquaculture
- Ontario Ministry of Natural Resources
- Ontario Parks
- Southern Regional Aquaculture Center
- Vermont Fish and Game Department
- Wildlife Services Operations

Groups Affected by These Problems

- Catfish Farmers
- Aquaculture producers, distributors and retailers
- Consumers
- Sportfish guides and outfitters
- Wildlife managers

National Wildlife Research Center Scientists Address Aquaculture Losses

Wildlife Services' (WS) National Wildlife Research Center (NWRC) is the only Federal research facility devoted exclusively to resolving conflicts between people and wildlife through the development of effective, selective and socially responsible methods, tools, and techniques. The NWRC's field station in Starkville, Mississippi, is located in the heart of the primary aquaculture producing area of the southeastern U.S. and was established to develop methods to reduce the impacts of fish-eating birds on aquaculture stocks.

In the past 35 years, populations of fish-eating birds have increased dramatically and caused substantial economic impacts on 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 economic impact of fish-eating birds on aquaculture production and natural resources and to develop methods to reduce depredation impacts on southeastern catfish, baitfish, and crawfish industries. Current research is aimed at gaining information about the abundance, distribution, and foraging behavior of fish-eating birds; economic impacts associated with their foraging activities; and diseases they transmit at aquaculture facilities. Information gathered as a consequence of this research provides a basis for developing new strategies, techniques, and tools for reducing damage.

Applying Science and Expertise to Wildlife Challenges

Population Trends of Fish-Eating Birds—NWRC scientists are using telemetry and banding techniques to track large-scale movements, population trends, and demographics of double-crested cormorants and American white pelicans. Satellite telemetry data reveal cormorants migrate to two key wintering locations. Western populations winter mainly in the lower Mississippi alluvial valley and eastern populations winter in the U.S. Atlantic States. This research will be used to evaluate various alternatives for managing impacts of these species on commercial and natural resources.

Cormorant Damage to Catfish Aquaculture—The U.S. catfish industry is valued at more than $572 million per year in processed product sales, with over 50 percent of catfish production originating from Mississippi. NWRC biologists recently completed a decade-long field study that utilized data on cormorant food habits, bioenergetics, distribution, and abundance to evaluate cormorant impacts on catfish aquaculture. Cormorants used catfish ponds extensively from January through April, with the greatest economic damage occurring in February and March. During the study, between 1,347 and 1,775 metric tons of catfish were consumed by cormorants in the Delta region of Mississippi. This depredation translated into a loss to the industry of $5.6 to $12.0 million annually or approximately 2-5 percent of gross farm sales.

Cormorant Movements—NWRC scientists used satellite telemetry to evaluate movements and migration patterns of double-crested cormorants captured near southeastern catfish aquaculture ponds. Results demonstrated that cormorants migrated along the Mississippi, Missouri, and Ohio River Valleys. The average duration of spring migration was 12 days. During this period the cormorants traveled an average of 43 miles/70 kilometers per day. These data indicate that cormorants tend to stay in one general region throughout winter if adequate food resources are available and their roosting sites are undisturbed, providing further evidence that aquaculture is utilized extensively by wintering cormorants. Catfish farmers, aquaculturists, and resource managers are using these data to more efficiently refine the timing of and resources devoted to cormorant management activities.

Cormorant Breeding Colony Dynamics—NWRC scientists and partners conducted a long-term study of cormorant breeding colony dynamics in the Great Lakes. This research

was a cooperative effort involving Mississippi State University, the Canadian Wildlife Service, Ontario Ministry of Natural Resources, Ontario Parks, and Trent University. Survival estimates indicate approximately 80 percent mortality for first year birds, decreasing to over 20 percent thereafter. These data indicate some regional differences in reproductive parameters and suggest that management decisions should be based on local or regional population information. Population models reveal that a combination of adult culling and egg oiling would have the greatest efficacy for reducing population growth.

Aging Cormorants—NWRC scientists and collaborators at West Virginia University have identified a biomarker in the skin that is a predictor of age in double-crested cormorants. This information may lead to a rapid technique for identifying age of cormorants and many other species of birds without the need for more costly and logistically difficult methods. This technique will help quantify the demographics of cormorant populations, thus allowing for the optimization of management strategies for maintaining population viability while minimizing damage.

Cormorant Diet—NWRC scientists used fatty acid profiles to distinguish between game fish and farm-raised channel catfish in the fatty tissue of double-crested cormorants. Results indicated that it may be possible not only to distinguish between farm-raised channel catfish and game fish in the diet of cormorants, but also to identify the sources of the farm-raised channel catfish in the diet. Biologists and chemists are continuing to investigate the possibility of using fatty acid profiles to assess the actual impact of fish-eating birds on catfish aquaculture and recreational fisheries.

Harassment of Cormorants—NWRC scientists evaluated the utility of harassment programs involving spring migrating cormorants for reducing predation on vulnerable spawning stocks of walleye and yellow perch at two locations in Michigan. Overall harassment deterred 90 percent of cormorant foraging attempts, with an average of less than 6 percent of the cormorants taken lethally at each site. Both walleye and yellow perch abundance increased significantly at each location. These results support the hypotheses that cormorant predation on spawning aggregations of sportfish is a significant mortality factor, and that cormorant management can reduce sportfish mortality and increase fish abundance. Continuation of cormorant harassment programs and fishery assessments will determine whether improvement of targeted sport fisheries is sustained.

American White Pelican Disease Ecology—In collaboration with parasitologists at Mississippi State University College of Veterinary Medicine, the Thad Cochran Warmwater Aquaculture Center, and the Southern Regional Aquaculture Center, NWRC scientists described the life cycle for a virulent species of trematode infecting catfish in the southeastern U.S. and confirmed that American white pelicans serve as a host for this parasite. Results indicated that American white pelicans can transmit this parasite among catfish ponds. Double-crested cormorants, great blue herons, and great egrets did not appear to serve as hosts for these trematodes. Parasite life-cycle studies indicate that even low infection of trematodes in pelicans can result in large numbers of trematode eggs deposited into catfish ponds. In addition, NWRC scientists confirmed that an introduced species of snail can serve as an intermediate host to the parasite. These studies underscore the importance of preventing pelican use of aquaculture facilities and understanding the biology and epidemiology of the disease organism.

Management Activites at Cormorant Nesting Colonies—Large colonies of double-crested cormorants breed in the Les Cheneaux Islands region of Lake Huron, Michigan. NWRC scientists and colloborators evaluated the effectiveness of WS cormorant management as a means of improving the local yellow perch fishery. Management activities included egg-oiling to prevent reproduction and culling of some birds. Research documented an 83 percent decline in the number of cormorant foraging attempts and an increase in yellow perch and walleye abundance at locations where these management activities were in place. Management also resulted in reductions of over 90 percent in the annual numbers of young cormorants produced and 70 percent in the total cormorant population.

Great Egrets as Vectors for *Aeromonas hydrophila* (VAH) Among Catfish Ponds—Recent severe disease outbreaks in channel catfish aquaculture have been associated with a highly virulent strain of the bacterium VAH. Given that VAH is known to infect birds, NWRC researchers hypothesized that fish-eating birds may serve as a reservoir for VAH and spread the pathogen from pond to pond. NWRC researchers conducted experimental studies that showed that great egrets that were fed VAH-infected catfish excrete viable VAH. Shedding occurred up to two days after the birds were switched to a non-infected fish diet. At necropsy on day seven, nasal swabs from two great egrets were VAH-positive. Great egrets show strong potential as vectors for VAH transmission to catfish ponds. Furthermore, the VAH colonization of the birds' nasal passages indicates that fish-eating birds could serve as a reservoir for the pathogen.

Selected Publications:

DORR, B. S., S. L. HANISCH, P. H. BUTCHKO, and D. G. FIELDER. 2012. Management of double-crested cormorants to improve sport fisheries in Michigan: 3 case studies. Human-Wildlife Interactions 6:140-153.

DORR, B. S., L. W. BURGER, S. C. BARRAS and K. GODWIN. 2012. Double-crested Cormorant distribution on catfish aquaculture in the Yazoo River Basin of Mississippi. Wildlife Society Bulletin 36: 70-77.

KING, D.T., B.K STRICKLAND, AND A. RADOMSKI. 2012. Winter and summer home ranges and core use areas of double-crested cormorants captured near aquaculture facilities in the southeastern United States. Waterbirds 35 (Special Publication 1): 124-131.

KING, D.T., B.K STRICKLAND, AND A. RADOMSKI. 2012. Migration patterns of double-crested cormorants wintering in the southeastern United States. Waterbirds 35 (Special Publication 1): 132-137.

FERGUSON, T. L., B. J. RUDE, and D. T. KING. 2011. Nutrient utilization and diet preference of American white pelicans consuming either a mono- or multi-species diet. Waterbirds. 34: 218-224.

GUILLAUMET, A., B. DORR, and G. WANG. 2012. Towards optimized population control efficiency in space and time: A modeling framework adapted to a colonial waterbird. Ecological Modeling 235-236:95-101.

GUILLAUMET, A., B. S. DORR, G. WANG, J. D. TAYLOR III, R. B. CHIPMAN. H. SCHERR, J. BOWMAN, K. F. ABRAHAM, T. J. DOYLE, and E. CRANKER. 2011. Determinants of local and migratory movements of Great Lakes double-crested cormorants. Behavioral Ecology 22:1096-1103.

HANSON, K. C., T. L. DEVAULT, and S. J. DINSMORE. 2010. Increased abundance and first breeding record of the neotropic cormorant on the alluvial plain of Mississippi. Southeastern Naturalist 9:385-394.

KING, D. T., B. F. BLACKWELL, B. S. DORR, J. L. BELANT. 2010. Effects of aquaculture on migration and movement patterns of double-crested cormorants. Human-Wildlife Conflicts 4:77-86.

Major Research Accomplishments:

- WS research showed double-crested cormorants tend to stay in one general region throughout winter if adequate food resources are available and their roosting sites are undisturbed. These data provide further evidence that aquaculture provides an ideal environment for wintering cormorants.
- WS and collaborators identified a biomarker in the skin of double-crested cormorants that is a predictor of age.
- WS research showed fatty acid profiles developed from cormorant fatty tissues can distinguish between game fish and farm-raised channel catfish in the diet of cormorants.
- WS and their cooperators demonstrated that American white pelicans are a host of the Bolbophorus trematode, which can be devastating to the catfish aquaculture industry.
- WS research documented a large decline in numbers of double-crested cormorant foraging attempts, and an increase in walleye populations at lakes in Michigan as a result of an ongoing cormorant management program.
- WS and their cooperators demonstrated that great egrets show strong potential as vectors for the transmission of a virulent strain of Aeromonas hydrophila to catfish farms.

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Avian and Invasive Species Population Management

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Major Cooperators

- Florida Power and Light Company
- Innolytics, LLC
- National Park Service
- U.S. Navy
- U.S. Geological Survey
- U.S. Fish and Wildlife Service

Groups Affected By These Problems

- Airports
- Airlines
- Air travelers
- Homeowners
- Business owners
- City managers
- Military installations
- Electric utility companies
- Broadcast and communication tower owners and operators

National Wildlife Research Center Scientists Address Problems Associated with Invasive Species and Overabundant Bird Populations

Wildlife Services' (WS) National Wildlife Research Center (NWRC) is the only Federal research organization devoted exclusively to resolving conflicts between people and wildlife through the development of effective, selective, and socially responsible methods, tools, and techniques.Scientists at NWRC's field station in Gainesville, Florida, conduct research to resolve problems caused by invasive species, such as Burmese pythons and monk parakeets, and overabundant native bird species, such as vultures and crows. This research facility is a uniquely designed 26-acre site with large outdoor test pens and aviaries which allow research to be conducted under natural environmental conditions. As land-use patterns change and urban populations surge into previously uninhabited areas, wildlife conflicts, inevitably, increase. Of growing concern are problems associated with some abundant native bird species that have shown the capacity to readily adapt to residential settings. Additionally, populations of invasive or non-native species, such as feral pigeons, monk parakeets, Burmese pythons, and Nile monitors, continue to grow with increasing detrimental impacts to native ecosystems and human health and safety.

Applying Science & Expertise to Wildlife Challenges

Detection of Invasive Reptiles Using Environmental DNA—Molecular methods involving water-borne environmental DNA (eDNA) have proved useful for detecting various vertebrates. The Burmese python has quickly become the highest profile invasive reptile of the many established in Florida. The species has been breeding in the wild in extreme south Florida for over a quarter-century. In conducting control programs and assessing eradication efforts, methods to detect the presence of this invasive species in the environment would be of great value. To that end and given the species' affinity for water, NWRC researchers evaluated the use of eDNA to detect the presence of Burmese pythons. Using species-specific primers developed for this purpose, researchers demonstrated, for the first time, that reptile DNA can be detected in a water source and quantified the rate of degradation of the eDNA. Utilization of eDNA enables the detection and monitoring of this elusive species at reduced costs. The method may also be modified and used to detect other invasive reptilian species in natural water sources.

Monitoring Vulture Movements with Satellite Telemetry—Many wildlife management efforts require researchers to assess the location and movements of animals. NWRC researchers used Satellite Global Positioning System-Platform Transmitter Terminal (GPS-PTT) transmitters attached to vultures with a backpack harness to gather hourly data on the birds' altitude, speed, and heading in addition to position (latitude and longitude). These data were used to model the birds' movement patterns in relation to aircraft operations at the Marine Corps Air Station (MCAS) in Beaufort, SC. The 2-year study involved 22 vultures equipped with GPS-PTT transmitters and revealed that greater than 60 percent of vulture flight activity occurred from 4 to 9 hours after sunrise at altitudes below 200 meters. Black vultures consistently spent less time in flight (8.4 percent) than did turkey vultures (18.9 percent), and black vultures flew at higher altitudes than did turkey vultures in all seasons except summer when altitudinal distributions did not differ. NWRC researchers combined altitude of in-flight locations of vultures with three-dimensional flight patterns of aircraft to visualize where vulture-aircraft interactions were most likely to occur. This provides a novel method for airfield managers to assess bird-strike risk and to focus corrective actions. Continuation of aggressive harassment coupled with flexible training schedules to avoid times and altitudes of high vulture activity will decrease hazards to aircraft posed by these birds. Recently, the research approach developed for MCAS-Beaufort has been expanded to investigate vulture behavior and movements at Kennedy Space Center, Eglin Air Force Base, and Key West Naval Air Station in Florida.

United States Department of Agriculture
Animal and Plant Health Inspection Service

New Tools for Controlling Invasive Reptiles—Reducing populations of invasive snakes and lizards requires a variety of management tools. For instance, to improve the trapping efficiency of large constrictor snakes in Florida, NWRC researchers developed a live trap specifically designed to reduce the capture of non-target species. The trap is constructed of cage wire which allows small rodents and snakes to pass through the mesh. The trap is configured with two widely spaced adjustable weight-sensing levers. Each has an independent release mechanism and both must be depressed at the same time to spring the trap. Thus, only long, heavy snakes such as boas and pythons will spring the trap.

NWRC researchers also screened toxicants for use in the management of the invasive black spiny-tailed iguana. Of the compounds tested, zinc phosphide produced 100 percent mortality at dose levels as little as 25 milligrams per lizard. This is equivalent to about 0.5 percent zinc phosphide in bait, a rate lower than currently used in commercial rodenticide baits. Researchers conclude that zinc phosphide has potential as a useful tool for reducing populations of invasive lizards, such as the black spiny-tailed iguana, provided species-specific delivery methods are developed.

Quantifying Feral Swine Impacts to Archaeological Resources—Feral swine are well known as environmentally destructive invasive animals in many areas around the world where they degrade native habitats, harm rare plant and animal species, damage agricultural interests, and spread disease. NWRC scientists and colleagues are the first to quantify the potential for feral swine to disturb and destroy archaeological sites. The study was conducted in south-central Florida at Avon Park Air Force Range, a base comprising over 98,800 acres/40,000 hectares and containing many archaeological sites. Forty-two percent of the sites studied showed some level of swine disturbance, including 47 percent of the sites known to have artifacts within 8 inches/20 centimeters of the surface (well within swine rooting depths). Sites with shallow artifact depositions appeared highly vulnerable to disturbance by feral swine, threatening the historical origin, composition, arrangement, and location of the objects. The findings will aid land and resource managers in their efforts to protect archaeological resources from feral swine damage.

Management of Invasive Bird Species—Invasive bird species management often involves a combination of nonlethal and lethal methods for reducing populations. Monk parakeets are an invasive species in Florida and several other States. They construct large stick nests in electric utility substations and power poles thereby causing power outages and increasing maintenance costs. In cooperation with Florida Power and Light Company, NWRC researchers developed an effective oral contraceptive called Diazacon for use with monk parakeets. Prior to submitting the necessary data to the U.S. Environmental Protection Agency (EPA) for registration of Diazacon, NWRC researchers analyzed the potential impacts of the contraceptive to non-target species, specifically bird-eating raptors that might feed on parakeets that had ingested Diazacon-treated bait. The analysis showed that a raptor would have to eat 50 monk parakeets daily (an impossible task) before it would be rendered temporarily infertile due to Diazacon residues in its prey. These findings enhance the likelihood of registration for Diazacon as an avian contraceptive.

Another invasive bird species of interest is the common mynah. Mynahs damage crops, create nuisance problems, and threaten native bird species in many countries. Mynahs were introduced in American Samoa in the 1980s. Since their introduction, they have become the most frequently observed avifauna in developed areas in the country. While the actual threat to ecological systems is currently unknown, the American Samoa Department of Marine and Wildlife Resources is concerned that expanding myna populations will exert competitive pressures on native species, such as the Samoan starling and white-collared kingfisher. Additionally, the mynahs are increasingly becoming social nuisances through nesting, foraging and vocalization behaviors. The government and general population of American Samoa would like to eradicate these birds before populations are too large to control. In collaboration with officials in American Samoa, NWRC scientists evaluated the toxicity of the registered pesticide DRC-1339 as a potential tool for mynah management. NWRC researchers determined the acute oral LD_{50} (the dose needed to kill 50 percent of a sample population) for common mynahs were 1.19 milligrams of DRC-1339 per kilogram of body weight. According to the EPA's classification, DRC-1339 would be classified as "very highly toxic" to common mynahs on an acute oral basis. In a second trial, NWRC scientists demonstrated the efficacy of lethal bait (cooked white rice treated with DRC-1339) to captive mynahs. Based on the findings from these trials, plans are underway to conduct a field efficacy study in support of registering DRC-1339 for use in America Samoa.

Development of Population Monitoring Methods—The ability to monitor wildlife populations helps managers to optimize and assess various management activities. The passive tracking index methodology is one monitoring technique developed by NWRC researchers that is being used to monitor feral swine populations in conjunction with control activities. A benefit of this methodology is its ability to simultaneously monitor co-occurring species, such as coyotes and deer. NWRC researchers are currently developing monitoring procedures for large invasive lizards in Florida to aid in the eradication and control of these species.

Selected Publications:

AVERY, M. L., J. D. EISEMANN, K. L. KEACHER, AND P. J. SAVARIE. 2011. Acetaminophen and zinc phosphide for lethal management of invasive lizards Ctenosaura similis. Current Zoology 57:625-629.

AVERY, M. L., J. S. HUMPHREY, T. S. DAUGHTERY, J. W. FISCHER, M. P. MILLESON, E. A. TILLMAN, W. E. BRUCE, AND W. D. WALTER. 2011. Vulture flight behavior and implications for aircraft safety. Journal of Wildlife Management 75:1581-1587.

AVERY, M. L., E. A. TILLMAN, K. L. KEACHER, J. E. ARNETT, AND K. J. LUNDY. 2012. Biology of invasive monk parakeets in south Florida. Wilson Journal of Ornithology 124:581-588.

ENGEMAN, R. M., C. BETSILL, AND T. RAY. 2011. Making contact: rooting out the potential for exposure of commercial production swine facilities to feral swine in North Carolina. EcoHealth 8:76-81.

ENGEMAN, R. M., K. J. COUTURIER, R. K. FELIX, JR., AND M. L. AVERY. 2012. Feral swine disturbance at important archaeological sites. Environmental Science and Pollution Research. On-line DOI 10.1007/s11356-012-1367-1.

ENGEMAN, R. M., E. JACOBSON, M. L. AVERY, AND W. E. MESHAKA JR. 2011. The aggressive invasion of exotic reptiles in Florida with a focus on prominent species: a review. Current Zoology 57:599-612.

JACOBSON, E. R., D. G. BARKER, T. M., MAULDIN, R. AVERY, M. L., ENGEMAN, R. AND S. SECOR. 2012. Environmental temperatures, physiology and behavior limit the range expansion of invasive Burmese pythons in southeastern USA. Integrative Zoology 7:271-285.

SAVARIE, P. J., R. M. ENGEMAN, R. E. MAULDIN, T. MATHIES, AND K. L. TOPE. 2011. Tools for managing invasions: acceptance of non-toxic baits by juvenile Nile monitor lizards and Burmese pythons under laboratory conditions. International Journal of Pest Management 57:309-314.

WALTER, W. D., J. W. FISCHER, J. S. HUMPHREY, T. S. DAUGHTERY, M. P. MILLESON, E. A. TILLMAN, AND M. L. AVERY. 2012. Using three-dimensional flight patterns at airfields to identify hotspots for avian-aircraft collisions. Applied Geography 35:53-59.

Major Research Accomplishments:

- WS collected and analyzed unique information on black and turkey vulture movements, flight altitudes, and activity patterns and developed models to assist Marine Corps Air Station-Beaufort, South Carolina, in reducing risks of bird-aircraft collisions.

- WS developed an innovative method for detecting environmental DNA of invasive Burmese pythons in water so that the presence of these secretive reptiles can be verified. This new technology will enable managers to rapidly survey large areas of habitat and assist in operational control programs to remove these invasive reptiles.

- WS collaborated on a review and analysis of physiological requirements and behavior of invasive Burmese pythons to assess the potential invasive range of the species. Results indicate there is minimal chance of Burmese pythons establishing viable populations beyond their current range in the subtropical environment of south Florida.

- WS documented impacts of feral swine rooting activity on important archaeological resources in south-central Florida. This represents the first published quantified description of such impacts by feral swine.

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Reducing Blackbird and Starling Conflicts

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Major Cooperators

- Gowan Company
- Kansas Feedlot Association
- Louisiana Blackbird Committee
- Louisiana Rice Producers Association
- Louisiana Rice Research Board
- Louisiana State University, Louisiana Rice Research Station
- Michigan State University
- Missouri Rice Research and Merchandising Council
- National Sunflower Association
- North Dakota State University
- North Dakota Department of Agriculture
- Ohio Dairy Association
- Ohio State University
- Syngenta Crop Protection
- USA Rice Federation

Groups Affected By These Problems

- Consumers and producers of sunflower, rice, corn, diary, meat, and other products
- Feedlot Owners Association
- National and State Fruit Grower Associations
- National Sunflower Association
- North Dakota Department of Agriculture
- North Dakota Game and Fish Department
- Processors, manufacturers, suppliers, and sellers of sunflower, rice, fruit, corn, dairy, and meat
- South Dakota Department of Agriculture
- South Dakota Game, Fish and Parks
- South Dakota Oilseed Council
- Utility companies

National Wildlife Research Center Scientists Address the Concerns of Farmers, and Feedlot, Dairy and Urban Area Managers

Wildlife Services' (WS) National Wildlife Research Center (NWRC) is the only Federal research organization devoted exclusively to resolving conflicts between people and wildlife through the development of effective, selective, and socially responsible methods, tools, and techniques. NWRC's field station in Bismarck, North Dakota, evaluates and develops methods for managing national blackbird damage to sunflower, rice, and corn in the Great Plains. The field station also leads research on national problems involving bird damage to fruit crops; Canada goose damage to sprouting crops; European starling damage and diseases in urban areas, feedlots and dairies; and woodpecker damage to utility structures and buildings.

Blackbirds and European starlings damage grain crops and eat livestock feed, resulting in significant economic losses to agricultural producers. Cedar waxwings and robins damage blueberries, cherries, grapes, and apples causing millions of dollars in damage to these high-value crops. NWRC scientists are studying ways to refine current damage abatement methods and develop new methods for reducing damage. Additionally, researchers are looking for nonlethal methods to expand capabilities to target specific problem-causing birds. Red-winged blackbirds, common grackles, yellow-headed blackbirds, and brown-headed cowbirds cause an estimated $20 million worth of damage to newly planted and ripening rice in Arkansas, California, Louisiana, Missouri, and Texas; $15 million worth of sunflower in North Dakota and South Dakota; and $35 million worth of ripening and newly-planted corn nationally. Some individual rice and sunflower growers report 100 percent losses due to bird depredation. Birds, especially European starlings, cedar waxwings, and robins, cause $41 million in damage in the leading fruit growing states of California, Michigan, New Jersey, New York, North Carolina, Pennsylvania, and Washington.

NWRC scientists routinely work with producers, commodity groups, research boards, universities, and local, State and Federal agencies to develop safer and more effective methods to reduce bird depredation on seeded and ripening sunflower, corn, rice, and fruit crops to improve profitability for growers. To develop new methods and tools, NWRC scientists conduct multifaceted studies involving the use of both captive and free-ranging birds to determine the status of blackbird populations in the sunflower-, corn- and rice-growing states and fruit-eating birds in apple-, grape-, blueberry- and cherry-growing states; estimate the economic impacts of birds on the crops; evaluate and develop nonlethal repellants for deterring birds; and improve the effectiveness and safety of avicides for reducing depredating populations.

Applying Science and Expertise to Wildlife Challenges

Blackbird Population Management Modeling—DRC-1339 is a slow-acting avicide used to reduce local populations of European starlings, blackbirds and other birds. It is difficult to accurately estimate the number of birds killed with DRC-1339 because carcass searches and other types of counts are not accurate predictors of take at staging area bait sites. To improve mortality estimates associated with current linear models and DRC-1339 use, NWRC scientists developed a semi-mechanistic model that combines mechanistic modeling of environmental and biophysical processes with statistical modeling of DRC-1339 toxicities, avian physical and physiological traits, and foraging behavior. The scientists used simulated baiting scenarios in Missouri and Louisiana to compare take between the two models. Compared to the linear model, the semi-mechanistic model estimates ranged from

5 percent higher to 59 percent lower, depending on the species and gender compositions of the blackbird flocks. On average, the new model's estimates were 24 percent lower than the linear model. Unlike the linear model, the new model accounts for the effects of meteorological and environmental conditions that likely influence feeding rates at DRC-1339 bait sites. NWRC researchers believe that the semi-mechanistic model represents a more scientifically rigorous approach than the linear model toward estimating take that can be applied to all staging area bait applications regardless of region or time of year.

European Starlings' Role in the Spread of Salmonella— Characterizing and mitigating diseases introduced by wildlife to concentrated animal feeding operations (CAFO) can reduce the spread of microorganisms throughout the environment while increasing agricultural productivity. To better understand the disease risks associated with bird use of CAFO, NWRC scientists assessed the capacity of European starlings to spread *Salmonella enterica* to cattle, their feed, and water. Scientists found that Salmonella enterica contamination of cattle feed troughs and water troughs increased as more starlings entered feed troughs, indicating that starlings are a source of S. enterica contamination in CAFO. Thus, employment of starling management tools such as population control, habitat management, exclusionary devices, and bird repellants may reduce the amplification and spread of this disease within livestock production systems.

Ultraviolet Cues Used in Blackbird Food Selection— Although it has long been known that birds use ultraviolet (UV) wavelengths for mate selection, researchers have now learned that UV wavelengths also influence bird feeding behavior and food selection. While UV wavelengths are invisible to humans, NWRC researchers found that birds exposed to an UV-absorbent, post-ingestive repellent subsequently avoided UV-absorbent and UV-reflective food. In studies with captive red-winged blackbirds, researchers learned that blackbirds shift preferences for both familiar and unfamiliar flavors based on their feeding experiences and rely on visual cues to avoid food previously paired with negative consequences. The researchers hope to use these findings to improve our understanding and management of bird damage to agriculture.

European Starlings May Move Pathogens Among Feedlots— NWRC and North Dakota State University scientists monitored site use and movements of European starlings during the winter at two concentrated animal feeding operations (CAFO) in central Kansas. Their research investigated the possible role of starlings in pathogen transmission at CAFO. Few birds (9 percent) moved between feedlots. Starlings rarely completely abandoned the feedlot where they were first captured, but 40 percent of the birds temporarily visited other feedlots. The furthest distance a bird was detected from its original capture site was 42 miles/68 kilometers. Scientists speculate that the limited frequency of time spent at non-capture-site feedlots may lower, but not eliminate, the potential risk of starlings spreading pathogens among feedlots. Researchers still recommend management strategies to reduce starling populations within feedlots and, thereby, the subsequent risk of the birds spreading pathogens to other feedlots.

Anthraquinone to Alleviate Non-Target Take From Rodenticides—Rodenticides, such as zinc phosphide, are often used to control rodent populations that cause damage in croplands and rangelands. Zinc phosphide breaks down rapidly after ingestion and poses little risk to predators and scavengers that might consume treated rodents; however, birds that directly consume the rodenticide bait may be at risk. In an effort to reduce nontarget hazards to birds during rodent control efforts, NWRC researchers evaluated whether the addition of the registered goose repellent anthraquinone to rodenticide baits would prevent consumption of the baits by certain birds. Anthraquinone, which occurs naturally in some plants, produces a laxative effect when eaten. In addition, anthraquinone absorbs near-ultraviolet light that is visible to most birds. This color cue may facilitate the repellency effect in birds. In studies involving captive birds, NWRC researchers treated 2 percent zinc phosphide baits typically used in rodenticide applications with 2 to 2.5 percent anthraquinone (Arkion® Life Sciences). No mortality or signs of zinc phosphide toxicosis were observed among the 20 Canada geese, 24 horned larks, and 47 ring-necked pheasants that were offered the repellent-treated zinc phosphide baits. Although some geese and pheasants initially sampled treated baits, all birds survived and subsequently avoided treated baits throughout the remainder of the study. However, anthraquinone may affect consumption of repellent-treated rodenticide baits by target species such as black-tailed prairie dogs. Supplemental performance testing and field efficacy studies are necessary for further development of a combined bird-repellent rodenticide bait.

Selected Publications:

CARLSON, J. C., A. B. FRANKLIN, D. R. HYATT, S. E. PETTIT, and G. M. LINZ. 2011. The role of starlings in the spread of Salmonella within concentrated animal feeding operations. J. Applied Ecology 48:479–486.

FORCEY, G. M., W. E. THOGMARTIN, G. M. LINZ, and W. J. BLEIER. 2011. Land use and climate influences on waterbirds in the prairie potholes. Journal of Biogeography 38:1694–1707.

GAUKLER, S. M., H. J. HOMAN, G. M. LINZ, and W. J. BLEIER. 2012. Use of feedlots and roost sites by radio-tagged European starlings. Human-Wildlife Interactions 6:30–37.

HOMAN, H. J., R. S. STAHL, and G. M. LINZ. 2013. Comparison of two models for estimating mortality from baitings with Compound DRC-1339 Concentrate avicide. Crop Protection 45:1-5.

LINZ, G. M., J. B. WINTER, and W. J. BLEIER. 2012. Evaluation of elevated bait trays for attracting blackbirds (Icteridae) in North Dakota. Crop Protection 41:30–34.

WERNER, S. J., S. K. TUPPER, J. C. CARLSON, S. E. PETTIT, J. W. ELLIS, and G. M. LINZ. 2012. The role of a generalized ultraviolet cue for blackbird food selection. Physiology & Animal Behavior 106:597–601.

WERNER, S., S. K. TUPPER, S. E. PETTIT, J. C. CARLSON, and G. M. LINZ. 2011. Anthraquinone repellent to reduce non-target take of non-target birds from zinc phosphide rodenticide applications. Applied Animal Behavior Science 135:146–153.

WERNER, S. J., G. M. LINZ, J. C. CARLSON, S. E. PETTIT, S. K. TUPPER, and M. M. SANTAR. 2011. Anthraquinone-based bird repellent for sunflower crops. Applied Animal Behaviour Science 129:162–169.

Major Research Accomplishments:

- WS research discovered that ultra-violet vision in birds was important for food selection and could be used in the development of bird repellents to protect crops.
- WS developed a model to estimate the avicide DRC-1339's effectiveness and impact on blackbird populations.
- WS determined that combining anthraquinone with rodenticide bait helps to prevent the consumption of bait by non-target bird species, such as Canada geese, ring-necked pheasants, and horned larks.
- WS and North Dakota State University scientists found that managing starling populations might be a strategy for reducing the spread of disease within livestock production systems.

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Ecology of Emerging Viral and Bacterial Diseases in Wildlife

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- Colorado State University
- Colorado School of Public Health
- DOI/USGS/Biological Resources Division
- Private feedlot owners
- State Departments of Public Health
- The Ohio State University
- Wildlife Services Operations
- Wildlife Services National Disease Program
- USDA/APHIS/Veterinary Services

Groups Affected By These Problems:

- Consumers
- Federal, State, and local governments
- Livestock and poultry producers
- Public health organizations and hospitals
- U.S. military
- Wildlife and natural resource managers

National Wildlife Research Center Scientists Examine the Roles of Wildlife in the Transmission and Spread of Emerging Infectious Pathogens

Wildlife Services' (WS) National Wildlife Research Center (NWRC) is the only Federal research organization devoted exclusively to resolving conflicts between people and wildlife through the development of effective, selective, and socially responsible methods, tools, and techniques.

Considerable concern exists around the world about recent emerging infectious diseases, of which 75 percent are zoonotic, meaning the pathogens causing the disease can be transmitted between animals and humans. Wildlife plays a critical role in both the emergence and increased incidence of pathogens transmittable and causing disease in livestock and humans. In the last two decades, approximately 72 percent of emerging infectious diseases originated in wildlife, such as highly-pathogenic H5N1 avian influenza virus that originated in Asia and subsequently spread across the Eastern Hemisphere. In addition, wildlife has increasingly been implicated in the spread of re-emerging pathogens, such as antibiotic-resistant bacteria that are causing significant problems associated with agricultural, animal, and human health. Thus, wildlife populations often play a key role in diseases that directly impact humans and agriculture. NWRC is at the forefront of research and surveillance for many of these pathogens. Much of this effort has focused on avian influenza viruses and pathogenic bacteria, including antibiotic-resistant strains.

Avian influenza viruses (AIV) are found naturally in waterfowl and other wild bird species. There are 144 known subtypes of AIV but few of these subtypes cause serious diseases in birds. However, mutation of the virus can lead to infection of new wildlife species, domestic livestock (primarily poultry), and humans. These mutations can result in AIV strains that are highly pathogenic. For example, the highly pathogenic strain of H5N1 AIV originated from a low pathogenic strain of AIV in wild waterfowl and mutated into a highly pathogenic strain in Asia. This strain spread across the Eastern Hemisphere and caused considerable economic loss and mortality in domestic poultry, as well as human deaths. Thus, understanding the ecology of low pathogenic strains of AIV in the wild is critical for the prevention of future influenza epidemics and global pandemics that affect both livestock and humans. NWRC scientists have played a key role in understanding the ecology of AIV in wildlife and how they may transmit AIV from natural systems to agricultural operations and humans.

Pathogenic bacteria have become an increasing health risk to both livestock and humans. These bacteria can cause illness in humans, ranging from food poisoning to life-threatening disease. In livestock, such bacteria can cause considerable loss in production. An additional complication is when these strains become resistant to antibiotics and, hence, are difficult to treat with traditional means. These "superbugs" have recently become a problem in hospitals, where they often defeat the last line of defense, antibiotics, in a physician's arsenal of drugs. Recently, a number of antibiotic-resistant strains of pathogenic bacteria have been found in wildlife but the role of wildlife in transmitting and spreading these bacterial strains is largely unknown. Research at NWRC is beginning to unravel the role of wildlife in maintaining and spreading both pathogenic bacteria and antibiotic-resistant strains of those bacteria.

Applying Science and Expertise to Wildlife Challenges

Mallards Shed Light on Avian Influenza Viral Shedding and Transmission—NWRC scientists studied (1) how long, and at what levels mallard ducks shed AIV, (2) the best sampling methods (i.e., oral-pharyngeal swabs, cloacal swabs, and fecal swabs) for detecting the virus associated with mallards, and (3) whether the virus can be transmitted through a water source shared by infected and uninfected mallards. Researchers experimentally inoculated 3-month-old and 6-month-old mallards with a subtype of low pathogenic AIV commonly found in wild duck populations. Fecal samples had significantly higher

virus concentrations than oral-pharyngeal or cloacal swabs, and the older ducks shed significantly more virus than younger ducks regardless of the sample type tested. Uninfected mallards became infected after using a water source that infected ducks had previously used. These results are important for surveillance purposes and suggest that water samples and fecal samples may be excellent alternatives to traditional cloacal and oral-pharyngeal swabbing of live-captured waterfowl. Furthermore, duck age may be important when interpreting viral shedding. Differential, age-related shedding could affect prevalence estimates, modeling of virus spread, and subsequent risk assessments. Epidemiologic modeling of disease dynamics can be used to develop control strategies that limit disease spread and ultimately control outbreaks. To elucidate important factors affecting avian influenza dynamics, NWRC scientists are studying the impact of viral dose on the subsequent course of infection in mallards to determine if the initial dose affects the duration of infection, the quantity of virus shed, and the time of peak viral load shed by an individual. Also of importance are the exposure histories of individual ducks. NWRC scientists are determining the duration of antibodies to avian influenza in mallards to ascertain whether an infection in 1 year will impact a subsequent exposure to the same virus the following year. These studies are revealing that the ability to detect antibodies to avian influenza in mallards may be relatively short-lived after an infection and that the duration of an elevated antibody titer may also be dependent on the exposure dose of the initial infection. NWRC scientists are also studying mallards to determine how many secondary infections are likely to occur from exposure to a single infected individual and how variable AIV transmission is among individuals.

Avian Influenza Viruses in Wild Mammals: Assessing the Risk to Agriculture—Anecdotal reports have suggested that select mammalian species may be periodically exposed to AIV. However, the viral shedding capability of most peridomestic (i.e., living in close contact to humans) mammalian species and their potential role(s) in AIV ecology are largely unknown. NWRC scientists studied the potential of several mammalian species to shed AIV by various routes. Of the three species tested (raccoons, cottontail rabbits, and striped skunks), all yielded evidence of shedding of a low pathogenic H4N6 AIV frequently found in waterfowl in the United States. The most prominent shedding was noted in striped skunks and cottontail rabbits through the nasal route, and, to a lesser extent, the oral route. Environmental transmission through virus-contaminated water was detected in raccoons. These three species are commonly associated with agricultural operations and suburban areas. Thus, when infected, these mammals could potentially play a role in the movement of AIV and subsequently pose a biosecurity risk to agricultural operations. Information pertaining to the virus shedding potential of these animals is essential for agricultural risk assessments.

Intercontinental Movement and Diversity of Avian Influenza Viruses in the U.S.—A national interagency avian influenza surveillance plan was initiated in 2006 for early detection of highly pathogenic avian influenza viruses (HPAIV) in wild birds. The plan included a variety of wild bird sampling strategies including the testing of fecal samples from aquatic areas throughout the United States from April 2006 through December 2007. Although HPAIV was not detected through this surveillance effort, NWRC researchers were able to obtain 759 waterfowl fecal samples from across the continental United States that were positive for low pathogenic avian influenza virus (LPAIV). Researchers used 136 DNA sequences obtained from these samples along with samples from a public influenza sequence database for a phylogenetic assessment of AIV diversity in the United States, based on the hemagglutinin (HA) genes. Sequences from all HA subtypes, except H5, H7, H14 and H15, were analyzed to examine genetic variation, exchange between Eurasia and North America, and geographic distribution of LPAIV in wild U.S. birds. This study confirmed intercontinental exchange of some AIV HA subtypes (including a newly documented H9 exchange event), as well as identifying subtypes that do not regularly experience intercontinental gene flow but have been circulating and evolving in North America for at least the past 20 years. These HA subtypes have high levels of genetic diversity with many lineages co-circulating within the wild birds of North America. The surveillance effort that provided these samples demonstrates that such efforts provide important information about the ecology of AIV circulating in North America.

Wildlife and the Spread of Pathogenic and Antibiotic-resistant Bacteria—NWRC scientists have studied the potential spread of pathogenic bacteria to animals in agricultural facilities and humans in a variety of wildlife species ranging from European starlings to deer and elk. Scientists studied the local movements of European starlings and their potential role in carrying Salmonella among feedlots by sampling European starlings, cattle feed, cattle water troughs, and cattle feces on feedlots for Salmonella enteric. Results suggested that European starlings may be a source for S. enterica in cattle feed and water, which likely contributes to infections throughout the associated cattle herd. This finding suggests that European starlings not only are an important source for S. enterica infections in cattle but may also move pathogens within and among cattle feedlots.

In 2008, eight children playing on a soccer field in Evergreen, Colorado, were sickened with a strain of Shiga-toxin producing *E. coli* (STEC); five of these children were subsequently hospitalized. Ultimately, the source of these infections was genetically linked to feces from wild elk, which used the soccer field for foraging. STEC causes an estimated 265,000 enteric illnesses, 3,700 hospitalizations and 31 deaths in the United States each year with infection of people by one strain (STEC O157) alone costing an estimated $405 million. This motivated public health officials to question whether wild elk were a source of STEC infections in Colorado. NWRC scientists studied this problem by sampling elk and deer feces in urban areas of Colorado in comparison with those sampled in wild areas and areas used by free-ranging cattle. Elk and deer using urban areas had much higher incidence of STEC (11 percent) than areas used by free-ranging cattle (2 percent) or wild areas (0 percent). This suggested that there is some connection between STEC incidence in elk and deer and their use of urban areas. While the reasons for this are currently unknown, NWRC scientists are working to unravel the sources of infection and the ultimate implications for human health. In addition to pathogenic bacteria, there is considerable concern about the spread of antibiotic-resistant strains of bacteria that are becoming increasingly prevalent. In health facilities, these are often referred to as “superbugs” that resist traditional medical treatment with antibiotics. NWRC scientists studied the role of wildlife in disseminating antibiotic-resistant bacteria to and from commercial livestock facilities. They found that a large percentage of wild raccoons using livestock facilities were infected with one or more strains of antibiotic-resistant bacteria and frequently visited feed troughs used by cattle on the livestock facilities. Thus, wild raccoons may be an alternate source of antibiotic-resistant bacteria entering the food chain and causing problems for agricultural, animal, and human health.

Selected Publications:

CARLSON, J. C., A. B. FRANKLIN, D. R. HYATT, S. E. PETTIT, and G. M. LINZ. 2011. The role of starlings in the spread of Salmonella within concentrated animal feeding operations. Journal of Applied Ecology 48:479-486.

FARNSWORTH, M. L., W. L. KENDALL, P. F. DOHERTY, R. S. MILLER, G. C. WHITE, J. D. NICHOLS, K. P. BURNHAM, and A. B. FRANKLIN. 2011. Targeted surveillance for highly pathogenic avian influenza in migratory waterfowl across the conterminous United States. Pages 143-155 In: S. K. Majumdar, F. J. Brenner, J. E. Huffman, R. G. McLean, A. I. Panah, P. J. Pietrobon, S. P. Keeler, and S. Shive. Pandemic influenza viruses: Science, surveillance, and public health. Pennsylvania Academy of Sciences, Camp Hill, Pennsylvania.

FRANKLIN, A. B., K. K. VANDALEN, and K. P. HUYVAERT. 2011. Avian influenza virus in aquatic environments: An ecological perspective. Pages 59-72 in: S. K. Majumdar, F. J. Brenner, J. E. Huffman, R. G. McLean, A. I. Panah, P. J. Pietrobon, S. P. Keeler, and S. Shive. Pandemic influenza viruses: Science, surveillance, and public health. Pennsylvania Academy of Sciences, Camp Hill, Pennsylvania.

HUYVAERT, K. P., J. S. CARLSON, K. T. BENTLER, K. COBBLE, D. L. NOLTE, and A. B. FRANKLIN. 2012. Freshwater clams as bioconcentrators of avian influenza virus in water vector-borne and zoonotic diseases 12:904-906.

PEPIN, K. M., K. K., VANDALEN, N. L. MOOERS, J. W. ELLIS, H. J. SULLIVAN, J. J. ROOT, C. T. WEBB, A. B. FRANKLIN, and S. A. SHRINER. 2012. Quantification of heterosubtypic immunity between avian influenza strains H3N8 and H4N6 in multiple avian host species. Journal of General Virology 93:2575-2583.

PIAGGIO, A. J., S. A. SHRINER, K. K. VANDALEN, A. B. FRANKLIN, T. D. ANDERSON, and S. O. KOLOKOTRONIS. 2012. Molecular surveillance of low pathogenic avian influenza viruses in wild birds across the United States: inferences from the hemagglutinin gene. PLoS ONE 7:e50834.

SHRINER, S. A., K. K. VANDALEN, N. L. MOOERS, J. W. ELLIS, H. J. SULLIVAN, J. J. ROOT, A. M. PELZEL, and A. B. FRANKLIN. 2012. Low-pathogenic avian influenza viruses in wild house mice. Plos ONE 7:e39206.

Major Research Accomplishments:

- WS conducted research on the roles of wildlife in shedding avian influenza virus and related this information to the potential of subsequent transmission to domestic animals and humans.
- WS is evaluating the role of wildlife as transmitters of bacterial pathogens to and among livestock facilities and human populations.
- WS is elucidating the role of wildlife in the transmission and spread of antibiotic-resistant bacteria to and from commercial livestock facilities.
- WS sequenced wild bird fecal samples to study intercontinental movements of avian influenza virus and the implications for introduction of pandemic influenza strains into the United States.

Wildlife Services

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National Wildlife Research Center

FY 2012

Contraceptive Technologies for Use in Wildlife Population and Disease Management

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Major Cooperators:

- Australia's Invasive Animal Cooperative Research Centre
- Colorado State University
- Florida Department of Agriculture and Consumer Services
- Florida Power and Light Company
- Innolytics, LLC
- National Park Service
- United Kingdom's Food and Agricultural Research Agency
- U.S. Air Force (Avon Park, Florida)
- University of Pittsburg

Groups Affected by These Problems:

- Airports, airlines, airline passengers
- Electric utility companies
- Farmers
- Landscapers
- Motorists, pedestrians
- Natural resource managers
- Pet owners
- Ranchers/Livestock producers
- Urban and suburban residents

National Wildlife Research Center Scientists Study Wildlife Contraception

Wildlife Services' (WS) National Wildlife Research Center (NWRC) is the only Federal research organization devoted exclusively to resolving conflicts between people and wildlife through the development of effective, selective, and socially responsible methods, tools, and techniques.

Research on the reproductive management of various avian and mammalian species that cause damage or threaten public health and safety is a high priority for WS. The severity of human-wildlife conflicts often is directly related to wildlife population density; many problems are exacerbated as wildlife populations become larger. In many urban and suburban settings, for example, overabundant deer create safety hazards for motorists, consume ornamental shrubs, harbor and transmit diseases and parasites (e.g., Lyme-disease-bearing ticks), and degrade habitat quality in public parks and other locations. Rodents carry a variety of diseases (e.g., plague, hantavirus) and damage rangelands and crops, resulting in the loss of millions of dollars in agricultural production. Overabundant feral horses in several western states degrade the quality of the habitat and create ecological and political problems. Stray dogs in many countries pose a potential public health risk, primarily due to bite injuries and the spread of rabies.

The goal of NWRC's wildlife contraceptive research is to develop injectable and oral contraceptives to manage overabundant wildlife populations. In 2009, APHIS successfully registered with the U.S. Environmental Protection Agency the first immunocontraceptive vaccine for wildlife. The single-shot, multi-year vaccine called GonaCon™ Immunocontraceptive Vaccine (GonaCon) was initially registered for use in female white-tailed deer, especially in urban and suburban areas where traditional lethal options are limited. Research has shown GonaCon to be an effective reproductive inhibitor in many other mammal species including elk, feral horses, bison, prairie dogs, ground squirrels, and feral dogs, and cats. Future NWRC research with GonaCon likely will involve studies to support expanded registration to other species, to develop oral delivery systems, and to prevent transmission of wildlife diseases. Wildlife contraceptives, such as GonaCon, can be used in conjunction with other tools in an integrated program to manage local, overabundant wildlife species.

Applying Science and Expertise to Wildlife Challenges

Use of GonaCon on Wild Horses—Overpopulation of wild horses and burros is a significant concern in the Unites States, as these animals can overgraze native plant species and compete with livestock and local wildlife for food and habitat. The Bureau of Land Management (BLM) estimates that approximately 31,500 horses and 5,800 burros are roaming on BLM-managed rangelands in 10 Western States. The estimated current free-roaming population exceeds by nearly 11,000 the number that the BLM has determined can exist in balance with other public rangeland resources and uses. Current management options are limited with the majority of actions involving the removal of horses and burros from the range and either putting them up for adoption or holding them indefinitely in captivity. Wildlife officials need additional nonlethal methods to manage populations of wild horses. Administering immunocontraceptive vaccines to control the fertility of free-ranging horses is a potential option to manage overabundant local populations. In January 2013, GonaCon's registration was expanded to include its use to manage fertility in wild and feral horses and burros. The vaccine is available for use by employees of APHIS' WS and Veterinary Services programs, the U.S. Bureau of Land Management, the U.S. Fish and Wildlife Service, the U.S. National Park Service, the U.S. Department of Defense, Federally-recognized Indian tribes, State agencies responsible for wild or feral horse and burro management, public and private wild horse sanctuaries, or persons working under their authority. Delivery of the product is by hand injection, jab stick, or darting.

Experimental Use Permit for GonaCon in Bison—Preliminary laboratory data indicate that GonaCon not only is an effective contraceptive in bison, but also potentially retards the spread of brucellosis, an infectious disease that affects bison, elk, cattle, and many other mammals. Consequently, WS and Veterinary Services initiated a joint field study in southern Colorado to evaluate the contraceptive efficacy and duration of GonaCon in bison under free-ranging conditions. The study complements an ongoing study in Montana that tests GonaCon as a means of slowing the spread of brucellosis in bison. If these studies demonstrate that GonaCon is effective in bison, APHIS will likely pursue a product registration from EPA.

Combined Rabies-Contraceptive Vaccines for Raccoons— NWRC scientists conducted preliminary tests to evaluate the feasibility of a combined rabies-GonaCon vaccine for use in raccoons. WS operations biologists vaccinate hundreds of raccoons and other medium-sized mammals annually in response to localized rabies outbreaks. However, in areas where raccoon populations are high, the risk remains high that rabies will continue due to the production of susceptible young. NWRC scientists investigated whether immunocontraception is feasible for controlling raccoon population densities while sustaining a high immune status within adult populations in urban areas where the risk of rabies is high. Thirty-two raccoons were inoculated with either GonaCon, the rabies vaccine IMRAB® or both vaccines to simulate trap-vaccinate-release procedures used by the WS Oral Rabies Vaccination Program. Results show GonaCon prevents pregnancy in raccoons without interfering with the development of rabies antibodies stimulated by IMRAB®. To comply with registration requirements, NWRC scientists are conducting a breeding experiment as a second method to evaluate the contraceptive. They also plan to evaluate if GonaCon is as effective in young-of-the-year raccoons as it appears to be in adult raccoons.

GonaCon Use in Black-Tailed Prairie Dogs—Management of prairie dogs includes toxicants, fumigants, barriers, and relocation. Nonlethal methods that allow the existence of prairie dogs but help to minimize damage related to population growth are preferred, especially in urban and suburban areas. Researchers evaluated the immune responses and health effects of captive and wild black-tailed prairie dogs injected with GonaCon vaccine. No adverse effects of GonaCon were noted on the animals' weight or blood chemistry. The antibody titers recorded in the animals indicate that GonaCon has the potential to contracept prairie dogs for 1 year or more in the field.

Selected Publications:

GIONFRIDDO, J. P., A. J. DENICOLA, and K. A. FAGERSTONE. 2011. Efficacy of GnRH immunocontraception of wild white-tailed deer in New Jersey. Wildlife Society Bulletin 35:142-148.

GIONFRIDDO, J. P., A. J. DENICOLA, L. A. MILLER, and K. A. FAGERSTONE. 2011. Health effects of GnRH immunocontraception of wild white-tailed deer in New Jersey. Wildlife Society Bulletin 35:149-160.

LEVY, J. K., J. A. FRIARY, L. A. MILLER, S. J. TUCKER, and K. A. FAGERSTONE. 2011. Long-term fertility control in female cats with GonaCon™, a GnRH immunocontraceptive. Theriogenology 76:1517-1525.

MASSEI, G., D. P. COWAN, J. COATS, F. BELLAMY, R. QUY, S. PIETRAVALLE, M. BRASH, and L.A. MILLER. 2012. Long-term effects of immunocontraception on wild boar fertility, physiology and behaviour. Wildlife Research 39:378-385.

SANDERS, D. L., F. XIE, R. E. MAULDIN, J. C. HURLEY, L. A. MILLER, M. R. GARCIA, R. W. DEYOUNG, D. B. LONG, and T. A. CAMPBELL. 2011. Efficacy of ERL-4221 as an ovotoxin for feral pigs (Sus scrofa). Wildlife Research 38:168-172.

YODER, C. A., B. A. MAYLE, C. A. FURCOLOW, D. P. COWAN, and K. A. FAGERSTONE. 2011. Feeding of grey squirrels (Sciurus carolinensis) with the contraceptive agent DiazaCon tm: effect on cholesterol, hematology, and blood chemistry. Integrative Zoology 6:409-419.

YODER, C. A., and L. A. MILLER. 2010. Effect of GonaCon™ vaccine on black-tailed prairie dogs: immune response and health effects. Vaccine 29:233-239.

Major Research Accomplishments:

- APHIS was granted an EPA registration for the use of the GonaCon™ Immunocontraceptive Vaccine to manage fertility in wild and feral horses and burros. WS continues to conduct research to expand the vaccine's registration to other species.
- WS is investigating the use of GonaCon in conjunction with the rabies vaccine on raccoons and feral or stray dogs. The immunocontraceptive could reduce populations of these animals in certain areas, thus, decreasing the potential spread of the disease.
- WS requested an Experimental Use Permit from the EPA to conduct contraceptive research on free-roaming dogs on tribal reservations in the United States.
- WS found GonaCon to be effective at reducing fertility in black-tailed prairie dogs.

Wildlife Services

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National Wildlife Research Center

FY 2012

Predator Damage Management

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Major Cooperators:
- Utah Division of Wildlife Resources
- Utah State University
- Montana Fish, Wildlife and Parks
- Colorado Parks and Wildlife
- Wyoming Department of Game and Fish
- U.S. Army
- U.S. Forest Service
- Welder Wildlife Foundation
- Wildlife Conservation Society
- Wyoming Animal Damage Management Board
- Wyoming Department of Agriculture

Groups Affected By These Problems
- Environmental organizations
- Land management agencies
- Livestock producers
- U.S. citizens, urban and rural residents
- Wildlife managers

National Wildlife Research Center Scientists Study Predation and New Ways to Protect Livestock and People

Wildlife Services' (WS) National Wildlife Research Center (NWRC) is the only Federal research organization devoted exclusively to resolving conflicts between people and wildlife through the development of effective, selective, and socially responsible methods, tools, and techniques.

Data on carnivore population dynamics, ecology, and behavior are necessary to understand predation patterns on livestock, game species, threatened and endangered species, and in urban areas. These data are also needed for effective depredation management, but significant gaps of knowledge exist with regard to predator-prey, predator-livestock, and predator-predator relationships. NWRC is adopting a multi-disciplinary approach to study interactions among predators and the impact of predators and predator removal on ecosystems, wildlife population dynamics, and livestock predation.

The development of new predator management tools to reduce livestock losses and protect public safety is also a high priority for NWRC. Livestock depredation costs producers approximately $138 million each year. For the sheep and lamb industry alone, predators account for approximately 36 percent of the total losses from all causes. Concerns for public health and safety, as well as animal welfare, have resulted in wildlife managers seeking methods to reduce the risk of conflicts associated with predators. Research conducted by scientists at NWRC's field station in Logan, Utah, is focused on finding new tools and techniques to reduce conflicts with carnivores. In addition, NWRC researchers are developing improved methods for capturing carnivores and monitoring their behaviors and movements.

Applying Science and Expertise to Wildlife Challenges

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

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

Predation on Endangered Black-Footed Ferrets—Researchers investigated whether landscape features could be used to predict predation risk from coyotes and great horned owls on endangered black-footed ferrets. Exposure to areas near likely owl perches

reduced ferret survival, but landscape features potentially associated with coyote movements had no appreciable effect on survival. These results suggest that future decisions concerning the location of reintroduction sites should consider the location and distribution of landscape features potentially used by great horned owls.

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

Improving Forensic DNA Identification of Predators—WS operations personnel need to identify predator species from depredation events and forensic genetic techniques offer tremendous potential. Unfortunately, non-invasive DNA (e.g., saliva, feces) degrades rapidly and to varying degrees depending on field conditions. Therefore, degradation of non-invasive DNA is the limiting factor for identifying predators from depredated carcasses. A study at the NWRC Utah Field Station in Logan, Utah, and the Wildlife Science Center in Columbus, Minnesota, is underway to determine degradation rates of DNA (saliva) left behind by predators on depredated sheep and calves and identify methods of optimal field collection for depredation events that increase success rates of predator identification in the laboratory.

Livestock Protection Dogs in Areas with Wolves and Grizzly Bears—Livestock protection dogs have been used in the United States for decades as a non-lethal tool to protect livestock from coyote depredation. WS research is investigating whether select breeds of livestock protection dogs, such as the larger breeds still used in Europe, are effective at reducing livestock losses to larger carnivores, such as wolves and grizzly bear. Field work began in January 2013 and will continue for several years. The goal of the study is to identify the best breed(s) of livestock protection dogs to guard herds from grizzly bears and wolves and maintain this non-lethal tool for producers.

Selected Publications:

ATWOOD, T. C., J. K. YOUNG, J. P. BECKMANN, S. W. BRECK, J. FIKE, O. E. RHODES Jr., and K. D. BRISTOW. 2011. Modeling connectivity of black bears in a desert sky island archipelago. Biological Conservation 144:2851-2862.

AUSBAND, D. E., J. K. YOUNG, B. FANNIN, M. S. MITCHELL, J. L. STENGLEIN, L. P. WAITS, and J. A. SHIVIK. 2011. Hair of the dog: Obtaining samples from coyotes and wolves noninvasively. Wildlife Society Bulletin 35:105–111.

BARUCH-MORDO, S., S. W. BRECK, K. R. WILSON, and J. BRODERICK. 2011. The carrot or the stick? Evaluation of education and enforcement as management tools for human-wildlife conflicts. PLoS ONE 6:e15681.

BRECK, S. W., B. M. KLUEVER, M. PANASCI, J. OAKLEAF, D. L. BERGMAN, W. BALLARD and L. HOWERY. 2011. Factors affecting predation on calves and producer detection rates in the Mexican wolf recovery area. Biological Conservation 144:930-936.

GESE, E. M., P. S. MOREY, and S. D. GEHRT. 2012. Influence of the urban matrix on space use of coyotes in the Chicago metropolitan area. Journal of Ethology 30:413-425.

POESSEL, S. A., S. W. BRECK, D. E. BIGGINS, T. M. LIVIERI, K. R. CROOKS and L. ANGELONI. 2011. Landscape features influence postrelease predation on endangered black-footed ferrets. Journal of Mammalogy 92:732-741.

SEIDLER, R. G. and E. M. GESE. 2012. Territory fidelity, space use, and survival rates of wild coyotes following surgical sterilization. Journal of Ethology 30:345-354.

YOUNG, J. K., K. A. OLSON, R. P. READING, S. AMGALANBAATAR and J. BERGER. 2011. Is wildlife going to the dogs? Impacts of feral and free-roaming dogs on wildlife populations. BioScience 61:125-132.

Major Research Accomplishments:

- WS predation studies indicated that year-round calving, especially in areas with high predator densities, is subject to higher losses primarily because calves are exposed to mortality agents for longer periods of time rather than having higher natural rates of mortality.
- WS studies showed snowmobile use and subsequent snow compaction in areas may inadvertently allow for increased competition between lynx and coyotes by facilitating coyote access to winter lynx habitats.
- WS research observed that the survival of reintroduced endangered black-footed ferrets decreased when the animals were exposed to areas near likely great-horned owl perches. However, landscape features potentially associated with coyote movements had no appreciable effect on survival.
- WS research showed rub stations for coyotes and wolves provide an inexpensive way to gather hair and subsequent DNA samples for use in monitoring populations, estimating abundance, and exploring genetic diversity.
- WS study showed territory fidelity, space use, and survival rates of surgically sterilized coyote packs were similar to intact coyote packs. Because surgical sterilization of coyotes does not affect territory fidelity, survival rates, or home range maintenance, it may serve as an effective tool to reduce conflict over long time periods. Previous WS research has shown that surgically sterilized coyotes had significantly lower depredation rates of sheep compared to intact coyotes.

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FY 2012

Reducing Mammalian Damage in Forested and Riparian Ecosystems

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Major Cooperators

- British Columbia Ministry of Forests and Range
- Mississippi State University
- Oregon Forest Industries Council
- Oregon Department of Forestry
- Oregon Department of Fisheries and Wildlife
- Oregon State University
- Portland State University
- The Jack Berryman Institute
- USDA Forest Service
- U.S. Department of Defense
- Washington Forest Protection Association
- Washington Department of Fisheries and Wildlife
- Washington Department of Natural Resources

Groups Affected By These Problems

- Commercial timber producers
- Gardeners/Landscapers
- Homeowners
- Natural resource managers
- Noncommercial forest landowners
- Orchard managers
- State departments of transportation

National Wildlife Research Center Scientists Develop Methods to Reduce Timber Damage

Wildlife Services' (WS) National Wildlife Research Center (NWRC) is the only Federal research facility devoted exclusively to resolving conflicts between people and wildlife through the development of effective, selective, and socially responsible methods, tools, and techniques. NWRC's expertise in Corvallis, Oregon, focuses primarily on wildlife damage to forest resources.

Wildlife impacts on regenerating forests following wildfire or harvesting 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. Other mammals such as bears and porcupines damage mature trees. North American beaver 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.

Applying Science and Expertise to Wildlife Challenges

Testing Tools to Protect Forest Resources—Use of commercial repellents and frightening devices are of interest to land managers as non-lethal options to reduce browse damage by deer. However, research has shown that repellents can be cost prohibitive and often provide little to only short-term protection. Deer also habituate quickly to frightening devices. Cost-effective and longer lasting tools are needed for application in forest management. NWRC scientists recently evaluated the effects of two commercial products used to repel deer in western Oregon. When used during the spring to protect young Douglas fir seedlings during leader growth, individuals treated with Seadust Wildlife Controllant™ experienced less browse damage than untreated seedlings. Future evaluations will determine if protection lasts through critical wintering periods without reapplication. NWRC scientists also evaluated the efficacy of a bioacoustic device, Deer Shield® Pro, in repelling black-tailed deer from residential urban areas. Results suggest that preexisting habituation to humans limits the effect of the device; however, new studies are underway to evaluate Deer Shield Pro in early successional forest patches where deer cause damage to seedlings. Future research will address the cost-benefits of utilizing commercial products such as these in forest operations.

Understanding Tree Chemistry and Dietary Behaviors—Many human-wildlife conflicts are the result of animal foraging behavior and activity. NWRC researchers are discovering how wildlife species respond to select chemicals in the plants they eat. Initial results suggested that when given a choice, black-tailed deer prefer to eat conifer seedlings with low terpene levels. Terpenes are found in the essential oils of plants. They have a strong smell and may thus protect the plant from browsing animals. Further research demonstrated that seedling age also can influence animal foraging behavior. Current studies are evaluating the efficacy of selecting for these traits and deploying them in an integrated management design to reduce deer browse in reforestation efforts.

Mountain Beaver Genetics—Mountain beaver are endemic to the Pacific Coast of California, Oregon, Washington, and British Columbia, Canada, and to the Sierra Nevada Mountains of California, and Nevada. There are seven subspecies of mountain beaver. The U.S. Department of the Interior's Fish and Wildlife Service has classified one of these subspecies, *Aplodontia rufa 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 (Washington and Oregon), mountain beaver cause significant

damage to forest resources 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 taxonomic relationships and population demographics. NWRC scientists have recently completed a molecular taxonomic study of this species and discovered that mountain beaver found in Washington are a single subspecies when it was previously considered two distinct subspecies. Furthermore, scientists confirmed the uniqueness of the coastal California subspecies including the endangered *A. r. nigra* and the species of concern, *A. r. phaea*. To aid research efforts related to mountain beavers, NWRC scientists developed DNA markers from the *A. r. rufa* genome. These markers provide a new and powerful tool for studying *A. r. rufa* populations. A current study is using these DNA markers to test whether mountain beaver move across forested landscapes to new areas where forest harvesting operations create optimal habitat.

Better Understanding of Beaver Ecology—North American beaver are found throughout the continent and are commonly referred to as ecosystem engineers because they modify habitat through dam building. Research has shown that beaver dams increase local biodiversity; however, dams also cause flooding and alterations to stream flow that result in crop damage, flooded timber, and habitat destruction. More research is needed to better understand the impacts of beaver ecology. In the Pacific Northwest, beaver dams provide important habitat for threatened and endangered anadromous fishes such as Mid-Columbia River steelhead and coho salmon. Collaborative efforts with researchers at Oregon State University are using spatial analyses to evaluate how beaver respond to anthropogenic activities used to improve fish habitat. At Mississippi State University, another collaborative study is evaluating beaver movement on a military installation that has experienced high beaver damage to forest resources. Study results suggest that beaver home range sizes increased with increasing plant biomass and proportions of woody plant cover. Additionally, the speed of beaver movements increases as they move further away from the safety of their lodges, particularly during the breeding season.

Selected Publications:

CARRILLO, C. D., D. L. BERGMAN, J. TAYLOR, D. NOLTE, P. VIEHOEVER, and M. DISNEY. 2009. An overview of historical beaver management in Arizona. Proceedings of the Wildlife Damage Management Conference 13:216-224.

FIELD, K. L., A. A. BACHMANOV, J. A. MENNELLA, G. K. BEAUCHAMP, and B. A. KIMBALL. 2009. Protein hydrolysates are avoided by herbivores but not by omnivores in two-choice preference tests. PLoS ONE Jan 2009. (www.plosone.org) doi:20.1371/journal.pone.0004126.

KIMBALL, B. A. and J. D. TAYLOR II. 2010. Mammalian herbivore repellents: tools for altering plant palatability. Outlooks on Pest Management 21:181-187.

KIMBALL, B. A. and K. R. PERRY. 2009. Evaluating new protein sources for development of a deer repellent product. Crop Protection 28:364-366.

KIMBALL, B. A., F. PFUND, M. GOURLEY, D. L. GRIFFIN, and J. H. RUSSELL. 2011. Silvicultural attempts to induce browse resistance in conifer seedlings. International Journal of Forestry Research. Article ID 108529.

KIMBALL, B. A., J. TAYLOR, K. R. PERRY, and C. CAPELLI. 2009. Deer responses to repellent stimuli. Journal of Chemical Ecology 35:1461-1470.

PIAGGIO, A. J., M. A. NEUBAUM, H. YUEH, C. E. RITLAND, J. J. JOHNSTON, and S. L. PERKINS. 2009. Development of 10 polymorphic microsatellite loci isolated from the mountain beaver, Aplodontia rufa rufa (Rafinesque). Molecular Ecology Resources 9:323-325.

TAYLOR, J. 2011. Identifying and managing for wildlife damage during stand initiation. Northwest Woodlands, Winter Edition 2011:16-17, 29.

TAYLOR II, J. D., D. L. BERGMAN, and D. L. NOLTE. 2009. An overview of the International Beaver Ecology and Management Workshop. Proceedings of the Wildlife Damage Management Conference 13:225-234.

Major Research Accomplishments:

- WS is evaluating the effectiveness of commercial products, such as repellents and scare devices, to reduce deer damage.
- WS is working to determine if conifer seedlings selected for heritable traits such as known monoterpene profiles can be used to reduce browsing by deer.
- WS used molecular genetic techniques to redefine the taxonomic profiles of mountain beaver subspecies where they cause damage to forest resources.
- WS is using spatial analyses to reduce negative and increase positive impacts of beaver damming behavior.

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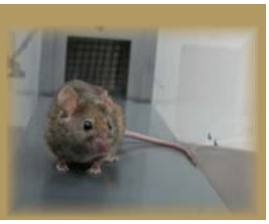
Controlling Rodent Populations and Damage with an Emphasis on Invasive House Mice and Native Voles



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Major Cooperators

- California Department of Food and Agriculture
- Colorado State University
- Global Materials Technology
- Island Conservation, Inc.
- University of California-Davis
- U.S. Department of Defense
- U.S. Fish and Wildlife Service
- U.S. National Park Service

Groups Affected By These Problems

- Conservationists
- Farmers
- Livestock producers
- Military bases
- Natural resource managers
- Urban citizens

National Wildlife Research Center Scientists Assess and Develop Methods to Manage Native Rodents and Eradicate Introduced, Invasive Rodents

Wildlife Services' (WS) National Wildlife Research Center (NWRC) is the only Federal research organization devoted exclusively to resolving conflicts between people and wildlife through the development of effective, selective, and socially responsible methods, tools, and techniques.

Rodents occur worldwide and have adapted to most types of ecosystems. Rodents provide many important ecosystem functions and although most rodent species do not cause serious damage problems, a small number of species do. Rodents damage ripening crops, forestry and nursery trees, rangelands, ornamental plants, and property, including cables and irrigation pipes. They also consume and contaminate stored food, transmit diseases, and contribute to the decline of native flora and fauna on islands. Many tools are used to reduce rodent populations and mitigate damage. NWRC researchers develop and evaluate rodenticides, barriers, and other tools to eliminate or reduce the damage caused by native and invasive rodents.

Applying Science and Expertise to Wildlife Challenges

Ground Squirrel Barriers for Underground Missile Sites—Richardson's ground squirrels pass through or under chain link security fences, triggering sensors and undermining facility infrastructure at Intercontinental Ballistic Missile (ICBM) sites in the western U.S. Among potential solutions to ground squirrel intrusions at these remote sites are permanent barriers, extending both above and below ground. NWRC biologists tested several barrier systems in the rodent buildings at NWRC's outdoor animal research facility in Colorado, using wild-caught Richardson's ground squirrels from deactivated ICBM sites at Malmstrom Air Force Base, Montana. Several barrier systems were identified that have a high potential to prevent movement by Richardson's ground squirrels through or under standard, chain link-fenced areas. Effective above-ground barriers included clear, polycarbonate plastic, and a 2x4-inch woven wire fence with 2 strands of electrified tape near the soil surface. Effective below-ground barriers included a pea gravel-filled trench, and a small-mesh expanded metal sheets. The barriers prevented both above- and below-ground intrusions by ground squirrels. These barrier systems will be field tested at ICBM sites to verify their effectiveness.

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

Efficacy of a Cholecalciferol Plus Diphacinone Bait for California Voles—NWRC researchers determined the efficacy of a new cholecalciferol plus diphacinone bait for use with California voles in California agricultural fields where they have developed resistance to chlorophacinone bait. In no-choice tests with captive voles, results showed that the pelleted bait was highly effective (100-percent mortality). Subsequent two-choice tests also showed a high efficacy (80-percent mortality). Field efficacy trials are planned.

Assessment of Anticoagulant Rodenticide Hazards to Non-Target Animals—Anticoagulant rodenticides are important and widely used tools for managing rats, ground squirrels, voles, and other rodents that damage agriculture, impact native flora and fauna, transmit diseases, or otherwise conflict with human interests. However, concerns about nontarget hazards to wildlife and other adverse environmental effects could limit the use of these rodenticides in the United States. There has been a growing concern that the use of anticoagulant rodenticides to control prairie dog populations may pose a significant hazard to animals that feed on dead or dying prairie dogs. NWRC biologists assessed chlorophacinone residues in captive prairie dogs under controlled conditions. Chlorophacinone levels quickly peaked in prairie dogs after being fed Rozol® prairie dog bait. The highest levels were recorded from animals euthanized on the third day after being offered the bait. Levels quickly declined thereafter and were significantly lower by the seventh day. The results also demonstrated that prairie dogs allowed unlimited access to the bait did not consume more bait nor did they have higher residue levels than those offered only 53g of bait. Results suggest that the highest risk of secondary exposure to chlorophacinone residues by non-target animals consuming prairie dogs exposed to the bait would occur within a few days after bait application and would drop quickly thereafter.

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

Development of a Food Bait Block for Use With Black-Tailed Prairie Dogs—Fertility control may be a useful tool for managing prairie dog populations in urban and suburban environments where rodenticide use is limited or socially unacceptable. However, an effective, oral delivery system is needed. NWRC biologists tested a food bait block delivery system that allows prairie dogs' access to bait over several days. Prairie dogs readily consumed the bait blocks which were stacked on vertical metal poles during the day. However, rabbits and mice also consumed the food bait blocks, mainly at night. Researchers are working to modify the delivery device to eliminate bait access at night.

Selected Publications:

SAVIDGE, J., G. WITMER, S. JOJOLA, J. PIERCE, and P. BURKE. 2012. Genetic evaluation of an attempted Rattus rattus eradication on Congo Cay, U.S. Virgin Islands, identifies importance of eradication units. Biol. Invasions 14:2343-2354.

SNOW, N., and G. WITMER. 2011. A field evaluation of a trap for invasive American Bullfrogs. Pacific Conservation Biology 17:285-291.

WITMER, G. W. and P. HALL. 2011. Attempting to eradicate invasive Gambian giant pouched rats (Cricetomys gambianus) in the United States: lessons learned. Pp. 131-134 in: Proceedings of the Symposium on Island Invasives: Eradication and Management. New Zealand.

WITMER, G. W., J. PIERCE, and W. C. PITT. 2011. Eradication of invasive rodents on islands of the United States. Pp. 135-138 in: Proceedings of the Symposium on Island Invasives: Eradication and Management. New Zealand.

WITMER, G., N. SNOW, R. MOULTON, and J. SWARTZ. 2012. An assessment of seedling damage by wild house mice and wild deer mice. Can. J. Forest Research 42:1168-1172.

WITMER, G., T. SHEFFELS, and S. KENDROT. 2012. The introduction, impacts, and management of a large, invasive, aquatic rodent in the United States. Pp. 49-89 in: D. Abreau and S. deBorbon (eds.). Marshes: Ecology, Management, and Conservation. Nova Science Publishers, Inc., NY.

WITMER, G., and W. PITT. 2012. Invasive rodents in the United States: ecology, impacts, and management. Pp. 47-75 in: J. Blanco and A. Fernandes (eds.). Invasive Species: Threats, Ecological Impact and Control Methods. Nova Science Publishers, Inc., NY.

WITMER, G. W., and P. FULLER. 2011. Vertebrate species introductions in the United States and its territories. Current Zoology 57:559-567.

Major Research Accomplishments:

- WS identified effective barrier systems to prevent ground squirrel access and subsequent damage to underground missile sites.
- WS determined house mouse damage to cottonwood seedlings can be severe and lead to seedling mortality.
- WS evaluated the efficacy of a new cholecalciferol plus diphacinone bait for use with California voles in California agricultural fields where voles have developed rodenticide resistance.
- WS assessed non-target hazards associated with chlorophacinone residues in dead or dying prairie dogs.
- WS determined sodium nitrite has the potential to be an effective rodenticide.

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Managing Invasive Species Impacts to Agriculture, Natural Resources, and Human Health and Safety

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Major Cooperators
- Guam
- Hawaii Agriculture Research Center
- Hawaii Department of Land and Natural Resources
- Hawaii Department of Agriculture
- Hawaiian Commercial and Sugar
- Hawaii Macadamia Nut Growers Association
- Hilo International Airport
- Kamehameha Schools (Bishop Estate)
- MacFarms of Hawaii
- Mauna Loa Mac Nut
- Monsanto Corporation
- Nature Conservancy
- Pioneer Hi-Bred Seed
- Syngenta Corporation
- Tropical Fruit Growers of Hawaii
- University of Hawaii
- U.S. Fish and Wildlife Service
- U.S. Department of Defense

Groups Affected By These Problems
- Commercial transportation industry
- Farmers/Homeowners
- Horticulture industry
- Natural resource managers
- Seed crop industry
- Tropical fruit and nut producers
- Wildlife and refuge managers

National Wildlife Research Center Scientists Develop Methods to Reduce Damage Caused by Invasive Species

Wildlife Services' (WS) National Wildlife Research Center (NWRC) is the only Federal research facility devoted exclusively to resolving conflicts between people and wildlife through the development of effective, selective, and socially responsible methods, tools, and techniques. NWRC's field station in Hilo, Hawaii, is ideally located to allow research biologists to develop methods needed to control invasive species damage to agricultural crops and native ecosystems on islands.

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

Invasive species are one of the greatest threats to Hawaii's agricultural economy, natural environment, and the health and lifestyle of Hawaii's people. Invasive vertebrate species cause millions of dollars worth of crop losses, the extinction of native species, the destruction of native forests, the spread of disease, and threats to the health and safety of residents. Scientists at the NWRC Hilo, Hawaii, field station are investigating a variety of methods to reduce damage caused by invasive species such as rodents, Coqui frogs, brown treesnakes, invasive birds, mongooses, and feral ungulates in Hawaii as well as throughout Pacific islands linked to Hawaii through transport and trade.

Applying Science and Expertise to Wildlife Challenges

Ensuring Safe Rodent Eradication Efforts—Rodenticides are used to eradicate invasive rodents from islands throughout the world. In 2011, the Palmyra Atoll Rainforest Restoration Project (composed of the U.S. Fish and Wildlife Service, The Nature Conservancy of Hawaii, and Island Conservation) attempted to eradicate rats from Palmyra Atoll (a remote island in the Pacific Ocean, approximately 1,000 miles south of Hawaii) in an effort to enhance the biodiversity of seabirds, native plants and terrestrial invertebrates. The eradication was implemented by applying Brodifacoum 25W Conservation, a rodenticide bait containing the second generation anticoagulant rodenticide brodifacoum, by air and ground application. Because the eradication effort used an APHIS pesticide label and implementation of the control operation required a label variance, the coalition contracted with NWRC to monitor the eradication's environmental effects. NWRC scientists measured the application rate and bait distribution on the ground following aerial application and documented the fate of bait, collected potential nontarget mortalities, and systematically collected soil, water, insects, geckos, fish, and crabs to determine environmental residue levels. NWRC's goal was to help evaluate any secondary hazards associated with the eradication effort.

Researchers found the overall rodenticide application rate to be within the limits specified by the Environmental Protection Agency's approved supplemental label. However, they also documented bait in the aquatic environment and considerable variation in the amount applied over small localized areas. Bait may have ended up in the aquatic environment due to shoreline configuration, island topography, overhanging vegetation, bird activity affecting baiting aircraft flight lines, wind strength and direction, pilot experience, and weather conditions at the time of the bait drop.

NWRC researchers found rodenticide residues in ants, cockroaches, geckoes, hermit crabs, fiddler crabs, and black-spot sergeant fish that were collected alive as part of scheduled environmental sampling activities during and after bait application. Fifty-one animal samples representing 15 species of birds, fish, reptiles, and invertebrates were

found dead and collected for residue analysis during systematic searches or collected opportunistically as potential nontarget mortalities during regular activities throughout the atoll. NWRC researchers detected rodenticide residues in 12 of 15 birds that were found dead on or around the atoll after the broadcast application. Affected avian species included bristle-thighed curlews, Pacific golden plovers, ruddy turnstones, and wandering tattlers. Affected non-avian species included mullet fish and Cardisoma spp. land crabs. Nontarget exposure to the rodenticide likely was a result of direct consumption of bait and secondary exposure through scavenging of poisoned rat carcasses.

More than one live rat was detected in July 2011, necessitating a third broadcast application of rodenticide bait over part of the Atoll. Rats have not been detected after the final broadcast. Monitoring for the presence of rats will continue through the summer of 2013 to determine whether rat eradication has been achieved. This type of collaboration, evaluation, and monitoring is critical to the success of the current project as well as future eradication projects.

Bait Delivery for Brown Treesnakes—The invasive brown treesnake has caused extensive economic and ecological damage to the Island of Guam. WS operational and research experts work on a variety of fronts to reduce damage caused by these snakes. In cooperation with Applied Design Corporation, a private engineering firm, NWRC scientists designed an automated aerial bait delivery system for use in brown treesnake control efforts. The first phase of the system's development is complete and consists of the bait delivery device. Additional components that remain to be developed include the design of bait package manufacturing equipment, integrated helicopter electronics, and integrated software systems. Once completed, this aerial delivery system will allow for the economical delivery of toxic brown treesnake bait to large, remote, and rugged areas of Guam.

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

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

Biosecurity Assessment for U.S. Military Operations in the Pacific—In 2006, the U.S. Department of Defense (DoD) proposed to restructure military assets in the Pacific, including relocating 8,600 Marines plus their dependents from Okinawa, Japan, to Guam. In addition to this translocation, the military also proposed to construct both inland and port facilities to support the move and future training, as well as additional offices, homes, and other facilities on Guam. Both the short term and long term increase of military activity over the next 10 years will result in an increase in the movement of cargo and people into Micronesia from Asia, the United States, and other parts of the world. With this increase in movement, the potential for the introduction of invasive species and wildlife-borne diseases also increases.

In an unprecedented effort, WS, along with other APHIS programs, the U.S. Geological Survey, and the Smithsonian Institute, assisted the DoD in the development of a risk assessment and biosecurity plan for Guam and the rest of Micronesia. WS' part of the assessment identified and quantified potential routes of introduction and the risks of introduction of 1) wildlife-related pathogens, such as rabies, avian malaria, West Nile virus, and H5N1 avian influenza virus, and 2) invasive species, such as brown treesnakes, Indian mynah, Asian beauty snakes, coqui frogs, and small Indian mongoose. More importantly, WS made numerous specific recommendations for eliminating or minimizing these threats with five key issues pertaining to all recommendations: funding, coordination and communication, education and training, control methods development, and enforcement.

Ecology of Invasive Rose-Ringed Parakeets—Feral populations of rose-ringed parakeets have significantly increased on the island of Kauai. Parakeet damage to kernels of corn cobs just prior to the harvest stage is especially serious. NWRC researchers completed a cooperative field study with Pioneer Hi-Bred International Inc., to determine the rose-ringed parakeet population size, home range and dispersal patterns, roost locations, habitat use, food preferences, daily movements and associated crop damage. Parakeet exposure to diseases such as avian influenza, Newcastle's disease, and avian psittacosis was also evaluated. NWRC researchers estimated the parakeet population to include more than 2,000 birds that ranged widely across the island to reach specific fields with seed farms. No diseases were detected in the birds sampled. NWRC researchers recommend damage management actions focus on specific agricultural fields and the birds' potential nesting areas.

Selected Publications:

BEARD, K. H. and W. C. PITT. 2012. Chapter 26: Caribbean tree frog (Eleutherodactylus coqui). Pp. 311-319. In: Handbook of Global Freshwater Invasive Species. Earthscan, London. Ed. Robert A. Francis (Invited Submission).

ENGEMAN R. M., W. C. PITT, A. R. BERENTSEN, and J. D. EISEMANN. 2012. Assessing spatial variation and overall density of aerially broadcast toxic bait during a rat eradication on Palmyra Atoll. Environmental Science and Pollution Research. DOI: 10.1007/s11356-012-1050-6.

MATHIES, T., W. C. PITT, and J. A. RABON. 2012. Boiga irregularis (Brown Treesnake) Diet. Herpetological Review. 43(1) 143-144.

OLSON, C., K. H. BEARD, and W. C. PITT. Biology and Impacts of Pacific Island Invasive Species: Eleutherodactylus planirostris, the greenhouse frog (Anura: Eleutherodactylidae). Pacific Science. 66:255-270.

PITT, W. C., L. C. DRISCOLL, and R. T. SUGIHARA. 2011. Efficacy of rodenticide baits for the control of three invasive rodent species in Hawaii. Archives of Environmental Contamination and Toxicology 60(3): 533-542.

PITT, W. C., L. C. DRISCOLL, and E. A. VANDERWERF. 2011. A rat-resistant artificial nest box for cavity-nesting birds. Human-Wildlife Interactions. 5:100-105.

Pitt, W. C., R. T. Sugihara, L. C. Driscoll, and D. S. Vice. 2011. Physical and behavioral abilities of commensal rodents related to design of selective rodenticide bait stations. International Journal of Pest Management 57:189-193.

PITT, W. C., M. HIGASHI, and T. M. PRIMUS. 2011. The effect of cooking on diphacinone residues in feral pig tissues. Journal of Food and Chemical Toxicology. 49:2030-2034.

PITT, W. C., K. H. BEARD, R. DORATT. 2012. Management of invasive coqui frog populations in Hawaii. Outlooks on Pest Management. 23(4): 166-169.

PITT, W. C., D. VICE, D. LUJAN, D. VICE, and G. WITMER. 2012. Freeing islands from rodents: broadcast rodenticides help native species recover. Wildlife Professional 6: 33-34.

SHIELS, A.B. 2011. Frugivory by introduced black rats (Rattus rattus) promotes dispersal of invasive plant seeds. Biological Invasions 13: 781-792.

WALKER, L. R., and A. B. SHIELS. 2012. Landslide Ecology. Cambridge University Press, Cambridge, U.K.

Major Research Accomplishments:

- WS was an integral part of the largest environmental monitoring effort conducted in conjunction with a U.S. rodent eradication effort on Palmyra Atoll (a remote island in the Pacific Ocean, approximately 1,000 miles south of Hawaii).
- WS and a private engineering firm designed an automated aerial bait delivery system for use with the invasive brown treesnake.
- WS determined cooking had little effect on residual rodenticide concentrations in feral swine tissues from pigs exposed to rodenticide bait. Experts caution that the consumption of swine meat obtained from areas with active rodent control programs should be avoided.
- WS developed a risk assessment and biosecurity plan for U.S. military operations in the Pacific. The assessment identified possible routes of introductions for wildlife-related pathogens and invasive species.
- WS conducted a comprehensive study of invasive rose-ringed parakeet ecology and damage to agricultural crops in Hawaii.

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Feral Swine Damage Control Strategies

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Major Cooperators

- Animal Control Technologies Australia
- Archbold Biological Station
- Invasive Animals Cooperative Research Centre
- MacArther Agro-ecology Research Center
- Sul Ross State University
- Texas A&M University-Kingsville
- Texas Department of Agriculture
- Texas Parks and Wildlife Department
- University of Florida
- USDA/APHIS/Veterinary Services
- Wildlife Services Operations

Groups Affected By These Problems

- Consumers
- Livestock producers and farmers
- Meat processors
- Sporting organizations
- U.S. citizens and landowners
- Wildlife and natural resource managers

National Wildlife Research Center Scientists Provide Basic Ecological Information to Develop Feral Swine Damage Control Strategies.

Wildlife Services' (WS) National Wildlife Research Center (NWRC) is the only Federal research organization devoted exclusively to resolving conflicts between people and wildlife through the development of effective, selective, and socially responsible methods, tools, and techniques

As increased urbanization leads to a loss of traditional wildlife habitat, the potential for conflicts between people and wildlife increases. Such conflicts can take many forms, including property and natural resource damage, human health and safety concerns, and disease transmission among wildlife, livestock, and humans.

The high reproductive rate and adaptability of feral swine has resulted in populations that have dramatically increased in size and distribution. This invasive animal now occurs across much of the United States where it causes a range of agricultural and environmental damage through depredation, rooting, and wallowing activities. Furthermore, feral swine compete with native wildlife and livestock for habitats, are carriers of exotic and endemic diseases, and transmit parasites to livestock and humans. It is estimated that feral swine in the United States cause more than $1 billion in damages and control costs each year.

Applying Science and Expertise to Wildlife Challenges

Effects of Baiting on Feral Swine Culling Success—How feral swine respond to control operations is an important consideration in developing optimal management plans. To better understand feral swine behavior, NWRC scientists studied the effects of supplemental feeding/baiting on feral swine movements and the likelihood of baiting to reduce dispersal of swine under culling pressure on the Rob and Bessie Welder Wildlife Foundation (WWF) in San Patricio County, Texas. By placing global positioning system (GPS) collars on feral swine, scientists were able to track movement throughout control operations. Population-wide culling activities included trapping and shooting around a centralized bait station. Feral swine home ranges did not differ between the bait station site and other non-baited sites. However, the daily movement rates of feral swine at bait station sites were 39 percent greater than movement rates of animals in non-baited areas. Opposite to what was expected, baiting stations did not reduce movement in the treatment areas. WS does not recommend the use of baiting as an alternative to fencing for containing feral swine during culling activities.

Tuberculosis and Feral Swine—There is little information regarding the diseases and parasites found in feral swine populations in the Texas border region. This information is needed to understand risks from trans-boundary diseases and to devise and evaluate control strategies. Information from the Texas border region is of particular importance because of the natural movements of wildlife, legal movements of livestock, and illegal movements of animals and animal products from and to Mexico, where many diseases, including bovine tuberculosis, may be present in domestic livestock. Bovine tuberculosis is caused by the bacterium *Mycobacterium bovis*. In a recent NWRC study, approximately 400 feral swine were opportunistically sampled for *M. bovis* in southern Texas. Though no evidence of *M. bovis* infection was found in the swine, researchers recommend continued periodic and strategic sampling of feral swine for *M. bovis* in high-risk areas since feral swine are capable of becoming reservoirs of the disease.

Improving Traps for Feral Swine—Without an effective registered toxicant in place, trapping continues to be one of the primary methods for controlling feral swine populations. As such, numerous trap designs are currently used to capture feral swine; however, drop nets had never been evaluated. In a study conducted in Oklahoma, NWRC scientists compared the effectiveness and efficiency of a drop-net and a traditional corral trap for trapping feral swine. A mark and recapture analysis showed more swine were removed with drop-nets

than with corral traps. Efficiency estimates for the average time per capture were 1.9 and 2.3 hours for drop-nets and corral traps, respectively. Feral swine did not appear to exhibit trap shyness around drop-nets, which often allowed the researchers to capture entire sounders (family units) in a single drop. Use of drop-nets also eliminated capture of non-target species. Results of this study indicate that drop-nets are an effective tool for capturing feral swine.

Monitoring Feral Swine Populations with Mark-Recaptur— Land managers often use a variety of lethal control methods to combat growing feral swine problems. NWRC researchers evaluated the use of the biomarker tetracycline hydrochloride (TH) and mark-recapture techniques for monitoring the effectiveness of feral swine control methods. Researchers established and observed feral swine bait stations containing TH-treated sour corn. TH is a palatable and ingestible antibiotic that establishes a permanent fluorescent mark on growing bone and teeth. Using data on the number of feral swine observed consuming TH-treated bait and the number of animals subsequently removed from the population with TH-marked teeth, researchers calculated population estimates. TH proved to be a suitable marker for mark-recapture estimates of feral swine. The technique also included several advantages over traditional population monitoring techniques, such as reduced animal capture and handling costs; the ability to euthanize captured animals instead of releasing them for future recapture; and the ability to employ a variety of recapture methods.

Feral Swine Activity Near Domestic Swine Facilities—A major concern with feral swine is their potential to maintain and transmit diseases to domestic swine. The domestic swine industry is dominated by operations that maintain some level of biosecurity. However, a portion of the industry is considered “backyard” or transitional production. It is these smaller operations that provide opportunities for disease transmission between feral and domestic swine through fence lines and contaminated surfaces. To help aid in disease management, NWRC researchers collected data on feral swine movements, habitat preference, and the influence of boundaries and corridors near 28 small-scale domestic swine facilities in Texas. Data from collared feral swine showed they preferred habitat characteristics commonly found surrounding domestic swine facilities. Feral swine also demonstrated a disproportionate use of specific vegetation types as compared to their availability during both wet and dry periods. Additionally, the presence of paved, 2-lane roads influenced movements of feral swine. This information aids in the development of targeted management and eradication strategies near domestic swine facilities, particularly in emergency situations such as disease outbreaks.

Selected Publications:

CAMPBELL, T. A., D. B. LONG, M. J. LAVELLE, B. R. LELAND, T. L. BLANKENSHIP, and K. C. VERCAUTEREN. 2012. Impact of baiting on feral swine behavior in the presence of culling activities. Preventive Veterinary Medicine 104:249–257.

CAMPBELL, T. A., D. B. LONG, L. R. BAZAN, B. V. THOMSEN, S. ROBBE-AUSTERMAN, R. B. DAVEY, L. A. SOLIZ, S. R. SWAFFORD, and K. C. VERCAUTEREN. 2011. Absence of Mycobacterium bovis in feral swine (Sus scrofa) from the southern Texas border region. Journal of Wildlife Diseases 47:974–978.

CAMPBELL, T. A., D. B. LONG, and G. MASEI. 2011. Efficacy of the Boar-Operated-System to deliver baits to feral swine. Preventive Veterinary Medicine 98:243–249.

CARDENAS-CANALES, E., T. A. CAMPBELL, Z. GARCIA-VAZQUEZ, A. CANTU-COVARRUBIAS, J. FIGUEROA-MILLAN, R. W. DEYOUNG, D. G. HEWITT, F. C. BRYANT, and J. ORTEGA-SANTOS. 2011. Nilgai antelope in northern Mexico as a possible carrier for cattle fever ticks and Babesia bovis and Babesia bigemina. Journal of Wildlife Diseases 47:777–779.

LAPIDGE, S., J. WISHART, L. STAPLES, K. FAGERSTONE, T. CAMPBELL, J. EISEMANN. 2012. Development of a feral swine toxic bait (HOG-GONE®) and bait hopper (HOGHOPPER™) in Australia and the USA. Proceedings of the Wildlife Damage Management Conference 14:19–24.

LAVELLE, M. J., K. C. VERCAUTEREN, J. W. FISCHER, G. E. PHILLIPS, T. HEFLEY, S. E. HYGNSTROM, S. R. SWAFFORD, D. B. LONG, and T. A. CAMPBELL. 2011. Evaluation of fences for containing feral swine under simulated depopulation conditions. Journal of Wildlife Management 75:1200–1208.

LONG, D. B., and T. A. CAMPBELL. 2012. Box traps for feral swine capture: a comparison of gate styles in Texas. Wildlife Society Bulletin 36(4):741-746.

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RAMIREZ, E. R., M. C. DOMINGUEZ-BRAZIL, C. W. LAWSON, S. M. BURNS, R. GUARNEROS-ALTOMIRANO, S. J. DEMASO, W. P. KUVLESKY, Jr., D. G. HEWITT, J. A. ORTEGA-S., and T. A. CAMPBELL. 2012. Home ranges of female Rio Grande wild turkeys in southern Texas. Southwestern Naturalist 57:198–201.

REIDY, M. M., T. A. CAMPBELL, and D. G. HEWITT. 2011. A mark-recapture technique for monitoring feral swine populations. Rangeland Ecology and Management 64:316–318.

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WYCKOFF, A. C., S. E. HENKE, T. A. CAMPBELL, D. G. HEWITT, and K. C. VERCAUTEREN. 2012. Movement and habitat use of feral swine near domestic swine facilities. Wildlife Society Bulletin 36:130–138.

Major Research Accomplishments:

- WS evaluated the use of bait stations to contain feral swine during simulated culling activities and found bait stations to be ineffective at containing animals, but facilitated removals.
- WS determined that drop-net traps were more successful in capturing feral swine than traditional corral traps. Researchers also found box traps with rooter gates captured more juvenile feral swine, resulting in more total captures than box traps with side-swing gates.
- WS studied feral swine movement and habitat use near domestic swine facilities and found animals preferred habitat characteristics commonly found surrounding domestic swine facilities.
- WS found no evidence of *Mycobacterium bovis* in feral swine populations within the southern Texas border region.
- WS developed a mark-recapture population monitoring technique that complements feral swine damage management activities.
- WS evaluated ERL-4221 as an ovotoxin for feral swine and found the chemical to be ineffective at reducing total ovary mass, number of follicles, and number of corporal lutea.

Wildlife Services

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National Wildlife Research Center

FY 2012

Economic Research of Human-Wildlife Conflicts: Methods and Applications

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- **Major Cooperators**
- California Department of Agriculture, Vertebrate Pest Control Research and Advisory Committee
- Colorado State University
- Cornell University
- Global Alliance for Rabies Control
- Michigan State University
- Ontario Ministry of Natural Resources, Canada
- Texas A&M University
- Texas Department of State Health Services
- The Ohio State University
- University of Hawaii
- USDA National Rabies Management Program
- WS Operations Personnel

- **Groups Affected By These Problems**
- Agricultural producers
- International wildlife conservation organizations
- State county agricultural commissioners
- State game and fish agencies
- State natural resource agencies
- State public health agencies
- Wildlife Services managers

National Wildlife Research Center Economists Use Benefit-Cost Analyses to Quantify Economic Impacts of Human-Wildlife Conflicts

The Wildlife Service's (WS) National Wildlife Research Center (NWRC) is the only Federal research organization devoted to resolving human-wildlife conflicts through the development of effective, selective, and socially responsible methods, tools, and techniques.

The 2011 Research Needs Assessment of USDA/APHIS/WS ranked economic assessments of diverse management techniques, products, and programs third among the eleven most frequently cited data requirements by WS programs and staff. Economics research at NWRC seeks to meet this need and to satisfy The Government Performance and Results Act of 1993 by acquiring accounting-type, outcome-based data of program efficiency.

NWRC economists conduct research to determine the potential benefits (savings) and costs involved in reducing the impacts of introduced invasive species, emerging wildlife-transmitted diseases, and traditional wildlife-caused damages to agriculture, property, and natural resources, as well as wildlife-posed risks to public health and safety.

Applying Economic Expertise to the Challenges of Wildlife Damage Management

Cost of Starling Damage to Dairy Farms—More than 200 million invasive European starlings live in North America. When gathering in large flocks—numbering in the thousands—these birds exact a large toll on agriculture. To better quantify the damage from European starling-livestock interactions at dairies, NWRC economists looked at starling-related costs associated with the consumption of cattle feed, increased feed spoilage, and higher veterinary expenses. To better characterize these interactions, NWRC researchers surveyed dairy operators in Pennsylvania. The survey results indicated that starling damage at dairies costs the State more than $10 million annually in lost productivity. Results also indicated that Pennsylvania dairies lose approximately 6 percent (or 178 million pounds) of cattle feed to starlings each year, costing farms thousands of dollars in additional feed. Dairies with large starling populations were associated with higher occurrences of Johne's disease (up to a 148-percent increase) and Salmonella (up to a 900-percent increase) in their herds, resulting in increased veterinary costs compared to farms with lower starling numbers. These research efforts aid in the development of effective, practical, and cost-effective management strategies.

Preventing Wildlife Rabies Saves Lives and Money—Rabies is an acute, fatal viral disease that can infect people and animals. The disease's impact on society can be great. The cost of detection, prevention, and control of rabies in the United States alone exceeds $300 million annually. Approximately 90 percent of the reported rabies cases in the United States occur in wildlife. Raccoons and skunks account for the most reported cases, but bats, foxes, and coyotes are also among those commonly infected. Since 1995, WS has been working cooperatively with Federal, State, and local agencies; universities; and other partners to reduce rabies in wildlife. Each year, WS and cooperators distribute about 6.5 million oral rabies vaccination (ORV) baits in selected States to create zones where raccoon rabies can be contained.

NWRC economists have assessed the value of WS' ORV efforts on several fronts. Initially, simulation models were developed to determine likely scenarios related to the spread of raccoon rabies if WS' ORV program were terminated. Based on these scenarios, economic models were then developed to determine the likely economic consequences of abandoning the ORV program. Economists estimated that an enhanced rabies program

(i.e., one that pushes for the full eradication of the raccoon strain of rabies) would likely prevent an estimated $48 million to $456 million in rabies-related damages. Enhancing the ORV program was estimated to cost between $58 million and $158 million. Thus, the return on investment for national ORV programs in wildlife could be as high as $8 for every dollar spent.

On a more local scale, NWRC economists evaluated the return on investment of a coyote ORV program in Texas. From 1995 to 2006, south Texas implemented an ORV program to eliminate a rabies outbreak in domestic dogs and coyotes. The cost of the 10-year program was approximately $26 million. However, an economic analysis estimated that the program's overall savings ranged from $89 million to $346 million in avoided rabies-related damages, indicating that between $4 and $13 were saved for every dollar spent.

NWRC economists also collaborated with the California Department of Health Services to determine the direct and indirect economic costs of human rabies exposure in two California counties. Results indicated that the average cost of a single suspected rabies exposure was approximately $4,000. Using these identified costs, WS economists then assessed the potential benefits and costs of ORV baiting to eliminate or prevent the spread of skunk rabies in California. The results showed that for every dollar invested in wildlife rabies control and prevention, the return value in benefits could be as high as $6.35.

Results from analyses like these provide an economic basis for decision-making and serve as a guide for future ORV baiting campaigns in the United States and other countries.

Wildlife Costs to Agriculture. In 2002 (the most recent year for which data are known), USDA's National Agricultural Statistics Service estimated the annual cost of wildlife damage to agriculture was approximately $944 million. WS activities help reduce damage to livestock and aquaculture, as well as fruit, vegetable, and grain crops. In California, WS experts help to prevent rodent and bird damage to numerous crops, including avocados and wine grapes. California accounts for the majority of the annual U.S. production of avocados ($200 million) and wine grapes ($2.1 billion). WS reduces this damage by hazing animals with propane cannons and using repellents, barriers, netting, and toxicants. NWRC economists estimated the net benefits of bird and rodent control on a per-acre basis and accounted for crop savings, property damage avoided, and control costs. In avocado production, the net benefit of bird control was estimated to be $60 to $196 per acre, and the net benefit of rodent control was estimated to be $574 to $1,117 per acre. In wine grape production, the net benefit of bird control was $956 to $1,600 per acre, and the estimated benefit for rodent control was $390 to $832 per acre.

Taking the analysis further, NWRC economists estimated the total impact of bird and rodent damage to the California economy due to decreased agricultural yields and increased pest control costs for 22 selected crops. Multiple economic models were integrated to estimate the economic impact to the State, including the use of an input-output model for a subset of California's 10 leading agricultural counties. The total estimated revenue lost annually in the 10 counties/22 selected crops due to bird and rodent damage ranged from $168 million to $504 million. The total estimated number of jobs lost annually ranged from 2,100 to 6,300.

Estimating the economic impacts associated with wildlife damage, including predation, disease, and crop loss, provides valuable information to decision-makers about whether, when, and how much damage management is appropriate. The need for NWRC economic studies is expected to continue to grow in the coming years as more decision-makers request information to aid in making difficult financial decisions.

Selected Publications:

ANDERSON, A., SHWIFF, S., GEBHARDT, K., RAMÍREZ, A. J., SHWIFF, S., KOHLER, D. AND LECUONA, L. 2012. Economic evaluation of vampire bat (Desmodus rotundus) rabies prevention in Mexico. Transboundary and Emerging Diseases. doi: 10.1111/tbed.12007

GEBHARDT, K., A. M. ANDERSON, K. N. KIRKPATRICK, AND S. A. SHWIFF. 2011. A review and synthesis of bird and rodent damage estimates to select California crops. Crop Protection 30:1109-1116.

SHWIFF, S. A., K. N. KIRKPATRICK, AND K. GODWIN. 2011. Economic evaluation of beaver management to protect timber resources in Mississippi. Human-Wildlife Interactions 5:306-314.

SHWIFF, S. A., C. P. NUNAN, K. N. KIRKPATRICK, AND S. S. SHWIFF. 2011. A retrospective economic analysis of the Ontario red fox oral rabies vaccination programme. Zoonoses and Public Health 58:169-177.

SHWIFF, S., C. AENISHAENSLIN, A. LUDWIG, P. BERTHIAUME, M. BIGRAS-POULIN, K. KIRKPATRICK, L. LAMBERT, AND D. BELANGER. 2012. Bioeconomic modelling of raccoon rabies spread management impacts in Quebec, Canada. Transbound Emerg Diseases. doi: 10.1111/j.1865-1682.2012.01351.x.

SHWIFF, S. A., J. C. CARLSON, J. H. GLASS, J. SUCKOW, M. S. LOWNEY, K. M. MOXCEY, B. LARSON, AND G. M. LINZ. 2012. Producer survey of bird-livestock interactions in commercial dairies. Journal of Dairy Science 95:6820-6829.

SHWIFF, S. A., A. ANDERSON, B. P. CULLEN, L. WHITE, AND S. S. SHWIFF. 2012. Assignment of measurable costs and benefits to wildlife conservation projects. Wildlife Research Review. http://dx.doi.org/10.1071/WR12102

Major Research Accomplishments:

- WS economic studies showed European starling damage at Pennsylvania dairies costs the State more than $10 million annually in lost productivity.
- WS economic studies estimated the return on investment for national Oral Rabies Vaccination programs in wildlife could be as high as $8 for every dollar spent.
- WS economists estimated the total impact of bird and rodent damage to the California economy due to decreased agricultural yields and increased pest control costs for 22 selected crops. The total estimated revenue lost annually ranged from $168 million to $504 million. The total estimated number of jobs lost annually ranged from 2,100 to 6,300.

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Ecology, Control, and Prevention of Terrestrial Rabies in Free-ranging Wildlife

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- **Major Cooperators**
- Artemis Technologies
- Centers for Disease Control and Prevention
- Cleveland Metroparks
- FoodSource
- Global Alliance for Rabies Control
- Kansas State University
- Lyssa, LLC
- MERIAL, Inc.
- New Mexico State University
- Purdue University
- Texas A&M University
- Texas State Department of Health Services
- University of Georgia
- University of Tennessee
- Wildlife Services Operations

- **Groups Affected By These Problems**
- Consumers
- Health officials
- Livestock producers and farmers
- Sporting organizations
- Veterinarians
- Wildlife and natural resource managers

National Wildlife Research Center Scientists Develop New Methods, Strategies to Reduce Rabies Transmission from Infected Wildlife to Humans, Domestic Animals, and Wildlife

Wildlife Services' (WS) National Wildlife Research Center (NWRC) is the only Federal research organization devoted exclusively to resolving conflicts between people and wildlife through the development of effective, selective, and socially responsible methods, tools, and techniques.

Increased urbanization, greater acceptance of and desire for living closer to free-ranging wildlife, and burgeoning wildlife numbers have led to increased conflict between people and wildlife. Such conflict can take many forms, including the transmission of diseases among wildlife, livestock, and humans. Indeed, many of the pathogens that cause animal disease also are capable of causing disease in humans. Appropriately, there is a great need to understand the processes mediating disease transmission among wildlife, livestock, and humans.

Rabies is an acute, fatal viral disease, most often transmitted through the bite of a rabid mammal, which can infect people as well as animals. Impacts to society from this and other wildlife diseases can be great. For instance, the cost of detection, prevention, and control of rabies in the United States exceeds $300 million annually.

In 2000, the Secretary of Agriculture enacted a Declaration of Emergency for rabies, citing threats to livestock and to public health and safety. In 2001, NWRC initiated research to help reduce the transmission of this disease.

In the United States terrestrial rabies can be found in many wild animals, including raccoons, skunks, gray foxes, arctic foxes, bobcats, and coyotes. In an effort to halt the spread and eventually eliminate terrestrial rabies in the United States, NWRC scientists are researching the behavior, ecology, movement, and population structure of raccoons and other wildlife hosts. They also are evaluating methods and techniques used to vaccinate wildlife against rabies to decrease the risk of transmission and maintenance of the disease in the wild.

Applying Science & Expertise to Wildlife Challenges

Safety and Efficacy of ONRAB® in Target and Nontarget Species—NWRC researchers are exploring a new oral rabies vaccine (ORV) called ONRAB for use on raccoons and skunks in the United States. In an initial field trial in West Virginia, ONRAB resulted in the highest seroconversion rate in raccoons ever observed for an ORV bait used in the United States with 49.4 percent of raccoons showing seroconversion post-ORV versus 9.6 percent pre-ORV. Unfortunately, the skunk sample size was too low to adequately assess the effects of the vaccine on skunks. In addition to conducting field trials with the target species, researchers also investigated the effects of the vaccine on nontarget species including wood rats, eastern cottontail rabbits, opossums, eastern wild turkey, and fox squirrels. These are all species whose habitats overlap with ORV target species. Evaluations of non-target species were conducted with captive animals and NWRC researchers tested fecal and oral swabs from animals dosed with the ONRAB vaccine at 10 times the rate that they could be exposed to in the wild. Viral ribonucleic acid (RNA) was detected in turkey feces up to 3 days post inoculation (dpi), opossum feces up to 6 dpi, cottontail feces up to 5 dpi, and fox squirrel feces through 7 dpi. Although over 40 percent of fox squirrels were still shedding viral RNA on 7 dpi, some showed signs of co-infections with Leptospira spp. This co-infection may have made them more susceptible to the vaccine or may have interfered with the test, resulting in false-positives. Minimal

shedding was observed via oral routes (and opossum nasal swabs), demonstrating that ONRAB has very minimal and temporary impacts on these nontarget species even when exposed to 10 times the expected dose. Results from these studies will aid in efforts to license ONRAB for use in the United States through the USDA-APHIS Center for Veterinary Biologics.

Role of Water Availability in Rabies Transmission—Since rabies can infect multiple species and has a high potential for cross-species transmission, an understanding of the role water availability may play in facilitating disease transmission could lead to better disease prevention strategies. NWRC researchers collected data on interactions among coyotes, bobcats, and gray foxes at 31 artificial water features in Texas. Results indicated that gray foxes behaved as subordinate competitors for these water sources, having both the shortest time intervals at the sites and using them almost exclusively (greater than 97 percent of visits) at night. In contrast, only 41 percent of coyote and 61 percent of bobcat visits to water sources occurred at night. Bobcats also spent more time at the sites, on average, than coyotes or gray foxes. The use of water sources by both coyotes and bobcats was directly related to the days since the last rainfall, with animals using artificial water sources more frequently as the time since last rainfall increased. Gray fox use of artificial water sources, on the other hand, was positively related to the availability of rugged escape terrain and inversely related to activity of the larger carnivores. These data suggest that while artificial water in arid environments of the southwestern United States may result in increased interactions and potential disease transmission among coyotes and bobcats, this may not be the case for gray foxes. Researchers also observed that 60 percent of the interspecies interactions recorded were between carnivores and cattle. These data indicate that the incidence of encounters at water features may be higher between carnivores and cattle than between carnivores and other carnivores, which suggests that these sites can lead to a higher probability of rabies virus transmission from wildlife to livestock.

Use of Infrared Thermography to Detect Rabies in Bats—The use of modern technology, including infrared thermography, in disease surveillance provides opportunities for insights into pathogen emergence, prevention, and control. This technology should have the capacity to identify diseased individuals within a population that are potentially manifesting clinical signs. NWRC researchers conducted a study that evaluated the use of infrared thermography to detect thermal changes associated with experimental rabies virus infection in big brown bats in a captive colony. Results indicated that when bats began to show clinical signs of rabies, 54 percent had detectable facial temperature decreases, compared to pre-inoculation temperatures. As a result, researchers believe that infrared thermography may be a useful noninvasive tool for use in rabies surveillance in bats.

Selected Publications:

ATWOOD, T. C., T. L. FRY, and B. R. LELAND. 2011. Partitioning of a limited resource by sympatric carnivores in the Chihuahuan Desert and the implications for disease transmission. Journal of Wildlife Management 75: 1609-1615.

BEASLEY, J., W. BEATTY, T. C. ATWOOD, S. JOHNSON, and O. E. RHODES. 2012. A comparison of methods for estimating raccoon abundance: implications for disease vaccination programs. Journal of Wildlife Management 76(6):1290-1297.

FRY, T. L., T. C. ATWOOD, and M. R. DUNBAR. 2010. Evaluation of rhodamine B as a biomarker in raccoons. Human-Wildlife Interactions 4:275-282.

FRY, T., K. VANDALEN, J. HURLEY, and P. NASH. 2012. Mucosal adjuvants to improve wildlife rabies vaccination. Journal of Wildlife Diseases 48:1042-6. DOI: 10.7589/2011-11-331.

SLATE, D., R. CHIPMAN, K. NELSON, C. CROSON, S. MILLS, C. RUPPRECHT, and K. VERCAUTEREN. Safety and immunogenicity of ONRAB in raccoons and skunks in West Virginia: 2011 field trial report. USDA/APHIS/WS/National Rabies Management Program. Report to USDA/VS/Center for Veterinary Biologics.

VERCAUTEREN, K., T. DELIBERTO, S. SHWIFF, C. ELLIS, R. CHIPMAN, and D. SLATE. 2012. Rabies in North America: need and call for a One Health Approach. In: Frey, S.N., editor. Proceedings of the 14th Wildlife Damage Management Conference, April 18-21, 2011, Nebraska City, NE; The Wildlife Damage Management Working Group of the Wildlife Society: 56-63.

Major Research Accomplishments:

- WS evaluated the efficacy of the ONRAB® vaccine for use in oral rabies vaccination programs. In an initial field trial in West Virginia, ONRAB resulted in the highest seroconversion rate in raccoons ever observed for an ORV bait used in the United States, with 49.4 percent of raccoons showing seroconversion post-ORV versus 9.6 percent pre-ORV. Data collected from this and non-target studies will aid in the registration of the vaccine for use in the United States.
- WS studies on the availability of water and rabies transmission among carnivores indicated that the incidence of encounters between carnivores and cattle at water features suggest these locations may lead to a higher probability of rabies virus transmission from wildlife to livestock.
- WS determined that infrared thermography may be a useful noninvasive tool for use in rabies surveillance in bats.

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Management of Ungulate Disease and Damage

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Major Cooperators
- Canadian Food Inspection Agency
- Colorado Division of Wildlife
- Colorado State University
- Michigan Department of Natural Resources
- Michigan State University
- National Park Service
- Private elk and deer farmers
- State departments of public health
- University of Nebraska
- University of Wisconsin
- University of Wyoming
- Wildlife Services Operations
- USDA/APHIS/Veterinary Services
- USDA/Agricultural Research Service
- U.S. Geological Survey
- Wisconsin Department of Natural Resources

Groups Affected By These Problems
- Captive cervid industry
- Consumers
- Livestock producers and farmers
- Meat processors
- Rural communities
- Sporting organizations
- State and Federal agriculture and wildlife agencies
- Wildlife and natural resource managers

National Wildlife Research Center Scientists Study Chronic Wasting Disease, Bovine Tuberculosis, and Other Diseases in Wild and Domestic Ungulates

Wildlife Services' (WS) National Wildlife Research Center (NWRC) is the only Federal research organization devoted exclusively to resolving conflicts between people and wildlife through the development of effective, selective, and socially responsible methods, tools, and techniques.

As increased urbanization leads to a loss of traditional wildlife habitat, the potential for conflicts between people and wildlife increases. Such conflicts can take many forms, and recently potential for transmission of diseases among wildlife, livestock, and humans has received greater attention. Two diseases in particular—chronic wasting disease (CWD) and bovine tuberculosis (TB)—can be found in wild and captive ungulates.

The spread of CWD is of nationwide concern and additional research is needed to learn more about CWD 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 it is typically 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.

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

In 2000, the Secretary of Agriculture enacted a Declaration of Emergency for bovine TB, citing threats to livestock, and public health and safety. In 2001, NWRC initiated research that could assist in reducing or eliminating the transmission of this disease to cattle and humans. This research is especially critical in light of new bovine TB cases recently documented in New Mexico, Minnesota, and California.

Applying Science and Expertise to Wildlife Challenges

Detection of Volatile Organic Compounds in Animals as a Tool for Diagnosis of Bovine Tuberculosis—Volatile organic compounds (VOCs) are organic compounds that often emit unique odors and emission patterns. Because of these unique characteristics, VOCs have been identified as potential tools in disease surveillance. Recently, NWRC scientists and colleagues from APHIS Veterinary Services, the Tel-Aviv University and Technion-Israel Institute of Technology developed a method for collecting and analyzing VOCs from cattle. The scientists tested the method during an outbreak of bovine TB in cattle in the United States. Gas-chromatography and mass-spectrometry analysis

revealed the presence of two VOCs associated with a bovine TB infection in the exhaled breath of infected cattle. Based on these results, a nanotechnology-based array of sensors was then tailored for detection of bovine TB-infected cattle via breath. The system successfully identified all bovine TB-infected animals, while only 21 percent of the non-infected animals were classified as bovine TB-infected (were false positives). This technique could form the basis for a real-time cattle monitoring system that allows efficient and non-invasive screening for new bovine TB infections on dairy farms.

Detecting CWD from Cerebrospinal Fluid—NWRC researchers evaluated whether cerebral spinal fluid (CSF) could be used to diagnose CWD in elk. As part of the evaluation, NWRC collected the CSF from 6 captive and 31 free-ranging adult elk at necropsy and evaluated it for the presence of CWD via protein misfolding cyclic amplification (PMCA). In addition, each animal's obex (i.e., part of the brain) was examined by immunohistochemistry (e.g., process for detecting proteins in cells). Four of the six captive animals were CWD-positive and euthanized due to signs of terminal CWD. The remaining two were CWD-negative. None of the 31 free-range animals showed overt signs of CWD, but 12 tested positive for CWD by immunohistochemistry. PMCA detected CWD in only three of the four captive animals showing clinical signs of CWD. Furthermore, PMCA did not detect CWD in any of the nonclinical animals that tested positive by immunohistochemistry. NWRC researchers concluded that CWD prions can be detected in the CSF of elk but only relatively late in the course of the disease. Therefore, the use of PMCA with CSF could be used as a confirmatory test for CWD, but it should not be used as a diagnostic tool.

Role of Environmental Metals in CWD Transmission— Understanding the role of environmental metals, such as divalent cations (i.e., atoms missing two electrons), in the spread of CWD can provide valuable information for assessing risk and may lead to CWD therapies and prevention through dietary manipulation. NWRC researchers collected environmental samples from CWD-negative and CWD-positive ranches in Colorado and Canada and conducted a cation analysis. The researchers detected a statistically significant difference between cation ratios in positive and negative ranches. Based on this information, a bioassay was conducted utilizing CWD-inoculated, cervidized transgenic mice (i.e., mice containing deer genes) that were given either normal rodent food and normal water or a cation-modified diet and modified water. CWD-inoculated mice on the cation-modified diet lived significantly longer than those on the normal diet. These finding are significant considering that the mode of inoculation (intracerebrally) and dose were both unnatural, suggesting that the effects may be more pronounced in a host species (deer or elk) inoculated in a more natural manner. Work is currently underway to determine the mechanism responsible for these effects as well as the effect of dietary supplementation of omega fatty acids in the mouse model.

Intranasal CWD Inoculation of White-tailed Deer— Determining all potential CWD transmission routes in wild animals is important in controlling and preventing the disease. One method of transmission demonstrated experimentally has been the inoculation of massive dosages into the oral cavity. Based on pathological data, this route of infection does not seem to be compatible with the naturally occurring disease. Much time and effort has been spent by landowners to remove top soil in captive facilities in an effort to prevent indirect CWD transmission. However, this technique has been unsuccessful. If the CWD prion is located in the dirt and dust surrounding the farm, inhaling these particles may cause disease. The nasal passages of fourteen white-tailed deer were inoculated six times at 1 week apart with a mixture of either CWD-positive (12 deer) or CWD-negative (2 deer) brain homogenate and montmorillonite clay dust. The deer were euthanized and samples were collected at necropsy for immunohistochemistry analysis. Results show that montmorillonite clay dust is an efficient carrier of CWD. Positive tissues were observed in deer as early as 98 days after the last inoculation. This verifies that the intranasal route is a viable route of infection and that dust, a natural route of exposure, is capable of delivering the infected material intranasally.

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

Elk and Fence-Line Disease Transmission—Direct and indirect contact through fences at captive elk farms may play a role in the transmission of diseases such as CWD and bovine TB. NWRC researchers examined the effectiveness of a baited electric fence, as an addition to an existing single woven-wire fence (2.4 meters high), for altering behavior and reducing fence-line contact between elk. Researchers documented 426 contacts between elk (direct transmission risk) or the woven-wire fence (indirect transmission risk) during trials without the electric fence. When the electric fence was installed, there were no contacts between adult elk or the woven-wire fence. Researchers note that this approach targets behavior modification of farmed elk routinely exposed to the electric fence, not wild elk that may occasionally approach from the outside. The results of this study suggest that adding a baited electric fence inside an existing woven-wire-fenced enclosure has the potential to provide a cost-effective means of minimizing contacts between farmed and wild elk.

Passive Integrated Transponders (PIT) in Darts—Methods to individually mark and identify free-ranging wildlife without the added expense of initial trapping and handling of animals would be useful to wildlife managers. A passive integrated transponder (PIT) is a tag that is injected under the skin or into the muscle of an animal. It contains a series of numbers and letters used to identify individual animals, and the numbers can be recalled by passing a "PIT Tag Reader" over the implanted tag. NWRC researchers successfully injected PIT into captive elk using dart guns. The PIT remained functional during recaptures for at least 4 months. The long-term use of PIT can increase the efficiency of monitoring efforts.

Selected Publications:

BLACKWELL, B., T. SEAMANS, L. TYSON, J. BELANT, and K. VERCAUTEREN. 2012. Exploiting antipredator behavior in white-tailed deer for resource protection. Wildlife Society Bulletin. 36:546-553.

FISCHER, J. W., G. E. PHILLIPS, D. M. BAASCH, M. L. LAVELLE, and K. C. VERCAUTEREN. 2011. Modifying elk (Cervus elaphus) behavior with electric fencing at established fence-lines to reduce disease transmission potential. Wildlife Society Bulletin 35:9-14.

LAVELLE M. J., HYGNSTROM S. E., HILDRETH A. M., CAMPBELL T. A., LONG D. B., HEWITT D. G., BERINGER J. and K. C. VERCAUTEREN. 2012. Utility of improvised video-camera collars for collecting contact data from white-tailed deer: Possibilities in disease transmission studies. Wildlife Society Bulletin:n/a-n/a. DOI: 10.1002/wsb.216.

LAVELLE, M. J., K. C. VERCAUTEREN, T. J. HEFLEY, G. E. PHILLIPS, S. E. HYGNSTROM, D. B. LONG, J. W. FISCHER, S. R. SWAFFORD, and T. A. CAMPBELL. 2011. Evaluation of fences for containing feral swine under simulated depopulation conditions. Journal of Wildlife Management. 75: 1200-1208.

NICHOLS, T., T. SPRAKER, T. GIDLEWSKI, J. POWERS, G. TELLING, K. VERCAUTEREN, and M. ZABEL. 2012. Detection of prion protein in the cerebrospinal fluid of elk (Cervus Canadensis nelson) with chronic wasting diseases using protein misfolding cyclic amplification. Journal of Veterinary Diagnostic Investigation 24:746-749.

PELED, N., R. IONESCU, P. NOL, O. BARASH, M. MCCOLLUM, K. VERCAUTEREN, M. KOSLOW, R. STAHL, J. RHYAN, and H. HAICK. 2012. Detection of volatile organic compounds in cattle naturally infected with mycobacterium bovis. Sensors and Actuators B: Chemical 171-172:588-594.

SAUNDERS, S. E., J. C. BARTZ, K. C. VERCAUTEREN, and S. L. BARTELT-HUNT. 2011. An enzymatic treatment of soil-bound prions effectively inhibits replication. Applied and Environmental Microbiology. 77:4313-4317.

SAUNDERS, S. E., J. C. BARTZ, K. C. VERCAUTEREN, and S. L. BARTELT-HUNT. 2010. Enzymatic digestion of chronic wasting disease prions bound to soil. Environmental Science and Technology. 44:4129-4135.

VERCAUTEREN K. C., J. L. PILON, P. B. NASH, G. E. PHILLIPS, and J. W. FISCHER. 2012. Prion Remains Infectious after Passage through Digestive System of American Crows (Corvus brachyrhynchos). PLoS ONE 7(10): e45774. doi:10.1371/journal.pone.0045774

VERCAUTEREN, K., M. LAVELLE, T. GEHRING, and J. LANDRY. 2012. Cow dogs: use of livestock protection dogs for reducing predation and transmission of pathogens from wildlife to cattle. Applied Animal Behaviour Science. 140:128-136.

WALTER, W. D., J. BERINGER, L. P. HANSEN, J. W. FISCHER, J. J. MILLSPAUGH, and K. C. VERCAUTEREN. 2011. Factors affecting space use overlap by white-tailed deer in an urban landscape. International Journal of Geographic Information Systems 25:379-392.

WALTER, W. D., C. W. ANDERSON, R. SMITH, M. VANDERKLOK, J. J. AVERRILL, and K. C. VERCAUTEREN. 2012. On-farm mitigation of transmission of tuberculosis from white-tailed deer to cattle: literature review and recommendations. Veterinary Medicine International. 2012:616318. DOI:10.1155/2012/616318.

WHITE, S. N., K. I. O'ROURKE, T. GIDLEWSKI, K. C. VERCAUTEREN, M. R. MOUSEL, G. E. PHILLIPS, and T. R. SPRAKER. 2010. Increased risk of chronic wasting disease in Rocky Mountain elk associated with decreased magnesium and increased manganese in brain tissue. Canadian Journal of Veterinary Research 74: 50-53.

Major Research Accomplishments:

- WS and colleagues developed a method for collecting and analyzing volatile organic compounds from the exhaled breath of cattle. This technique could form the basis for a real-time cattle monitoring system that allows for the non-invasive screening of bovine TB infections in cattle.
- WS determined that prions and thus diseases like CWD and scrapie can survive the crow digestive system. Consequently, a crow that scavenges on a CWD-positive carcass can potentially transport infective prions a long distance and deposit them via their feces in new locations.
- WS determined that CWD can be transmitted in deer via the inhalation of contaminated dust.
- WS discovered CWD-inoculated mice fed a cation-modified diet lived significantly longer than those on a normal rodent diet. A better understanding of the role of environmental metals, such as divalent cations, in the spread of CWD in deer and elk may lead to CWD therapies and prevention through dietary manipulation.

Wildlife Services

Protecting People
Protecting Agriculture
Protecting Wildlife

National Wildlife Research Center

FY 2012

Chemical and Metabolic Approaches for Minimizing Human-Wildlife Conflicts

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Major Cooperators

- APHIS Veterinary Services
- British Columbia Ministry of Forests and Range
- California Department of Food and Agriculture
- Case Western Reserve University
- Colorado State University
- Drexel University
- Island Conservation
- Karolinska Institutet (Sweden)
- Landcare Research (New Zealand)
- Monell Chemical Senses Center
- U.S. Department of Defense
- U.S. Department of the Interior Office of Insular Affairs
- U.S. Fish and Wildlife Service
- U.S. Geological Survey Patuxent Wildlife Research Center
- VetAgro Sup (France)

Groups Affected By These Problems

- Agricultural producers
- Consumers of agricultural products
- Industry groups
- State wildlife and natural resource managers

National Wildlife Research Center Scientists Use Chemistry to Resolve Wildlife Damage

Wildlife Services' (WS) National Wildlife Research Center (NWRC) is the only Federal research facility devoted exclusively to resolving conflicts between people and wildlife through the development of effective, selective, and socially responsible methods, tools, and techniques.

To help meet the increasing need for new, Federally-approved chemical tools for use in wildlife damage management, NWRC scientists design and test methodologies to identify, analyze, and develop new drugs, repellents, toxicants, and other chemically-based wildlife damage management tools. These methodologies are used to support U.S. Environmental Protection Agency (EPA) and U.S. Food and Drug Administration (FDA) registration requirements. NWRC scientists are experienced in a variety of scientific disciplines, including pharmacology, environmental fate, chemical synthesis, toxicology, chemical ecology, computer modeling and formulation chemistry.

Applying Science and Expertise to Wildlife Challenges

Biomarkers for Monitoring Wildlife Populations—One focus of NWRC research is the development of diagnostic methods in support of risk assessments and the management of wildlife diseases that may impact domestic animal and/or human health. Identifying the point of origin of contaminants and disease agents (e.g., wildlife) is a critical first step in developing management practices to ensure the safety of the food supply and protect animal health. For example, NWRC researchers discovered mallards infected with avian influenza (AV) produced feces with higher concentrations of acetoin (3-hydroxy-2-butanone) than non-infected mallards. Building on this finding, researchers trained biosensor mice to discriminate between healthy and AV-infected ducks on the basis of fecal odors. These results suggest that chemical and/or biosensor-based field monitoring of waterfowl population health could potentially be achieved.

In another study, breath samples collected from tuberculosis-infected and non-infected cattle were analyzed by gas chromatography/mass spectroscopy to determine chemical profiles. These profiles led to the development of diagnostic methods for identifying infected animals. These same data are being used to develop Linear Discriminant Analysis models for classifying infection status of cattle. Preliminary evaluation of an alternative breath analysis instrument called the NA-NOSE suggests that this commercially available technology is a promising tool for routine diagnosis.

Investigating Wildlife Chemical Ecology—NWRC responds to emerging pests and diseases by developing novel methods to reduce damage caused by herbivory. For example, to determine how black-tailed deer respond to the flavor, color, texture, and smell of plants while browsing, NWRC researchers offered captive and free-ranging deer rooted cuttings and seedlings of western redcedar with varying monoterpene content. Monoterpenes are chemicals found in conifer plants that have a repellent effect on foraging mammals. Experiments demonstrated that browse preference for individual western redcedar plants was a function of the amount of monoterpene in the leaves of the plants. Researchers note that sense of smell may play a significant role in both fine- and coarse-scale browse behaviors of deer as they employ a risk-averse foraging strategy. This information may prove useful for developing "browse-resistant" seedlings for reforestation efforts.

Evaluating Chemical Agents to Improve Toxicant Efficacy and Minimize Secondary Hazards—In response to a need for safer toxicants, NWRC researchers are exploring chemical, biochemical, toxicological, and molecular biological techniques for evaluating existing and novel chemical agents. These agents may aid in the development of

novel toxicants or improve existing toxicants while also reducing environmental hazards. NWRC researchers are also investigating ways to lower pesticide concentrations in rodenticides and other baits in order to reduce the amount of these compounds in the environment.

Voles cause significant damage to agricultural crops in California—Both chlorophacinone and zinc phosphide are registered as rodenticides to help control vole populations in California. NWRC studies include efforts to increase the effectiveness of these rodenticides while also lowering pesticide concentrations. Recently, NWRC researchers micro-encapsulated zinc phosphide to prevent oral detection and bait shyness of the rodenticide by voles. This enabled researchers to also reduce the concentration of zinc phosphide in baits from 2 to 0.5 percent. Significant vole mortality was still achieved at this lower concentration.

In certain areas, voles have become resistant to chlorophacinone bait. NWRC researchers are working to improve the bait's effectiveness by investigating natural products and inert ingredients as possible inhibitors of chlorophacinone metabolism in voles. Five compounds ranged in their ability to inhibit the metabolism of chlorophacinone from 2.5 to 36 percent. Of these, two were selected for further testing and were found to be more effective in female than male voles at all concentration ranges tested. Future studies will focus on combining the inhibitors with chlorophacinone baits to increase bait effectiveness.

Providing Analytical Support to Wildlife Services—NWRC's Analytical Chemistry Laboratory provides support for all research projects being conducted at the Center's headquarters in Fort Collins, Colorado, the Center's field stations located throughout the United States, and WS operational programs. This chemistry assistance supports a variety of research topics, including avian infertility; bovine tuberculosis; rabies; wildlife hazards to aviation; wildlife damage to forest resources; bird damage to rice, sunflowers, and aquaculture; and waterfowl disease.

Selected Publications:

HOMAN, H. J., R. S. STAHL, and G. M. LINZ. 2011. Comparing a bioenergetics model with feeding rates of caged European starlings. J. Wildl. Manage. 75:126-131.

HUSSEY, A. M., B. A. KIMBALL, and J. M. FRIEDMAN. 2011. Assessment of tannin variation in tamarisk foliage across a latitudinal gradient. Open Environ. Biol. Monitor. J. 4:32-35.

KIMBALL, B. A., J. H. RUSSELL, and P. K. OTT. 2012. Phytochemical variation within a single plant species Influences Foraging Behavior of Deer. Oikos. 121:743-751.

KIMBALL, B. A., F. PFUND, M. GOURLEY, D. L. GRIFFIN, and J. H. RUSSELL. 2011. Silvicultural attempts to induce browse resistance in conifer seedlings. Int. J. For. Res. Article ID 108529.

RATTNER, B. A., K. E. HORAK, S. E. WARNER, D. D. DAY, C. U. METEYER, S. V. VOLKER, J. D. EISEMAN, and J. J. JOHNSTON. 2011. Acute toxicity, histopathology, and coagulopathy in American kestrels (Falco sparverius) following administration of the rodenticide diphacinone. Environ. Toxicol. Chem. 30(5):1213-1222.

RATTNER, B. A., K. E. HORAK, R. S. LAZARUS, K. M. EISENREICH, C. U. METEYER, S. F. VOLKER, C. M. CAMPTON, J. D. EISEMANN, and J. J. JOHNSTON. 2012. Assessment of toxicity and potential risk of the anticoagulant rodenticide diphacinone using Eastern screech-owls (*Megascops asio*). Ecotoxicology. 21(3):832-46.

Major Research Accomplishments:

- WS developed a physiologically-based pharmacokinetic model for anticoagulant rodenticides. The model will aid in the development of new rodenticides that minimize tissue residue levels in target animals, thus minimizing risks to non-target species.
- WS research found that encapsulated zinc phosphide resulted in 80-percent vole mortality when formulated at 0.5 percent, a significantly lower concentration than the 2 percent that is currently being used.
- WS experiments demonstrated that deer browse preference for individual western redcedar plants was a function of the amount of monoterpene in the leaves of the plants. Seedlings bred for elevated monoterpene content are currently being tested in field studies.
- WS research led to the development of a field monitoring method for detecting low pathogenic avian influenza in waterfowl.
- WS developed a method for collecting and analyzing volatile organic compounds associated with tuberculosis infection in the exhaled breath of infected cattle.
- WS developed a method for aging double-crested cormorants by determining the concentrations of pentosidine and hydroxyproline in skin samples.
- WS research identified two compounds that show promise in improving the efficacy of rodenticide bait for use with voles.

Wildlife Services

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National Wildlife Research Center

FY 2012

Product Registration: Providing Tools for Wildlife Services

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Major Cooperators

- Association of Fish and Wildlife Agencies
- International pesticide product developers
- Private pesticide and repellent registrants
- State pesticide regulatory agencies
- State wildlife management agencies
- U.S. Fish and Wildlife Service
- Wildlife Services Operations

Groups Affected By These Problems

- Farmers, ranchers, and livestock producers
- Federal, State, and private natural resource managers
- Urban and suburban residents

National Wildlife Research Center Maintains Chemical Tools for Wildlife Damage Management

The NWRC Registration Unit serves many roles within Wildlife Services (WS), but the majority of its work is focused in three general areas. First, the Registration Unit provides regulatory guidance to NWRC management and scientists on product development. Second, it assists WS Operations personnel with regulatory issues for using chemical control methods to manage wildlife damage. Third, as part of the WS Pesticide Coordinating Committee (PCC), the Registration Unit works closely with other committee members, including APHIS' Policy and Program Development, Environmental and Risk Analysis Services office, WS Operational Support Staff, and the Pocatello Supply Depot to ensure APHIS chemical-based vertebrate pest management tools are current and meet State and Federal regulations.

APHIS holds product registrations with the U.S. Environmental Protection Agency (EPA) for rodenticides, predacides, avicides, repellents, a snake toxicant, an avian repellent and a contraceptive vaccine. APHIS also holds Investigational New Animal Drug (INAD) applications with the U.S. Food and Drug Administration (FDA) for immobilizing agents used in animal damage management. To maintain or expand authorized use of these products, the Registration Unit works closely with NWRC scientists to ensure that studies conducted for regulatory purposes meet EPA and FDA guidelines.

In addition to these primary functions, the Registration Unit also provides technical and regulatory assistance and information to state WS programs, Federal and State agricultural and conservation agencies, academic institutions, non-governmental groups, and private industry. Many of the requests for assistance come from WS Operations personnel seeking new products or improvements to existing products, or looking for help interpreting product labels to ensure proposed applications are legal.

Applying Science and Expertise to Wildlife Challenges

APHIS Pesticide Product Registrations—APHIS currently holds registrations through the EPA for eleven active ingredients formulated into 23 Federally-registered vertebrate pesticide products. These products meet the needs of bird management (five avicide products and one avian repellent), rodent management (11 rodenticide products), predator management for livestock and threatened and endangered species protection (four predacide products), brown treesnake management on Guam (one toxicant), and white-tailed deer, wild horse and wild burro management (a contraceptive vaccine for reducing fertility). In addition, APHIS maintains two INAD permits with the FDA. These INADs allow WS employees to use immobilizing agents when removing problem birds from urban areas and for sedating coyotes and wolves captured during research activities.

Rodenticides—Rodenticide issues continue to be a large focus of the NWRC. With the EPA's rodenticide risk mitigation measures becoming fully implemented in 2012, the array of products available for commensal and agricultural uses is becoming more restricted. To meet the changing market, the NWRC is working closely with private rodenticide manufacturers to investigate new product chemistries or use patterns that will fill the void created by the impact of EPA's mitigation measures. A top priority for this effort is to focus on formulations and uses that minimize the impact on nontarget species and the environment. The NWRC helps to assess the registration potential of rodenticide developments and acts as the liaison between regulators and product developers.

The NWRC serves as the primary WS contact for registration issues related to eradicating rodents from islands for the protection of threatened and endangered species and critical habitats. Since securing three rodenticide registrations in 2007 for this purpose, the NWRC has provided regulatory guidance or direct assistance on nine rodent eradication

projects in the Pacific and the Caribbean regions to protect nesting seabirds and unique island habitats. Many of these projects involved working with the EPA to secure product labeling appropriate for the conditions of each eradication project.

In 2011, the NWRC was an integral part of the largest environmental monitoring effort conducted in conjunction with a U.S. Fish and Wildlife Service-sponsored rodent eradication effort. The eradication project occurred on Palmyra Atoll and employed a rodenticide application rate nearly six times higher than currently allowed on approved product labels. The goal of the eradication effort was to enhance the biodiversity of seabirds, native plants and terrestrial invertebrates on the atoll by removing invasive rats. NWRC scientists evaluated the overall impact of the eradication effort on nontarget species and the environment by measuring the application rate and bait distribution on the ground following aerial application and documented the fate of bait, collected carcasses of potential nontarget mortalities, and systematically collected soil, water, insects, geckos, fish, and crabs to determine environmental residue levels.

NWRC continues to coordinate a consortium of private companies who register zinc phosphide-based rodenticide products. Collectively, this consortium gathers data to maintain EPA registrations of zinc phosphide rodenticides and works to develop appropriate precautionary language on product labels. The consortium has saved WS hundreds of thousands of dollars and saved consortium members millions of dollars by consolidating EPA data requirements and providing clarifying information.

Bird Management Tools—DRC-1339 (Starlicide) continues to be a valuable tool for managing damage caused by birds. APHIS holds EPA registrations for five DRC-1339 based products that are used to manage damage caused by blackbirds and invasive European starlings at feedlots and agricultural fields, gulls at landfills, pigeons roosting on structures, and crows and ravens preying on livestock and threatened and endangered species. In 2012, the EPA began reevaluating DRC-1339 data and product labels under their Registration Evaluation program. As a result of this evaluation, EPA asked APHIS and the other DRC-1339 registrant (Virbac Animal Health) to provide more than 20 new data submissions in areas of terrestrial and aquatic toxicology, environmental persistence and human health and safety. If ultimately required, these data submissions would cost the U.S. Government and the other private registrant nearly $2.3 million. In response to this request, the NWRC assembled and submitted to EPA existing published and unpublished data, waiver requests and drafted new product label language in an effort to reduce the registration costs.

Over the past decade, the NWRC has responded to an increasing number of requests from WS operational staff for new control tools for addressing crow, raven and blackbird damage problems. As a result, the number of State-specific DRC-1339 registrations has increased to more than 25. In an effort to reduce the administrative burden associated with this high volume of product registrations and to provide WS operational staff with greater flexibility in using DRC-1339 to address crow, raven and blackbird problems, the NWRC and PCC submitted a new product label allowing greater flexibility for use in feedlots. NWRC and PCC are also working to include these uses on the label used to protect field crop, endangered species, and human health and safety.The NWRC also provides significant guidance to scientists and private industry on the development of anthraquinone and currently registered fungicides for avian repellent uses. Current projects are aimed at developing chemical repellents for seed treatment and foliar applications in corn, sunflower, and rice.

Wildlife Contraceptives—The NWRC is a world leader in the development of effective wildlife contraceptives. In 2009, NWRC researchers successfully registered with the EPA the first immunocontraceptive vaccine for use in wildlife when they registered GonaCon™ Immunocontraceptive Vaccine (GonaCon) as single-shot, multi-year vaccine for female white-tailed deer. GonaCon promises to be useful for managing not only urban white-tailed deer where traditional options are limited, but also populations of other species. In January 2013, the EPA registration for GonaCon was expanded to include wild and feral horses and burros. Research has shown GonaCon to be an effective reproductive inhibitor in these species as well as elk, bison, prairie dogs, ground squirrels, and feral dogs and cats. NWRC and its collaborators are investigating the use of GonaCon for reducing the spread of rabies in feral dogs and raccoons, preventing adrenocortical disease in pet ferrets, and preventing the spread of brucellosis in bison. The vaccine is being used for research purposes in the United States, Mexico, Europe, New Zealand, and Australia. Future NWRC research with GonaCon likely will involve studies to support expanded registration to other species, to develop oral delivery systems, and to prevent transmission of wildlife diseases.

Registration of Predacides—APHIS holds four registrations for using sodium cyanide and sodium fluoroacetate (Compound 1080) as predacides. These products are used at the request of ranchers to protect livestock from coyote predation or at the request of conservation organizations for protecting threatened, endangered or economically important species. These compounds are currently being reviewed by the EPA for the adequacy of supporting data and product label restrictions. Given the volume of data APHIS submitted to EPA in response to the 2007 petition to cancel these products and the new restrictions imposed at that time, the NWRC does not anticipate new regulatory actions resulting from EPA's current review of these products.

Given the societal concerns around the use of the traditional predacides described above, the NWRC is investigating new compounds in a search for safer, more humane predacides. In 2011, NWRC began collaborating with a private Australian company to investigate the possibility of developing the compound para-aminopropiophenol (PAPP) as a predacide. PAPP was originally developed in the 1960s as an antidote for human radiation poisoning. In historical pharmaceutical trials, PAPP was found to be specifically more toxic to carnivores than to birds and humans. PAPP is currently registered in New Zealand for the control of stoats and feral cats. Initial product development efforts on PAPP in the United States are ongoing.

Development of a Feral Swine Toxicant—Feral swine are an increasing problem in the United States and around the world. They destroy native vegetation, prey on wildlife and livestock, and transmit diseases to humans and livestock. WS is pursuing an EPA registration of sodium nitrite for use as a feral swine toxicant. Sodium nitrite is a preservative for pork and other meats that happens to be toxic to live swine. NWRC signed a Cooperative Research and Development Agreement with the Invasive Species Cooperative Research Centre in Australia to share existing Australian registration data that may be appropriate to support an EPA product registration. Additionally, NWRC is conducting laboratory studies with sodium nitrite to gather acute oral avian toxicology, avian dietary toxicology, and end-product toxicology data. Field studies on various delivery systems are being conducted in Texas with future efforts planned for Mississippi, Florida, Michigan, and Missouri. This partnership will save APHIS

hundreds of thousands of dollars in EPA registration data development costs. A private Australian company has also partnered with NWRC to provide funding to investigate sodium nitrite as a rodenticide.

International Activities—NWRC helps to transfer WS products and technologies to countries around the world. Over the past 3 years, the NWRC has worked with the governments of American Samoa, Israel, New Zealand, and Australia to improve their ability to manage pest bird populations using DRC-1339 products. The NWRC is also working with Australia, New Zealand, England, and Mexico to transfer wildlife contraceptive technology. Collaborative work with Canada, New Zealand, and numerous small Pacific Island nations has aided in their efforts to use rodenticides as a conservation tool to protect off-shore islands.

Information Sharing: Environmental Risk Assessment and New Management Tools—In 2011, NWRC launched an online searchable NWRC Chemical Effects Database containing historical data for approximately 7,000 chemicals analyzed and evaluated for repellency, toxicity, reproductive inhibition and immobilization on a variety of plants, birds, mammals, and amphibians. The database is useful to researchers worldwide who are involved in environmental risk assessments and the development of new damage management tools.

Selected Publications:

AVERY, M. L., J. D. EISEMANN, K. L. KEACHER, and P. J. SAVARIE. 2011. Acetaminophen and zinc phosphide for lethal management of invasive lizards Ctenosaura similis. Current Zoology 57:625-629.

EISEMANN, J. D., S. J. WERNER, and J. R. O'HARE. 2011. Registration considerations for chemical bird repellents in fruit crops. Outlooks on Pest Management 22:87-91.

ENGEMAN, R. M., W. C. PITT, A. R. BERENTSEN and J. D. EISEMANN. 2012. Assessing spatial variation and overall density of aerially broadcast toxic bait during a rat eradication on Palmyra Atoll. Environ Sci Pollut Res Int. DOI 10.1007/s11356-012-1050-6.

LAPIDGE, S. J., J. WISHART, L. STAPLES, K. A. FAGERSTONE, T. A. CAMPBELL, and J. D. EISEMANN. 2012. Development of a Feral Swine Toxic Bait (Hog-Gone®) and Bait Hopper (Hog-Hopper™) in Australia and the USA. Pages 19-24 in S. N. Frey, editor. Proceedings of the Fourteenth Wildlife Damage Management Conference, Nebraska City, NE. The Wildlife Damage Management Working Group of The Wildlife Society.

RATTNER, B. A., K. E. HORAK, R. S. LAZARUS, K. M. EISENREICH, C. U. METEYER, S. F. VOLKER, C. M. CAMPTON, J. D. EISEMANN, and J. J. JOHNSTON. 2012. Assessment of toxicity and potential risk of the anticoagulant rodenticide diphacinone using Eastern screech-owls (Megascops asio). Ecotoxicology 21:832-846.

RATTNER, B. A., K. E. HORAK, S. E. WARNER, D. D. DAY, C. U. METEYER, S. F. VOLKER, J. D. EISEMANN, and J. J. JOHNSTON. 2011. Acute toxicity, histopathology, and coagulopathy in American kestrels (Falco sparverius) following administration of the rodenticide diphacinone. Environmental Toxicology and Chemistry 30:1213-1222.

Major Registration Accomplishments:

- APHIS was granted an EPA registration for the use of the GonaConTM Immunocontraceptive Vaccine to manage fertility in wild and feral horses and burros. WS continues to conduct research to expand the vaccine's registration to other species.
- WS was an integral part of the largest environmental monitoring effort conducted for a U.S. rodent eradication effort on Palmyra Atoll (a remote island in the Pacific Ocean, approximately 1,000 miles south of Hawaii).

Vertebrate Control Products Currently Registered or Approved for Use by USDA APHIS				
Taxa	**APHIS Products**	**Mode of Action**	**Species**	**Uses Unique to APHIS**
RODENTS	Zinc Phosphide (3 products)	Lethal	Voles, mice, rats, hares, woodchucks, ground squirrels, muskrats, nutria, prairie dogs	Some
	Strychnine (4 products)	Lethal	Pocket gophers	No
	Gas Cartridge (1 product)	Lethal	Prairie dogs, ground squirrels, woodchucks, marmots	No
	Diphacinone (1 product)	Lethal	Invasive rodents on islands	Yes
	Brodifacoum (2 products)	Lethal	Invasive rodents on islands	Yes
CANINE PREDATORS	Large Gas Cartridge (1 product)	Lethal	Coyotes, red foxes, striped skunks	Yes
	M-44 Cyanide Capsules (2 products)	Lethal	Coyotes, red foxes, gray foxes, arctic foxes, feral dogs	Some
	Livestock Protection Collar Compound 1080	Lethal	Coyotes	Yes
	Tranquilizer Trap Device	Non-lethal Immobilizing Agent	Wolves, coyotes, feral dogs	Yes
CERVIDS	GonaCon Immunocontraceptive Vaccine	Non-lethal Contraceptive	White-tailed deer, wild horses and burros	Yes
BIRDS	Compound DRC-1339 Concentrate (4 labels)	Lethal	Gulls, pigeons, ravens, crows, magpies, starlings, blackbirds	Yes
	Compound DRC-1339 Concentrate—Feedlots	Lethal	Blackbirds, starlings, grackles, cowbirds	Some
	Mesurol Aversive Conditioning Egg Treatment	Non-lethal	Crows, ravens	Yes
	Alpha-chloralose	Non-lethal	Geese, ducks, coots, pigeons, ravens	Yes
	Corn Oil	Non-Lethal	Canada geese	No
SNAKES	Acetaminophen	Lethal	Brown treesnakes	Yes
	Cinnamon, Clove and Anise Oil	Non-lethal Repellent	Snakes	No