United States Department of Agriculture
Animal and Plant Health Inspection Service
Miscellaneous Publication No. 1606

Innovative Solutions to Human–Wildlife Conflicts

National Wildlife Research Center Accomplishments, 2009

U.S. Department of Agriculture
Animal and Plant Health Inspection Service
Wildlife Services

National Wildlife Research Center
4101 LaPorte Ave.
Fort Collins, CO 80521–2154
http://www.aphis.usda.gov/wildlife_damage/nwrc

Main Telephone Number:
(970) 266–6000
FAX: (970) 266–6032

Information Services:
(970) 266–6015
FAX: (970) 266–6010
e-mail: nwrc@aphis.usda.gov

Animal Care:
(970) 266–6204

Major Research Areas:
(970) 266–6000
Agriculture and Resource Protection
Invasive Species
Technology Development
Wildlife Diseases

cover photo
Free-ranging populations of wild pigs (also called feral swine) cause extensive damage to field crops such as corn, milo, rice, watermelon, peanuts, hay, turf, and wheat.
(APHIS/NWRC, Laurie Paulik)

NWRC Field Stations:

Bismarck, ND
(701) 250–4467
FAX: (701) 250–4408

Corvallis, OR
(541) 737-1353
(Formerly Olympia, WA)

Gainesville, FL
(352) 375–2229
FAX: (352) 377–5559

Hilo, HI
(808) 961–4482
FAX: (808) 961–4776

Kingsville, TX
(361) 593–2426
FAX: (361) 593–4311

Logan, UT
(435) 797–2505
FAX: (435) 797–0288

Millville, UT
(435) 245–6091
FAX: (435) 245–3156

Philadelphia, PA
(267) 519-4930
FAX: (267) 519-4930

Sandusky, OH
(419) 625-0242
FAX: (419) 625-8465

Starkville, MS
(662) 325-8215
FAX: (662) 325-8704

The U.S. Department of Agriculture (USDA) prohibits discrimination in all its programs and activities on the basis of race, color, national origin, age, disability, and where applicable, sex, marital status, familial status, parental status, religion, sexual orientation, genetic information, political beliefs, reprisal, or because all or part of an individual's income is derived from any public assistance program. (Not all prohibited bases apply to all programs.) Persons with disabilities who require alternative means for communication of program information (Braille, large print, audiotape, etc., should contact USDA's TARGET Center at (202) 720–2600 (voice and TDD). To file a complaint of discrimination, write to USDA, Director, Office of Civil Rights, 1400 Independence Avenue, S.W., Washington, D.C. 20250–9410, or call (800) 795–3272 (voice) or (202) 720–6382 (TDD). USDA is an equal opportunity provider and employer.

Mention of companies or commercial products does not imply recommendation or endorsement by USDA over others not mentioned. USDA neither guarantees nor warrants the standard of any product mentioned. Product names are mentioned solely to report factually on available data and to provide specific information.

This publication reports research involving pesticides. All uses of pesticides must be registered by appropriate State and/or Federal agencies before they can be recommended.

CAUTION: Pesticides can be injurious to humans, domestic animals, desirable plants, and fish or other wildlife if they are not handled or applied properly. Use all pesticides selectively and carefully. Follow recommended practices for disposal of surplus pesticides and pesticide containers.

Issued July 2010

Message From the Director

These are trying times for research institutions across the globe, and the National Wildlife Research Center (NWRC) is no exception. With the current state of our Nation's economy, funding remains tight for all organizations—both inside and outside government—and we daily face the challenges of how to stretch budgets to accomplish our work in the most cost-effective way possible. Despite these challenges, the research and support staffs at the NWRC have once again risen to the occasion, demonstrating their commitment to the mission of the program. It is a pleasure to lead an organization whose energy, productivity, impact, and commitment remain resolute in lean times and prosperous times.

Though the Center's staff is relatively small (about 170 employees), our work has national and global impacts. The staff is able to leverage its broad range of skills not only through collaborations with each other, but also with scientists from other organizations within the United States and abroad. On average in 2009, each of the Center's 15 research projects involved collaboration with 9 Wildlife Services' State operational programs, 10 other government or private organizations, and 5 universities. This is a testament to the high energy level and reputation of the Center's scientists, as we have seen an increasing desire from other organizations to partner with us on research projects.

Through our collaborative work this year, the Center has made significant contributions in the areas of agricultural crop protection, aviation risk assessment and safety, invasive species, and wildlife disease diagnostics and ecology. Examples of this work include:

- In collaboration with the private sector, NWRC scientists have been key partners in the development of lighting systems for aircraft to increase alerting and escape behavior in birds to reduce bird-aircraft collisions.
- Working closely with other Federal labs and universities, NWRC scientists have improved disease and pathogen diagnostic methods in wildlife, such as remote thermography for the detection of febrile animals and improved water sampling systems for the detection of avian influenza.
- Cooperating with academic and State agency partners, NWRC scientists have developed better understanding of complex trophic interactions among animals in ecosystems. While it is more straightforward to understand an individual species' impact on commodities or activities, the effects in complex ecosystems are less straightforward. For instance, invasive species such as coqui frogs are not only a nuisance because of noise, but also impact the structure of native insect communities. Loss of these insects then impacts the structure of the soil and surface substrates of an ecosystem, which in turn affects vegetation.

As we review the events of the past year, it is essential that we also look ahead. The methods we use to address human-wildlife conflicts must evolve to continue to meet new challenges facing U.S. animal and ecosystem health. In carrying out this work, NWRC is committed to:

Developing strategically smart surveillance systems. Wildlife disease biosecurity and risk assessments will be an area of expanded activity for NWRC research. These efforts will focus on developing optimal surveillance systems and identifying practical, cost-effective management options.

Environmentally sensitive approaches to agricultural sustainability. Agricultural sustainability is a high priority for APHIS. When it comes to crop damage, reducing the levels of pesticides needed to minimize damage and loss caused by rodents and birds will be a critical area of NWRC research and development.

Reducing reliance on animal models in product development. While 75 percent of the research conducted at the NWRC is geared toward nonlethal methods, the remaining work on lethal pesticide development is vital for the protection of human health and agricultural production. APHIS is committed to minimizing the use of whole animal models while fulfilling its obligation to meet regulatory guidelines. We will continue to explore *in vitro* cell culture or other model systems for product development, toxicity testing, and registration support.

Understanding the economic impacts of wildlife damage. We will continue to quantify the types of direct and indirect damage associated with wildlife damage management. This information aids in the prioritization of APHIS resources to address human-wildlife conflicts.

Improving technology transfer. We will continue to deliver and transfer technology to the private sector to ensure that the methods developed by our laboratories are made available as practical management tools for responsible organizations and enterprises.

Fiscal accountability. Federal budgets are under pressure, as is the case for the academic and private sectors. We will continue to improve the cost efficiency of research and development by leveraging resources with our partners.

It is my privilege to introduce the NWRC's accomplishments for 2009.

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

Contents

Introduction

The mission of the National Wildlife Research Center (NWRC) is to apply scientific expertise to resolve human-wildlife conflicts while maintaining the quality of the enviroment shared with wildlife.

NWRC researchers evaluated the effectiveness of adding a molasses-baited electric fence to an existing woven-wire fence to reduce fence-line contact between elk. *(APHIS/NWRC, Justin Fischer)*

National Wildlife Research Center

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

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

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

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

NWRC research falls under four principal areas that reflect APHIS' commitment to "protecting agricultural and natural resources from agricultural animal and plant health threats, zoonotic diseases, invasive species, and wildlife conflicts and diseases"[1]:

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

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

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

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

In addition to the four main research areas, the NWRC maintains several support functions, including animal care, administration, information transfer, archives, quality assurance, facility development, and legislative and public affairs.

[1] *From APHIS Strategic Plan (2007-2012).*

Construction Update

NWRC's 43-acre headquarters campus is located on the Foothills Research Campus of Colorado State University (CSU) in Fort Collins, CO. During fiscal year (FY) 2009, several planning and design activities took place related to completing the Master Plan for NWRC headquarters. (The NWRC Master Plan describes the buildings and other facilities proposed for the Center's Fort Collins, CO, headquarters campus; the plan was created and implemented in the 1990s, and the campus is now nearing completion.)

Wildlife Disease Research Building

Wildlife Services is in the final planning stage to construct a new biosafety level 3-Agriculture (BSL-3 Ag) research facility, called the Wildlife Disease Research Building (WDRB), at NWRC headquarters in Fort Collins, CO. This proposed 16,000 square-foot building will greatly expand Wildlife Services' ability to respond to emergencies and resolve important issues involving livestock and/or human diseases that are transmitted to wildlife. The WDRB will be the last major building constructed according to the Master Plan for NWRC headquarters.

To support both experimental and field investigations, the WDRB will include a complete laboratory infrastructure and animal testing capability that provides support for diagnostics methods development, vaccine development, risk assessments, and wildlife disease surveillance and monitoring activities. The diagnostic methods development function will include rapid diagnostics for wildlife diseases, such as avian influenza, rabies, tuberculosis, and West Nile virus.

In addition, other activities at the new facility will focus on the development of diagnostic and screening assays for multiple diseases from single samples. The WDRB will have expanded capabilities for high throughput testing (robotic processing) and controlled biosafety environments. These capabilities will enable NWRC to process large numbers of samples for multiple diseases in surveillance and monitoring efforts.

The WDRB will expand NWRC's small, existing BSL-3 wildlife disease research capabilities and increase opportunities for collaborative research with universities and other organizations. The "Ag" designation in the BSL-3 description of the WDRB indicates that each animal room is being designed as primary containment for diseased animals, meaning the animals can roam free in the rooms and/or be contained in open cages; neither of these situations is allowed in standard BSL-3 containment structures. The WDRB will include BSL-3 laboratories, four large BSL-3 Ag animal holding and testing suites, and other ancillary support spaces for wildlife disease research purposes. The animal rooms will be capable of housing animals as large as deer and feral swine.

The WDRB will be owned by a private developer and leased to APHIS through the General Services Administration (GSA). The concept design of the WDRB was completed in August 2009. In partnership with GSA, a formal solicitation for offers from private developers began in May 2009. The final design, development of construction documents, final commissioning and approval, and actual construction of the WDRB building will take approximately 2 to 3 years after the award is made. The estimated completion date for the WDRB building is FY 2012-13.

Overview of NWRC Research

NWRC research focuses on agriculture and resource protection, technology development, wildlife diseases, and invasive species.

Xenarc™ high-intensity discharge lamp used in a recent study at the NWRC's Ohio field station in which vehicle lighting was evaluated relative to the initiation of avoidance behavior by free-ranging, white-tailed deer in response to vehicle approach. *(APHIS/NWRC, Thomas Seamans)*

Agriculture and Resource Protection

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

Aviation Safety

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

Enhancing the Perceived Threat of Vehicle Approach to Deer. In semi-controlled experiments with free-ranging white-tailed deer, NWRC scientists in Sandusky, OH, tested how the spectrum from two currently available automobile lighting systems might alert deer to approaching vehicles. Most cars are equipped only with tungsten-halogen (TH) lamps, which may not be a strong enough spectrum for deer to see at night. Scientists measured the flight-initiation distance of white-tailed deer to an approaching vehicle relative to lighting scenarios involving standard TH lamps alone and in combination with a Xenarc™ high-intensity discharge (HID) lamp set to constant illumination or pulsed. Numerous trials were conducted at various times during the night and seasonally to ascertain which lighting scenario was most effective. Scientists found that a combination of TH lamps and constant illumination of an HID lamp increased the distance at which white-tailed deer reacted to an approaching vehicle by as much as 20 meters. These findings could aid in the development of new vehicle lighting systems that enhance deer detection of approaching vehicles and, thus, lower the number of deer-vehicle collisions occurring in the United States and abroad.

Avian Visual System Configuration and Behavioral Response to Object Approach. The ways in which birds respond to approaching objects is critical when it comes to their ability to detect predators, forage, flock, and avoid collision with static or moving structures (e.g., automobiles, aircraft, and wind turbines). Biologists measured responses by brown-headed cowbirds and mourning doves to an approaching ground-based vehicle with a vehicle lighting regimen and examined the visual system properties of both species. Results indicated that vehicle lighting can influence avoidance behavior by cowbirds, and that their reactions to vehicle approach and light treatments were affected by ambient light. Avoidance behavior by doves was not affected by light treatments, although doves became alert more quickly (on average by 3.3 seconds) than cowbirds. These findings provide insight on how object lighting might be used to reduce bird-structure/vehicle collisions, an increasing source of mortality in birds.

Investigation Into Earthworm Control at Airports. Earthworms, though generally considered beneficial for soil conditioning, can become a hazard at airports. When found in large numbers on runways or taxiways after heavy rainfall, they create slippery

conditions for aircraft rolling over them. Additionally, earthworms attract birds, especially gulls, thereby increasing the risk of bird strikes to aircraft that are landing or taking off. In the United States, no pesticides are registered for earthworm control. NWRC is conducting trials at its Sandusky, OH, field station to develop simple procedures using naturally occurring products to reduce earthworm numbers on runways and taxiways. In laboratory trials, ground mustard mixed with a physical irritant (e.g., coal slag) has shown promise in keeping worms off of treated plots.

Using Satellite Telemetry To Reduce Risk of Osprey Collisions With Military Aircraft. A true conservation success story, osprey populations in North America have staged a dramatic recovery during the past few decades to the point that breeding populations of osprey adjacent to military airbases and civil airports now pose a risk to aircraft. North American ospreys often migrate to their wintering areas in central and South America through numerous areas used by military aircraft. To learn more about the movements of ospreys and their risk to aviation safety, NWRC scientists captured 13 adult ospreys in Virginia and fitted them with solar-powered global positioning system (GPS) satellite transmitters. During fall 2008, ospreys traveled an average distance of 4,600 kilometers to their wintering grounds in the Caribbean or in South America. Female ospreys begin their fall migrations in August, whereas males typically began migrating in September. Scientists compared the flight characteristics and geographic routes of migrating ospreys with airspace areas used by the U.S. military to identify the time periods and locations when the risk of osprey-military aircraft collisions was greatest. The results from this study will assist in scheduling the timing and routing of military training flights to reduce the risk of osprey-aircraft collisions.

An example of a laboratory experiment testing whether naturally occurring products can prevent earthworms from crawling onto airport runways, where they often attract birds hazardous to aircraft. *(APHIS/NWRC, Thomas Seamans)*

NWRC scientists are using satellite telemetry to gain new insights into the breeding, migration, and wintering ecology of ospreys. Information from this research is being used to reduce the risk of osprey collisions with military aircraft. *(APHIS/NWRC, Brian Dorr)*

NWRC Hosts Media Event To Highlight Aviation-Related Research. On July 24, 2009, researchers at the Sandusky, OH, field station hosted a media event highlighting efforts to reduce wildlife hazards to aviation. The NWRC; FAA; Precise Flight, Inc; Purdue University; and Indiana State University are working collaboratively to learn more about how birds detect and respond to approaching objects. Results from experiments have direct implications for the design of aircraft lighting systems. Current efforts involve the field testing of lighting systems using small, remote-controlled planes and captive Canada geese. The news media were able to observe demonstrations of these research activities and interview researchers during the event.

For more information on NWRC aviation safety research, contact Dr. Travis DeVault at Travis.L.DeVault@aphis.usda.gov.

Aquaculture

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

Double-crested cormorants sitting on nest. *(APHIS/NWRC, Tommy King)*

Great Lakes Cormorant Management Program. NWRC, Wildlife Services' field operations, and USDA's Forest Service collaborated to reduce predation of sportfish by double-crested cormorants during the spring migration and nesting season at two locations in the Les Cheneaux Islands region of Lake Huron, MI. The management program enlisted designated agents to protect fishery resources through an integrated program of lethal measures (shooting), egg-oiling, and nonlethal methods. The agents receive training, supervision, and supplies from Wildlife Services and, in return, volunteer their time to harrass birds and disperse them from roosts. NWRC research documented an 83-percent decline in the numbers of cormorant foraging attempts and an increase in yellow perch and walleye abundance at locations where these management programs are in place. Management also resulted in a greater than 90 percent reduction in the number of young cormorants produced annually and a greater than 70 percent reduction in total cormorant numbers.

Movements of Double-Crested Cormorants Captured Near Aquaculture Facilities in the Southeastern United States. The numbers of double-crested cormorants wintering in the southeastern United States have increased dramatically during the last 30 years, at the same time as the rise of the aquaculture industry in this region. These cormorants commonly forage at commercial aquaculture facilities and, consequently, come into conflict with farmers. Various interest groups are seeking ecologically sound strategies for minimizing the negative effects of burgeoning cormorant populations.

NWRC researchers conducted a study to determine migration patterns and estimate winter and summer home ranges of 28 cormorants that were captured in the southeastern United States and fitted with satellite transmitters. The objectives were to determine the timing and routes of migration and find out if age, body mass, aquaculture facility density, and roost site availability influenced home range sizes.

Four cormorants (three immature, one adult) did not migrate and stayed in the southeastern United States throughout the year. In the spring, cormorants captured in Alabama migrated east of the Mississippi River and primarily west of the Appalachian Mountains. Cormorants from Arkansas, Louisiana, and Mississippi migrated north along the Mississippi River Valley, the Missouri River Valley, and/or the Ohio River Valley. The earliest departure for spring migration was March 26, whereas the latest departure was May 12. Adult cormorants

Cormorants are banded by NWRC staff as part of a population study. *(APHIS/NWRC, Tommy King)*

departed for spring migration earlier than immature cormorants. The average departure date for fall migration was October 1. The mean duration of spring migration was 12 days, and cormorants traveled an average of 70 kilometers (km) per day.

The mean home range size and core use area of satellite transmitter-marked cormorants wintering in the southeastern United States from 1999 to 2001 was 17,490 km^2 and 1,550 km^2, respectively. The size of winter home range was not affected by region, age class, or body mass. The summer home range and core use area of marked cormorants was 30,547 km^2 and 3,124 km^2 respectively. The results from this study will help aquaculture producers and resource managers refine resource allocations when managing cormorant populations and depredation.

Use of Fatty Acid Profiles To Identify 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 source of the farm-raised channel catfish in the diet. Biologists and chemists are continuing to investigate the possibility of using fatty acid analysis to assess the actual impact of fish-eating birds on catfish aquaculture and recreational fisheries.

Methods for Determining Age of 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. They also successfully developed a nonlethal technique to obtain samples of the biomarker from wild birds. This information may lead to a rapid technique for identifying the age of cormorants and many other species of birds without the need for more costly and logistically difficult methods. The technique may also be applicable across a wide range of wildlife, potentially providing a valuable resource in the conservation and management of species of societal concern.

For more information on NWRC aquaculture research, contact Dr. Fred Cunningham at Fred.R.Cunningham@aphis.usda.gov.

Agricultural Crop Protection

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

Evaluation of Flight Control® Plus as a Goose Repellent. Since the 1970s, the number of Canada geese and cackling geese wintering in the Willamette and Lower Columbia River Valleys of Oregon has increased from 25,000 to 300,000. While at these sites, the geese forage on agricultural crops, decreasing yields and ultimately causing negative economic impacts for landowners. During the November 2007 and February 2008 growing seasons, NWRC biologists evaluated the efficacy of Flight Control Plus (active ingredient is anthraquinone) as a goose repellent within crimson clover fields in western Oregon. Flight Control Plus was applied (9.4 liters) to emergent crimson clover seedlings using ground spray equipment. Scientists found no difference in the number of crimson clover seedlings within anthraquinone-treated versus untreated plots throughout the growing season. However, more goose pellets were found among untreated plots than anthraquinone-treated plots. Investigators detected up to 282 ppm (parts per million) and 478 ppm anthraquinone within treated plots subsequent to the November 2007 and February 2008 repellent applications, respectively. Residues declined to 17 ppm anthraquinone within treated plots 4 weeks after the February application and <1 ppm 5 to 6 weeks prior to harvest. No negative effects of anthraquinone seed treatments for crimson clover and winter wheat were observed during environment-controlled germination testing. Based on these findings, the scientists recommended additional field efficacy studies of anthraquinone-based goose repellents to develop cost-effective applications to assist western Oregon agricultural producers in managing goose damage.

For more information regarding NWRC research on bird damage to crops, contact Dr. George Linz at George.M.Linz@aphis.usda.gov.

Biologists evaluated the efficacy of Flight Control® Plus as a goose repellent within crimson clover fields in western Oregon. *(APHIS/NWRC, George Linz)*

Hawaii Bird Management in Seed Crops. Hawaii is a major location for producing seeds in order to breed and evaluate new strains and increase the number of selected varieties. Approximately 95 percent of the commercial seed crop produced in Hawaii is corn seed; the remaining 5 percent includes soybean, cotton, sunflower, and wheat. Birds are a major source of seed loss, plant destruction, and potential movement of viable seeds to other areas. Depredation of individual plants may result in the loss of many years of research costing millions of dollars. Another significant issue is when birds carry seeds off company property. To combat these losses, companies typically employ bird chasers who monitor plantings during daylight hours and chase away any birds that land. For a typical research seed farm of 80 acres, bird chasers may cost $500,000 annually. To help address these problems, NWRC biologists surveyed fields to identify the bird species responsible for damage, monitored birds to review the extent of the damage, and planted experimental plots to quantify the damage. The researchers' goal was to determine the extent of bird damage in seed crops (corn and soybean), develop a management plan for the Wildlife Services operational program in Hawaii to implement, and then evaluate the results of an operational control program.

Before control operations started, more than 1,400 rock doves, 1,300 spotted doves, 800 zebra doves, and 100 francolins were on a seed production farm on Maui at one time. Data gathered at experimental plots suggested that, in the absence of bird chasers, birds reduced the survival of soybean plants by more than 53 percent and corn plants by more than 43 percent. Most of the damage in experimental plots was caused by black and gray francolins. The operational control program greatly reduced the number of francolins and removed many doves. After the control program, francolin numbers decreased by 75 percent. After 9 months of operational control, birds damaged less than 1 percent of soybean and corn plants in the absence of bird chasers.

Black and gray francolins are a threat to corn and soybean seeds produced in the Hawaiian Islands. *(U.S. Geological Survey/National Biological Information Infrastructure, John J. Mosesso)*

For more information about NWRC research in Hawaii, contact Dr. Will Pitt at Will.Pitt@aphis.usda.gov.

Forestry Protection

Wildlife impacts on forest resources can be extensive. Reforestation efforts are greatly hindered by deer, elk, mice, mountain beavers, pocket gophers, and voles cutting and gnawing on seedlings during the first 5 years of tree growth. Other mammals such as bears, North American beavers, and porcupine damage established trees and alter water patterns that erode roads and railways, endangering human health and safety. NWRC scientists are developing nonlethal tools and methods to manage wildlife damage, including repellents and habitat and behavior modification.

Deer damage to a 1-year-old seedling. *(Southern Forest Insect Work Conference Archive/Southern Forest Insect Work Conference, Bugwood.org)*

Effects of Tree Phenotype and Ontogeny on Deer Browse. Browsing by deer and elk causes significant ecological and economic impacts annually to the timber industry and residential landscaping. This damage is most obvious and detrimental during the first 5 years of stand establishment. Research has shown that non-specifically applied repellents (i.e., so-called "area" repellents) are not effective for reducing deer/elk browse and that exclusion devices such as fences generally are cost prohibitive. Therefore, it is important to identify new nonlethal approaches and improve existing approaches.

For the past 4 years, scientists at the NWRC chemistry unit in Fort Collins, CO, and at the Olympia, WA, field station have collaborated with the British Columbia Ministry of Forests to investigate the effects of plant chemistry on deer diet selection by offering captive deer cloned copies of Western red cedar seedlings with known monoterpene content. (Monoterpenes are phytochemicals found in the essential oils of conifers.) Results have

Scientists at the NWRC field station in Olympia, WA, check browse damage by deer on red cedar seedlings. *(APHIS/NWRC)*

shown that deer make foraging choices based in part on the monoterpene content of seedlings. Because monoterpene content is a highly heritable trait, it is possible to breed seedlings with elevated monoterpene levels for deployment in an integrated management approach to reduce deer browse damage in reforestation efforts. Trials conducted in 2009 at the NWRC field station in Olympia revealed that deer foraging choices may also be influenced by the morphology of seedlings in conjunction with known monoterpene content. Future research will address the costs and benefits associated with the delayed planting of nursery trees with high monoterpene levels.

Defining Ungulate Browse Timing and Intensity. Oregon and Washington are the two leading U.S. producers of forest products. In western Oregon and Washington, the dominant commercial tree species is Douglas fir, which is generally planted at a density of 400 to 450 trees per acre and harvested on a 40- to 45-year rotation. In general, sites are chemically prepared for planting by aerial application, and logging slash is piled and burned. Between planting and harvest, silvicultural management may include pre-commercial thinning, fertilization, commercial thinning, and herbicide applications. Although timber companies invest in measures to prevent ungulate browse, there are no published results of cost-benefits associated with these actions. Furthermore, forest resource managers acknowledge that the measures are generally ineffective and that producers lose millions of dollars due to ungulate browse.

To better understand the timing and severity of deer and elk browse on reforestation efforts in western Oregon and Washington, NWRC researchers initiated two 5-year studies in 2007. After 2 years of monitoring seedlings in areas exposed to browse versus those excluded from browse, both bud cap-protected seedlings and plugs inside fences were taller and had a greater basal diameter than those seedlings outside the fences. Ungulate presence varied between units, but appears to be the greatest during October and late winter. In one unit comparison, greater than 30 percent of the seedlings received heavy terminal damage that likely will affect future growth. NWRC scientists will continue to monitor tree growth for an additional 3 years to gain knowledge on the timing, persistence, and level of damage ungulates (deer and elk) have on Douglas fir seedlings from 0 to 5 years of age. Researchers will use the results in conjunction with existing growth and yield models to better predict loss associated with ungulate browse. Ultimately, this information will allow managers to make better decisions for forest planning in areas providing habitat to deer and elk.

For more information about NWRC forestry research, contact Dr. Jimmy Taylor at Jimmy.D.Taylor@aphis.usda.gov.

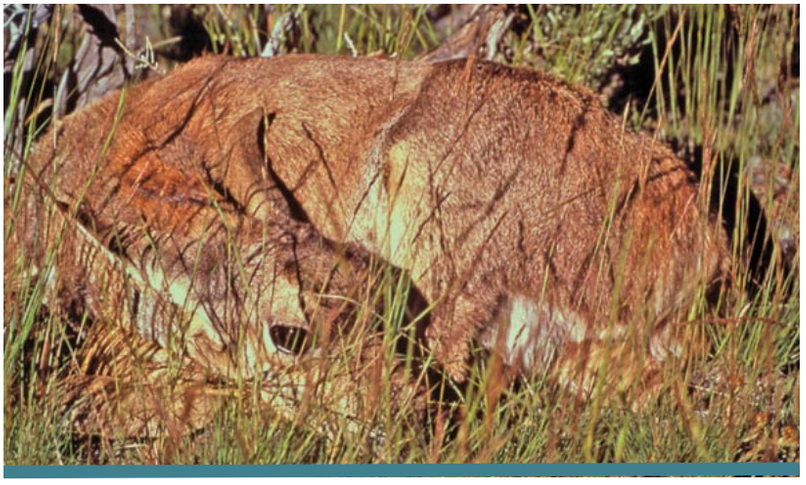
Predators

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

Wolf and Coyote Predation on Pronghorn Antelope Fawns in the Greater Yellowstone Ecosystem. Scientists at the NWRC field station in Logan, UT, are investigating whether competition from wolves limits the distribution and abundance of coyotes and whether the elimination of wolves from some areas allows increased coyote predation. The scientists analyzed spatial and seasonal variation in wolf distribution and abundance in the southern Greater Yellowstone Ecosystem to test the hypothesis that the presence of wolves increases the survival rate of Pronghorn antelope fawns. The data collected show that fawn neo-natal survival rates were four times higher at sites used by wolves. The densities of resident coyotes were similar between wolf-free and wolf-abundant sites; however, the abundance of transient coyotes was significantly lower in areas used by wolves. Therefore, the differential effects of wolves on solitary coyotes may be an important mechanism by which wolves limit coyote densities.

Jaguar Foraging Ecology in Brazil. The jaguar is a large carnivore of Central and South America. To date, kill rates and predation patterns by jaguars have not been well documented. However, over the past decade, NWRC biologists carried out a study into the foraging ecology of jaguars in Brazil in an area with both livestock and native prey, documenting kill rates, characteristics of prey killed, patterns of predation, and the influence of prey size on the duration at kill sites and the time interval between kills. Initial field work took place between 2001 and 2004, with final data analysis completed in 2009.

Between October 2001 and April 2004, 10 jaguars equipped with global positioning system (GPS) collars were monitored. Researchers collected



Young pronghorn antelope. *(DOI/NPS, W.L. Miller)*

data at 11,787 GPS locations and identified 1,105 clusters of locations as sites of concentrated use (e.g., kill sites, bed sites, dens). Prey remains were found at 415 kill sites, and 438 prey items were documented. Kills were composed of cattle, caiman, peccaries, feral hogs, marsh deer, giant anteaters, capybaras, brocket deer, and other avian, mammalian, and reptilian species. Individual jaguars differed in the proportion of each species they killed, as well as the proportion of native prey versus cattle killed by individual cats. Although all 10 cats killed cattle, 5 killed a high proportion of cattle, while 3 killed few cattle. Males and females killed cattle in similar proportions. In contrast, male jaguars killed a higher proportion of peccaries than females, while female jaguars killed more caiman than males. The mean kill rate for all jaguars was 4 days between known consecutive kills, with no statistical difference in kill rates among the 10 cats. The time interval to the next subsequent kill by jaguars increased with increasing prey size. Jaguars also increased the length of time at a carcass as prey size increased. Jaguar kill rates on peccaries steadily increased over the 4-year study. In contrast, kill rates on cattle decreased during the same period. Rainfall and subsequent water levels on the Pantanal were the main driver of seasonal kill rates by jaguars on cattle and caiman; as water levels increased, predation on caiman increased as caiman became more dispersed on the landscape. Conversely, as water levels fell, caiman became less plentiful, and cattle were moved out into the pastures, thereby increasing their availability to more jaguars.

Scientists are radio-collaring jaguars like this one in the Pantanal region of Brazil to study predation patterns; the photo shows Utah State University graduate student Sandra Cavalcanti. *(APHIS/NWRC, Eric Gese)*

For more information about predator management behavior and ecology, contact Dr. Eric Gese at Eric.M.Gese@aphis.usda.gov.

Economics

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

The Economic Impact of Double-Crested Cormorants to Central New York. Over the last 30 years, the population of double-crested cormorants—a large, fish-eating, colonial-nesting waterbird—has increased dramatically in the Great Lakes region. Recreational fishing is an important socio-economic activity in upstate New York, including Oneida Lake, which is commonly referred to as the "The Walleye Lake of New York State." Current research suggests that predation by cormorants has caused declines in the sport fish populations at Oneida Lake and a decrease in the number of non-resident anglers visiting Oneida Lake.

To assess the economic effectiveness of the cormorant management program, NWRC undertook an economic assessment of cormorant damage to Oneida Lake. The methodological approach was to value both the direct and indirect economic impacts of cormorants in the region and to assess the monetary benefits and costs associated with APHIS Wildlife Services' cormorant management program. The study employed an input-output model to estimate the indirect amount of revenue and number of jobs lost in the region due to cormorant damage. A benefit-cost analysis was used to compare the benefits of mitigating cormorant damage in the area to the costs of the cormorant management program. Costs were the total expenditures of the cormorant control program from 1998 to 2005 (e.g., salaries, boat operation, and equipment). Benefits were the potential savings associated with the projected number of non-resident anglers who either continued or returned to fish at Oneida Lake due to the cormorant management program. Total benefits from 1998 to 2008 were calculated for three levels of potential decrease in non-resident anglers.

The total estimated tourism revenue lost in the Oneida Lake Region due to cormorant damage over a 15-year period ranged from $100 to $500 million, and the total estimated number of jobs

Cormorants cause millions of dollars in damage to fisheries and the recreational fishing industry. *(APHIS/NWRC, Laurie Paulik)*

lost ranged from 3,000 to 12,000. A benefit-cost comparison provided ratios to evaluate the overall program efficiency and determine the return per dollar invested in the cormorant management program. The benefit-cost ratios calculated over the life of the program (1998 to 2005) ranged from 14 to 48 across the different levels of estimated benefit—meaning that for every $1 spent on the cormorant management program, $14 to $48 in benefits was realized. Additionally, the results indicated that the cormorant control program saved between 1,446 and 5,014 jobs in the Oneida Lake Region during the 8 years following implementation of the cormorant management program.

The Economic Evaluation of Remote Trap Monitors. Legislative changes to State regulations surrounding the use of traps and other capture devices have greatly impacted the manner in which these devices can be used. In many cases, the revisions to trapping legislation have resulted in decreased trap check intervals. This change has increased the costs of using capture devices and thereby decreased the efficiency of Wildlife Services specialists who rely on these devices as a tool to manage human-wildlife conflicts. Research has suggested that the use of trap monitors could reduce costs and increase specialist efficiency. Trap monitor systems function as a remote notification system that can identify the status of the trap. This system can be used as an alternative to visual trap inspections, which has the potential to reduce costs.

This year, NWRC used a benefit-cost analysis to evaluate the economic efficiency of using trap monitors, comparing the costs of the trap monitor system to the benefits of reduced Wildlife Services personnel time and resources. This type of analysis aids wildlife managers in their decisionmaking by helping to identify situations in which the use of trap monitor systems reduces costs and determine the return per dollar invested in these systems.

Wildlife Services specialists attached trap monitors to traps during their normal duties at two study sites located in west and central Texas. The study site in west Texas used an “out-and-back” trap line configuration in which traps were located at the end of a four-wheel drive road or in a draw requiring the specialist to go “out and back” to check the trap. The study site in central Texas used an “array” trap line configuration in which traps fan out from a central location, which requires the specialist to check the traps in a circular pattern. The specialists kept logs of a range of data variables to establish the economic benefits and costs associated with use of the trap monitors. The specialists also recorded GPS waypoints, such as trap and trap monitor locations, ranch entrances and exits, and other locations where the monitor signal could be received.

Results of the benefit-cost analysis indicate that, based on the probability of the trap being triggered, use of trap monitors at the “out and back” trap line in the west Texas study site was cost efficient if a 10-day trap check law existed. Similarly, use of trap monitors at the “array” trap line in central Texas was cost efficient if a 3-day trap check law existed.

The scientists identified multiple factors that can influence the realized cost savings associated with the use of trap monitors. In general, the use of trap monitors is economical under the following conditions:

- when shorter trap check intervals exist (e.g., due to legislation or the trapping of sensitive species),
- when the probability of having to check the trap for reasons other than a captured target species is low (e.g., when few non-target species are trapped, when there is high bait integrity, or when there are minimal climatic effects on the trap set or monitor), and
- if wages, mileage, or other personnel costs increase.

Quantifying these factors is an important part of identifying the cost savings associated with the use of trap monitors and ultimately determining the situations in which these monitors will provide efficiency gains and overall programmatic savings. Although factors such as specificity and humaneness are also important in the decisionmaking process regarding the use of any capture device, results from this economic analysis provide additional important information to aid managers.

For information on NWRC's economic research, contact Dr. Stephanie Shwiff at Stephanie.A.Shwiff@aphis.usda.gov.

Technology Development

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

Chemistry-Based Tools

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

Voles eat out the lower, fleshy "heart" of the artichoke vegetable, making them unsellable. These characteristic gnaw marks are about one-eighth of an inch wide and three-eighths of an inch long; they are found in irregular patches and at various angles at the leaf base. *(APHIS/NWRC)*

The Use of Liver Microsome Preparations To Examine Anticoagulant Rodenticide Resistance in Meadow Voles. Meadow voles cause significant damage to agricultural crops. The anticoagulant rodenticide chlorophacinone has been used in artichoke fields in northern California for nearly 2 decades to control vole populations and reduce damage. Although initially quite efficacious, anecdotal evidence is accumulating and indicates that vole populations have developed resistance to chlorophacinone and are increasingly difficult to manage. For this study, NWRC researchers isolated liver microsomes from voles captured from populations identified by farmers to be resistant to chlorophacinone and areas that had never been baited with chlorophacinone to investigate possible metabolic differences between the two populations. The study found that microsome preparations from resistant populations of voles metabolized significantly more chlorophacinone than non-resistant voles.

A Physiologically Based Pharmacokinetic Model of Diphacinone in Wistar Rats. Diphacinone is a first-generation indanedione anticoagulant rodenticide used to manage pests such as rats, mice, and other rodents. Non-target species are potentially exposed to anticoagulant rodenticides through a variety of pathways as a result of their widespread use. Since secondary exposure of non-target species to anticoagulant rodenticides is primarily through the consumption of animals that have ingested anticoagulant bait, determining tissue concentrations of diphacinone in target animals is an integral component of risk assessment.

To establish the time-dependent distribution of diphacinone in rodents, NWRC researchers gave male and female Wistar rats oral doses of diphacinone at approximately the lethal dosage (LD)25 and LD10 levels and then euthanized the animals at time points ranging from 6 to 224 hours after exposure. The researchers used reversed-phase ion-pair liquid chromatography to determine the concentrations of diphacinone in the liver, kidneys, lungs, muscle, whole blood, and whole body remainder. These data were used to develop physiologically based pharmacokinetic models (PBPK) for diphacinone in rodents. NWRC will use these models to make quantitatively based estimates of rodenticide tissue concentrations and further apply them to develop improved risk assessment strategies. Extrapolating the validated male and female rat models to other animal species will further characterize the risk of mortality and sub-acute coagulopathy resulting from diphacinone exposure in non-target animals. NWRC can use the insights gained from the modeling of these rodent data to support the development of PBPK models for other species of interest.

Currently, the research has revealed that, when administered the same dose of diphacinone, female rats have higher residue levels than males in all tissues at all time points. This may play a role in the differing toxicity of diphacinone between male and female rats. In both genders, the highly perfused tissues (i.e., liver, lung, and kidney) were the ones with the highest residue concentration. This is important when viewed in the context of risk assessment for determining the possible dose a non-target secondary species would receive after consuming an animal that had eaten diphacinone bait.

The PBPK model makes good estimates of diphacinone residues in most tissues. This will be useful for risk assessment, as it will allow scientists to estimate the risks (non-target mortality) for various baiting scenarios. This model can also be used to estimate the efficacy (target mortality) for diphacinone rodenticide baiting scenarios and identify which of these baiting strategies poses the least risk to non-target wildlife.

For more information about pesticide-resistance studies, contact Dr. Bruce Kimball at Bruce.A.Kimball@aphis.usda.gov.

Fladry has been shown to be an effective deterrent against wolves, especially for penned sheep operations. *(Oregon Department of Fish and Wildlife)*

Capture and Frightening Devices

Most wildlife damage managers prefer nonlethal solutions to wildlife damage problems when these approaches are economical and acceptable to both society and the agricultural industry. However, lethal methods must sometimes be employed when the relocation of animals is not feasible or when nonlethal methods prove ineffective. NWRC scientists developed and tested new devices, attractants, and aversive conditioning devices to capture specific species more selectively and efficiently or to keep wildlife away from livestock and agricultural areas.

Evaluation of Coda NetLauncher® for Capturing Birds. Many bird species are captured for conservation, management, monitoring, and research purposes in order to monitor zoonotic diseases (e.g., avian influenza and West Nile virus). A frequent capture method utilizes cannon nets that employ combustive or explosive propellants to project nets. However, recent regulatory changes limit the use of cannon nets. Researchers at NWRC's field station in Mississippi modified and evaluated the Coda NetLauncher, a modified capture system that does not use combustive or explosive propellants, is lightweight and compact, can be launched from up to one-fourth of a mile away, and does not require that users have intensive special training or certifications. Modification and field testing of the capture system on a variety of bird species is currently underway.

For more information about this capture device study, contact Dr. Fred Cunningham at Fred.R.Cunningham@aphis.usda.gov.

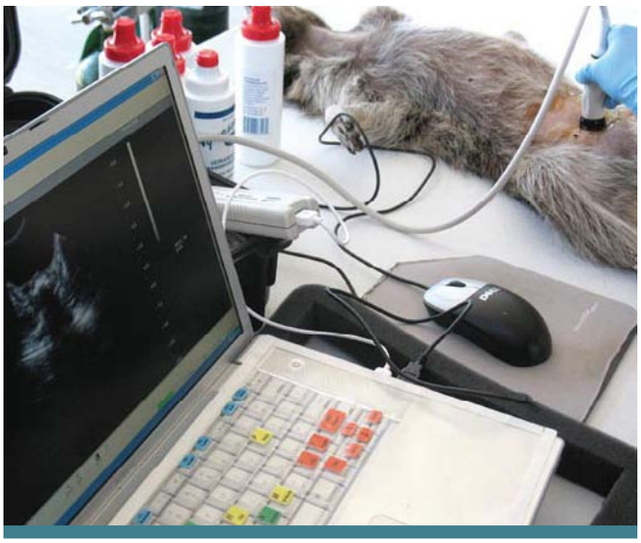
Electrified and Standard Fladry for Protecting Livestock From Wolves. Wolf predation on livestock can cause economic and emotional hardships for livestock producers, complicating the balance of wolf conservation with other human interests. New management tools that decrease the risk of predation may offer additional flexibility and/or efficiency for both livestock producers and wildlife management agencies. Scientists at the NWRC field station in Logan, UT, examined (1) the efficacy of electrified fladry compared to fladry alone at protecting a food source from wolves in captivity; (2) the efficacy of electrified fladry for reducing wolf use of pastures and preventing depredations; and (3) the applicability of electrified fladry to different situations. (Fladry is a string of flags or other similar material, typically tied to a fence line, used to contain or exclude wild animals from a specific area.) Both fladry and electrified fladry were effective in excluding wolves from a food resource for short periods of time (1 to 14 days), though electrified fladry was more effective. In the wild, wolf activity at ranches was insufficient to determine if electrified fladry successfully prevented livestock depredations. However, researchers found that the use of electrified fladry may be limited by costs associated with its purchase, and that the application and effectiveness of electrified fladry may limit its overall usefulness for addressing wolf-livestock conflict.

For more information about predator deterrent methods, contact Dr. Eric Gese at Eric.M.Gese@aphis.usda.gov.

Population and Reproductive Control

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

Determining the Efficacy of GonaCon™ and IMRAB® in Raccoons as a Potential Tool in Controlling the Spread of Rabies. The National Cooperative Oral Rabies Vaccination Program (ORV) is tasked by APHIS Wildlife Services to control and prevent the spread of terrestrial rabies, particularly raccoon rabies, in the United States. Presently, raccoon rabies is endemic east of the Appalachian



Ultrasound is being used to evaluate the pregnancy status of study raccoons. *(APHIS/NWRC)*

Mountains, with breaches in this barrier occurring periodically within the ORV buffer. Lethal removal is one method to control breaches in the rabies barrier and decrease raccoon populations after an outbreak. However, the ORV program is also exploring other options that would reduce the spread of the raccoon strain of rabies.

One such option under consideration for suburban and urban areas is the use of trap-vaccine-release (TVR) programs. Each year, Wildlife Services biologists vaccinate hundreds of medium-sized predators, such as raccoons, 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.

NWRC researchers developed GonaCon, a vaccine that stimulates the production of antibodies to inhibit reproduction in a variety of animals. The vaccine binds to the gonadotropin-releasing-hormone (GnRH), which signals the production of other sex hormones. The antibodies bind to the GnRH and reduce its ability to stimulate a cascade of sex hormones. GonaCon has elicited an immune response that renders both males and females immunologically sterile for up to 2 years. GonaCon has been tested in a variety of mammals, including white-tailed deer, ground squirrels, feral dogs and cats, and wild horses, among others.

Immunocontraception To Investigate Elk Fertility Control in Rocky Mountain National Park.
Overabundant elk populations are dramatically altering native plant communities and may be limiting the abundance and diversity of other wildlife species at Rocky Mountain National Park in Colorado. After extensive agency and public review of five management alternatives, the U.S. Department of the Interior's (DOI) National Park Service (NPS) decided to implement a carefully regulated plan to lethally remove some of the elk. This plan provided an opportunity for scientists to test a new wildlife contraceptive agent, GonaCon, on adult female elk targeted for subsequent lethal removal. NWRC scientists provided vaccine and "Good Laboratory Practices" oversight for NPS and CSU designed to examine the effects of GonaCon treatment on adult female elk.

The elk study was initiated in January 2008, when 120 adult female elk were captured, marked,

As part of a study to examine the effects of GonaCon™ treatment on adult female elk at Rocky Mountain National Park, 60 adult female elk were captured, marked, given a single injection of GonaCon vaccine, and released at their capture sites. *(APHIS/NWRC)*

given injections, and released at their capture sites. Sixty of the elk were each given a single injection of GonaCon vaccine, and 60 others (control animals) were injected with sterile saline. Beginning in January 2009 and continuing for 3 years, the researchers will recapture and euthanize some of the elk from each of these two treatment groups each winter, collect blood samples, and conduct necropsies to determine the reproductive and general health status of the animals and the contraceptive efficacy of GonaCon vaccine. They are also examining the injection site to document any reactions to the injections. None of the 10 GonaCon-treated elk that were recaptured in January 2009 was pregnant, compared to a 90-percent pregnancy rate in the control group. However, all 10 GonaCon-treated animals had pyogranulomatous inflammatory lesions, ranging from 4 cm^3 to more than 100 cm^3, in the muscle at the injection sites. NWRC scientists are working to reduce granuloma effects in treated animals.

The field study at Rocky Mountain National Park will continue through 2011, enabling scientists to evaluate the efficacy and safety of GonaCon as a multi-year, single-injection contraception agent for elk.

Testing the Effectiveness of a Combination of Rabies and Contraceptive Vaccines for Management of Disease in Feral Dogs. Parenteral[2] vaccination campaigns are integral to the elimination of canine rabies. GonaCon has been used successfully as an immunocontraceptive in a variety of mammals, and by inference, dogs would be ideal candidates for testing. A contraceptive at the time of rabies vaccination may reduce fecundity and the abundance of dogs, as well as maximize their immunity to rabies.

NWRC scientists conducted a preliminary test to evaluate a combination rabies and contraceptive vaccine by assessing the effects of GonaCon on rabies virus-neutralizing antibody production in dogs after administering a veterinary rabies vaccine. This study included 18 feral/free-ranging dogs: 6 were given GonaCon only, 6 were given rabies vaccination only, and 6 received both GonaCon and rabies vaccination. The scientists evaluated antibody levels in the dogs over a period of 82 days. The use of the immunocontraceptive GonaCon did not affect the dogs' ability to develop antibodies to rabies after receiving the rabies vaccine. Thus, GonaCon provides a potential immunocontraceptive for use in combination with rabies vaccine to address overabundance in dog populations and better manage rabies.

Use of Contraceptive Vaccines To Manage Feral Horses. Overpopulation of wild horses is a significant concern in the western United States, as these animals can overgraze indigenous plant species and compete with local wildlife for food and habitat. The current management strategy of removal and adoption is expensive. Given legislative constraints on management options, wildlife officials need nonlethal methods to manage populations of wild horses. Administering immunocontraceptive vaccines to control the fertility of free-ranging horses is a potential option to address overabundant local populations.

In 2008, NWRC scientists completed a 3-year study that investigated the effects of contraception on the behavior of feral horses; data analysis was completed in 2009. During the study, the scientists treated female feral horses located in the Virginia Range outside Reno, NV, with a single injection of either SpayVac® (PZP), GonaCon, or a sham vaccine. SpayVac blocks fertilization

[2] The term "parenteral" means "taken into the body in a manner other than through the digestive canal."

of the egg, whereas GonaCon blocks the release of reproductive hormones. NWRC followed the horses until 2008, identifying the animals using a combination of coat color, white markings, and freeze brands. There was individual variability in the responses to the vaccine; however, for individual horses that responded well to the vaccine, contraception lasted for several years. Contraceptive treatments did not alter male-female relationships, sexual behaviors, or band fidelity.

For more information about NWRC's contraceptive studies, contact Dr. Lowell Miller at Lowell.A.Miller@aphis.usda.gov.

Wild horses are protected legally from human hunters and have few natural predators. In the absence of these checks, wild horse and burro populations increase on average by about 15 to 20 percent each year. (*DOI/Bureau of Land Management, Utah State Office)*

NWRC Registration Unit

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

GonaCon™ has great potential as an additional management tool for urban/suburban deer populations or other environments where alternate management options are limited. *(APHIS/NWRC)*

The Registration Unit was exceptionally busy in 2009. The following information lists highlights of the Registration Unit's accomplishments this year:

- Obtained registration approval from EPA for the wildlife contraceptive GonaCon for use in female white-tailed deer in September 2009.
- Sent two experimental use requests to the EPA and began working on the registration package for an entirely new predacide.
- Provided regulatory services and consultation for studies evaluating the efficacy of contraceptives on six species, rodent eradication efforts on six islands, and myna bird eradication in American Samoa.
- Contributed heavily to an EPA request for information on Wildlife Services' use of the M-44 and Compound 1080 for predator control.
- Completed numerous other projects, including consultation on the development of bird and snake repellents and modifications to existing product labels.

Development of Bird Management Tools. DRC-1339 continues to be a valuable tool for managing damage caused by birds. Since 1996, APHIS has held EPA registrations for five DRC-1339 based products. These products are used to manage damage caused by blackbirds in feedlots and roost staging areas, gulls at landfills, pigeons roosting on structures, and crows and ravens preying on livestock and threatened and endangered (T&E) species. Wildlife Services biologists requested the assistance of the NWRC Registration Unit to obtain registration for uses of DRC-1339 that are not covered by these five labels. As a result, APHIS now has nearly 25 Special Local Needs registrations (State-issued registrations also known as "24[c]" registrations), most of which are for managing burgeoning corvid problems. In response, NWRC's Registration Unit has begun a project to consolidate nearly all of the Special Local Needs labels into the existing, section 3, APHIS product labels. Consolidating these labels will provide more flexibility nationwide for managing damage caused by corvids. NWRC plans to submit these label changes to EPA in early 2010.

Over the past year, the NWRC Registration Unit also responded to numerous other requests for DRC-1339. The staff worked cooperatively with DOI's Fish and Wildlife Service (FWS) and APHIS Wildlife Services to propose amending the DRC-1339 Gull label to allow the use of DRC-1339 in New England for the protection of T&E species against laughing gull predation. Additionally, the Government of American Samoa has entered into a cooperative agreement with the NWRC to develop a product to control myna birds in American Samoa. Once registered, this product could be useful for managing damage caused by myna birds in Florida and Hawaii as well. In the last year, the Wildlife Services' Pocatello Supply Depot has received numerous requests to sell DRC-1339 to foreign governments facing bird damage problems. Australia, South Africa, and Israel have placed orders. As part of the Wildlife Services Pesticide Coordinating Committee, NWRC's Registration Unit assisted with the development of standard guidelines for selling APHIS pesticide products to foreign parties.

Lastly, the NWRC has been working to develop avian repellents for use in bird damage management. This work is a cooperative research effort between private pesticide registrants and NWRC scientists. NWRC's Registration Unit provided significant guidance on the development of currently registered fungicides as avian repellents for use in fruit crops. Primarily a private pesticide registrant-led effort, the registration of anthraquinone for use in food crops has received considerable attention. NWRC provided consultation services for developing anthraquinone uses in crimson clover, forage grasses, sunflower, corn, and rice. Full registrations for some of these uses are expected in 2011. At the request of the Oregon Department of Agriculture's Pesticides Division, NWRC scientists cooperated with a private rodenticide manufacturer and the registrant of anthraquinone to determine if a zinc phosphide-based rodenticide product treated with anthraquinone would repel Canada geese without interfering with the rodenticide efficacy. This research, which is ongoing, was initiated in response to recent nontarget mortality in Canada geese associated with activities to control voles in Oregon alfalfa fields.

Registration of Predacides. In response to a 2007 petition calling for the cancellation of sodium cyanide and compound 1080, EPA requested in 2008 that APHIS provide information for the agency's evaluation of these products. APHIS holds four registrations for these materials as predacides and uses these products at the request of ranchers who are losing sheep and goats to coyote predation. Working in conjunction with Wildlife Services' field operations staff in FY 2009, the NWRC Registration Unit helped write an 84-page informational packet for EPA on the use of sodium cyanide and compound 1080 as predacides. The packet contained data summaries for previous years, including the amount of chemical used; the number of target and non-target animals taken; full descriptions of events related to the accidental exposure of these products to humans, T&E species, and companion animals; the economics of predation management; and background on APHIS' decisionmaking process for the use of chemical control measures. APHIS also provided EPA with a description of accountability procedures for Wildlife Services' use of these measures. EPA denied the petition that called for cancellation of the registrations and allowed Wildlife Services to continue using these materials, with only minor changes to regulatory use restrictions. NWRC expects that EPA will finalize the text of these changes in FY 2010.

In 2004, the NWRC began developing a new predacide based on theobromine and caffeine, materials extracted from cocoa, coffee, and tea. The effort demonstrated that these materials can be formulated into an effective product for managing coyote depredation. In 2009, the NWRC Registration Unit began developing the EPA-required registration data for this product. Efforts are now underway to develop product chemistry, toxicity, and efficacy data that will support an application to conduct a large-scale field efficacy study. This effort involves developing more than 60 data submissions, a product label, and a protocol for the field efficacy study. Current plans are to submit an Experimental Use Permit application to EPA in 2010 and begin the field efficacy study in 2011.

Registration of GonaCon™ Immunocontraceptive Vaccine for Use on White-Tailed Deer. On September 29, 2009, the NWRC Registration Unit received notice that GonaCon immunocontraceptive vaccine had been approved for registration by the EPA. The registration marks a major milestone in NWRC's 15-year effort to develop contraceptives for managing wildlife. GonaCon has great potential as an additional management tool for urban/suburban deer in environments where alternate management options are limited. The product will be available for use on white-tailed deer and must be administered via hand injection. GonaCon is classified "Restricted Use," available only to certified pesticide applicators in the State where the product is intended for use. In addition, use of this product is further restricted to APHIS Wildlife Services or State wildlife management agency personnel or persons working under their authority. This newly registered product became available for sale beginning in January 2010.

In 2009, NWRC scientists conducted GonaCon efficacy studies on four additional species. GonaCon is being tested on two species of tree squirrels on the campuses of Clemson University and the University of California-Davis as a tool to reduce squirrel damage to landscape trees. In conjunction with the NPS in 2009, NWRC scientists began testing GonaCon on wild horses in the Theodore Roosevelt National Park as part of a 5-year study. Researchers are conducting this project under an Experimental Use Permit obtained through the EPA. Finally, NWRC scientists are collaborating with the Navaho nation to evaluate GonaCon in conjunction with a rabies vaccine (IMRAB®) on wild and feral dogs.

Island Conservation Uses of Rodenticides. In November 2007, EPA granted APHIS three registrations for using brodifacoum- and diphacinone-based rodenticides to eradicate invasive rodents from island ecosystems. This was a cooperative effort between APHIS Wildlife Services and FWS. These three products serve as the backbone of all U.S.-based rodent eradication efforts on islands. In FY 2009, these products were used on five islands, and plans are being made for eradication efforts on three more islands within the next 2 years.

Because the three products are already registered, conducting these eradication efforts required little additional EPA approval. However, the NWRC Registration Unit provided a substantial amount of guidance as these projects were planned. Wildlife Services conducted eradication projects on four islands (two in Florida, one in Guam, and one in Hawaii). A non-profit organization attempted to eradicate rodents on a 7,000-acre island in the Aleutian Islands. In two instances (Egmont Key and Grassy Key, FL), eradication requirements were outside the allowable methods on the approved labels. In these cases, the Registration Unit worked to obtain Emergency Use Permits from EPA, allowing the projects to proceed. Additionally, recognizing the conservation benefits of this technology, the Registration Unit provided guidance (at the request of a private rodenticide manufacturer) for developing chlorphacinone-based rodenticides for island conservation purposes.

For more information about NWRC registration activities, contact John Eisemann at John.D.Eisemann@aphis.usda.gov.

Wildlife Diseases

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

Rabies

Rabies is an acute, fatal viral disease most often transmitted through the bite of a rabid mammal. It can infect people as well as animals, and the impacts to society from this and other wildlife diseases can be great. In the United States, terrestrial rabies is found in many wild animals, including raccoons, skunks, gray foxes, arctic foxes, and coyotes. In an effort to halt the spread and eventually eliminate terrestrial rabies in the United States, NWRC scientists are conducting research on the behavior, ecology, movements, and population structures of raccoons and gray foxes. They are also evaluating methods and techniques used to vaccinate free-roaming wildlife against rabies and decrease the risks of transmission and maintenance of the disease in the wild.

Evaluation of Bobcats as Potential Vectors of the Texas Gray Fox Variant of Rabies. Although all mammals are susceptible to rabies virus infection, only a few species are important reservoirs and/or vectors of the disease. The vast majority of rabies cases reported to the Centers for Disease Control and Prevention (CDC) each year occur in wild animals, particularly raccoons, skunks, bats, and red and gray foxes. The Texas gray fox variant of rabies is a strain adapted to and maintained by gray foxes in Texas. This strain of the disease has been present in Texas since 1946. In the mid-1990s, NWRC scientists began conducting bait and vaccine studies to develop an optimal vaccine delivery system. This work led to the establishment of an epizootic zone and implementation of the gray fox ORV program in west-central Texas. The program was largely successful until 2006, when the number of positive cases rose by 82 percent. (This increase was the result of dry climactic conditions in 2005 that caused the foxes to move out of the vaccination zone, which left many of them unvaccinated that year.)

Since 2007, cases of fox-variant rabies have been documented not only in gray foxes, but also in coyotes and bobcats west of the epizootic zone boundary. The occurrence of fox-variant rabies west of the zone is cause for concern on several fronts. First, 2007 marks the first time since 1996 that fox-variant rabies has been documented west of the epizootic zone. Additionally, anecdotal evidence

NWRC scientists are evaluating whether bobcats are capable of maintaining and transmitting the gray fox rabies variant to other mammals. *(DOI/NPS, Joshua Boles)*

suggests that either the viral genome has mutated or the variant may now be propagated through contact between coyotes and/or bobcats. In either event, it is plausible that coyotes and bobcats may be capable of maintaining the chain of infection independent of gray foxes. If this is true, the ability of coyotes and bobcats to transmit fox-variant rabies will represent new health risks to humans, companion animals, and livestock. In addition, because a relatively large number of bobcats were diagnosed as having this variant, the presumption is that bobcats in west Texas may be able to maintain and transmit this variant to other mammals. If this is the case, due to the behavior and social structure of bobcat populations, rabies may be difficult to control in bobcats.

Scientists compared the efficacy of the bELISA as a serum screening assay to the agar gel immunodiffusion (AGID) assay, which is currently used as a screening tool for large-scale influenza surveillance in poultry. *(APHIS/NWRC)*

Therefore, NWRC scientists initiated a study to determine if a small quantity of rabies virus—one that would be sufficient to enable infected bobcats to infect another animal from a bite—can be found in the salivary glands of bobcats after they have been experimentally inoculated with a gray fox variant of rabies. This information will be vital for use in any control or eradication efforts conducted by the Texas Department of Human Health Services and APHIS Wildlife Services in Texas. Four wild, captive bobcats were each given 1 milliliter X 10^4 titer (1 X 10^4) of rabies virus in the masseter muscle. Three of the bobcats developed mild clinical signs of rabies. One bobcat was negative for rabies virus. Each was later euthanized; upon necropsy and evaluation, one bobcat had 6.6 X 10^4 and 2.1 X 10^6 rabies virus in salivary glands, and one had 1.2 X 10^3 and 1.6 X 10^4 rabies virus in salivary glands. Data is still pending on the fourth cat.

Titers of rabies virus collected during necropsy indicated that a sufficient amount was present to cause infection in other mammals (including other bobcats, coyotes, and foxes) if bitten by bobcats. Because only mild clinical signs of aggressive behavior were observed in the three bobcats that developed signs of rabies, more research is needed to determine whether bobcats infected with the gray fox variant of rabies can develop sufficient aggression to bite others and transmit the virus.

For more information on NWRC's rabies research, contact Dr. Mike Dunbar at Mike.R.Dunbar@aphis.usda.gov.

Emerging Viral and Bacterial Diseases

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

Development of a New Laboratory Assay To Detect Influenza A Antibodies in Domestic and Wildlife Species. In response to a need for a rapid, reliable, and inexpensive technique for large-scale surveillance of influenza A virus exposure in wildlife, NWRC and Iowa State University (ISU) scientists developed an epitope-blocking, enzyme-linked immunosorbent assay (bELISA) that rapidly detects antibodies to influenza A virus in taxonomically diverse domestic and wild vertebrate species. The researchers compared the efficacy of the bELISA as a serum screening assay to the agar gel immunodiffusion (AGID) assay that is currently used as a screening tool for large-scale influenza surveillance in poultry. The concordance between the AGID assay and bELISA was 94 percent for experimentally challenged raccoons, but only 71 percent for experimentally challenged mallards. The bELISA was more sensitive than the AGID assay for both species, as demonstrated by the detection of antibodies to influenza A virus in more samples, at earlier time points in experimental infection studies, and at higher serial dilutions. In summary, NWRC and ISU succeeded in developing a sensitive, inexpensive, objective, species-independent bELISA platform that can be performed in most laboratories and can screen for a variety of influenza A virus-specific subtypes.

Experimental Infections on Mallards Shed Light on Avian Influenza Viral Shedding and Transmission Through Water. NWRC scientists conducted a study to determine (1) how long and at what levels the avian influenza virus remains in mallards; (2) the best sampling methods (i.e., oral-pharyngeal swabs, cloacal swabs, and fecal swabs) for detecting the virus in 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 avian influenza virus 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 the very young ducks regardless of the sample type tested. Uninfected mallards became infected after swimming in 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 results from experimental infections or surveillance. Differential shedding could affect prevalence estimates, modeling of virus spread, and subsequent risk assessments.

NWRC scientists are investigating how long and at what levels the avian influenza virus remains in mallards and are determining if the virus could be transmitted through a water source shared by infected and uninfected mallards. *(APHIS/NWRC)*

Collared peccaries range from southern Brazil to the southwestern United States, overlapping with the range of feral swine. There is a concern that peccaries could transmit influenza A virus to feral swine in the United States. *(DOI/NPS, Joshua Boles)*

Collared Peccaries May Serve a Similar Role to Swine in the Evolution of Influenza Viruses. Swine have long been considered important in the evolution of influenza A viruses (IAV) because these animals are capable of becoming intracellularly infected with both avian and human influenza virus subtypes simultaneously. This potential for co-infection allows for the genetic reassortment of IAV, which could lead to evolutionary shifts, interspecies transmission, and even pandemics. Collared peccaries and feral swine fill comparable ecological niches; however, the similarity between these species is the product of convergent evolution, as swine evolved in the Old World (and were subsequently introduced to the New World), and peccaries evolved in the New World.

In a collaborative study conducted in 2009 with CSU, NWRC scientists found that 17 percent of collared peccaries were exposed to IAV subtypes H1N1 and H3N1, which are of avian origin. In addition, peccaries have both avian and human influenza virus receptors throughout the trachea and lung. These results indicate that peccaries can play the same role as swine, serving as a potential mixing vessel for IAV from birds and humans. Collared peccaries range from southern Brazil to the southwestern United States, overlapping with the range of feral swine in those regions. This expansive range allows peccaries not only to traffic IAV across international borders throughout the Americas, but also to potentially transmit the virus to feral swine. This could lead to further spread of IAV by feral swine throughout the United States.

Potential of European Starlings To Transmit Disease in Texas Feedlots. NWRC specialists from the Center's field station in Bismarck, ND, and offices in Fort Collins, CO, studied the local movements of European starlings and their potential role in carrying diseases among feedlots. In December 2008, scientists captured and radio-tagged 50 European starlings at 3 large feedlots near Dumas, TX, and found that birds using concentrated animal feeding operations (CAFO) had strong fidelity to a daily feeding site.

Birds were recorded at their home capture site 65 percent of the time. Feedlot A, the least autonomous of the 3 feedlots, had a greater than 30 percent rate of exchange of its cohort with Feedlot B, 24 kilometers to the southeast. This inordinate rate of exchange perhaps occurred because a roosting site for the Feedlot A birds was a petroleum refinery that was shared by some birds from Feedlot B. The major roost for Feedlot B birds was a wetland roost on the northern shore of Lake Meredith, 30 kilometers to the southeast. The towns of Cactus and Etter, north of Dumas, and a large dairy located about 4 kilometers southwest of Feedlot A were also used as roosts. Some roosting occurred at the feedlots themselves. Other CAFOs were used by the birds, particularly birds from Feedlots A and C. These supplemental sites were mainly a few large dairies and small-sized (less than 1,000 head) feedlots that surrounded the A and C study sites. Birds captured and radio-tagged at Feedlot C in close proximity to Dumas used the town for roosting and also for daytime activities away from the feedlot. Only minor exchanges occurred between birds radio-tagged at Feedlots B and C.

Feedlots can attract thousands of European starlings. These birds eat valuable livestock feed; defecate on livestock, structures, and feed; and are a potential reservoir of diseases transmissible to livestock and humans. (*APHIS/NWRC, Jeff Homan*)

Scientists also sampled European starlings, cattle feed, cattle water troughs, and cattle feces on 10 CAFOs near Dumas, TX, for Salmonella enterica and Coccidia to determine if there is a relationship between European starlings and the occurrence of these diseases. Preliminary results suggest that European starlings may be a source for *S. enterica*, but not Coccidia, within cattle feed and water, which likely contributes to infections throughout the herd. This finding suggests that European starlings could be an important source for *S. enterica* infections in cattle.

Genetic Investigation of Influenza H1N1. NWRC scientists worked with a collaborator from the American Museum of Natural History to provide a rapid response to the April 2009 H1N1 outbreak in human populations. The scientists sequenced wild bird fecal samples (that had already been collected and characterized as part of USDA's national

surveillance effort for highly pathogenic H5N1 avian influenza) to study the genetic relatedness of the avian, swine, and human H1 and N1 subtypes. Study results found that the 2009 H1N1 human outbreak had evolutionary origins in both swine and bird influenzas, but that the origin of the human outbreak subtype of influenza virus was not recently derived from wild birds. In terms of evolution, the human outbreak H1 subtype arose out of a swine-derived and -dominated lineage that is closely related to predominantly human H1. Both of these lineages show multiple instances of host switching among birds, humans, and swine. Further, while the N1 subtype arose out of a swine-host lineage, this group is evolutionarily related to N1 largely from bird hosts, including wild birds. Evolution of the H1N1 influenza includes common exchanges among hosts such as birds (wild and domestic), swine, and humans. Ongoing research across host species will contribute to an understanding of the contemporaneous and evolutionary circulation of influenza viruses.

For more information about NWRC's research on Emerging Viral and Bacterial Diseases, contact Dr. Alan Franklin at Alan.B.Franklin@aphis.usda.gov.

Chronic Wasting Disease

The spread of chronic wasting disease (CWD) in wild and captive cervids is of great nationwide concern. More research is needed to fill information gaps about disease transmission at the interface between wild and domestic cervids. CWD infects elk, white-tailed deer, mule deer, and moose, but is not known to naturally infect other species of wildlife (including predators and scavengers), livestock, or humans. There is no treatment for CWD, and 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.

There has been heightened concern recently about the potential for disease transmission between farmed and wild cervids through game-farm fences. Cervid facilities with only a single perimeter fence of woven wire may play a role in direct and indirect transmission of diseases such as chronic wasting disease and bovine tuberculosis.
(APHIS/NWRC, Kurt VerCauteren)

Can Electric Fencing Used in Conjunction with Woven Wire Reduce Contact Between Wild and Captive Elk? There has been heightened concern recently among livestock owners and wildlife managers about the potential for disease transmission between farmed and wild cervids through game-farm fences. Cervid facilities with only a single perimeter fence of woven wire may play a role in the direct and indirect transmission of diseases such as CWD and bovine tuberculosis. Over the past several years, NWRC researchers evaluated the effectiveness of adding a baited electric fence to an existing woven-wire fence to reduce fence-line contact between elk. The study and data analysis were completed in 2009.

The researchers used a surveillance camera system to monitor a 20-meter-long test fence area at an elk ranch in north-central Colorado from August 2006 to October 2007. Twenty-six trials were conducted (11 without electric fence during 48 total cumulative days and 15 with electric fence during 64 days) with different levels of motivation for contact between groups of elk separated by the test fence. Varying motivation levels included (1) separating rutting bulls from estrous cows, (2) separating rutting bulls from rutting bulls and estrous cows, (3) randomly splitting the herd, (4) separating cows from calves, and (5) excluding elk from supplemental grain feed. The electric fence in pen A was erected containing a test group of elk while pen B contained an attractant group. Researchers documented 426 contacts between elk in pen A with elk either in pen B or with the woven-wire fence during trials without electric fence. No contacts were documented between adult elk in pen A with elk either in pen B or the woven-wire fence during trials when the electric fence was in place; however, a small elk calf crawled under the electric fence. Overall, 24 of 25 elk exposed to the electric fence were completely deterred, for a success rate of 96 percent. Researchers have concluded that this novel fence design may be a more economical and equally effective alternative to double woven-wire fences.

Provisional Confinement for Emergency Response to Disease Outbreak in Deer. In the event of catastrophic disease outbreaks involving deer from a concentrated area, it is important for livestock owners and wildlife managers to have the ability to contain potentially infected deer quickly and effectively before and while they implement other management actions. Fences are the most logical tool for containment, and the efficacy of this tool directly relates to the motivation level of the deer to jump the fences. Many temporary or semi-permanent electric fence designs are effective under varying levels of motivation. A more permanent and effective solution is erecting a high (2.4 meters), woven-wire mesh fence that can exclude or contain nearly all highly motivated deer. However, high woven-wire fences require extensive planning and site preparation, and installation can be time-consuming and disruptive to deer nearby.

As part of a 2009 study, NWRC researchers and biologists from the University of Nebraska, Lincoln and FWS constructed a temporary 42-ha enclosure of 2.1-meter polypropylene mesh fence to determine how effective it could be in confining free-ranging white-tailed deer in a disease management scenario. Researchers conducted observations along the perimeter during two 3-week periods (one before and one after erecting the fence) to determine how the fence affected deer movements. They found that the fence achieved

nearly complete confinement of the deer, as demonstrated by 259 observed deer breaches prior to erecting the fence compared with 1 deer breach after the fence was built. A minimum of 15 deer were effectively contained during the study. If used in conjunction with minimally disturbing measures (e.g., the use of sharpshooters and suppressed rifles), the fencing strategy could be a valuable component of emergency response efforts relative to catastrophic disease outbreaks.

For more information on NWRC's CWD research, contact Dr. Kurt VerCauteren at Kurt.C.VerCauteren@aphis.usda.gov.

The State of Hawaii and other Pacific islands are concerned about the spread and impacts of coqui frogs. *(APHIS/NWRC, Rogelio Doratt)*

Invasive Species

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

Amphibians and Reptiles

Although worldwide distributions of many a amphibians and reptiles are declining, a handful of species are spreading rapidly throughout tropical regions of the world. The most notable of these species include coqui frogs, cane toads, bullfrogs, brown treesnakes (BTS), and Burmese pythons. NWRC researchers are developing effective methods to detect incipient populations and implement control methods.

Testing New Toxicants for Invasive Frogs. Coqui frogs are native to the Caribbean but have invaded and affected Hawaiian floriculture and agriculture industries, as well as real estate, private industry, and human health. Frogs found in certified nurseries result in quarantine issues that impact the exportation of disease- and pest-free nursery products to the U.S. mainland and destinations abroad. Coqui frogs also threaten Hawaii's fragile habitat of rare and endangered plants and animals.

Scientists at NWRC's field station in Hawaii, in collaboration with the County of Hawaii and the

Hawaii Department of Agriculture, recently released findings from studies on the effectiveness of potassium bicarbonate and sodium bicarbonate (baking soda) as toxicants for invasive coqui frogs in Hawaii. The studies investigated the toxicity of these chemicals to coqui frogs, determined the lowest application that would cause 80 percent mortality to the frogs after 24 hours, and determined an application rate and solution concentration for possible registration to help control this invasive species. Scientists evaluated the efficacy of two applications (a powder and a slurry solution) and six products (Bi-Carb Old Fashioned Fungicide®, Kaligreen®, Milstop®, Remedy®, Flow-K®, and U.S. Pharmacopeia grade of potassium bicarbonate) under laboratory conditions.

Native to the eastern United States, bullfrogs have spread to the western United States and to several other countries and islands around the world. Because of their size and voracious appetite, they cause significant, negative impacts to native species of vertebrates and invertebrates. *(iStock photo, Bruce MacQueen)*

Though both sodium and potassium bicarbonate were effective, potassium bicarbonate has more promise for use, as it is already registered for use as a fungicide. Scientists found that there was greater than 80 percent frog mortality after 24 hours when (1) Flow-K and Milstop were applied as a dust at an application rate equivalent to 100 pounds of product per acre or (2) when frogs were exposed to the 12 percent potassium bicarbonate in a slurry/solution mixture in water.

Based on the results of this study, NWRC and its partners plan to conduct future studies on the field efficacy and nontarget effects of potassium bicarbonate and evaluate other chemicals for their efficacy as potential frog toxicants.

Effective Toxicants for Invasive Bullfrogs. Although native to the eastern United States, bullfrogs have been translocated to the western United States and several other countries and islands around the world. Because of their size and voracious appetite, they cause significant, negative impacts to native species of vertebrates and invertebrates. Effective and efficient control methods are needed to manage invasive bullfrogs. Current methods such as hand- or net-capture are labor intensive and relatively ineffective. While no toxicants have been identified or registered for bullfrogs, an effective toxicant could allow a cost-effective control alternative for this invasive species.

To help address this issue, NWRC researchers tested solutions of five chemicals (caffeine, citric acid, calcium hydroxide [hydrated lime], sodium bicarbonate, and permethrin) known to be effective in the control of invasive coqui frogs by applying one or two dermal sprays of 4 milliliters of the test

solution. Only caffeine proved effective (100 percent mortality) at the concentration tested (10 percent). Additional studies might identify other effective toxicants for invasive bullfrogs. NWRC is conducting ongoing research to identify an effective delivery system that will not harm the environment or non-target animals.

NWRC Researchers Test a Multiple-Capture Trap for Invasive Bullfrogs. Biologists in Fort Collins, CO, tested a multiple capture trap (MCT) for invasive bullfrogs at a pond at the Pueblo Chemical Depot in Pueblo, CO. The researchers used MCTs developed in Australia for invasive cane toad control. Several types of lures were used, including light, crickets, and shiny metal flashers. The floating traps were quite successful in the infested pond with as many as seven bullfrogs captured overnight in one trap. However, many bullfrogs were observed near the traps and were never captured, indicating the need to develop more effective lures.

For more information on NWRC's frog research, contact Dr. Will Pitt at Will.Pitt@aphis.usda.gov

Non-Prey Bait Take by Brown Treesnakes Under Field Conditions. Brown treesnakes (BTS) were accidentally introduced to Guam in the late 1940s or early 1950s and have caused extensive economic and ecological damage to the island. In just half a century, the BTS has exterminated most of Guam's native forest birds and greatly reduced its population of fruit bats and native lizards. Wildlife Services actively manages BTS populations on Guam to prevent their spread to other Pacific islands, especially Hawaii. For logistical and economic reasons, there is a need to develop an effective bait to replace dead neonatal mice (DNM) used in BTS eradication efforts on Guam. DNM treated with acetaminophen (an oral toxicant for BTS) is an emerging technique for controlling snakes on a landscape scale. DNM serve as a lure attractant and bait matrix and are very well accepted by BTS under field conditions. DNM are the bait of choice for delivery of acetaminophen to BTS in the field (U.S. EPA Registration No. 56228-34). However, DNM are relatively expensive (about $0.65 each), have to be shipped frozen from the continental United States and maintained frozen until applied in the field, and have a field life of only 2 to 3 days. An artificial bait matrix that is less expensive, can be stored at room temperature before application in the field, and has a longer field life would be more efficient for operational use.

Over the past several years, NWRC researchers conducted several studies to address this issue, with results showing that (1) DNM decomposition products have the potential to enhance consumption (bait take) of non-prey food items, and (2) it may be possible to develop non-prey items as a practical bait matrix for BTS. In the latest study (conducted in 2009), NWRC researchers evaluated five different types of commercial dog snack treat products. Compared to DNM, these products are less expensive, can be stored at room temperature, and do not decompose readily under field use conditions. Researchers evaluated the five products in two ways—untreated and treated with 48-hour-old DNM decomposition products—and then

compared bait take to unadulterated DNM (uDNM). The 2-day cumulative bait take for uDNM was 80 percent. As compared to treated beef consumption in previous studies, treated dog snacks are not as acceptable. This indicates that manufactured, processed food types may not be useful as matrices for incorporating additives to enhance bait consumption by snakes. Future studies will investigate bait take of beef treated with solvent extractions from decomposed DNM.

BTS Pheromone Development. NWRC scientists conducted research on the sex pheromone of the female BTS. The goal of this research was to develop a pheromone-based tool for detecting small incipient BTS populations in locations off Guam and for monitoring snake densities on Guam in areas where populations have been operationally reduced to low levels.

In one 2009 laboratory study, the scientists investigated the phenology of sex pheromone expression in female BTS during ovarian growth (when pheromone production is thought to occur). The researchers conducted bioassays on a weekly basis, using males to assay for pheromone in skin lipid samples; the samples were collected from reproductive and non-reproductive females over the 6-week period of follicular growth and a subsequent 3-week period of follicular atresia (breakdown of the ovarian follicles). The researchers presented skin lipid samples obtained from the females with filter paper wipes to males side-by-side with control samples, including samples from other males. Males spent significantly more time tongue-flicking samples of female skin secretions than control samples (weeks 3 through 9). Although tongue-flick time was greater for samples from reproductive versus non-reproductive females in 7 of 9 weeks, researchers observed significant differences only after the onset of follicular atresia in weeks 6 and 9.

This work shows that (1) the female BTS sex pheromone exists, (2) it is expressed in a slightly more potent form in reproductive than non-reproductive females, (3) potency does not appear to vary substantially during ovarian growth, and (4) potency is maintained even during the premature death of developing eggs in ovaries. The unexpected finding that non-reproductive females express a relatively potent form or level of the pheromone raises the possibility that the quantities needed for operational use could be obtained easily by "harvest" from snakes collected during normal operational control.

Also in 2009, NWRC scientists conducted a follow-up study on Guam and determined the female skin lipid yield from all mature females captured during a 30-day period from all traps in current operational use. The researchers captured and examined a total of 319 snakes. Of these, 42 females

Burmese pythons have become an established invasive species in Florida, where they pose serious threats to native wildlife. *(APHIS/NWRC)*

were unequivocally sexually mature (but non-reproductive), and 9 were reproductive (containing enlarging ovarian follicles). A series of solvent washes was used to collect skin lipids from the skin surfaces of 26 non-reproductive and 6 reproductive females, which produced total dry lipid yields of 782 and 176 milligrams, respectively. The researchers are currently conducting storage stability tests paired with male bioassays on this material to determine the chemical stability and duration of bioactivity. If bioactivity can be retained under storage conditions, "harvest" of pheromone—even from the relatively few reproductive females caught per year—would likely meet the operational needs of a pheromonally based detection tool.

For more information on NWRC BTS research, contact Dr. Will Pitt at Will.Pitt@aphis.usda.gov.

Captive Nile monitor lizard used for bait preference studies under laboratory conditions. *(APHIS/NWRC, Ken Tope)*

Burmese Python and Nile Monitor Lizard Bait Preferences. The pet industry legally sells Burmese pythons and Nile monitor lizards in the continental United States; however, these reptiles have become established invasive species in Florida. Most likely, they were introduced into the environment by escaping from captivity or through intentional release by their owners or by pet traders to establish populations that could be culled and sold. Invasive populations of Burmese pythons and Nile monitor lizards need to be controlled and eradicated because both species can survive in ecologically sensitive habitats where they pose serious threats to native wildlife.

While there are no established, systematic operational control techniques for these reptiles, Florida State and Federal agencies have initiated inquiries and meetings for developing control strategies. Acetaminophen, currently used in an integrated program for controlling BTS on Guam, could have a role in controlling pythons and lizards. In 2009, NWRC investigators found that acetaminophen-treated DNM baits are lethal to both small pythons and lizards. In anticipation of the development of acetaminophen as an oral toxicant for these two species, NWRC researchers conducted bait evaluations this year to determine bait preference for pythons and lizards.

Development of Control Methods for Burmese Pythons. In collaboration with State and Federal partners, NWRC researchers at the Florida field station and at Fort Collins headquarters initiated studies in 2009 to (1) assess the usefulness of sex pheromones for attracting pythons to traps, (2) evaluate improved trapping methods for removing

pythons, and (3) determine the potential utility of infrared cameras for detecting pythons from low-level aircraft. These ongoing trials are being conducted within a large outdoor test pen at the Florida field station, where NWRC is maintaining nine pythons captured in south Florida.

As part of this study, the researchers evaluated nine inanimate non-toxic baits (DNM, Coturnix quail chick, Coturnix quail egg, Zebra finch egg, squid, ground turkey, chicken liver, tilapia fish, and Pup-Peroni® [a commercial beef flavored dog treat]) in randomized one-choice tests during a 24-hour period. Both fresh baits and baits aged for 24 hours at 85 degrees Fahrenheit and 50-percent humidity were tested. Only two of the nine fresh baits—DNM and quail chick—were accepted by both pythons and lizards. Acceptance by pythons was 75 percent for both DNM and quail chick; acceptance by lizards of DNM and quail chick was 88 percent and 75 percent, respectively. Fresh tilapia fish, ground turkey, finch eggs, and chicken liver were also accepted (63 to 88 percent) by lizards, but not by pythons. For the aged baits, pythons accepted only the quail chick (50 percent), whereas lizard acceptance of DNM, tilapia, turkey, finch egg, quail chick, and chicken liver was 63 to 88 percent. Pup-Peroni, classified as a synthetic bait matrix, was not preferred by either species; from a total of eight offerings (four fresh and four aged), pythons did not accept any Pup-Peroni. Lizards accepted only one Pup-Peroni bait from a total of 16 offerings (8 fresh and 8 aged). These data indicate that natural unadulterated baits have the potential for delivering an oral toxicant to Burmese pythons and Nile monitor lizards.

For more information about NWRC python and lizard research, contact Dr. Mike Avery at Michael.L.Avery@aphis.usda.gov.

Birds

Invasive bird species cause thousands of dollars in damage to agriculture and property, and they compete with native birds for food and nesting space. NWRC is developing methods and tools to prevent or reduce the damage caused by birds such as the European starling, monk parakeet, feral pigeon, and cattle egret.

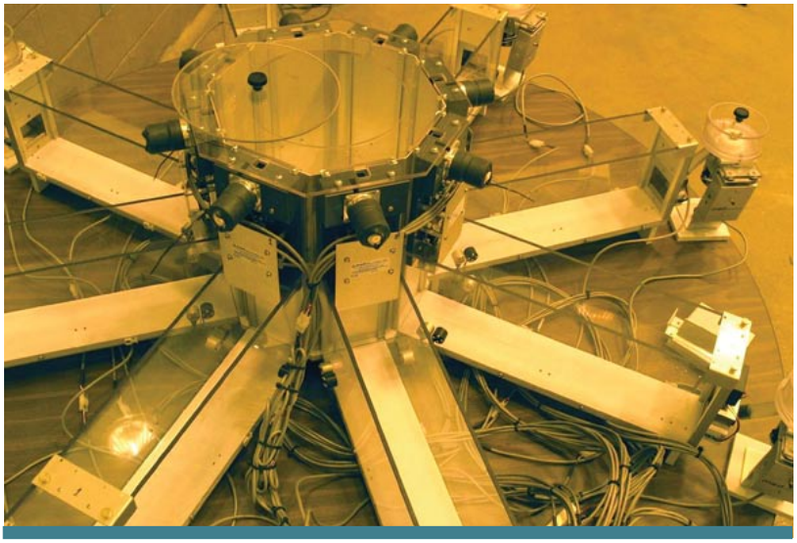
Reduction of an Invasive Sacred Ibis Population in South Florida. The "sacred ibis" is a non-native bird from Africa that is seen as a threat to Florida native species. This bird is also present in Europe, where it has demonstrated an ability to adapt to human-altered environments and spread into natural areas, competing with and preying upon native species. In south Florida, a burgeoning sacred ibis population has developed in recent years. Because of its documented negative impacts in other countries, the sacred ibis population in Florida was identified by Palm Beach County officials for rapid response and removal. In 2009, NWRC biologists worked with Wildlife Services staff in Florida, along with other Federal and State officials, to locate and recover free-flying ibis. Part of this operation involved outfitting ibis with satellite transmitters to help determine the birds' roosting and feeding locations. Through June 2009, recovery efforts resulted in the removal of more than 70 birds from south Florida, and there were no ibis sightings in the area for several months thereafter. Monitoring efforts continue to verify that all birds have been found and removed.

The sacred ibis, native to Africa, has established a burgeoning population in south Florida. NWRC outfitted ibis with satellite transmitters to help determine the birds' roosting and feeding locations and assisted in removing more than 70 birds from the field. *(WikiCommons, Greg Tee)*

Regional Management of Black Vultures Considered. Black vulture populations are expanding throughout the eastern United States, and recent population modeling by NWRC, the U.S. Geological Survey, and FWS indicates that greater numbers of birds than what is currently permitted could be culled without adversely affecting population levels. A scientist from the NWRC field station in Gainesville, FL, participated in a meeting to discuss management options for the black vulture. The meeting was held in October 2008 in Richmond, VA. Participants included APHIS Wildlife Services State Directors and representatives from Maryland/Delaware, North Carolina, Pennsylvania, South Carolina, Virginia, and West Virginia; the Virginia Department of Game and Inland Fisheries; local power companies;

the College of William and Mary; and FWS. It was agreed that further consideration should be given to developing a regional black vulture management strategy, although no specific guidelines for such a plan were developed. There was also consensus that additional study of vulture movements using satellite telemetry would contribute to understanding more fully the regional population dynamics of the species, which would in turn aid development of management plans.

For more information on NWRC's invasive bird research, contact Dr. Mike Avery at Michael.L.Avery@aphis.usda.gov.



Eight-arm radial maze used to study the behavior of three species of commensal rats. *(APHIS/NWRC, Gary Witmer)*

Rodents

Invasive rats and house mice, the Gambian giant pouched rat, and nutria have had a damaging impact on native animal habitat, agriculture, T&E species, property, and human health and safety. NWRC researchers are developing and evaluating rodenticides, barriers, and other tools to eliminate or reduce the damage caused by these invasive mammals.

Identifying Effective Attractants and Rodenticide Baits for Gambian Rats. Native to Africa, Gambian giant pouched rats are an invasive species on Grassy Key, FL. Because of their large size, they pose a serious threat to native species and agricultural crops, especially if this species invades mainland Florida. They are also a potential vector for disease. For example, the rats were implicated in a monkeypox outbreak in humans in the Midwestern United States in 2003. Wildlife Services initiated eradication and detection efforts in the Florida Keys, but baiting and trapping the sparse population of Gambian rats has proven difficult.

To help address this challenge, NWRC biologists tested 15 attractants for use in traps for capturing or detecting Gambian rats, using a simulated natural environment room at the Center's headquarters in Fort Collins, CO. The biologists found that similar scents (i.e., feces and urine) from other Gambian rats were the best attractant, but peanut butter, anise, ginger, and fatty acid scents could also be useful. In another study, NWRC tested several rodenticide baits with captive Gambian rats from Florida in multiple choice food trials: two formulations of diphacinone baits, and one formulation each of brodifacoum, chlorophacinone, zinc phosphide, and bromethalin bait. Only the

brodifacoum and zinc phosphide baits were highly effective. In future Gambian rat control efforts, NWRC recommends that the acute rodenticide, zinc phosphide, or the second-generation anticoagulant, brodifacoum, be used.

Behavior of Invasive Rats in an Unfamiliar Environment. Invasive rats pose a threat to native flora and fauna species, especially on islands where native species have evolved in the absence of terrestrial predators. Effective detection and eradication is essential to preserve the island's ecosystem integrity. A better understanding of the behavior of rats when they first arrive in a new setting could lead to the development of more effective methods for detecting and eradicating rats from insular ecosystems.

NWRC biologists in Fort Collins, CO, used an eight-arm radial maze to study the behavior of three commensal rat species in a novel environment with various familiar and unfamiliar stimuli. While there were some differences in responses by species and sex, most rats sought out and spent considerable time in the den box, suggesting an immediate need for security when in an unfamiliar setting. Rats also sought out the feces of other rats, suggesting the need for social contact or reproduction.

The management implications of the study results are two-fold. First, the detection of newly arriving rats on islands may be aided by the strategic placement of den boxes that are highly acceptable to rats. Wildlife managers could inspect the den boxes periodically (or use a remote-sensing system) for evidence of rats. Secondly, the den boxes could be scented with the feces of other rats to further attract invading rats to the den boxes. This protocol might also hold the rats near the invasion site for a longer period before they begin seeking other shelter, food sources, or mates. Combined, these efforts might make potential control programs more effective in eradicating the invasive rodents.

Effective Rodenticides for the Eradication of Roof Rats on Egmont Key, FL. Roof rats were accidently introduced to Egmont Key, an FWS National Wildlife Refuge near Tampa Bay, FL, during a shoreline stabilization program in 2000. The rats pose a threat to all ground-nesting native species and could also damage historic structures in the area. FWS contracted Wildlife Services to design and conduct an eradication program for these rats using an island-wide grid of bait stations and an effective rodenticide. NWRC biologists conducted a study to determine if the proposed rodenticide formulations (Ramik® Green pellets or Ramik Mini-Bars, both 0.005 percent diphacinone) would be palatable to, and effectively kill, roof rats from Egmont Key.

As part of this study, wild-caught roof rats were transported to the NWRC field station in Gainesville, FL, for an efficacy trial. Researchers presented the individually caged rats with one of the rodenticide baits, along with their normal maintenance diet in a two-choice test. Both rodenticides resulted in high mortality—80 percent for Ramik Green pellets and 90 percent for the Ramik Mini-Bars. NWRC recommended that Ramik Mini-Bars be used in the eradication program on Egmont Key. In addition to the high efficacy of the Mini-Bars, their large size was effective in reducing potential hazards to the island's gopher tortoises; in contrast, the tortoises could potentially feed on the small, Ramik Green pellets. Using the results of this research, Wildlife

Services conducted a successful eradication program on Egmont Key in early 2009.

For more information about NWRC's continental rodent research, contact Dr. Gary Witmer at Gary.W.Witmer@aphis.usda.gov.

Improving Attractants for Nutria. Nutria are an invasive species from South America that cause significant damage to aquatic ecosystems in North America. Although trapping is effective for reducing nutria damage, better lures are needed to attract individuals to trap sites. As part of a recent study to address this issue, researchers at the NWRC field station in Olympia, WA, isolated and identified volatile compounds of nutria anal scent gland extract. The researchers then created and evaluated combinations of synthetic attractants based on the major constituents of the extract and tested the response of wild-caught nutria. While no formulation was statistically better than others in pairwise comparisons, the attractant made from saturated fatty acids and the attractant made from a complete esterification of fatty acids and alcohols showed promise for further investigation. The scientists plan to test these attractants in the marshes of Louisiana and continue developing additional tools to reduce nutria impacts to natural resources.

For more information about NWRC's nutria research, contact Dr. Jimmy Taylor at Jimmy.D.Taylor@aphis.usda.gov.

Feral Swine

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

Feral Pigs Threaten Unique Florida Native Plant Communities. Feral pigs can have a serious impact on natural resources, including ecologically sensitive sites such as wetland habitat for rare and endangered plant and animal species. The Avon Park Air Force Range (APAFR) is a 106,034-acre, U.S. Department of Defense training installation located in central Florida. In 2009, concern for the future of its unique native plant resources led APAFR personnel to enlist the expertise of the

Nutria are an invasive species from South America that cause significant damage to aquatic ecosystems in North America. *(DOI/FWS, Steve Hillebrand)*

APHIS Wildlife Services program in documenting the amount of pig damage and initiating a pig removal program. NWRC biologists used highly sensitive GPS units to map the damage and catalogue its severity on 35 study areas throughout the APAFR. These data are being updated periodically as the pig removal program proceeds in order to document the effectiveness of the program in protecting the sensitive plant resources.

Feral swine are included as one of only 14 mammals on the World Conservation Union's list of "100 of the World's Worst Invasive Alien Species" due to their severe impact on biological diversity and human activities, as well as their illustration of biological invasion issues. As feral swine populations continue to expand across the United States, wildlife biologists, State agriculture agencies, and policymakers from States in which feral swine damage is an emerging problem are seeking guidance on effective management tools and techniques. To this end, NWRC scientists partnered with the Caesar Kleberg Wildlife Research Institute at Texas A&M University-Kingsville to develop innovative feral swine damage management tools and disease abatement strategies. The scientific approach of this project will combine studies of free-ranging and captive feral swine and other wildlife.

Feral Swine Behavior Relative to Aerial Gunning in Southern Texas. Feral swine threaten natural and agricultural resources through their destructive feeding behavior, competition with native wildlife, and impacts on domestic animal agriculture. NWRC evaluated aerial gunning on feral swine to determine if this management method altered the home range and core area sizes of feral swine populations, distances between home range centers, and distances moved by surviving animals. Researchers collected data before, during, and after aerial gunning efforts in southern Texas using GPS collars deployed on 25 adult feral swine at 2 study sites. Data showed that home range and core area sizes did not differ between pre- and post-aerial gunning. Feral swine moved at a greater rate during the aerial gunning phase than during the pre- and post-periods. The researchers concluded that aerial gunning had only minor effects on the behavior

NWRC tested non-target exclusion feeder systems for feral swine as a means to deliver baits containing pharmaceuticals in a rangeland ecosystem of southern Texas. *(APHIS/NWRC, Tyler Campbell)*

Invasive feral swine impact resources through their destructive feeding behavior, competition with native wildlife, and impacts to domestic animal agriculture. *(APHIS/Wildlife Services)*

of surviving swine and that this removal method should be considered a viable tool in contingency planning for a foreign animal disease outbreak.

Baits for Pharmaceutical Delivery to Feral Swine. NWRC evaluated eight oral delivery systems designed to deliver pharmaceuticals to feral swine on two properties in southern Texas. Modified PIGOUT® Feral Pig Bait was used throughout the trials to compare species-specific visitation and removal rates. During trial 1, feral swine bait removal rates differed among the treatments, with fish-flavored and vegetable-flavored plus FeralMone® baits being removed at a greater rate than expected, and fish-flavored plus FeralMone baits being removed at a lesser rate than expected. During trial 2, feral swine bait removal rates did not differ among treatments. The consistent finding of high bait removal by nontarget species has shown the need for an oral delivery system specific to swine in southern Texas.

Evaluation of Feral Swine-Specific Feeder Systems. NWRC evaluated candidate non-target exclusion feeder systems as a means to deliver baits containing pharmaceuticals to feral swine in a rangeland ecosystem of southern Texas. In this study, researchers from the NWRC field station in Kingsville, TX, baited three, non-target exclusion feeder system prototypes with whole kernel corn and fishmeal baits. They then monitored each feeder system for 4 weeks (from November to December 2008) using motion-sensing digital photography. The percentage decrease in bait removal following the activation of the boar-operated systems (BOS) feeder was 48 percent for feral swine and 100 percent for all other species. The percentage decrease in bait removal following the activation of the non-target exclusion device was 19, 28, 100, and 100 percent for raccoons, feral swine, white-tailed deer, and collared peccaries, respectively. The importance of the BOS feeder at delivering baits to only feral swine in a rangeland setting cannot be overstated. The NWRC recommends further evaluation of the BOS feeders within rangeland and other ecosystems of the United States.

Chemical Sterilization of Captive Feral Swine with a Third Generation GnRH Vaccine. In recent years, scientists have made advances in immunocontraceptive vaccines involving GnRH (e.g.,GonaCon™) to control feral swine populations. However, one obstacle with the GonaCon vaccine is its high cost of formulation.

NWRC scientists initiated a study to seek low-cost alternatives. aXent, a division of the Imaxio Company, has developed an adjuvant-free immunization technology for veterinary vaccine applications. This proprietary technology has dramatically improved the immunogenicity of antigens. However, because this technology has not been evaluated within a GnRH vaccine for swine, it is unknown whether this is a cost-effective alternative. NWRC scientists evaluated the effectiveness of a third generation GnRH vaccine at sterilizing male feral swine in a captive setting. The scientists found reduced testosterone production in feral swine that were given one and two doses of the third generation GnRH vaccine. Similarly, there was impaired sperm development in feral swine given the third generation GnRH vaccine. These initial findings suggest the third generation GnRH vaccine is effective at sterilizing male feral swine.

For more information about NWRC feral swine research, contact Dr. Tyler Campbell at Tyler.A.Campbell@aphis.usda.gov.

Awards and Research Collaborations

NWRC often collaborates with various government agencies, universities, private-sector industries, and others to develop new tools and techniques for resolving human-wildlife conflicts.

GonaCon™ has great potential as an additional management tool for urban/suburban deer populations or other environments where alternate management options are limited. *(U.S. Geological Survey/National Biological Information Infrastructure, Charles H. Warren)*

Awards

During 2009, NWRC received recognition in several areas including contraception research, publications, and green building innovation.

Award for OvoControl® Contraceptive Research. NWRC was awarded the 2009 Governor's Award for Research Impact in Natural Resource Management for its role in the development of OvoControl®, an oral contraceptive bait for Canada geese, ducks, and feral pigeons. Colorado Governor Bill Ritter presented the award at a special reception in February 2009. The award ceremony was sponsored by CO-LABS, a consortium of federally funded scientific laboratories, universities, businesses, local governments, and community leaders organized to establish Colorado as a global leader in research and technology. The consortium also enhances the potential for new partnerships, technology transfer, and jobs. The award's review panel was impressed with NWRC's careful study of OvoControl's efficacy, toxicity to other species, standards for safe use, and potential unintended environmental consequences prior to the bait's commercialization.

Recognition of Green Accomplishments. In April 2009, the City of Fort Collins, CO, recognized the NWRC as a Silver Level partner of the Climate Wise program. The Climate Wise program was initially developed by Fort Collins to help local businesses reduce greenhouse gases. Businesses that join the program receive:

- free technical assessments that help them identify, implement, measure, and report actions that reduce greenhouse gas emissions;
- public recognition for their commitment and progress towards reducing greenhouse gases; and
- training and networking opportunities throughout the year with peer companies.

NWRC joined the Climate Wise program in 2008. Plaques to recognize the new Climate Wise Partners were presented by the Mayor of Fort Collins.

2008 Outstanding Research Publication Awards. The NWRC Publication Award was created to encourage the development and exchange of information by NWRC personnel to the scientific community and to appropriately recognize contributions to the wildlife management profession. The winners are selected by a committee of NWRC research scientists after a review of all publications produced the previous year. In 2009, two awards for 2008 publications were presented:

- "Indirect effects and traditional trophic cascades: a test involving wolves, coyotes, and pronghorns" by Kim Murray Berger, Eric M. Gese, and Joel Berger (published in *Ecology*), and
- "An invasive frog, Eleutherodactylus coqui, increases new leaf production and leaf litter decomposition rates through nutrient cycling in Hawaii" by Hans Sin, Karen H. Beard, and William C. Pitt (published in *Biological Invasions*).

The article by Kim Murray Berger and co-authors used an observational study design that pulled several pieces of evidence together in an effective, well-analyzed fashion. Specifically, over a 3-year period, the authors used spatial and seasonal heterogeneity measures of wolf distribution and abundance to assess corresponding coyote effects on the survival of pronghorn antelope fawns. The authors demonstrated that fawn survival rates

were four-fold higher at sites used by wolves. Their data indicate the importance of alternative food web pathways in structuring the dynamics of ecosystems. These findings will be important in developing predator control strategies.

The paper by Hans Sin and co-authors is a significant contribution to scientific literature for examining the effects of invasive species on ecosystem processes. Specifically, the authors evaluated the effects of coqui frogs on invertebrates, herbivory, plant growth, leaf litter decomposition rates, leaf litter chemistry, and throughfall chemistry across two study sites in Hawaii. The authors concluded that these invasive frogs have the potential to reduce endemic invertebrates and increase nutrient cycling rates, which may confer a competitive advantage to invasive plants in an ecosystem where native species have evolved in nutrient-poor conditions. The paper is an excellent example of a well-designed study that incorporates field data collected in a quasi-experimental design, which was then integrated into a pathway analysis model.

NWRC researchers helped collect biological samples from immobilized African lions in Zambia to evaluate the animals' disease status. *(APHIS/NWRC)*

Research Collaborations

NWRC often collaborates with various government agencies, universities, private-sector industries, and others to develop new tools and techniques for resolving human-wildlife conflicts. In fiscal year (FY) 2009, NWRC scientists collaborated with 54 universities, 26 corporations and businesses, 27 U.S. Government agencies, 28 State agencies, 4 municipal or local governments, 8 foreign governments, and 26 nongovernmental organizations.

Scientists Assist in Capture of African Wildlife and in Training Zambian Biologists. During May 19 through June 10, 2009, NWRC wildlife biologists assisted with immobilizing, capturing, and collecting biological samples from four African lions and two African wild dogs—an endangered species—in and around the South Luangwa National Park near Mfuwe, Zambia. The African Wild Dog Conservation Trust (AWDCT) of New Zealand and the Zambian Wildlife Authority (in Lusaka, Zambia) requested that NWRC scientists provide their expertise in evaluating the disease status and interaction of lions, wild dogs, and spotted hyenas with diseased domestic village dogs. The scientists assisted in training Zambian and AWDTC scientists in wildlife immobilization and biological sample collection, preservation, and storage. The scientists also gave presentations on rabies and tuberculosis in wildlife to the local Zambian wildlife staff.

Wildlife Disease Meeting With Italian Scientists. Two scientists from the Institut of Zooprophylacica Emiglia Romano (in Brescia, Italy) visited the NWRC headquarters in Fort Collins, CO, to learn about research activities on avian influenza, West Nile virus, and other zoonotic diseases. They also discussed surveillance methods and diagnostic testing for these diseases with NWRC wildlife disease scientists.

Scientists From Taiwan's Animal Health Research Institute Visit. In October 2008, three scientists from the Animal Health Research Institute in Taiwan visited NWRC headquarters in Fort Collins, CO. During their 2-day visit, the Taiwanese scientists met with NWRC wildlife disease scientists, APHIS Wildlife Services' National Wildlife Disease Program staff, and faculty from the Department of Fish, Wildlife, and Conservation Biology at Colorado State University (CSU) to discuss surveillance methods and research activities on avian influenza, West Nile virus, and Japanese encephalitis. The visit was very successful, and invitations to visit Taiwan were extended to further information exchange between the two organizations.

Uruguayan Scientists Visit. Scientists from the Uruguayan National Institute for Agricultural Research and the Ministry of Livestock, Agriculture and Fisheries visited NWRC headquarters in April 2009. The purpose of the visit was to strengthen relationships and collaborate with USDA agencies involved in research on bird pest management in cereal and oilseed crops. In particular, the Uruguayan scientists hope to work with NWRC researchers studying avian reproductive control and developing methods for preventing predation on sheep.

APHIS Scientists Host Chinese Delegation. NWRC and APHIS Veterinary Services' Centers for Epidemiology and Animal Health hosted a delegation of 16 directors and scientists from multiple Chinese government agencies, including the Department of Agriculture and Animal Industry, the China Animal Health and Epidemiology Center, the China Institute of Veterinary Drug Control, the Bureau of Animal Health, and the Animal Disease Control and Prevention Center. NWRC and Veterinary Services representatives provided information on APHIS' animal health expertise, including the agency's operational work and research on animal disease surveillance and risk analysis, wildlife diseases, and animal damage management. Tours of the APHIS facilities in Fort Collins, CO, were provided as well.

Thai Veterinary Officers Visit. On April 9, 2009, NWRC headquarters staff hosted two veterinary officers from the Bureau of Epidemiology, Department of Disease Control, Ministry of Public Health in Nonthaburi, Thailand. The veterinarians came to learn about NWRC research on oral rabies vaccines and baits. The Thailand veterinarians are responsible for the feral-dog-and-cat rabies control program in Thailand and are considering the use of oral vaccines to enhance their efficiency in vaccinating dogs and cats to better control rabies in their country. They were also interested in, and received information on, the use of infrared thermography. This technology can be used to detect rabid animals and is also effective in the remote and rapid detection of foot-and-mouth disease in domestic ungulates and high pathogenic avian influenza in chickens.

Supporting Student Research

NWRC scientists conduct collaborative research, maintain formal affiliations and adjunct professorships, teach courses, and serve on graduate student committees at numerous colleges and universities throughout the country. These activities help strengthen and expand the expertise and capabilities of academic institutions, as well as provide students with opportunities to work directly with professional wildlife biologists on wildlife research and management issues.

NWRC Scientist Presents "Life After Graduate School." In February 2009, a scientist from NWRC's field station in Hilo, HI, gave a presentation to a University of Hawaii senior-seminar class. The presentation included information about pursuing scientific careers and the college graduate student experience. Additionally, the presentation emphasized how important obtaining a higher education degree can be in providing a broad range of opportunities to students in their chosen field of interest. The NWRC scientist also discussed current research conducted at the field station in Hilo to address the threat invasive vertebrate species pose to Hawaii.

NWRC Field Station in Logan, UT, Hosts Tour for Students. In March 2009, a scientists and an animal care specialist from the NWRC field station in Logan, UT, provided a 3-hour tour for students attending The Wildlife Society's 2009 Western Student Conclave. The tour was one of the most well-attended field trips during the conclave and included 35 students plus advisors. Attendees learned about the field station's history, long-term collaboration with Utah State University, and research activities. Students were also taught about animal care and handling and techniques, such as fladry, radio-activated guards, and capture devices that NWRC scientists are studying.

NWRC Scientists Guest Teach Telemetry Laboratories. In March 2009, two scientists from the NWRC field station in Starkville, MS, taught telemetry to a wildlife techniques class at Mississippi State University. The scientists demonstrated basic VHF (very high frequency) telemetry methods, brought telemetry equipment for exhibit, and designed a field exercise for 30 students. The field exercise comprised hands-on experience in homing and triangulation techniques for acquiring animal locations.

NWRC Scientists Present Research to Wildlife Damage Management Class. In March 2009, biologists with NWRC's field station in Starkville, MS, visited Mississippi State University to give a presentation to the Wildlife Damage Management class in the Wildlife and Fisheries Department. The class was composed of advanced undergraduate and graduate students. The biologists provided an overview of the function and mission of NWRC, information on specific program and project research topics and findings, and employment opportunities with NWRC.

NWRC Provides Training on Invasive Parakeets. In June 2009, a professor and three students from Brooklyn College, NY, visited the NWRC's field station in Gainesville, FL, in a collaborative effort to learn more about the ecology and behavior of invasive monk parakeets. This species is native to South America, but now has thriving populations in many parts of the United States, including New York City. Brooklyn College students and faculty will be studying campus and adjacent-neighborhood parakeets to determine population size, nesting behavior, movement patterns, and genetic relationships. At the NWRC field station, the student group obtained hands-on experience in trapping, handling, measuring, and marking monk parakeets. In addition to this practical training, NWRC staff provided general overviews of NWRC research activities and the APHIS Wildlife Services program.

Monk parakeets are native to South America. Released by their American owners either intentionally or unintentionally, the parakeets have formed stable, feral populations in Florida, Connecticut, and New York. *(APHIS/NWRC, Mike Avery)*

Information and Communication

NWRC proactively disseminates scientific and technical information to help resolve human-wildlife conflicts and build a better understanding of the Federal role in wildlife damage management.

Captive Nile monitor lizard used for bait preference studies under laboratory conditions. *(APHIS/NWRC, Ken Tope)*

Information and Outreach

Publications, presentations, and the NWRC Web site are some of the mechanisms the Center uses to transfer information to stakeholders, the public, scientific community, and State and Federal agencies.

Outreach. In 2009, NWRC and APHIS Legislative and Public Affairs staff responded to 62 media requests for information regarding NWRC research activities. NWRC also hosted more than 2,200 visiting scientists, students, stakeholders and others at the NWRC headquarters office in Fort Collins, CO, and field stations across the country. The Center's bi-annual report *Managing Wildlife Damage Informational Notebook* was also updated and provided to the U.S. Congress. An electronic copy of this report is available on the Wildlife Services Web page at www.aphis.usda.gov/wildlife_damage/content/wp_c_ws_2008_Notebook.shtml.

The NWRC seminar program offers a valuable forum for the exchange of ideas among Center staff, field station personnel, visiting scientists, and Wildlife Services staff. During 2009, NWRC hosted 18 seminars in Fort Collins, CO, including presentations by speakers from various universities, foreign wildlife organizations, and NWRC headquarters and field staff.

NWRC Web Site. In 2009, the NWRC Information Services Unit updated the NWRC Web site by adding 2008 research accomplishments and a link to one-page flyers about each research project. New Web site pages include a livestock-protection-dog Web page for producers and other interested users, a rotating "Spotlight" feature written by APHIS Public Affairs staff, and short biographies of all previous Center directors.

Online Accessibility of NWRC Resources and Outreach Products. All NWRC-authored publications from 1980 to the present are now available electronically through the NWRC Library Online Catalog (http://207.67.203.77/u95010staff/opac/search/SimpleSearch.asp). Current publications can also be found on the NWRC Publications Web page or through the National Agricultural Library's AgSpace Digital Repository. An informational kiosk at NWRC headquarters in Fort Collins, CO, was also updated this year with new photos and information.

Documenting the History of NWRC. In 2009, work in the NWRC Archives/Records Management Unit focused on organizing historical records and making them accessible through the Center's Library Online Catalog. The archives staff sorted and catalogued material from old defunct field stations, research projects, and unpublished reports. In the area of records management, archives staff continued to focus on educating various staff constituencies regarding retention, filing, records regulatory requirements, and electronic records. They also completed and implemented a comprehensive disaster plan that will help ensure NWRC is prepared in the event of an emergency that impacts records.

Meetings, Workshops, and Conference Presentations

To help promote collaboration and the exchange of scientific information, NWRC scientists often present at, host, or attend national and international scientific meetings. The following is a list of such events NWRC staff attended in October 2008 to September 2009.

- 31st National Sunflower Association Sunflower Research Forum (Fargo, ND)
- American Ornithologists' Union 125th Meeting (Portland, OR)
- Annual Aquaculture America Meeting (Seattle, WA)
- Brown Treesnake Working Group (Saipan, Commonwealth of the Northern Mariana Islands)
- Deer Damage Management Workshop (Iowa and Nebraska)
- European Wildlife Disease Association (Rovinj, Croatia)
- Great Lakes Double-Crested Cormorant Management Coordination Meeting (Lansing, MI)
- International Invasive Bird Conference (Freemantle, Western Australia)
- International Livestock Emergency Response Conference (Tucson, AZ)
- International *Mycobacterium bovi* Conference (Wellington, New Zealand)
- Ohio Coordinating Committee for the Control of Depredating Birds (Fremont, OH)
- Oregon Processed Vegetable Growers and the Oregon Horticulture Society-Vegetable Section (Salem, OR)
- Pan-American Congress of Veterinary Sciences (Guadalajara, Mexico)
- The Wildlife Society 15th Annual Meeting (Miami, FL)
- The Wildlife Society 16th Annual Meeting (Monterey, CA)
- Virginia Chapter of the Wildlife Society (Richmond, VA)
- Waterbird Society 32nd Annual Meeting (South Padre Island, TX)

Publications

The transfer of scientific information is an important part of the research process.

Fladry has been shown to be an effective deterrent against wolves, especially for penned sheep operations. *(Oregon Department of Fish and Wildlife)*

Publications

The transfer of scientific information is an important part of the research process. NWRC scientists publish in a variety of peer-reviewed journals that cover a wide range of disciplines, including wildlife management, genetics, analytical chemistry, ornithology, and ecology.

Allan, B.F.; Langerhans, B.; Ryberg, W.A., et al. 2009. Ecological correlates of risk and incidence of West Nile virus in the United States. *Oecologia* 158 (4): 699–708.

Arjo, W.M.; Fisher, C.E.; Armstrong, J.; Breck, S.; Slate, D. 2008. Effects of natural barriers and habitat on the western spread of raccoon rabies in Alabama. *Journal of Wildlife Management* 72 (8): 1725–35.

Atwood, T.C.; DeLiberto, T.J.; Smith, H.J.; Stevenson, J.S.; VerCauteren, K.C. 2009. Spatial ecology of raccoons related to cattle and bovine tuberculosis in northeastern Michigan. *Journal of Wildlife Management* 73 (5): 647–54.

Atwood, T.C.; Gese, E.M. 2008. Coyotes and recolonizing wolves: social rank mediates risk–conditional behaviour at ungulate carcasses. *Animal Behaviour* 75 (3): 753–62.

Atwood, T.C.; Gese, E.M.; Kunkel, K.E. 2009. Spatial partitioning of predation risk in a multiple predator-multiple prey system. *Journal of Wildlife Management* 73 (6): 876–84.

Avery, M.L.; Keacher, K.L.; Tillman, E.A. 2008. Nicarbazin bait reduces reproduction by pigeons (*Columba livia*). *Wildlife Research* 35 (1): 80–5.

Avery, M.L.; Tillman, E.A.; Humphrey, J.S. 2008. Effigies for dispersing urban crow roosts. In: Timm, R.M.; Madon, M.B., eds. *Proceedings of the 23rd Vertebrate Pest Conference,* 17–20 March 2008, San Diego, CA. Davis, CA: University of California, Davis: 84–7.

Avery, M.L.; Yoder, C.A.; Tillman, E.A. 2008. Diazacon inhibits reproduction in invasive monk parakeet populations. *Journal of Wildlife Management* 72 (6): 1449–52.

Bartel, R.A.; Knowlton, F.F.; Stoddart, L.C. 2008. Long-term patterns in mammalian abundance in northern portions of the Great Basin. *Journal of Mammalogy* 89 (5): 1170–83.

Baruch-Mordo, S.; Breck, S.W.; Wilson, K.R.; Theobald, D.M. 2008. Spatiotemporal distribution of black bear-human conflicts in Colorado, USA. *Journal of Wildlife Management* 72 (8): 1853–62.

Berentsen, A.R.; Dunbar, M.R.; Ebersol, R.; McLean, R.G. 2008. Risks associated with the transmission of bovine tuberculosis from white-tailed deer to cattle in Michigan: current research. In: Timm, R.M.; Madon, M.B., eds. *Proceedings of the 23rd Vertebrate Pest Conference,* 17–20 March 2008, San Diego, CA. Davis, CA: University of California, Davis: 277–9.

Berentsen, A.R.; Dunbar, M.R.; Fitzpatrick, C.E.; McLean, R.G. 2008. Barriers, corridots, and raccoon variant rabies in northeastern Ohio: research in progress. In: Timm, R.M.; Madon, M.B., eds. *Proceedings of the 23rd Vertebrate Pest Conference,* 17–20 March 2008, San Diego, CA. Davis, CA: University of California, Davis: 275–6.

Berger, K.M.; Gese, E.M.; Berger, J. 2008. Indirect effects and traditional trophic cascades: a test involving wolves, coyotes, and pronghorn. *Ecology* 89 (3): 818–28.

Blackwell, B.F.; DeVault, T.L. 2009. Richard A. Dolbeer: scientist, innovator, manager, and mentor. *Human-Wildlife Conflicts* 3 (2): 296–7.

Blackwell, B.F.; Fernandez-Juricic, E.; Seamans, T.W.; Dolan, T. 2009. Avian visual system configuration and behavioral response to object approach. *Animal Behaviour* 77 (3): 673–84.

Blackwell, B.F.; Schafer, L.M.; Helon, D.A.; Linnell, M.A. 2008. Bird use of stormwater-management ponds: decreasing avian attractants on airports. *Landscape and Urban Planning* 86 (2): 162–70.

Blackwell, B.F.; Seamans, T.W. 2008. Food scraps composting and vector control. *BioCycle:* 49 (6): 35–7.

Blackwell, B.F.; Seamans, T.W. 2009. Enhancing the perceived threat of vehicle approach to deer. *Journal of Wildlife Management* 73 (1): 128–35.

Blaum, N.; Engeman, R.M.; Wasiolka, B.; Rossmanith, E. 2008. Indexing small mammalian carnivores in the southern Kalahari, South Africa. *Wildlife Research* 35 (1): 72–9.

Breck, S.W.; Lance, N.; Seher, V. 2009. Selective foraging for anthropogenic resources by black bears: minivans in Yosemite National Park. *Journal of Mammalogy* 90 (5): 1041–1044.

Breck, S.W.; Williams, C.L.; Beckmann, J.P.; Matthews, S.M.; Lackey, C.W.; Beecham, J.J. 2008. Using genetic relatedness to investigate the development of conflict behavior in black bears. *Journal of Mammalogy* 89 (2): 428–34.

Bruggers, R.L. 2009. Setting research priorities at WS' National Wildlife Research Center. *Human-Wildlife Conflicts* 3 (2): 161–4.

Burke, P.W.; Witmer, G.W.; Jojola, S.M.; Nolte, D.L. 2008. Improved nutria trapping success. In: Timm, R.M.; Madon, M.B., eds. *Proceedings of the 23rd Vertebrate Pest Conference,* 17–20 March 2008, San Diego, CA. Davis, CA: University of California, Davis: 59–62.

Campbell, T.A. 2009. Las enfermedades del venado cola blanca en Norteamerica: situacion actual y desafios (white-tailed deer diseases in North America: current situation and challenges). In: *Proceedings of the XI International Seminar on the white-tailed deer*, October 2009, Guadalupe, Nuevo León, Mexico. Guadalupe, N.L., Mexico: Regional Livestock Union of Nuevo Leon: 1–11.

Campbell, T.A.; Corn, J. 2008. Recent range expansion of invasive feral hogs. *South Texas Wildlife* 12 (2): 3–4.

Campbell, T.A.; DeYoung, R.W.; Wehland, E.M.; Grassman, L.I.; Long, D.B.; Delgado-Acevedo, J. 2008. Feral swine exposure to selected viral and bacterial pathogens in southern Texas. *Journal of Swine Health and Production* 16 (6): 312–5.

Campbell, T.A.; Long, D.B. 2008. Mammalian visitation to candidate feral swine attractants. *Journal of Wildlife Management* 72 (1): 305–9.

Campbell, T.A.; Long, D.B. 2009. Feral swine damage and damage management in forested ecosystems. *Forest Ecology and Management* 257 (12): 2319–26.

Campbell, T.A.; Long, D.B. 2009. Strawberry-flavored baits for pharmaceutical delivery to feral swine. *Journal of Wildlife Management* 73 (4): 615–9.

Cariappa, C.A.; Ballard, W.; Breck, S.; Piaggio, A.J.; Neubaum, M. 2008. Estimating population size of Mexican wolves noninvasively (Arizona). *Ecological Restoration* 26 (1): 14–6.

Carlson, D.A.; Gese, E.M. 2008. Reproductive biology of the coyote (*Canis latrans*): integration of mating behavior, reproductive hormones and vaginal cytology. *Journal of Mammalogy* 89 (3): 654–64.

Carlson, D.A.; Gese, E.M. 2009. Influence of exogenous gonadotropin-releasing hormone on seasonal reproductive behavior of the coyote (*Canis latrans*). *Theriogenology* 72 (6): 773–783.

Cavalcanti, S.M.; Gese, E.M. 2009. Spatial ecology and social interactions of jaguars (Panthera onca) in the southern Panatal, Brazil. *Journal of Mammalogy* 90 (4): 935–45.

Chastant, J.E.; Fioranelli, P.B.; King, T.D. 2008. Fledgling double-crested cormorants rehearse a food manipulation technique with woody debris, algae, and shells. *Waterbird*s 31 (1): 147–148.

Chipman, R.B.; DeVault, T.L.; Slate, D.; Preusser, K.J.; Carrara, M.S.; Friers, J.W.; Algeo, T.P. 2008. Nonlethal management to reduce conflicts with winter urban crow roosts in New York: 2002–2007. In: Timm, R.M.; Madon, M.B., eds. *Proceedings of the 23rd Vertebrate Pest Conference,* 17–20 March 2008, San Diego, CA. Davis, CA: University of California, Davis: 88–93.

Clark, L. 2009. Sapro-Zoonotic risks posed by wild birds in agricultural landscapes. In: Sapers, G.M.; Solomon, E.B.; Matthews, K.R. *The Produce Contamination Problem: Causes and Solutions.* New York: Elsevier/Academic Press: 119–142.

Conner, M.M.; Ebinger, M.R.; Knowlton, F.F. 2008. Evaluating coyote management strategies using a spatially explicit, individual-based, socially structured population model. *Ecological Modelling* 219 (1–2): 234–47.

Cummings, J.L.; Handley, L.W.; MacBryde, B.; Tupper, S.K.; Werner, S.J. 2009. Dispersal of viable row-crop seeds of commercial agriculture by farmland birds: implications for genetically modified crops. *Environmental Biosafety Research* 7 (4): 241–52.

Curtis, P.D.; Richmond, M.E.; Miller, L.A.; Quimby, F.W. 2008. Physiological effects of gonadotropin-releasing hormone immunocontraception on white-tailed deer. *Human-Wildlife Conflicts* 2 (1): 68–79.

Darrow, P.A.; Shivik, J.A. 2008. A pilot evaluation of trap monitors by the USDA WS Operational Program. In: Timm, R.M.; Madon, M.B., eds. *Proceedings of the 23rd Vertebrate Pest Conference,* 17–20 March 2008, San Diego, CA. Davis, CA: University of California, Davis: 213–7.

Darrow, P.A.; Skirpstunas, R.T.; Carlson, S.W.; Shivik, J.A. 2009. Comparison of injuries to coyote from 3 types of cable foot-restraints. *Journal of Wildlife Management* 73 (8): 1441–1444.

Delutes, III, J.J.; Engeman, R.M. 2009. *Chelydra serpentina serpentina* (common snapping turtle). Nesting behavior and site selection. *Herpetological Review* 40 (1): 73–4.

DeVault, T.L.; Kubel, J.E.; Glista, D.J.; Rhodes Jr., O.E. 2008. Mammalian hazards at small airports in Indiana: impact of perimeter fencing. *Human-Wildlife Conflicts* 2 (2): 240–7.

DeYoung, R.W.; Zamorano, A.; Mesenbrink, B.T.; Campbell, T.A. 2009. Landscape-genetic analysis of population structure in the Texas gray fox oral rabies vaccination zone. *Journal of Wildlife Management* 73 (8): 1292–1299.

Doffitt, C.M.; Pote, L.M.; King, D.T. 2009. Experimental *Bolphorus damnificus* (Digenea: Bolbophoridae) infections in piscivorous birds. *Journal of Wildlife Diseases* 45 (3): 684–91.

Dorr, B.S.; Burger, L.W.; Barras, S.C. 2008. Evaluation of aerial cluster sampling of double-crested cormorants on aquaculture ponds in Mississippi. *Journal of Wildlife Management* 72 (1634): 1640.

Dunbar, M.R.; Johnson, S.R.; Rhyan, J.C.; McCollum, M. 2009. Use of infrared thermography to detect thermographic changes in mule deer (*Odocoileus hemionus*) experimentally infected with foot-and-mouth disease. *Journal of Zoo and Wildlife Medicine* 40 (2): 296–301.

Dusek, R.J.; McLean, R.G.; Kramer, L.D.; Ubico, S.R. 2009. Prevalence of West Nile virus in migratory birds during spring and fall migration. *American Journal of Tropical and Medical Hygiene* 81 (6): 1151–1158.

Engeman, R.M.; Bard, A.; Smith, H.T.; Groninger, N.P. 2009. Relating ten years of Northern raccoon road-kill data to their attraction to sea turtle nests. *Herpetological Conservation and Biology* 4 (3): 340–344.

Engeman, R.M.; Constantin, B.U.; Gruver, K.S.; Rossi, C. 2009. Managing predators to promote endangered species and promote their successful reproduction. In: Columbus, A.; Kuznetsov, L., eds. *Endangered Species: New Research.* New York: Nova Science Publishers, Inc.: 171–187.

Engeman, R.M.; Constantin, B.U.; Christie, M.L.; Hall, P.T. 2009. *Ctenosaura similis* (black spiny-tailed iguana), *Gopherus polyphemus* (gopher tortoise). Concurrent burrow use. *Herpetological Review* 40 (1): 84.

Engeman, R.M.; Constantin, B.U.; Hardin, S.; Smith, H.; Meshaka, Jr., W.E. 2009. "Species pollution" in Florida: a cross-section of invasive vertebrate issues and management responses. In: Wilcox, C.P.; Turpin, R.B., eds. *Invasive Species: Detection, Impact and Control.* New York: Nova Science Publishers, Inc.: 179–197.

Engeman, R.M.; Duquesnel, J.A.; Cowan, E.M.; Smith, H.T.; Shwiff, S.A.; Karlin, M. 2008. Assessing boat damage to seagrass bed habitat in a Florida park from a bioeconomics perspective. *Journal of Coastal Research* 24 (2): 527–32.

Engeman, R.M.; Kennedy, M.; Constantin, B.U.; Christie, M.L.; Hall, P.T. 2009. *Ctenosaura similis* (black spiny-tailed iguana), *Coluber constrictor priapus* (southern black racer). Non-predatory killing. *Herpetological Review* 40 (1): 84–5.

Evangelista, P.; Engeman, R.; Tallents, L. 2009. Testing a passive tracking index for monitoring the endangered Ethiopian wolf. *Integrative Zoology* 4 (2): 172–8.

Fagerstone, K.A.; Miller, L.A.; Eisemann, J.D.; O'Hare, J.R.; Gionfriddo, J.P. 2008. Registration of wildlife contraceptives in the United States of America with OvoControl and GonaCon immunocontraceptive vaccines as examples. *Wildlife Research* 35 (6): 586–92.

Field, K.L.; Bachmanov, A.A.; Mennella, J.A.; Beauchamp, G.K.; Kimball, B.A. 2009. Protein hydrolysates are avoided by herbivores but not by omnivores in two-choice preference tests. *PLoS ONE* 4(1): e4126 (January 5), *www.plosone.org/article/info:doi/10.1371/journal.pone.0004126.*

Field, K.L.; Kimball, B.A.; Mennella, J.A.; Beauchamp, G.K.; Bachmanov, A.A. 2008 Avoidance of hydrolyzed casein by mice. *Physiology & Behavior 93 (1–2): 189–99.*

Figueroa, J.A.; Kimball, B.A.; Perry, K.R. 2008. Lagomorph and rodent responses to two protein hydrolysates. *Crop Protection* 27 (3–5): 851–4.

Fike, J.A.; DeVault, T.L.; Rhodes, O.E. 2009. Identification of 24 polymorphic microsatellite markers for the double-crested cormorant (*Phalacrocorax auritus*). *Molecular Ecology Resources* 9 (4): 1183–5.

Foley, A.M.; Pierce, B.; Hewitt, D.G.; DeYoung, R.W.; Campbell, T.A.; Hellickson, M.W.; Feild, J.; Mitchell, S.; Lockwood, M.A.; Miller, K.V. 2009. Survival and movements of translocated white-tailed deer in South Texas. *Proceedings of the 2008 Annual Meeting of the Southeastern Association of Fish and Wildlife Agencies* 62: 25–30.

Forcey, G.M.; Linz, G.M.; Thogmartin, W.E.; Bleier, W.J. 2008. Modeling wetland blackbird populations as a function of waterfowl abundance in the Prairie Pothole Region of the United States and Canada. *Environmental Bioindicators* 3 (2): 124–35.

Fricke, K.A.; Cover, M.A.; Hygnstrom, S.E.; Genoways, H.H.; Groepper, S.R.; Hams, K.M.; VerCauteren, K.C. 2008. Historic and recent distributions of elk in Nebraska. *Great Plains Research* 18 (2): 189–204.

Frost, C.J.; Hygnstrom, S.E.; Tyre, A.J., et al. 2009. Probabilistic movement model with emigration simulates movements of deer in Nebraska, 1990–2006. *Ecological Modelling* 220 (19): 2481–2490.

Gaukler, S.M.; Homan, H.J.; Dyer, N.W.; Linz, G.M.; Bleier, W.J. 2008. Pathogenic diseases and movements of wintering European starlings using feedlots in central Kansas. In: Timm, R.M.; Madon, M.B., eds. *Proceedings of the 23rd Vertebrate Pest Conference,* 17–20 March 2008, San Diego, CA. Davis, CA: University of California, Davis: 280–2.

Gilsdorf, J.M.; VerCauteren, K.C.; Hygnstrom, S.E.; Walter, W.D.; Boner, J.R.; Clements, G.M. 2008. An integrated vehicle-mounted telemetry system for VHF telemetry applications. *Journal of Wildlife Management* 72 (5): 1241–6.

Gionfriddo, J.P.; Gates, N.B.; DeNicola, A.J.; Fagerstone, K.A.; Miller, L.A. 2008. Field test of GonaConTM immunocontraceptive vaccine in free-ranging female fallow deer. In: Timm, R.M.; Madon, M.B., eds. *Proceedings of the 23rd Vertebrate Pest Conference,* 17–20 March 2008, San Diego, CA. Davis, CA: University of California, Davis: 235–9.

Gionfriddo, J.P.; Eisemann, J.D.; Sullivan, K.J.; Healey, R.S.; Miller, L.A.; Fagerstone, K.A.; Engeman, R.M.; Yoder, C.A. 2009. Field test of a single-injection gonadotrophin-releasing hormone immunocontraceptive vaccine in female white-tailed deer. *Wildlife Research* 36 (3): 177–84.

Glista, D.J.; DeVault, T.L. 2008. Road mortality of terrestrial vertebrates in Indiana. *Proceedings of the Indiana Academy of Science* 117: 55–62.

Glista, D.J.; DeVault, T.L.; DeWoody, J.A. 2008. Vertebrate road mortality predominantly impacts amphibians. *Herpetological Conservation and Biology* 3 (1): 77–87.

Glista, D.J.; DeVault, T.L.; DeWoody, J.A. 2009. A review of mitigation measures for reducing wildlife mortality on roadways. *Landscape and Urban Planning* 91 (1): 1–7.

Gubanyi, J.A.; Savidge, J.A.; Hygnstrom, S.E.; VerCauteren, K.C.; Garabrandt, G.W.; Korte, S.P. 2008. Deer impact on vegetation in natural areas in southeastern Nebraska. *Natural Areas Journal* 28 (2): 121–9.

Hagy, H.M.; Linz, G.M.; Bleier, W.J. 2008. Optimizing the use of decoy plots for blackbird control in commercial sunflower. *Crop Protection* 27 (11): 1442–7.

Hall, J.S.; Bentler, K.T.; Landolt, G.; Elmore, S.A., et al. 2008. Influenza infection in wild raccoons. *Emerging Infectious Diseases* 14 (12): 1842–8.

Hall, J.S.; Minnis, R.B.; Campbell, T.A.; Barras, S., et al. 2008 . Influenza exposure in the United States feral swine populations. *Journal of Wildlife Diseases* 44 (2): 362–8.

Hellickson, M.W.; Campbell, T.A.; Miller, K.V.; Marchinton, R.L.; DeYoung, C.A. 2008. Seasonal ranges and site fidelity of adult male white-tailed deer (*Odocoileus virginianus*) in Southern Texas. *Southwestern Naturalist* 53 (1): 1–8.

Homan, H.J.; Linz, G.M.; Unrein, G.W.; Thiele, J.R.; Hobbs, J.M. 2008. Movements of European starlings captured at a winter roost in Omaha, Nebraska. In: Springer, J.T.; Springer, E.C., eds. *Proceedings of the 20th North American Prairie Conference,* 23–26 July 2006, University of Nebraska at Kearney, Kearney, Nebraska. Kearney: University of Nebraska at Kearney: 79–82.

Humberg, L.A.; DeVault, T.L.; Rhodes Jr., O.E. 2009. Survival and cause-specific mortality of wild turkeys in Northern Indiana. *American Midland Naturalist* 161 (2): 313–22.

Hygnstrom, S.E.; Josiah, S.J.; Skelton, P.D.; Gilsdorf, J.A. 2009. White-tailed deer browsing and rubbing preferences for trees and shrubs that produce non-timber forest products. *HortTechnology* 19: 111–8.

Hygnstrom S.E.; Trindle, B.D.; VerCauteren, K.C. 2008. Managing Deer Damage in Nebraska. *NebGuide* g1822 (February). University of Nebraska-Lincoln Extension, Institute of Agriculture and Natural Resources. www.ianrpubs.unl.edu/live/g1822/build/g1822.pdf.

Johnson, S.R.; Dunbar, M.R.; Martinez, L.; Jones, R.L.; Bowen, R.; Gordy, P. 2009. Experimental inoculation of coyotes with *Mycobacterium Bovis:* Susceptibility and shedding. In: Richey, M., ed. *Proceedings of the 112th Annual Meeting of the United States Animal Health Association,* 23–29 October 2008, Greensboro, NC. St. Joseph, MO: United States Animal Health Association: 94–97.

Johnston, J.J.; Bunning, R.; Taylor, N.; Griffin, D. 2008. Benzoate adjuvant to increase the utility of methylxanthine pesticides: identification of a potential rodenticide formulation for organic food production. In: Timm, R.M.; Madon, M.B., eds. *Proceedings of the 23rd Vertebrate Pest Conference,* 17–20 March 2008, San Diego, CA. Davis, CA: University of California, Davis: 166–9.

Jojola, S.M.; Witmer, G.W.; Burke, P.W. 2009. Evaluation of attractants to improve trapping success of nutria on Louisiana coastal marsh. *Journal of Wildlife Management* 73 (8): 1414–1419.

Kandel, H.; Johnson, B.; Deplazes, C.; Linz, G.; Santer, M. 2009. Sunflower treated with Avipel (anthraquinone) bird repellent. Paper presented at the 31st National Sunflower Association Sunflower Research Forum, January 2009, in Fargo, ND. www.sunflowernsa.com/uploads/Kandel_Avipel_Repellant_09.pdf.

Kemp, J.M.; Miller, L.A. 2008. Oral vaccination and immunocontraception of feral swine using *Brucella suis* with multimeric GnRH protein expression. In: Timm, R.M.; Madon, M.B., eds. *Proceedings of the 23rd Vertebrate Pest Conference,* 17–20 March 2008, San Diego, CA. Davis, CA: University of California, Davis: 250–2.

Killian,G.; Kreeger, T.J.; Rhyan, J.; Fagerstone, K.; Miller, L. 2009. Observations on the use of Gonacon™ in captive female elk (*Cervus elaphus*). *Journal of Wildlife Diseases* 45 (1): 184–8.

Killian, G.J.; Thain, D.; Diehl, N.K.; Rhyan, J.C.; Miller, L.A. 2008. Four-year contraception rates of mares treated with single-injection porcine zona pellucida and GnRH vaccines and intrauterine devices. *Wildlife Research* 35 (6): 531–9.

Killian, G.J.; Wagner, D.; Fagerstone, K.A.; Miller, L.A. 2008. Long-term efficacy and reproductive behavior associated with GonaCon™ use in white-tailed deer (*Odocoileus virginianus*). In: Timm, R.M.; Madon, M.B., eds. *Proceedings of the 23rd Vertebrate Pest Conference,* 17–20 March 2008, San Diego, CA. Davis, CA: University of California, Davis: 240–3.

Kimball, B.A.; Perry, K.R. 2008. Manipulating beaver (*Castor canadensis*) feeding responses to invasive tamarisk (*Tamarix* spp.). *Journal of Chemical Ecology* 34 (8): 1050–6.

Kimball, B.A.; Perry, K.R. 2009. Evaluating new protein sources for development of a deer repellent product. *Crop Protection* 28 (4): 364–6.

Kimball, B.A.; Russell, J.H.; DeGraan, J.P.; Perry, K.R. 2008. Screening hydrolyzed casein as a deer repellent for reforestation applications. *Western Journal of Applied Forestry* 23 (3): 172–6.

King, D.T.; Chastant, J.E. 2008. Water regurgitation by adult double-crested cormorants: a possible mechanism to assist in chick thermoregulation. *Waterbirds* 31 (2): 283–4.

Kluever, B.M.; Breck, S.W.; Howery, L.D.; Krausman, P.R.; Bergman, D.L. 2008. Vigilance in cattle: the influence of predation, social interactions, and environmental factors. *Rangeland Ecology & Management* 61 (3): 321–8.

Kozlowski, A.J.; Gese, E.M.; Arjo, W.M. 2008. Niche overlap and resource partitioning between sympatric kit foxes and coyotes in the Great Basin Desert of western Utah. *American Midland Naturalist* 160 (1): 191–208.

LeJeune, J.; Homan, H.J.; Linz, G.M.; Pearl, D.L. 2008. Role of the European starling in the transmission of *E. coli* 0157 on dairy farms. In: Timm, R.M.; Madon, M.B., eds. *Proceedings of the 23rd Vertebrate Pest Conference,* 17–20 March 2008, San Diego, CA. Davis, CA: University of California, Davis: 31–4.

Linz, G.M.; Homan, H.J.; Hagy, H.M.; Raetzman, J.M.; Penry, L.B.; Bleier, W.J. 2008. A grower's guide for planting wildlife conservation sunflower plots. Paper presented at the 30th National Sunflower Association Sunflower Research Forum, January 2008, in Fargo, ND. www.sunflowernsa.com/research/research-workshop/documents/Linz_GrowersGuide_08.pdf..

Lupold, S.; Linz, G.M.; Birkhead, T.R. 2009. Sperm design and variation in the New World blackbirds (Icteridae). *Behavioral Ecology and Sociobiology* 63 (6): 899–909.

Lupold, S.; Linz, G.M.; Rivers, J.W.; Westneat, D.F.; Birkhead, T.R. 2009. Sperm competition selects beyond relative testes size in birds. *Evolution* 63 (2): 391–402.

Massei, G.; Cowan, D.P.; Coats, J.; Gladwell, F.; Lane, J.E.; Miller, L.A. 2008. Effect of the GnRH vaccine GonaCon on the fertility, physiology and behaviour of wild boar. *Wildlife Research* 35 (6): 540–7.

Mathies, T.; Martin, D.J. 2008. Overwintering site selection by short-horned lizards (*Phrynosoma hernandesi*) in northeastern Colorado. *Journal of Herpetology* 42 (1): 163–71.

McLean, R.G.; Guptill, S.C. 2008. Use of bird-banding information to investigate disease, safety, and economic issues of birds and their interactions with humans. In: Jackson, J.A.; Davis, Jr., W.E.; Tautin, J., eds. *Bird Banding in North America: the First Hundred Years.* Cambridge, MA: Nuttall Ornithological Club: 231–44.

Meyerson, L.A.; Engeman, R.M.; O'Malley, R. 2008. Tracking non-native vertebrate species: indicator design for the United States of America. *Wildlife Research* 35(3): 235–41.

Miller, B.F.; Campbell, T.A.; Laseter, B.R.; Ford, W.M.; Miller, K.V. 2009. White-tailed deer herbivory and timber harvesting rates: implications for regeneration success. *Forest Ecology and Management* 258 (7): 1067–72.

Miller, L.A.; Fagerstone, K.A.; Kemp, J.; Killian, G.J. 2008. Immune mechanisms and characterization of injection site reactions involved in the multi-year contraceptive effect of the GonaCon™ vaccine. In: Timm, R.M.; Madon, M.B., eds. *Proceedings of the 23rd Vertebrate Pest Conference,* 17–20 March 2008, San Diego, CA. Davis, CA: University of California, Davis: 244–9.

Miller, L.A.; Fagerstone, K.A.; Wagner, D.C.; Killian, G.J. 2009. Factors contributing to the success of a single-shot, multi-year PZP immunocontraceptive vaccine for white-tailed deer. *Human-Wildlife Conflicts* 3 (1): 103–15.

Miller, L.A.; Gionfriddo, J.P.; Fagerstone, K.A.; Rhyan, J.C.; Killian, G.J. 2008. The single-shot GnRH immunocontraception vaccine (GonaCon™) in white-tailed deer: comparison of several GnRH preparations. *American Journal of Reproductive Immunology* 60 (3): 214–23.

Miller, L.A.; Gionfriddo, J.P.; Rhyan, J.C.; Fagerstone, K.A.; Wagner, D.C.; Killian, G.J. 2008. GnRH immunocontraception of male and female white-tailed deer fawns. *Human-Wildlife Conflicts* 2 (1): 93–101.

Moll, R.J.; Millspaugh, J.J.; Beringer, J.; Sartwell, J.; Woods, R.J.; VerCauteren, K.C. 2009. Physiological stress response of captive white-tailed deer to video collars. *Journal of Wildlife Management* 73 (4): 609–14.

Montplaisir, L.M.; Linz, G.M.; Tomanek, D.; Penry, L.B.; Bergman, D.L.; Homan, H.J. 2008. Movements of house sparrows captured at an experimental grain station in Fargo, North Dakota. In: Springer, J.T., ed. *Proceedings of the 20th North American Prairie Conference,* 23–26 July 2008, University of Nebraska at Kearney, Kearney, Nebraska: 69–71.

Moulton, L.L.; Linz, G.M.; Bleier, W.J. 2008. Breeding red-winged blackbird response to conspecific models placed in pre-copulatory position: implications for reproductive control. Paper presented at the 30th National Sunflower Association Sunflower Research Forum, January 2008, in Fargo, ND. www.sunflowernsa.com/research/research-workshop/documents/Moulton_RWBL_Control_08.pdf.

Moulton, L.L.; Linz, G.M.; Bleier, W.J. 2008. Breeding red-winged blackbird response to conspecific models placed in pre-copulatory position: implications for reproductive control. In: Timm, R.M.; Madon, M.B., eds. *Proceedings of the 23rd Vertebrate Pest Conference,* 17–20 March 2008, San Diego, CA. Davis, CA: University of California, Davis: 125–7.

Munoz-Igualada, J.; Shivik, J.A.; Dominguez, F.G.; Lara, J.; Gonzalez, L.M. 2008. Evaluation of cage-traps and cable restraint devices to capture red foxes in Spain. *Journal of Wildlife Management* 72 (3): 830–6.

Newman, J.R.; Newman, C.M.; Lindsay, J.R.; Merchant, B.; Avery, M.L.; Pruett-Jones, S. 2008. Monk parakeets: an expanding problem on power lines and other electrical utility structures. In: Goodrich-Mahoney, J.W.; Abrahamson, L.P.; Ballard, J.L.; Tikalsky, S.M., eds. *The Eighth International Symposium on Environmental Concerns in Rights-of-Way Management,* 12-16 September 2004, Saratoga Springs, NY. Boston, MA: Elsevier: 355-363.

Nichols, T.A.; Pulford, B.; Wyckoff, A.C., et al. 2009. Detection of protease-resistant cervid prion protein in water from a CWD-endemic area. *Prion* 3 (3): 1–13.

Nol, P.; Olsen, S.C.; Rhyan, J.C. 2009. Experimental infection of Richardson's ground squirrels *(Spermohilus richardsonii)* with attenuated and virulent strains of *Brucella abortus*. *Journal of Wildlife Diseases* 45 (1): 189–95.

Perry, K.R.; Miller, L.A.; Taylor, J. 2008. *Mycobacterium avium:* is it an essential ingredient for a single-injection immunocontraceptive vaccine? In: Timm, R.M.; Madon, M.B., eds. *Proceedings of the 23rd Vertebrate Pest Conference,* 17–20 March 2008, San Diego, CA. Davis, CA: University of California, Davis: 253–6.

Peters, M.B.; Beard, K.H.; Hagen, C.; O'Neill, E.M.; Mock, K.E.; Pitt, W.C.; Glenn, T.C. 2008. Isolation of microsatellite loci from the coqui frog, *Eleutherodactylus coqui. Molecular Ecology Resources* 8 (1): 139–41.

Petersen, M.L.; Linz, G.M.; Forcey, G.; Thogmartin, W.; Bleier, W.J. 2008. Evaluation of stop-level vs. route-level breeding bird survey counts for modeling the influence of land use and climate on breeding blackbird abundance in North Dakota. In: Timm, R.M.; Madon, M.B., eds. *Proceedings of the 23rd Vertebrate Pest Conference,* 17–20 March 2008, San Diego, CA. Davis, CA: University of California, Davis: 122–4.

Petersen, M.L.; Linz, G.M.; Forcey, G.; Thogmartin, W.; Bleier, W.J. 2008. Evaluation of stop-level vs. route-level breeding bird survey counts for modeling the influence of land use and climate on breeding blackbird abundance in North Dakota. Paper presented at the 30th National Sunflower Association Sunflower Research Forum, January 2008, in Fargo, ND. . www.sunflowernsa.com/research/research-workshop/documents/Petersen_BreedingBirdSurvey_08.pdf.

Phillips, G.E.; Thacker, T.C.; Rhyan, J.C.; Dunbar, M.R.; Salman, M.D. 2008. Efficacy of oral and parenteral routes of Mycobacterium bovis bacille Calmette-Guerin vaccination against experimental bovine tuberculosis in white-tailed deer *(Odocoileus virginianus)*: a feasibility study. *Journal of Wildlife Diseases* 44 (2): 247–59.

Piaggio, A.J.; Figueroa, J.A.; Perkins, S.L. 2009. Development and characterization of 15 polymorphic microsatellite loci isolated from Rafinesque's big-eared bat, Corynorhinus rafinesquii. *Molecular Ecology Resources* 9 (4): 1191–3.

Piaggio, A.J.; Johnston, J.J.; Perkins, S.L. 2008. Development of polymorphic microsatellite loci for the common vampire bat, *Desmodus rotundus* (Chiroptera: Phylostomidae). *Molecular Ecology Resources* 8 (2): 440–2.

Piaggio, A.J.; Miller, K.E.G.; Matocq, M.D.; Perkins, S.L. 2009. Eight polymorphic microsatellite loci developed and characterized from Townsend's big-eared bat, *Corynorhinus townsendii. Molecular Ecology Resources* 9 (1): 258–60.

Piaggio, A.J.; Navo, K.W.; Stihler, C.W. 2009. Intraspecific comparison of population structure, genetic diversity, and dispersal among three subspecies of Townsend's big-eared bats, *Corynorhinus towsendii townsendii, C. t. pallescens,* and the endangered *C. t. virginianus. Conservation Genetics* 10: 143–59.

Piaggio, A.J.; Neubaum, M.A.; Yueh, H.; Ritland, C.E.; Johnston, J.J.; Perkins, S.L. 2009. Development of 10 polymorphic microsatellite loci isolated from the mountain beaver, *Aplodontia rufa rufa* (Rafinesque). *Molecular Ecology Resources* 9: 323–5.

Pilon, J.L.; Nash, P.B.; Arver, T.; Hoglund, D.; VerCauteren, K.C. 2009. Feasibility of infectious prion digestion using mild conditions and commercial subtilisin. *Journal of Virological Methods* 161: 168–72.

Preusser, S.E.; Seamans, T.W.; Gosser, A.L.; Chipman, R.B. 2008. Evaluation of an integrated nonlethal Canada goose management program in New York (2004–2006). In: Timm, R.M.; Madon, M.B., eds. *Proceedings of the 23rd Vertebrate Pest Conference,* 17–20 March 2008, San Diego, CA. Davis, CA: University of California, Davis: 66–73.

Ramey, C.A.; Mills, K.H.; Robin, M. 2008. Synopsis of the Shoshone River skunk rabies epizootic in northwestern Wyoming. In: Timm, R.M.; Madon, M.B., eds. *Proceedings of the 23rd Vertebrate Pest Conference,* 17–20 March 2008, San Diego, CA. Davis, CA: University of California, Davis: 259–63.

Ramey, P.C.; Blackwell, B.F.; Gates, R.J.; Slemons, R.D. 2008. Oral rabies vaccination of a northern Ohio raccoon population: relevance of population density and prebait serology. *Journal of Wildlife Diseases* 44: 553–68.

Reed, L.M.; Johansson, M.A.; Panella, N.; McLean, R., et al. 2009. Declining mortality in American Crow *(Corvuv brachyrhyncbos)* following natural West Nile virus infection. *Avian Diseases* 53: 458–461.

Reidy, M.M.; Campbell, T.A.; Hewitt, D.G. 2008. Evaluation of electric fencing to inhibit feral pig movements. *Journal of Wildlife Management* 72: 1012–8.

Reidy, M.M.; Campbell, T.A.; Hewitt, D.G. 2008. Tetracycline as an ingestible biological marker for feral pigs. In: Timm, R.M.; Madon, M.B., eds. *Proceedings of the 23rd Vertebrate Pest Conference,* 17–20 March 2008, San Diego, CA. Davis, CA: University of California, Davis: 210–2.

Roberts, N.M.; Henzler, D.J.; Clark, L. 2009. Serologic evidence of avian influenza (H4N6) exposure in a wild-caught raccoon. *Avian Disease* 53: 455–7.

Root, J.J.; McLean, R.G.; Slate, D.; MacCarthy, K.A.; Osorio, J.E. 2008. Potential effect of prior raccoonpox virus infection in raccoons on vaccinia-based rabies immunization. *BMC Immunology* 9, no. 57 (October 3), www.biomedcentral.com/1471-2172/9/57.

Root, J.J.; Puskas, R.B; Fischer, J.W.; et al. 2009. Landscape genetics of raccoons *(Procyon lotor)* associated with ridges and valleys of Pennsylvania: implications for oral rabies vaccination programs. *Vector-Borne and Zoonotic Diseases* 9 (6): 583–588.

Runde, D.E.; Nolte, D.L.; Arjo, W.M.; Pitt, W.C. 2008. Efficacy of individual barriers to prevent damage to Douglas-fir seedlings by captive mountain beavers. *Western Journal of Applied Forestry* 23: 99–105.

Runge, M.C.; Sauer, J.R.; Avery, M.L.; Blackwell, B.F.; Koneff, M.D. 2009. Assessing allowable take of migratory birds. *Journal of Wildlife Management* 73: 556–65.

Russello, M.A.; Avery, M.L.; Wright, T.F. 2008. Genetic evidence links invasive monk parakeet populations in the United States to the international pet trade. *BMC Evolutionary Biology* 8, no. 217 (July 24), www.biomedcentral.com/1471-2148/8/217.

Safratowich, B.; Linz, G.M.; Bleier, W.J.; Homan, H.J. 2008. Avian use of rural roadsides with cattail (*Typha* spp.). *American Midland Naturalist* 159: 162–71.

Seamans, T.W.; Clemons, S.E.; Gosser, A.L. 2009. Observations of neck-collared Canada geese near John F. Kennedy International Airport, New York. *Human-Wildlife Conflicts* 3: 22–250.

Seamans, T.W.; Helon, D.A. 2008. Comparison of electrified mats and cattle guards to control white-tailed deer *(Odocoileus virginianus)* access through fences. In: Timm, R.M.; Madon, M.B., eds. *Proceedings of the 23rd Vertebrate Pest Conference,* 17–20 March 2008, San Diego, CA. Davis, CA: University of California, Davis: 206–9.

Seamans, T.W.; Helon, D.A. 2008. Evaluation of an electrified mat as a white-tailed deer *(Odocoileus virginianus)* barrier. *International Journal of Pest Management* 54: 89–94.

Sementelli, A.; Smith, H.T.; Meshaka Jr., W.E.; Engeman, R.M. 2008. Just green iguanas? *Public Works Management & Policy* 12: 599–606.

Shivik, J.A.; Palmer, G.L.; Gese, E.M.; Osthaus, B. 2009. Captive coyotes compared to their counterparts in the wild: does environmental enrichment help? *Journal of Applied Animal Welfare Science* 12: 223–235.

Shwiff, S.A.; Kirkpatrick, K.N.; DeVault, T.L.; VanDeValk, A.J.; Coleman, J.T.H.; Jackson, J.R. 2008. Methodology to quantify the economic impact of the double-crested cormorant *(Phalacrocorax auritus)* to the Oneida Lake Region, New York. In: Timm, R.M.; Madon, M.B., eds. *Proceedings of the 23rd Vertebrate Pest Conference,* 17–20 March 2008, San Diego, CA. Davis, CA: University of California, Davis: 103–7.

Shwiff, S.A.; Kirkpatrick, K.N.; Sterner, R.T. 2008. Economic evaluation of an oral rabies vaccination program for control of a domestic dog-coyote rabies epizootic: 1995–2006. *Journal of the American Veterinary Medical Association* 233 (11): 1736–41.

Shwiff, S.A.; Kirkpatrick, K.N.; Sterner, R.T.; Gebhardt, K. 2008. The economic impacts of bird and rodent damage to California crops: a methodology to select counties for input-output modeling. In: Timm, R.M.; Madon, M.B., eds. *Proceedings of the 23rd Vertebrate Pest Conference,* 17–20 March 2008, San Diego, CA. Davis, CA: University of California, Davis: 286–9.

Shwiff, S.A.; Sterner, R.T.; Hale, R.; Jay, M.T.; Sun, B.; Slate, D. 2009. Benefit-cost scenarios of potential oral rabies vaccination for skunks in California. *Journal of Wildlife Diseases* 45: 227–33.

Sin, H.; Beard, K.H.; Pitt, W.C. 2008. An invasive frog, *Eleutherodactylus coqui,* increases new leaf production and leaf litter decomposition rates through nutrient cycling in Hawaii. *Biological Invasions* 10: 335–45.

Sovada, M.A.; Pietz, P.J.; Converse, K.A.; King, D.T.; Hofmeister, E.K.; Scherr, P.; Ip, H.S. 2008. Impact of West Nile virus and other mortality factors on American white pelicans at breeding colonies in the northern plains of North America. *Biological Conservation:* 1021–31.

Spraker, T.R.; VerCauteren, K.C.; Gidlewski, T.; Schneider, D.A.; Munger, R.; Balachandran, A.; O'Rourke, K.I. 2009. Antemortem detection of PrP^{CWD} in preclinical, ranch-raised Rocky Mountain elk *(Cervus elaphus nelsoni)* by biopsy of the rectal mucosa. *Journal of Veterinary Diagnostic Investigation* 21: 15–24.

Stahl, R.S.; Johnston, J.J.; Linz, G.M. 2008. Estimating the efficacy of DRC–1339-treated rice bait in blackbird staging areas in North Dakota using a bioenergetics simulation. Paper presented at the 30th National Sunflower Association Sunflower Research Forum, January 2008, in Fargo, ND. www.sunflowernsa.com/research/research-workshop/documents/Stahl_DRC1339_08.pdf.

Stahl, R.S.; Werner, S.J.; Cummings, J.L.; Johnston, J.J. 2008. Computer simulations of baiting efficacy for raven management using DRC–1339 egg baits. In: Timm, R.M.; Madon, M.B., eds. *Proceedings of the 23rd Vertebrate Pest Conference,* 17–20 March 2008, San Diego, CA. Davis, CA: University of California, Davis: 94–7.

Sterner, R.T.; Sun, B.; Bourassa, J.B.; Hale, R.L.; Shwiff, S.A.; Jay, M.T.; Slate, D. 2008. Skunk rabies in California (1992–2003) - implications for oral rabies vaccination. *Journal of Wildlife Diseases* 44: 1008–13.

Sterner, R.T. 2008. The IPM paradigm: vertebrates, economics, and uncertainty. In: Timm, R.M.; Madon, M.B., eds. *Proceedings of the 23rd Vertebrate Pest Conference,* 17–20 March 2008, San Diego, CA. Davis, CA: University of California, Davis: 194–200.

Sterner, R.T. 2008. Reducing the uncertainty of IPM economics. In: Burton, E.N.; Williams, P.V., eds. *Crop Protection Research Advances.* Hauppauge, NY: Nova Science Publishers: 163–81.

Sterner, R.T. 2009. The economics of threatened species conservation: a review and analysis. In: Aronoff, J.B., eds. *Handbook of Nature Conservation.* Hauppauge, NY: Nova Science Publishers: 213–35.

Sterner, R.T.; Meltzer, M.I.; Shwiff, S.A.; Slate, D. 2009. Tactics and economics of wildlife oral rabies vaccination, Canada and the United States. *Emerging Infectious Diseases* 15 (8): 1176–1184.

Sullivan, H.J.; Blitvich, B.J.; VanDalen, K.K.; Bentler, K.T.; Franklin, A.B.; Root, J.J. 2009. Evaluation of an epitope-blocking enzyme-linked immunosorbent assay for the detection of antibodies to influenza A virus in domestic and wild avian and mammalian species. *Journal of Virological Methods* 161: 141–6.

Taylor, J.; Bergman, D.L.; Nolte, D.L. 2008. If you build it, they will come - management planning for a suburban beaver population in Arizona. In: Timm, R.M.; Madon, M.B., eds. *Proceedings of the 23rd Vertebrate Pest Conference,* 17–20 March 2008, San Diego, CA. Davis, CA: University of California, Davis: 43–6.

Taylor, J.; Strickland, B. 2008. Effects of roost shooting on double-crested cormorant use of catfish ponds - preliminary results. In: Timm, R.M.; Madon, M.B., eds. *Proceedings of the 23rd Vertebrate Pest Conference,* 17–20 March 2008, San Diego, CA. Davis, CA: University of California, Davis: 98–102.

Thiemann, G.W.; Stahl, R.S.; Baruch-Mordo, S.; Breck, S.W. 2008. Trans fatty acids provide evidence of anthropogenic feeding by black bears. *Human-Wildlife Conflicts* 2 (2): 183–93.

Tupper, S.K.; Cummings, J.L.; Engeman, R.M. 2009. Longevity of DayGlo fluorescent particle marker used to mark birds in flight pen and field. *Wildlife Research* 36 (319): 323.

VanDalen, K.K.; Anderson, T.D.; Killian, M.L.; Pedersen, J.C.; Franklin, A.B.; Piaggio, A.J. 2008. Increased detection of influenza A H16 in the United States. *Archives of Virology* 153: 1981–3.

VanDalen, K.K.; Shriner, S.A.; Sullivan, H.J.; Root, J.J.; Franklin, A.B. 2009. Monitoring exposure to avian influenza viruses in wild mammals. *Mammal Review* 39 (3).

VerCauteren, K.C.; Atwood, T.C.; DeLiberto, T.J.; Smith, H.J., et al. 2008. Sentinel-based surveillance of coyotes to detect bovine tuberculosis, Michigan. *Emerging Infectious Diseases* 14 (12): 1862–9 (December), www.cdc.gov/eid/content/14/12/1862.htm.

VerCauteren, K.C.; Lavelle, M.J.; Phillips, G.E. 2008. Livestock protection dogs for deterring deer from cattle and feed. *Journal of Wildlife Management* 72: 1443–8.

VerCauteren, K.C.; Seward, N.W.; Lavelle, M.J.; Fischer, J.W.; Phillips, G.E. 2009. Deer guards and bump gates for excluding white-tailed deer from fenced resources. *Human-Wildlife Conflicts* 3: 145–53.

Vice, D.S.; Engeman, R.M.; Hall, M.A.; Clark, C.S. 2009. Working dogs: the last line of defense for preventing dispersal of brown treesnakes from Guam. In: Helton, W.S., ed. *Canine Ergonomics: The Science of Working Dogs.* Boca Raton, FL: CRC Press: 195–204.

Walter, W.D.; VerCauteren, K.C.; Campa III, H.; Clark, W.R. 2009. Regional assessment on influence of landscape configuration and connectivity on range size of white-tailed deer. *Landscape Ecology* 24 (10): 1405–1420.

Walter, W.D.; VerCauteren, K.C.; Gilsdorf, J.M.; Hygnstrom, S.E. 2009. Crop, native vegetation, and biofuels: response of white-tailed deer to changing management priorities. *Journal of Wildlife Management* 73: 339–44.

Ward, A.I.; VerCauteren, K.C.; Walter, W.D.; Gilot-Fromont, E., et al. 2009. Options for the control of disease 3: targeting the environment. In: Delahay, R.J.; Smith, G.C.; Hutchings, M.R. eds. *Management of Disease in Wild Animals.* New York: Springer Japan: 147–168.

Werner, S.J.; Carlson, J.C.; Tupper, S.K.; Santer, M.M.; Linz, G.M. 2009. Threshold concentrations of an anthraquinone-based repellent for Canada geese, red-winged blackbirds, and ring-necked pheasants. *Applied Animal Behaviour Science* 121: 190–196.

Werner, S.J.; Cummings, J.L.; Pipas, P.A.; Tupper, S.K.; Byrd, R.W. 2008. Registered pesticides and citrus terpenes as blackbird repellents for rice. *Journal of Wildlife Management* 72: 1863–8.

Werner, S.J.; Cummings, J.L.; Tupper, S.K.; Goldade, D.A.; Beighley, D. 2008. Blackbird repellency of selected registered pesticides. *Journal of Wildlife Management* 72: 1007–11.

Werner, S.J.; Kimball, B.A.; Provenza, F.D. 2008. Food color, flavor, and conditioned avoidance among red-winged blackbirds. *Physiology & Behavior* 93: 110–7.

White, N.A.; Engeman, R.M.; Sugihara, R.T.; Krupa, H.W. 2008. A comparison of plotless density estimators using Monte Carlo simulation on totally enumerated field data sets. *BMC Ecology* 8, no. 6 (April 17), www.biomedcentral.com/1472-6785/8/6.

White, P.C.L.; Ford, A.E.S.; Clout, M.N.; Engeman, R.M.; Roy, S.; Saunders, G. 2008. Alien invasive vertebrates in ecosystems: pattern, process and the social dimension. *Wildlife Research* 35: 171–9.

Winter, J.B.; Linz, G.M.; Bleier, W.J. 2008. Avian use of rice-baited trays attached to cages with live decoy blackbirds in central North Dakota. Paper presented at the 30th National Sunflower Association Sunflower Research Forum, January 2008, in Fargo, ND. www.sunflowernsa.com/research/research-workshop/documents/Winter_RiceTrays_08.pdf.

Winter, J.B.; Linz, G.M.; Bleier, W.J. 2009. Avian use of rice-baited trays attached to cages with live decoy blackbirds in central North Dakota: research update. Paper presented at the 31st National Sunflower Association Sunflower Research Forum, January 2009, in Fargo, ND.. www.sunflowernsa.com/uploads/Winter_NonBlackbird_09.pdf.

Winter, J.B.; Linz, G.M.; Homan, H.J.; Bleier, W.J. 2008. Avian use of rice-baited trays attached to cages with live decoy blackbirds in central North Dakota. In: Timm, R.M.; Madon, M.B., eds. *Proceedings of the 23rd Vertebrate Pest Conference,* 17–20 March 2008, San Diego, CA. Davis, CA: University of California, Davis: 118–21.

Witmer, G.W.; Burke, P.W. 2008. The ability of a geotextile barrier material to exclude rodents. In: Timm, R.M.; Madon, M.B., eds. *Proceedings of the 23rd Vertebrate Pest Conference,* 17–20 March 2008, San Diego, CA. Davis, CA: University of California, Davis: 39–42.

Witmer, G.W.; Gionfriddo, J.; Pipas, M. 2008. Evaluation of physical barriers to prevent prairie dog colony expansion. *Human-Wildlife Conflicts* 2 (2): 206–11.

Witmer, G.W.; Pipas, M.; Burke, P.W.; Rouse, D.; Dees, D.; Manci, K. 2009. Raptor use of artificial perches at natural areas, City of Fort Collins, Colorado. *Prairie Naturalist* 40: 37–42.

Witmer, G.W.; Burke, P.W. 2009. Influence of vitamin K-rich plant foods on anticoagulant baiting efficacy in wild House mice, wild Norway rats, and wild Black rats. *Pacific Conservation Biology* 15: 87–91.

Witmer, G.W.; Burke, P.W.; Jojola, S.M. 2008. An evaluation of the effectiveness of potential Norway rat attractants. In: Timm, R.M.; Madon, M.B., eds. *Proceedings of the 23rd Vertebrate Pest Conference,* 17–20 March 2008, San Diego, CA. Davis, CA: University of California, Davis: 35–8.

Witmer, G.W.; Burke, P.W.; Jojola, S.; Nolte, D.L. 2008. A live trap model and a field trial of a nutria (Rodentia) multiple capture trap. *Mammalia* 72: 352–4.

Wyckoff, A.C.; Henke, S.E.; Campbell, T.A.; Hewitt, D.G.; VerCauteren, K.C. 2009. Feral swine contact with domestic swine: a serologic survey and assessment of potential for disease transmission. *Journal of Wildlife Diseases* 45: 422–9.

Yoder, C.A.; Miller, L.A.; Fagerstone, K.A. 2008. Population modeling of prairie dog contraception as a management tool. In: Timm, R.M.; Madon, M.B., eds. *Proceedings of the 23rd Vertebrate Pest Conference,* 17–20 March 2008, San Diego, CA. Davis, CA: University of California, Davis: 229–34.

Yost, M.C.; Pote, L.M.; Wise, D.J.; Dorr, B.S.; Richardson, T.D. 2009. *Biomphalaria havanensis* identified as a potential intermediate host for the digenetic trematode *Bolbophorus damnificus. North American Journal of Aquaculture* 71: 10–5.

Young, J.K.; Glasscock S.N.; Shivik J.A. 2008. Does spatial structure persist despite resource and population changes? Effects of experimental manipulations on coyotes. *Journal of Mammalogy* 89: 1094–1104.

Appendices

Appendix 1. List of 2009 NWRC Research Projects

1. Avian and Invasive Species Population Management
2. Defining Economic Impacts and Developing Strategies for Reducing Avian Predation in Aquaculture Systems
3. Defining Impacts and Developing Strategies To Reduce Mammalian Damage in Forested and Riparian Ecosystems
4. Development of Chemistry, Biochemistry and Computational Based Tools for Wildlife Damage Management
5. Documenting Impacts, Developing Control Strategies, and Applying Knowledge of Predator Behavior and Demographics To Protect Livestock and Natural Resources
6. Ecology of Emerging Viral and Bacterial Diseases in Wildlife
7. Economic Research of Human-Wildlife Conflicts: Methods and Applications
8. Evaluation and Management of Chronic Wasting Disease Transmission
9. Evaluation of Wildlife Food Plots, Repellents, and DRC-1339 "Take Models" for the Management of Blackbirds and Starlings in Sunflower Fields, Feedlots, and Dairies
10. Feral Swine (and Other Wildlife) Damage and Disease Abatement Strategies
11. Improved Technologies and Nonlethal Techniques for Managing Predation
12. Invasive Species and Technology Development
13. Investigating the Ecology, Control, and Prevention of Terrestrial Rabies in Free-Ranging Wildlife
14. Methods and Strategies To Manage Invasive Species Impacts to Agriculture in Hawaii
15. New Technologies To Deter Wildlife from Airports and Aircraft
16. Reproductive Control Methods: Applications for Contraceptives Using Existing Products and Exploration of New Non-Injection Techniques

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

Appendix 2. Acronyms and Abbreviations

AgSpace	National Agricultural Library Digital Repository
AGID	Agar gel immunodiffusion
APAFR	Avon Park Air Force Range
APHIS	Animal and Plant Health Inspection Service
AWDCT	African Wild Dog Conservation Trust
bELISA	Blocking enzyme-linked immunosorbent assay
BOS	Boar-operated systems
BSL-3 Ag	Biosafety Level 3-Agriculture
BTS	Brown treesnakes
CAFO	Concentrated animal feeding operations
CDC	Centers for Disease Control and Prevention
CO-LABS	Consortium of federally funded scientific laboratories and institutions
CSU	Colorado State University
CWD	Chronic wasting disease
DNA	Deoxyribonucleic acid
DNM	Dead neonatal mice
DOI	U.S. Department of the Interior
DRC-1339	Compound DRC-1339
EPA	U.S. Environmental Protection Agency
FAA	Federal Aviation Administration
FDA	Food and Drug Administration
FY	Fiscal year
FWS	Fish and Wildlife Service
GIS	Geographical information system
GnRH	Gonadotropin-releasing-hormone
GonaCon	GonaCon Immunocontraceptive Vaccine
GPS	Global positioning system
GSA	General Services Administration
HID	High-intensity discharge
IAV	Influenza A viruses
INAD	Investigational New Animal Drug
ISU	Iowa State University
LD10	Lethal dose for 10 percent of sample population
LD25	Lethal dose for 25 percent of sample population
MCT	Multiple capture trap
NASS	National Agricultural Statistics Service
NPS	National Park Service
NWRC	National Wildlife Research Center
ORV	Oral Rabies Vaccination
PBPK	Physiologically based pharmacokinetic
PPM	arts per million
PrP	Cellular prion protein
PZP	Porcine Zona Pellucida
T&E	Threatened and endangered species
TH	Tungsten-halogen
TVR	Trap-vaccine-release
uDNM	Unadulterated dead neonatal mice
USDA	U.S. Department of Agriculture
VHF	Very high frequency
WDRB	Wildlife Disease Research Building

Wildlife Services

NWRC

National Wildlife Research Center