USDA Animal and Plant Health Inspection Service
U.S. DEPARTMENT OF AGRICULTURE

Wildlife Services

Innovative Solutions to Human-Wildlife Conflicts

National Wildlife Research Center • Accomplishments, 2022

U.S. Department of Agriculture

Animal and Plant Health Inspection Service
Wildlife Services

The National Wildlife Research Center (NWRC) is part of Wildlife Services (WS), a program within the U.S. Department of Agriculture's (USDA) Animal and Plant Health Inspection Service (APHIS). Our mission is to apply scientific expertise to resolve human-wildlife conflicts while maintaining the quality of the environment shared with wildlife. NWRC develops methods and information to address human-wildlife conflicts related to the following:

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

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Cover: NWRC researchers are working with the Bureau of Land Management and others to develop contraceptives to help manage overabundant feral horse populations. *Photo by Adobe Stock*

Message From the Director

Jason Suckow, NWRC Director
Photo by USDA, Wildlife Services, Gail Keirn

Helen Keller once said, "Alone we can do so little; together we can do so much." Collaboration is key to many of Wildlife Services' (WS) successes. Whether it be WS scientists and field personnel working together to evaluate new wildlife damage management tools, cooperators funding a new area of wildlife research, or diverse stakeholders sharing ideas to help address a challenging wildlife damage issue, collaborations drive ingenuity, improve communications, and create trust.

In the Spotlight titled "Technology Transfer and New Tools" (page 14), we highlight some of the National Wildlife Research Center's (NWRC) recent collaborations with WS' Operational Program. As the research unit of WS, NWRC is tasked with developing new wildlife damage management methods for WS' Operational employees and others to use. Annually, the NWRC collaborates with hundreds of different agencies, universities, private companies, and non-governmental organizations. In this section, you'll read how we are working with WS airport biologists, a private company, and airports in eight States to evaluate a new repellent to deter wildlife from areas around runways. We're also partnering with our Operational colleagues to develop genetic techniques and web-based tools to inform management actions.

Expanding these networks and collaborations is critical.

In early 2023, WS hosted an in-person meeting for 80 of its biological science technicians at the NWRC headquarters office in Fort Collins, CO. Most of WS' 2,000-member workforce is comprised of technicians. They are our "boots-on-the-ground," interacting daily with WS' stakeholders and collaborators to provide technical assistance and manage wildlife damage. The goal of the 2023 meeting was to promote camaraderie and a common understanding of WS' mission, goals, and organizational structure. The attendees also received training to improve and expand their technical skills and expertise. For many, it was their first visit to the NWRC, and it provided an opportunity for operations and research employees to build connections and common understandings that will enhance our ability to address our stakeholders' needs.

WS' efforts to build collaborations will continue in May 2023 when we co-sponsor the 4th International Chronic Wasting Disease (CWD) Symposium in Denver, CO. Planning began in 2022 with representatives from WS, APHIS-Veterinary Services, U.S. Forest Service, Colorado State University, several agencies within the Department of the Interior, and wildlife agencies from Colorado and Wyoming. The symposium brings together hundreds of specialists and interested parties from around the world to address and discuss the unique challenges associated with CWD and its impacts on wild and captive cervids (e.g., deer, elk). We hope such discussions will lead to new collaborations and strengthen our Nation's ability to combat this deadly cervid disease. In the Spotlight titled "Supporting Wildlife Disease Research and Surveillance" (page 10), you can learn about NWRC's new CWD research project and prion laboratory, as well as our future CWD research goals.

These are just two examples of high-profile meetings that support collaborations. However, collaborations often begin with a simple phone call or email, when individuals reach out to one another. NWRC welcomes you to reach out to us, and we promise to do the same.

It is with pleasure that I present to you NWRC's 2022 research accomplishments.

Jason Suckow
Director
National Wildlife Research Center
USDA APHIS Wildlife Services
Fort Collins, CO

Sandhill cranes (pictured) weigh about 10 pounds and have a wingspan of 5 feet. WS conducts research and operational activities to prevent collisions between airplanes and wildlife, such as sandhill cranes.

Photo by USDA, Wildlife Services, Caroline Olson

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Wildlife contraceptives, such as GonaCon-Deer (pictured), are promising new tools for managing wildlife populations and diseases.
Photo by USDA, Wildlife Services

Fertility control methods can help manage conflicts from locally overabundant wildlife populations when used as part of an integrated management approach.

WS NWRC researchers are dedicated to finding biologically sound, practical, and effective solutions for resolving wildlife damage management issues. The following spotlights showcase our expertise and holistic approach to addressing today's wildlife-related challenges.

SPOTLIGHT

Fertility Control in Wildlife

Since the early 1900s, U.S. wildlife conservation efforts have focused on restoring, protecting, and managing many wildlife populations. In some cases, such as with white-tailed deer (*Odocoileus virginianus*) and Canada geese (*Branta canadensis*), these efforts have been so successful that species have become locally overabundant. Overabundant species cause various conflicts with people, ranging from minor nuisance issues to serious habitat and crop destruction, disease spread, and collisions with vehicles and aircraft.

Wildlife contraceptives and other fertility control methods are promising new tools for managing wildlife populations and diseases. NWRC scientists work with State fish and wildlife agencies, universities, zoos, international organizations, and private partners to develop, test, and register fertility control methods.

In 2009, APHIS successfully registered the first immunocontraceptive vaccine for wildlife with the U.S. Environmental Protection Agency (EPA). This vaccine called GonaCon Immunocontraceptive Vaccine (later renamed GonaCon-Deer; EPA Reg. No. 56228-40) was developed by NWRC scientists and initially registered for use in adult female white-tailed deer in urban and suburban areas. In 2013, GonaCon-Equine (EPA Reg. No. 56228-41) was registered for use in adult female wild or feral horses (*Equus caballus*) and burros (*Equus africanas asinus*).

Today, NWRC researchers are focused on new fertility control methods, particularly those that cause permanent sterility with one application. Other efforts help to expand existing product registrations, develop improved contraceptives and oral delivery systems, and determine how fertility control can be used to prevent wildlife disease spread.

Fertility control tools alone, however, cannot quickly reduce overabundant wildlife populations to healthy levels. Instead, the tools are most effective when used together with other wildlife management methods, such as trapping, relocation, or hunting. Immediate population goals can only be met by removing problem animals. Fertility control methods can then be used to slow the rate of population recovery or maintain populations at desired levels.

The following sections highlight WS research related to fertility control in wildlife.

Managing Overabundant Feral Horses and Burros

According to the U.S. Department of the Interior's Bureau of Land Management (BLM), there are an estimated 82,000 feral horses and burros (also known as wild horses and burros) on BLM-managed lands, mostly in the western United States. This is nearly three times what

NWRC worked with Colorado State University and the National Park Service to examine the long-term effectiveness of GonaCon-Equine to limit reproduction in free-ranging feral horses.
Photo by Adobe Stock

the rangeland can support, which is detrimental for feral horses, wildlife, and rangeland. Range managers are exploring the use of contraceptives to decrease feral horse and burro populations on public lands.

NWRC worked with Colorado State University and the National Park Service to examine the long-term effectiveness of the contraceptive vaccine GonaCon-Equine to limit reproduction in free-ranging feral horses, both as a single-shot vaccine and as a two-shot vaccine series. Twenty-nine adult, female feral horses at Theodore Roosevelt National Park in North Dakota were treated with a single dose of GonaCon-Equine by hand injection. Another 28 were given a sham treatment for comparison. After treatment, the mares were released and monitored annually for a total of eight years. After the first 4 years, the GonaCon-treated animals were recaptured, given a booster vaccination, released, and monitored for another 4 years.

"In the first 2 years following the first vaccination, we saw fewer foals born to treated versus untreated mares," states NWRC Fertility Control project leader, Dr. Jason Bruemmer. "The effects of the vaccine lasted even longer after the booster vaccination, with treated females giving birth to fewer foals than untreated mares for 3 consecutive years."

Although GonaCon significantly reduced foaling in the treated mares, researchers note that feral horses will need at least one booster vaccination to offer sustained reductions in population growth rates over time.

In a later study, additional mares were treated with GonaCon using remote darting to determine the effectiveness of darting and the best interval between primary and booster vaccinations. Results showed a significant increase in vaccine efficacy after the booster dose no matter if it was administered 6 months, 1 year, or 2 years later.

Another focus of NWRC's fertility control research is the development of products that cause permanent sterility with one application. For example, researchers are exploring methods to reduce ovarian follicular growth. By targeting follicular growth and oocyte (egg) development there is potential to prevent ovulation and accelerate the depletion of eggs in female mammals, thereby causing sterility.

In 2021, NWRC and Colorado State University researchers studied the effects of vaccination against two oocyte-specific growth factors (Bone Morphogenetic Protein-15 [BMP-15] and Growth

Differentiation Factor-9 [GDF-9]) on ovarian function in female horses. Results showed that both treatments changed ovarian functions, with BMP-15 significantly decreasing ovulation rates and the size of ovulatory follicles. Though this work is in its early stages, these findings will aid in the future development of a single-shot, permanent contraceptive for wild horses and burros.

Update on GonaCon Registrations for Prairie Dogs and White-Tailed Deer

In March 2022, the EPA registered GonaCon–Prairie Dogs (EPA Reg. No. 56228-64) for managing fertility in sub-adult or adult female black-tailed, white-tailed, and Gunnison's prairie dogs (*Cynomys* sp.).

Previous NWRC laboratory and field studies showed that GonaCon–Prairie Dogs controlled female fertility for at least one year. The product is hand injected and may only be used in prairie dog colonies that occur in urban and suburban areas, open spaces and natural areas, parks, campgrounds, airports, roadway medians, and other non-crop use sites.

"Because prairie dogs typically reach sexual maturity between 2 and 3 years old and live only 3 to 4 years, the vaccine provides a non-lethal tool for prairie dog population management in these areas where trapping and relocation activities are relatively expensive or prohibited," states NWRC registration manager, Emily Ruell.

The vaccine can be administered by WS employees, State wildlife management agency personnel, or persons working under their authority. Like other GonaCon products, the vaccine must also be registered with the State before use and is currently registered in Colorado and New Mexico. The registration adds to the suite of GonaCon products for wildlife.

GonaCon–Deer is currently registered for use in North Carolina, South Carolina, and New Jersey. In 2021, the EPA approved a label amendment for the federal GonaCon–Deer registration that allows for booster doses to be administered

In March 2022, the EPA registered GonaCon–Prairie Dogs for managing fertility in female prairie dogs.
Photo by Adobe Stock

to marked deer by remote darting or hand injection. Wildlife managers expect the use of remote darting will improve the feasibility and cost effectiveness of controlling deer populations with the vaccine.

"Allowing booster doses to be administered to marked animals via remote darting removes the need to repeatedly capture and immobilize the same animal," states Ruell.

Sharing Expertise Abroad: Invasive Hippos in Colombia

In the 1980s, drug kingpin Pablo Escobar illegally imported four hippopotamuses (*Hippopotamus amphibius*) to his private zoo at Hacienda Napoles near the Magdalena River in central Colombia. After his death by law enforcement, many of Escobar's exotic animals were rounded up and sent to zoos, but not the hippos. They have since grown their population to approximately 80 animals and experts fear there could be thousands of hippos in Colombia by 2060, if left unchecked.

In coordination with APHIS International Services, NWRC researchers traveled to Colombia in 2021 at the request of the Corporation of the Basins of the Rivers Negro and Nare (CORNARE)— the Colombian agency responsible for managing the invasive hippos. They brought with them an experimental contraceptive vaccine for hippos based on the existing GonaCon formulation registered with the EPA for use on white-tailed deer and horses.

"Based on previous studies, we know GonaCon can be effective at reducing fertility in a variety of mammal species," states NWRC Fertility Control project leader, Dr. Jason Bruemmer. "We are hopeful that it will prove effective in hippos and provide a nonlethal method for managing the invasive population in Colombia."

Bruemmer and his Colombian colleagues administered 22 doses of vaccine to both male and female hippos located in a lake near the Magdalena River. An additional 25 hippos were later vaccinated by CORNARE staff. Researchers also collected DNA from the treated animals

An invasive hippo in Colombia is darted with an experimental contraceptive vaccine based on the existing GonaCon immunocontraceptive vaccine for deer and horses.
Photo: U.S. State Department, Pedro Moreno

to genetically identify animals and potentially describe their relatedness to one another. Approximately 45 fecal samples were collected over several months to track reproductive hormone levels in the animals and determine vaccine efficacy. CORNARE researchers report no hippos have been born, yet they remain cautiously optimistic since accurate animal counts are difficult.

"When CORNARE called us for assistance, we were happy share our expertise and contraceptive product and we are looking forward to seeing the results," states Bruemmer. "It's rewarding to help other countries control invasive animals and plants."

Delivery of Fertility Control Vaccines

Delivering vaccines to wildlife is challenging. Injectable forms of fertility control vaccines (e.g., GonaCon) prevent fertility in several mammal species but often require capturing and handling animals. The oral delivery of these vaccines would greatly improve their ease-of-use. Currently, no oral fertility control products are available for use in mammals. Researchers from the NWRC and United Kingdom's Animal and Plant Health Agency hope to change that.

In a series of experiments, researchers are exploring a new approach that combines *Mycobacterium avium* cell wall fragments with an immunogen containing gonadotropin releasing hormone (GnRH). Both components cause strong immune responses. This new immunocontraceptive formulation is known as MAF-IMX294. The formulation blocks the binding of GnRH and the subsequent production of reproductive hormones. Using this formulation, researchers were able to demonstrate the first ever evidence of reduced fertility from oral dosing with an immunocontraceptive.

In the latest research using this formulation, captive laboratory Wistar rats (*Rattus norvegicus*) were treated with MAF-IMX294 and MAF-IMX294P (a more purified immunogen) by injection. Both formulations resulted in anti-GnRH antibody titers in 100 percent of the rats treated and significantly impaired fertility for approximately 4 months. Zero of 9 and 1 of 10 female rats treated with MAF-IMX294 and MAF-IMX294P, respectively, produced litters following the first mating challenge 45 days after treatment, compared to 9 of 9 control animals. The average time to first pregnancy was 166 days for MAF-IMX294 and 177 days for MAF-IMX294P. Furthermore, results showed that litter sizes were significantly reduced for subsequent litters in females returning to fertility following treatment with either formulation. Results suggest that immunocontraceptives might suppress overall litter sizes beyond the initial period of infertility. This could increase the potential long-term impact of immunocontraception in some species.

"Though our results are promising," states NWRC assistant director Dr. Doug Eckery, "we need to continue our investigations toward the oral delivery of these agents and permanent sterility after a single dose."

Future experiments will continue to investigate this formulation and others along with novel methods of oral delivery.

Next Steps—NWRC's fertility control research will continue to improve upon the use and delivery of GonaCon in a variety of wildlife species. It will also focus on the development of a potentially longer lasting, single dose immunocontraceptive targeting the development of egg cells in female mammals. Researchers are exploring the use of devices to alter animal behavior and disrupt mating, nesting, or other related reproductive activities to reduce reproductive success.

SPOTLIGHT

Supporting Wildlife Disease Research and Surveillance

NWRC continues to enhance its ability to identify and characterize wildlife pathogens and develop tools for identifying and mitigating disease risks to agriculture, the public, and wildlife. Our research helps to inform management for wildlife pathogens such as SARS-CoV-2 (the virus that causes COVID-19 in people), highly pathogenic avian influenza (HPAI), African swine fever (ASF), and rabies. We've also expanded our collaborations, staffing, and laboratory capabilities for disease diagnostics. By effectively using funds from the American Rescue Plan Act (ARP) and other sources, APHIS is strengthening our Nation's ability to detect and respond to emerging and zoonotic diseases in animals.

Below are highlights from some of our recent activities related to wildlife disease research and diagnostics.

Informing Disease Management

HPAI

In early 2022, routine surveillance by WS' National Wildlife Disease Program (NWDP) confirmed highly pathogenic Eurasian H5 avian influenza in a wild American wigeon (*Anas americana*) in South Carolina. Highly pathogenic viruses had not been detected in wild birds in the United States since 2016. Soon after the initial detection, HPAI was found in commercial and backyard poultry flocks. By the end of 2022, the virus was confirmed in 47 states, affecting more than 57 million domestic birds.

NWRC's disease research supports NWDP's surveillance efforts and APHIS' emergency response planning for HPAI and many other pathogens.

NWRC studies with captive European starlings have shown the birds can replicate and shed some avian influenza A viruses. Further studies show small flocks of starlings may successfully spread the virus to bobwhite quail through shared water and food.
Photo by Adobe Stock

WS is at the forefront of our Nation's efforts to understand the impacts of wildlife pathogens on animals, people, and the environment.

"Our research provides insights into the breadth of species that may be impacted by disease outbreaks," states NWRC research wildlife biologist, Dr. Jeff Root. "By combining information from laboratory and field studies, we can gauge disease risks associated with wildlife and then identify ways to prevent the spread of pathogens from wildlife to domestic animals and livestock."

For instance, NWRC studies with captive European starlings (*Sturnus vulgaris*) have shown that the birds can replicate and shed some avian influenza A viruses (IAV). When they shed these viruses, they typically do so at relatively low to moderate levels as compared to waterfowl. However, starlings can form large flocks during certain times of the year, and although a single starling may not shed enough virus to cause transmission, a large flock of starlings might. NWRC researchers evaluated the effect of European starling flock size on IAV transmission to bobwhite quail (*Colinus virginianus*), a species known to be highly susceptible to IAVs.

"Of the three flock sizes we evaluated—10, 20, and 30 birds—flocks as small as 10 IAV-infected starlings successfully spread the virus to quail through shared water and food resources," notes Root.

Based on these transmission results, researchers plan to conduct a similar study using domestic chickens as the potential IAV recipient. If found that starlings can spread the virus to chickens, this may lead to new biosecurity recommendations and starling mitigation efforts on and around domestic poultry facilities.

SARS-CoV-2

NWRC, university, and other Federal collaborators are doing similar work related to the SARS-CoV-2 virus in wildlife. Through a series of experimental infection studies, numerous wildlife species have been tested to determine their susceptibility to SARS-CoV-2 and their ability to shed the virus. Some of the species tested include raccoons (*Procyon lotor*), striped skunks (*Mephitis mephitis*), cottontail rabbits (*Sylvilagus* sp.), red foxes (*Vulpes vulpes*), coyotes (*Canis latrans*), and a variety of rodent species. Experimentally infected species that successfully replicated and shed the SARS-CoV-2 virus included striped skunk, red foxes, deer mice (*Peromyscus maniculatus*), and bushy-tailed woodrats (*Neotoma cinerea*). Future collaborations with Colorado State University will use captive animal studies to evaluate the transmission of SARS-CoV-2 within and between select wildlife species.

NWRC is also taking advantage of samples from the WS' Wildlife Tissue and Serum Archives. As part of the NWDP's routine wildlife surveillance and monitoring, samples from more than 1,000 wild animals—all from species demonstrated to be susceptible to SARS-CoV-2 infection—have been collected and archived since the beginning of the pandemic. These samples are being tested for antibodies to SARS-CoV-2, providing an opportunity to screen difficult-to-sample species, such as mountain lions (*Puma concolor*) and bobcats (*Lynx rufus*), and shedding light on SARS-CoV-2 exposure in wildlife over time.

Results from these and other studies are helping to target ongoing surveillance of the virus.

ASF

ASF is a highly contagious and deadly pig disease that affects domestic and wild swine. There is no treatment or effective vaccine for the disease. While not a threat to human health, the virus could devastate America's pork industry and food supply. ASF has never been detected in the United States but has recently been confirmed in countries as close as the Dominican Republic and Haiti.

"The United States is one of the world's largest pork producers and the second largest exporter of pork globally," states NWRC research biologist, Dr. Kim Pepin. "If the disease arrives here, it could cost an estimated $50 billion dollars over 10 years. Having tools and strategies for eliminating the virus if it gets to the United States is critical. One area of potential entry is through our invasive feral swine population."

Pepin and other NWRC researchers have developed models to predict ASF transmission in U.S. feral swine (*Sus scrofa*, also known as wild pigs). Users can enter values for various factors, such as feral swine density, movement, and interactions among swine, and receive an optimal culling radius for disease elimination. The application also shows the size of the culling area and the number of feral swine targeted for removal under different management conditions to aid in ASF preparedness and planning. Furthermore, NWRC geneticists are examining the genomes of pigs in Africa that are susceptible and resistant to ASF. The information will help researchers determine the susceptibility of U.S. feral swine to the virus.

Rabies

While not a new disease, rabies continues to re-emerge in new species and populations in the United States and remains a significant public health concern. Rabies is an acute, fatal viral disease—most often transmitted through the bite of a rabid mammal—that can infect people, domestic pets, livestock, and wildlife. Most U.S. rabies cases occur in wildlife, including raccoons, skunks, foxes, and bats. The cost of rabies detection, prevention, and control work in the United States exceeds $300 million annually.

NWRC rabies research enables adaptive management by tracking the reduction of rabies cases in targeted wildlife populations through the analysis of rabies surveillance data and management actions. Research also helps to refine and inform strategies for oral rabies vaccine (ORV) monitoring to measure animal population immunity across broad landscapes. Core research activities investigate the effectiveness of ORV bait shapes, sizes, attractants, and field strategies to improve bait consumption by targeted wildlife species, such as raccoons, skunks, and mongooses (*Urva auropunctata*).

Research also focuses on the ecology and densities of target and nontarget wildlife species in the United States to support ORV management. For example, researchers use wildlife population genetics to identify management units and determine the likely origins of specific animals detected in "rabies free" ORV zones. Recent NWRC studies on the foraging behavior and densities of invasive mongooses in Puerto Rico are helping the WS National Rabies Management Program and its partners adapt ORV baiting strategies for novel target populations.

Ramping up Chronic Wasting Disease Research

Chronic wasting disease (CWD) is a fatal neurological disease that affects several ungulates, including mule deer (*Odocoileus hemionus*), white-tailed deer, elk (*Cervus canadensis*), and moose (*Alces alces*) (collectively known as cervids). CWD is caused by abnormal proteins called prions. Prions change normal proteins in the host animal's cells, resulting in

NWRC's new prion laboratory supports research on chronic wasting disease. *Photo by USDA, Wildlife Services, Gail Keirn*

concentrations of abnormal proteins. Over time, these abnormal proteins accumulate in the central nervous and lymphatic systems, causing a degenerative lack of control and a "wasting-away" death. There is no known cure or vaccine for CWD. To date, CWD has been detected in 30 U.S. States and 4 Canadian provinces in free-ranging cervids and/or commercial captive cervid facilities.

From 2002 to 2019, NWRC was active in CWD research, conducting more than 100 basic and applied studies on deer and elk to help mitigate disease transmission at the wildlife-livestock interface. Results from this research helped to inform management and regulatory actions at the State and Federal levels.

NWRC's CWD efforts were renewed in 2022 with the creation of a new CWD research project and prion laboratory. Both laboratory and field research will focus on the development of new tools and techniques to aid CWD management in wild and captive cervids. The lab is equipped with advanced instruments that allow for the diagnostic testing of prions in collected samples and the development of improved and new methods for prion analysis.

"Creating this new CWD project and advanced laboratory will strengthen APHIS' and our partners' abilities to find and implement new solutions to combating this deadly disease in cervids," states NWRC assistant director, Dr. Jimmy Taylor.

Future CWD research will likely focus on evaluating the use of domestic dogs (*Canis lupus familiaris*) to detect CWD-volatile organic compounds in the breath and feces of deer and elk, as well as in environmental samples; exploring targeted sex- and age-class removal of deer to reduce CWD's spread and prevalence; and characterizing and mapping CWD prion strains across the United States to determine if and how the disease is different or evolving in different regions.

Enhancing Laboratory Capacity

NWRC's headquarters facility in Fort Collins, Colorado, is home to several unique and state-of-the-art laboratories. In addition to the new prion laboratory, NWRC maintains genetics, analytical chemistry, product formulation, microbiology/disease, toxicology, and wildlife contraceptive laboratories. In 2021 and 2022, NWRC's Laboratory Support Services Unit's (LSSU) Wildlife Disease Diagnostic Laboratory received ARP funding to conduct the initial screening and analysis of more than 10,500 nasal swab samples, and an equivalent number of sera samples, collected from white-tailed deer as part of SARS-CoV-2 surveillance efforts.

"WS Operations employees and their partners in 27 States and the District of Columbia collected deer samples," notes LSSU leader and microbiologist, Dr. Jeff Chandler. "Our staff ramped up quickly to handle the large influx of samples. We sent representative presumptive positive

More than 10,500 nasal swab samples were collected from hunter-harvested white-tailed deer as part of the 2021-2022 SARS-CoV-2 surveillance efforts.
Photo by USDA, Wildlife Services

samples to our colleagues at APHIS' National Veterinary Services Laboratories in Ames, Iowa, for confirmatory testing and whole genome sequencing."

LSSU's analysis of nasal swabs resulted in over 1,350 presumptive positives, an apparent prevalence rate of 12.8 percent, and the confirmation of SARS-CoV-2 in white-tailed deer in 26 States.

NWRC is planning additional white-tailed deer and other cervid surveillance for the winter of 2022 and 2023. Ongoing surveillance and research are needed to better understand the significance of SARS-CoV-2 in free-ranging white-tailed deer, including how the deer are exposed to the virus, which virus variants are in deer, and potential impacts, if any, to overall deer populations, other wildlife, and people.

Next Steps—NWRC will continue to grow its laboratory infrastructure, collaborations, expertise, and capabilities in support of APHIS' efforts to enhance wildlife disease surveillance and monitoring, disease diagnostics, risk assessment, and agency responses to disease outbreaks. These and other NWRC research activities related to HPAI, ASF, SARS-CoV-2, CWD, as well as other diseases and pathogens, advances our knowledge about how animals are exposed to various pathogens and the potential impacts to people, animals, and the environment.

SPOTLIGHT

Technology Transfer and New Tools

One of the main goals of NWRC's research and development is to produce new tools and methods for use by the WS Operational Program and others.

"Every day, WS field specialists and biologists work to resolve conflicts between people and wildlife," states WS western region director, Keith Wehner. "These operational experts often collaborate with the program's researchers at NWRC to develop and test new wildlife damage management tools and techniques."

WS also promotes the adoption of its research outcomes by other end users and strives to transfer and market new technologies. Methods of technology transfer vary and include publishing research findings, producing technical notes and factsheets, presenting at scientific meetings, hosting demonstrations and workshops, and protecting and licensing inventions for developing commercial products.

Below are examples of recent collaborations between WS' NWRC and Operations that led to the development and use of new wildlife damage management tools and techniques.

Evaluating Wildlife Repellents for Use at Airports

A variety of wildlife species—from birds to rodents to deer—can sometimes be found in airport environments leading to safety concerns for both wildlife and airline passengers. Collisions between wildlife and aircraft have increased in the past 30 years because of an increase in both hazardous wildlife species populations and aircraft movements. To help reduce the risk of these potentially dangerous interactions, WS

NWRC researchers partner with their colleagues in WS Operations to develop and test new wildlife damage management tools and techniques.

provides airport operators across the Nation with advice and recommendations on how to keep runways and flight paths clear of wildlife.

"As part of an effort to provide recommendations on the use of wildlife repellents at airports, WS is conducting a series of trials at airports in several States," states NWRC research wildlife biologist, Dr. Scott Werner.

NWRC researchers and WS Operations airport biologists from eight States (WA, SD, OK, WI, MI, VA, NC, and SC) partnered with Arkion Life Sciences, LLC to identify best management practices for applying an anthraquinone-based repellent called Flight Control® Max to reduce bird presence on airports.

Anthraquinone is a naturally occurring compound that is found in more than 200 plant species. When eaten, anthraquinone has a repellency effect in many wild birds and some wild mammals, including mice, voles, squirrels, prairie dogs, rabbits, raccoons, and feral swine. NWRC worked with Arkion to develop and register Flight Control® Max for use as a wildlife repellent.

"Arkion is providing their wildlife repellent for use in field trials at eight military, civil, and joint-use airports nationwide," states WS' Airport Wildlife Hazards Program national coordinator, Mike Begier. "WS personnel are applying the repellent at various locations on our cooperating airports. Working with NWRC researchers, our airport biologists are then surveying and comparing wildlife presence on treated and nearby untreated locations."

To date, four of the eight airports state they would continue to use the repellent to help reduce wildlife damage and hazards at their facilities. Researchers also learned that the repellent is not effective at deterring mourning doves (*Zenaida macroura*).

Flight Control® Max repellent remains visible on treated grass near an airport runway. The wildlife repellent is being evaluated at several airports nationwide. *Photo by USDA, Wildlife Services, Clay Mealman*

Final results will help to identify what worked and what didn't work and will be the basis for recommended best management practices for future use of the repellent at airports.

Developing Web Tools for Rabies Management

The goal of WS' National Rabies Management Program (NRMP) is to prevent the further spread of wildlife rabies and eventually eliminate terrestrial rabies in the United States.

Over the past 30 years, rabies management has grown in complexity in the United States, as wild animals, including skunks, raccoons, foxes, coyotes, and bats, have replaced the domestic dog as the primary reservoir for the disease. To prevent and monitor the spread of raccoon rabies, the NRMP and its cooperators distribute several million oral rabies vaccine (ORV) baits each year in select areas of the eastern United States. ORV campaigns also occur in other areas and for other wildlife species as needed.

Knowing how these management and surveillance actions are influencing the occurrence of wildlife rabies on the landscape allows the NRMP to make more informed and strategic management decisions.

"One question often asked by our collaborating State programs is how to determine the overall effectiveness of an ORV effort," states NRMP national coordinator, Rich Chipman. "NWRC researchers are helping us answer that question."

To do this, one must first identify what proportion of the targeted animal population has rabies antibodies. This is known as seroprevalence and needs to be determined for the population both before and after ORV baiting to understand the impact of a particular baiting event (i.e., a single treatment or a comparison between different bait types, densities, or distribution methods). Most experts recommend a population seroprevalence level between 60 to 80 percent to control and eliminate rabies from wildlife populations.

"To help ensure that NRMP rabies biologists collect and compare enough blood samples from trapped animals to detect a change in seroprevalence, we developed a quick and easy-to-use web application called the *Power Analyses for Seroprevalence Studies*," states NWRC computational biologist, Dr. Amy Davis. "Users can input the type of field trial or activity being conducted and then enter different values for the number of animals sampled before and after ORV, plus their expected seroprevalence levels."

The application provides a measure of "Power" and an associated sample size—that is, how likely NRMP rabies biologists will be able to detect a change in seroprevalence based on a particular sample size. The goal is to have a Power value between 0.8 and 1 (or 80 to 100 percent likelihood) at the lowest possible sample size to limit costs and save resources.

"The new web application takes advantage of powerful modeling approaches and makes them accessible to our biologists," continues Chipman. "Without the support of NWRC's researchers and their efforts to make such applications, it would be much more difficult and costly to fine-tune and evaluate our on-the-ground activities."

Using Genetics To Target Management

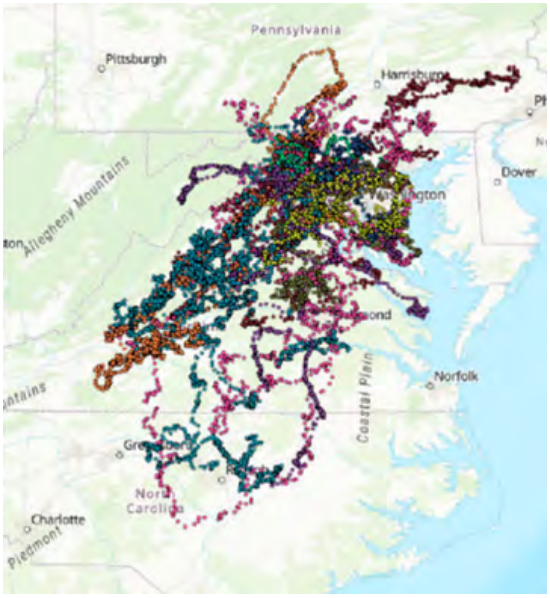
Information about wildlife populations and diseases can be difficult to obtain with traditional sampling techniques. This is especially true for rare or elusive wildlife and emerging diseases. The field of wildlife genetics uses DNA samples collected from tissue, blood, hair, feces, saliva, water, soil, and air to uncover valuable information about the presence of animals, their abundance, behavior, movements, and evolution. Genetic data can also help identify barriers to gene flow and connectivity between wildlife populations, which can guide management actions.

The Alleghany Mountains are part of the Appalachian Mountain Range of the eastern United States. WS biologists and field specialists in West Virginia have been working with NWRC geneticists to collect and analyze DNA samples from black vultures (*Coragyps atratus*) on both sides of the Alleghany Mountains to assess gene flow across the region. This builds upon 2 years of WS-West Virginia vulture telemetry and

patagial wing tag tracking data that indicates the birds are not crossing the mountains.

"Vultures are federally protected migratory birds that play an important role in our environment by cleaning up animal carcasses. However, their increasing and expanding populations are contributing to agricultural and property damage, and human health and safety concerns," states WS-West Virginia state director, John Forbes. "By sampling vultures on both sides of the mountains and comparing the genetic diversity of those samples, NWRC geneticists may show that the mountains serve as a geographic barrier, limiting gene flow and connectivity among the vulture populations. This would help us define effective vulture management units in this region."

If there is limited genetic connectivity between the vulture populations, then it is possible that a population controlled on one side of the mountains may stay reduced for some time before it is repopulated through immigration and reproduction.



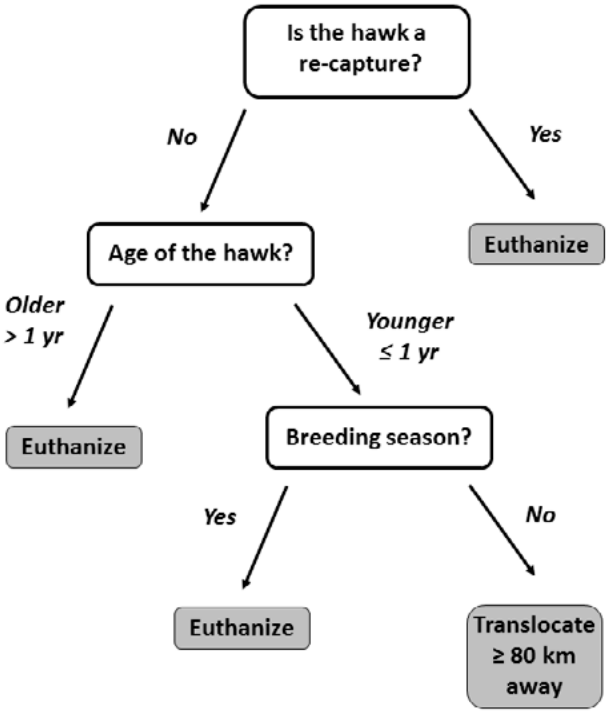
Data points from more than 350 tagged vultures showing no westward movement across the Alleghany Mountains. The mountains may serve as a natural barrier to dispersal and subsequent gene flow.
Image by USDA, Wildlife Services

NWRC and WS Operations are also using genetic data to improve feral swine eradication efforts.

NWRC geneticists have developed quantitative polymerase chain reaction (PCR) tests to detect feral swine eDNA in turbid waters, such as wallows. Environmental DNA (or eDNA) refers to DNA that is shed by an organism into the environment (for example, water, soil, or air). The genetic material could come from shed skin, hair, scales; mucous; urine; or feces.

WS Operational employees and NWRC researchers use eDNA sampling to locate the last remaining pockets of feral swine after eradication

NWRC geneticists have developed tests to detect feral swine eDNA in turbid waters, such as wallows. WS uses eDNA sampling to locate the last remaining pockets of feral swine after eradication efforts in States across the country.
Photo by Adobe Stock



NWRC researchers and WS-Illinois Operations employees created a simple management decision tree to help airport biologists manage red-tailed hawks captured at airports.
Image by USDA, Wildlife Services

efforts in States across the country and on some Caribbean islands. Water samples are collected in areas where remnant feral swine populations may occur, but where water is limited. Thus, the samples are more likely to include feral swine DNA, if swine are present. If feral swine DNA is detected, monitoring and trapping efforts are increased until the remaining swine are removed.

"Collecting water samples for eDNA analysis is a simple way for our personnel to gauge our feral swine control efforts," states WS-Missouri State director, Travis Guerrant. "Without the expertise and collaboration of NWRC's scientists, such a tool would not be available."

Best Management Practices for Translocating Red-Tailed Hawks

Each year, WS airport biologists capture and translocate more than 2,000 hawks and owls from airport environments where they pose a risk to aircraft. To identify factors that influence the success of red-tailed hawk (*Buteo jamaicensis*) translocations, NWRC researchers worked with WS-Illinois Operations field personnel from Chicago O'Hare International Airport to capture, age, tag, and translocate 577 red-tailed hawks from the airport.

"The cost of translocating the hawks in this study was more than $44,000. Because translocating raptors from airports is time-intensive and costly, we wanted to determine best management practices to help ensure translocations are successful," states NWRC research wildlife biologist, Dr. Brian Washburn.

Approximately 82 percent (475) of the translocated birds were never seen again and have unknown fates. Of the remaining 102 individual birds that returned to Chicago O'Hare and were resighted or recaptured, researchers discovered they were more likely to be older, had been moved during the breeding season, and had been translocated more than once. From these findings, the experts created and shared a simple management decision tree to help other airport biologists with

Airport biologists manage live trapping and translocating red-tailed hawks captured at airports.
Photo by USDA, Wildlife Services

the management of red-tailed hawks captured at airports.

"By modifying our management strategy slightly, we can focus our efforts on bird translocations that are most likely to be successful," states WS-Illinois state director, Scott Beckerman.

Recommended strategies include limiting the distance to translocation sites to approximately 50 miles, translocating only young red-tailed hawks (less than or equal to 1 year) during fall and winter months, and translocating an individual hawk only once.

"If these guidelines had been implemented with the hawks from our study, raptor hazard management and translocation costs would have been reduced by almost 73 percent," continues Washburn.

It's important to note that each airport situation is different and raptor translocation has strong public support. The findings from this study provide additional information to decision-makers as they consider their red-tailed hawk management options at airports.

WS' NWRC and Operations are conducting similar studies on other raptor species, such as American kestrels (*Falco sparverius*), Cooper's hawks (*Accipiter cooperii*), and great horned owls (*Bubo virginianus*) that are commonly translocated from airports.

Next Steps—NWRC continues to develop new tools and improve upon existing tools and techniques for use in wildlife damage management. Its collaborations with WS Operations and other agencies and organizations ensure that these methods are science-based, cost-effective, practical, and socially acceptable. New methods under development include detecting nutria eDNA in water samples and identifying vulture species and individuals from eDNA in vulture pellets. Experts are also evaluating the effectiveness of trained dogs as hazing tools for decreasing birds and other wildlife near airports.

2022 Accomplishments in Brief

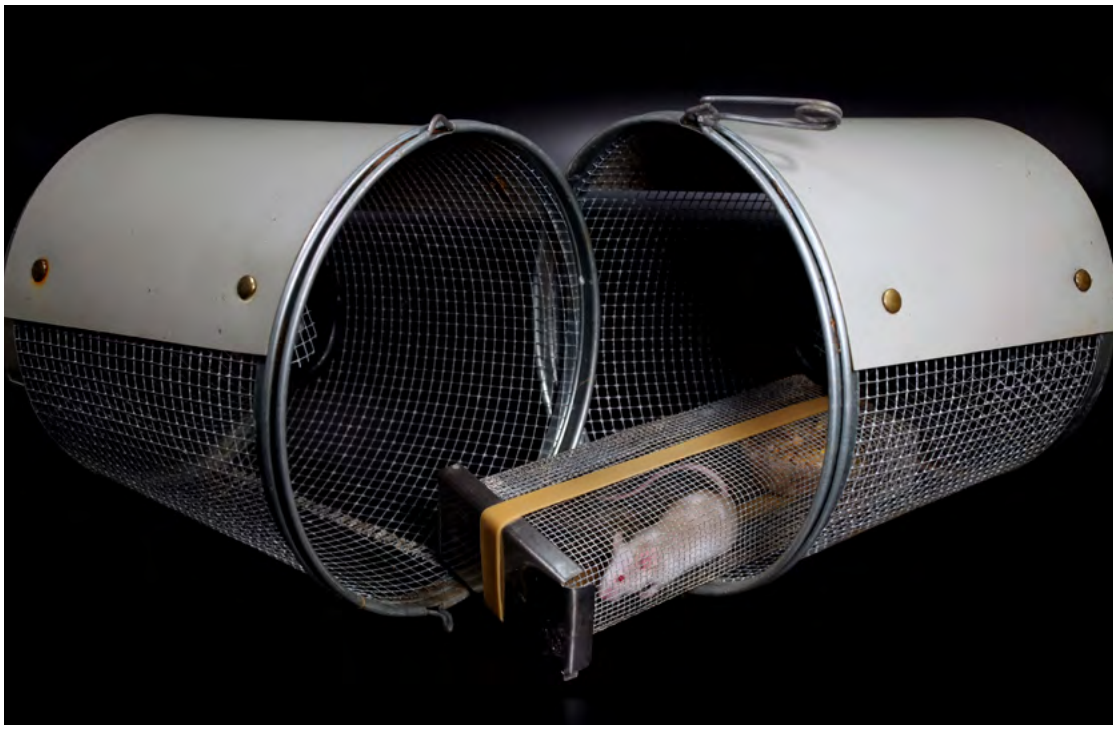
Using thermal optics at night to survey for rats during a rat eradication project in Dry Tortugas National Park, FL.
Photo by USDA, Wildlife Services, Alex Nicely

NWRC researchers and support staff conduct hundreds of studies each year to develop and evaluate tools and techniques for resolving wildlife damage issues.

WS NWRC employs about 150 scientists, technicians, and support staff who are currently devoted to 16 research projects (see Appendix 1). Below are brief summaries of select findings and accomplishments from 2022 not already mentioned in this year's report.

Devices

- **Baited Traps and Predation Risk.** Traps are sometimes used for conservation purposes to remove predators from areas where they prey upon threatened or endangered species. In Guam, traps baited with live mice (mouse-lure traps) are used to remove invasive brown treesnakes (*Boiga irregularis*) to prevent damage to property, human health and safety, and natural resources, including the protection of endangered bird species. However, baited traps may potentially increase predation risk by attracting predators to protected areas. NWRC and U.S. Geological Survey researchers evaluated whether mouse-lure traps for brown treesnakes influenced predation risks to endangered birds on the island. To simulate areas occupied by birds, researchers placed traps baited with live, domestic quail next to mouse-lure traps. For comparison, researchers placed isolated quail traps or mouse-lure traps in other areas. The researchers monitored traps using cameras to see if paired traps resulted in the mouse-lure traps attracting brown treesnakes to an area and increasing contact between snakes and the quail. Results



In Guam, traps baited with live mice (mouse-lure traps) are used to remove invasive brown treesnakes.
Photo by USDA, Wildlife Services, Shane Siers

showed that mouse-lure traps did not increase the risk of snakes interacting with the quail. Instead, results indicated that mouse-lure traps may have locally suppressed snakes. In some instances when snakes were caught in the quail traps, they tended to be larger and in better condition, suggesting that larger snakes may prefer bird versus mammalian prey. Researchers note that the strategic placement of mouse-lure traps within conservation areas may be beneficial for protecting bird species of conservation concern.

Contact: Page Klug

- **Foothold Traps for Otter Management and Restoration.** Foothold traps are often used to live capture wildlife for management and research purposes. Successful river otter (*Lontra canadensis*) restoration programs throughout North America use foothold traps extensively, but little has been done to describe and quantify injuries to otters by foothold traps. Researchers from several State wildlife agencies and NWRC evaluated injuries to river otters caught in three commercially available models of foothold traps (#11 double long-spring with standard jaws, #11 double long-spring with double jaws, and #2 coil-spring trap). Based on data from 70 captured river otters, researchers classified 78 percent (174) of the total injuries detected as "mild" and 17 percent (37) as "moderate". Less than 3 percent (11) of the injuries detected were classified as "moderately severe" or "severe." The three trap types tested met animal welfare criteria based on International Standards Organization guidelines. The criteria used in this assessment aids in future evaluations of river otter welfare when foothold traps are used for restoration, research, and population management.

  Contact: Jimmy Taylor

River otter restoration programs often use foothold traps to capture wild otters. Researchers from several State wildlife agencies and the NWRC evaluated injuries to river otters caught in three commercially available models of foothold traps.
Photo by Pennsylvania Game Commission

Pesticides

- **Public Attitudes Toward Feral Swine Toxicants.** A toxicant for feral swine may help to eradicate or control their populations, but little is known about public attitudes toward the use of toxicants for feral swine. NWRC and Colorado State University researchers analyzed responses from 2,100 rural and urban residents to a national, self-administered questionnaire on their beliefs and interactions with wildlife; knowledge and beliefs about feral swine and feral swine control methods; and respondent demographics. Of the six different lethal control methods presented to respondents, toxicant usage was the only one that most (51 percent) found to be unethical. Respondents noted that collateral harm to other animals (33 percent) and possible pain and suffering of feral swine (13 percent) were their primary concerns. This research suggests that the introduction of a feral swine toxicant in the United States could face significant opposition, particularly if the public's concerns are not well understood and addressed in product development and outreach.

  Contact: Keith Carlisle

Repellents

- **Anthraquinone-Based Repellent for Raccoons.** Wildlife repellents are non-lethal tools used to help reduce wildlife damage to property, agriculture, and human health and safety. Raccoons can damage homes and buildings and eat crops, such as commercial fruits, melons, corn, peanuts, and soybeans. Most significantly, raccoons can also transmit pathogens, such as the rabies virus, to pets and people. As part of efforts to develop new repellents for use with mammals, NWRC researchers conducted controlled feeding experiments to evaluate the efficacy of an anthraquinone-based repellent for raccoons. Anthraquinone is a naturally occurring, plant-based compound that is registered by the EPA for use as a bird repellent. Researchers fed captive raccoons whole corn treated at 0.5 percent, 1 percent, 1.5 percent, and 2 percent anthraquinone and examined their behavior related to overall food consumption and any changes in their approach, interaction, and extended interaction with the feed bowl. Feeding repellency was 26 to 37 percent for whole corn treated with 0.5–1.5 percent anthraquinone and 71 percent for whole corn treated with 2 percent anthraquinone. The amount of time raccoons spent interacting with and eating the food varied among treatments with the longest duration observed at 2 percent anthraquinone. The results aid in future research and field trials aimed at developing anthraquinone as a deterrent for raccoons or as an application to repel other species while still allowing for consumption (e.g., oral rabies vaccine baits) by raccoons.

  Contact: Scott Werner

NWRC researchers conducted controlled feeding experiments to evaluate the efficacy of an anthraquinone-based repellent for raccoons.
Photo by USDA, Wildlife Services, Alison Barbee

NWRC and Utah State University researchers studied the effects of fertility control on coyote behavior.
Photo by Adobe Stock

Other Chemical and Biological Methods

- **Effects of Fertility Control Techniques on Coyote Behavior.** Fertility control of wild carnivores has been proposed as a management tool for many decades. It has been shown to reduce depredations on livestock and wild ungulates, as treated territorial pairs no longer need to provide for young of the year. Fertility control can be accomplished via surgical or chemical sterilization. To learn more about the influence of gonadal hormones on the ability of carnivores to maintain territories, NWRC and Utah State University researchers examined the behavior of 179 surgically sterilized wild coyotes and coyote-red wolf (*Canis lupus rufus*) hybrids. One hundred and forty-three of the animals retained their gonadal hormones (tubal-litigated females, vasectomized males) while 36 did not (spayed females, neutered males). Results showed that the absence of gonadal hormones did not influence annual home-range size and home-range overlap, territory fidelity, and annual survival rates. Additionally, no differences were detected across sexes. Methods of fertility control that remove gonadal organs of coyotes and coyote-red wolf hybrids may prove useful for reducing livestock predation without concern for changes in behavior, mainly territoriality, space use, and survival.

  Contact: Eric Gese

- **Examining Cormorant Movement and Diet Using Stable Isotopes.** Double-crested cormorant (*Phalacrocorax auritus*) populations have significantly increased in North America leading to concerns about damage to resources, including sports fisheries, aquaculture, co-nesting species, and natural habitats. NWRC, Mississippi State University, and Tennessee Valley Authority researchers used stable isotope analysis (SIA) to evaluate how cormorants use various resources, particularly during over-wintering seasons and migration. Different environments are characterized by the presence of different isotopes (versions of a chemical element). These can be

incorporated into an animal's tissues through their diet. Researchers analyzed stable carbon (δ13C), nitrogen (δ15N) and sulfur (δ34S) isotope ratios in the liver and muscle tissues of cormorants collected at Guntersville Reservoir in Alabama. These isotope ratios were compared to those in fish species collected from the reservoir and nearby aquaculture ponds. Isotope ratio similarities of carbon, nitrogen, and sulfur in the Guntersville Reservoir fish and the sampled cormorants indicated that half of the sampled cormorants fed on fish from the reservoir during the winter. Data also showed the birds used the reservoir as a breeding ground, but likely contributed little damage to nearby aquaculture facilities. Understanding the migration patterns of cormorants and their use of resources informs management strategies. SIA can help identify cormorant populations that cause the most damage and aid in efforts to restore and protect habitats.

Contact: Brian Dorr

- **Antipredator Behavior Theory for Predicting Wildlife Responses.** Collisions between animals and vehicles (e.g., cars and airplanes) cause substantial economic damage and safety hazards to motorists and wildlife. To develop new methods for reducing animal-vehicle collisions, researchers are exploring the behavioral mechanisms involved in animal decision-making when confronted with an approaching vehicle. Formalizing those mechanisms in models could lead to the ability to predict how different species respond to vehicles. Current models based on antipredator behavior theory (i.e., when approached, animals become alert and engage in escape behavior to avoid predation) have been used to predict the distance at which animals must react to an approaching predator to escape, but it is unknown if antipredator behavior models can be applied to approaching high-speed vehicles. NWRC, Purdue University, and University of Georgia researchers reviewed and evaluated eight

NWRC, Mississippi State University, and Tennessee Valley Authority researchers used stable isotope analysis to evaluate how cormorants use various resources.
Photo by Adobe Stock

To develop new methods for reducing animal-vehicle collisions, NWRC and university researchers explored how animals make decisions when confronted with an approaching vehicle.
Photo by Adobe Stock

models for their applicability to animal-vehicle collisions. These included: the economic escape model, Blumstein's economic escape model, the optimal escape model, the perceptual limit hypothesis, the visual cue model, the flush early and avoid the rush (FEAR) hypothesis, the looming stimulus hypothesis, and the Bayesian model of escape behavior. Overall, no single antipredator behavior model successfully characterized all different types of escape responses relative to vehicle approach speed, but some models showed some levels of sensitivity for certain rules of escape behavior. Researchers note that animal escape behavior is likely the result of a combination of both short-term/physiological and long-term/evolutionary mechanisms. New escape behavior models should focus on identifying what cues animals use to assess risks specifically related to approaching high-speed vehicles, as well as the effects of animal experience and learning.

Contact: Brad Blackwell

- **Using Genetics To Identify Invasion Pathways.** Texas contains approximately 40 percent of the estimated 6.9 million feral swine distributed throughout the United States. To better understand invasion pathways and track dispersal of swine in Texas, NWRC researchers leveraged genetic data from more than 700 feral swine samples collected over 7 years by WS-Texas field specialists. The genetic analysis showed that large portions of the Texas landscape had broad connectivity and ongoing gene flow among feral swine populations. These results confirm that efforts to eliminate or reduce feral swine populations in Texas are challenged by gene flow and high feral swine density. The analysis also identified five smaller genetic clusters of feral swine with minimal immigration pressure (i.e., little feral swine movement into the area) where targeted management efforts could be effective. Researchers note that these genetic differences suggest distinct biological and perhaps anthropogenic processes are shaping the genetic structure of feral swine populations

in Texas. The findings aid in the prioritization of feral swine management efforts and the allocation of limited management resources.

Contact: Toni Piaggio

- **Classifying Gene Drives.** Gene drives are an emerging technology with tremendous potential to impact public health, agriculture, and conservation. Engineered gene drives are a genetic technique that targets and promotes the inheritance of a particular gene to increase its prevalence in a population. Given its complexity, gene drive technology can be difficult to understand. To address this difficulty, NWRC and APHIS-Biotechnology Regulatory Services researchers describe a gene drive classification system based on five functional characteristics. These characteristics are (1) the desired objective of the gene drive, (2) the mechanism used to achieve that objective, (3) the required number of organisms that need to be released to achieve the objective, (4) the expected spread or geographic range impacted by the gene drive, and (5) the environmental persistence of the gene drive. These collective characteristics can be described as the gene drive's architecture. The classification system will help guide regulatory evaluation and decision-making on gene drive technologies.

  Contact: Kim Pepin

Disease Diagnostics, Surveillance, Risk Assessment, and Management

- **Diversity of Coronaviruses Among Domestic and Free-Roaming Animals.** Coronaviruses are a group of RNA viruses that cause a variety of respiratory, gastrointestinal, and neurological diseases. Many different species of animals have been found to harbor multiple strains of coronaviruses. To better understand the diversity of coronaviruses in wild mammals, NWRC partnered with the U.S. Geological Survey, the Centers for Disease Control and Prevention, and Utah officials to sample animals on or near a SARS-CoV-2-infected mink (*Neovison vison*) farm in Utah in 2020. SARS-CoV-2 is a coronavirus that causes COVID-19 in people. Among the 365 animals sampled, including domestic cats (*Felis catus*), mink, rodents, raccoons, and skunks, 72 percent (261) of the animals harbored at least one coronavirus. Though the SARS-CoV-2 virus was only detected in mink, there was an unexpectedly high prevalence of other coronaviruses among the domestic and wild animals studied. Most of the coronaviruses detected belonged to the alpha- and beta-coronavirus genera with varying characterizations and relations to other coronaviruses. Researchers noted these results raise the possibility that mink farms could be potential hot spots for future viral spillover among species and the emergence of new pandemic coronaviruses.

  Contact: Susan Shriner

- **Plague Risk in the United States.** Plague is a disease that affects mammals. It is caused by the bacterium, *Yersinia pestis*. People often get plague after being bitten by a rodent flea that is carrying the plague bacterium or by handling an animal infected with plague. Plague was likely introduced into the United States around 1900, by rat–infested steamships that had sailed from affected areas. It has since spread from urban rats to rural rodent species and has become entrenched in many areas of the western United States. Routine animal surveillance and comprehensive records of human cases provide a unique opportunity for NWRC, Georgetown University, and University of Oslo researchers to test how plague reservoirs in the

NWRC and university researchers discovered that changing climates have made high elevation rodent communities more likely to support plague.
Photo by Adobe Stock

United States are responding to environmental change. Weather and plague data collected since 1950 and other environmental factors were used to model how climate change impacts infectious disease distribution. Researchers discovered that changing climates have made high elevation rodent communities and their associated habitats' soil biochemistry more likely to support plague—with suitability increasing up to 40 percent in some places—and that plague spillover risk to people at mid-elevations has increased as well, though more gradually. These results highlight the value of integrative surveillance for infectious diseases and the need for further research into ongoing climate change impacts.

Contact: Sarah Bevins

- **Link Between Invasive Mongoose and Leptospirosis.** Leptospirosis is an infectious disease caused by the bacteria *Leptospira*. Each year, it causes approximately 58,900 human deaths worldwide. *Leptospira* are maintained in animal hosts and transmitted to people through direct animal contact and environmental exposure to water and soil contaminated by the urine of infected animals. After the 2017 Hurricanes Irma and Maria, the Virgin Islands Department of Health (VIDOH) identified the first three cases of human leptospirosis documented in the U.S. Virgin Islands (USVI). Hurricane events can lead to increased transmission of leptospirosis due to human exposure to floodwaters. During 2019 and 2020, the VIDOH and partners including the NWRC and several other government agencies, collected small Indian mongooses to investigate *Leptospira* exposure and infection in this invasive species on the islands of St. Croix, St. Thomas, and St. John. Of the 256 mongooses tested, 34 percent were exposed to *Leptospira*, and the bacteria was isolated from 27 mongooses, making this species a potential disease reservoir and vector to people, domestic animals, and other wildlife in this region. This project also resulted in an increased capacity for the USVI to engage with a wide range of collaborators for strategic leptospirosis prevention and surveillance efforts.

  Contact: Are Berentsen

- **Accounting for Animal Movement in Vaccination Strategies.** Oral baiting is used to deliver vaccines to wildlife to prevent, control, and eliminate infectious diseases, such as rabies. One challenge is how to best distribute baits across the landscape to maximize encounters by target animal populations, particularly in developed areas where wildlife, such as raccoons, are abundant and baits are delivered along roads. NWRC researchers developed a model to evaluate how habitat features and landscape composition may influence raccoon movement, bait uptake, and oral rabies vaccine (ORV) seroconversion in Burlington, VT. Data from radio-collared raccoons were used to identify fine scale habitat preferences and characterize raccoon movements for model simulations. Then, researchers used the simulations to estimate

ORV uptake and seroconversion in the raccoon population under current habitat-based baiting operations and refined baiting strategies targeting specific habitat types. Results showed that refined habitat baiting strategies could improve seroprevalence over current operations targeting raccoon populations that are habitat specialists (i.e., they typically use wetlands or forested habitats), but gains were less pronounced when raccoons behave as habitat generalists. This suggests that refined habitat-based baiting strategies could increase raccoon population seroprevalence in developed areas, where practical, based on raccoon population biology and the composition and accessibility of preferred habitat types. This novel simulation approach provides a flexible framework to test alternative baiting strategies of raccoons or other wildlife across complex landscapes.

Contact: Amy Davis

- **Arctic Fox Survive Exposure to Rabies Virus.** The arctic fox (*Vulpes lagopus*) variant of the rabies virus occurs throughout the circumpolar north and impacts humans and animals in arctic and subarctic regions of North America. Although rabies virus infection is nearly always fatal once the virus enters the central nervous system, abortive infections or nonlethal exposures have been described in people and animals. NWRC researchers and collaborating Canadian government agencies and universities opportunistically analyzed serum from 41 arctic foxes captured and released at Karrak Lake in Nunavut, Canada, between 2011 and 2015, where some foxes were sampled across multiple years. Rabies virus antibodies were found in 15 percent (6) of the arctic foxes tested. The results are consistent with prior findings of abortive rabies virus infections in wildlife reservoirs and suggest that some arctic foxes survive exposure to the rabies virus in the central Canadian Arctic. Additional sampling and monitoring could

Rabies virus antibodies were found in 15 percent of the arctic foxes tested in Nunavut, Canada, meaning the animals survived exposure to the rabies virus.
Photo by Adobe Stock

further corroborate the evidence of abortive rabies virus infections and test for effects of rabies virus exposure on the long-term survival of arctic foxes.

Contact: Amy Gilbert

- **Mesocarnivore Occurrence and Rabies Management.** Mesocarnivores, such as gray foxes (*Urocyon cinereoargenteus*), striped skunk, bobcats, and coyotes, share similar habitats and roles in the environment, often competing for resources. Understanding these interactions can aid disease prevention and management. NWRC researchers partnered with WS Operations personnel and university scientists to gain insights into how gray foxes, striped skunks, bobcats, and coyotes live and coexist in a regional rabies hotspot across two mountain ranges in Arizona. Rabies is a virulent disease that can easily spillover from one mammalian species to another. Data from trail cameras and subsequent modeling showed detection probabilities for the species were impacted by elevation, season, and temperature, with the height of understory vegetation and canopy cover also influencing gray foxes and skunks. For example, gray foxes and skunks used a wide variety of vegetation communities but were detected more in sites with higher canopy and understory cover. Additionally, foxes and skunks used sites at lower elevations with warmer average daily temperatures. Bobcats were also detected at sites with warmer temperatures but used sites at higher elevations. Results suggest that these four species are influencing the space use of each other and are likely competing for resources seasonally. For example, skunk occurrence was positively influenced by fox and bobcat presence, but negatively influenced by coyotes. Distribution across space and time plays a role in species interactions and therefore disease spread. Understanding what vegetation communities, elevations, and general landscape features are more likely to be occupied by rabies vector species at certain times of the year can increase efficiency and minimize costs for disease management. Researchers recommend that rabies managers deliver oral rabies vaccine (ORV) baits onto the landscape when natural food resources are most scarce, particularly in the two drier seasons in Arizona (pre-monsoon spring and autumn). Baiting multiple times per year with a focus on these two seasons when mesocarnivores are most active on the landscape could optimize the number of individuals of all species that eat ORV baits.

  Contact: Kurt VerCauteren

- **Mapping Anthrax Risks Using Feral Swine Data.** Anthrax is a disease caused by the bacterium *Bacillus anthracis*. It can impact wildlife, free-ranging livestock, and people. *B. anthracis* spores exist in soil and the carcasses of animals that have died from anthrax, but the sampling efforts required to identify contaminated environments and subsequent outbreak risks are often too laborious or expensive to use. Feral swine are known to occasionally scavenge carcasses, as well as routinely root in soils for food. These behaviors, coupled with their documented resistance to anthrax, suggest that serologic surveillance of feral swine could be used to predict the presence of *B. anthracis* in the environment. NWRC and Colorado State University researchers and partners investigated whether the presence of anthrax antibodies in free-roaming feral swine could be used to measure anthrax distribution in anthrax-endemic and nonendemic regions of Texas. Of the 478 feral swine serum samples tested, 44 percent were positive for anthrax antibodies. The results suggest anthrax

Anthrax-causing bacterium spores exist in soil. Because feral swine often root in soil in search of food and are resistant to anthrax, researchers are investigating whether feral swine surveillance could be used to predict the presence of the bacterium in the environment.
Photo by Adobe Stocks

exposure in swine, when paired with location data, could serve as a proxy for the presence of *B. anthracis* in specific areas.

Contact: Courtney Bowden

- **Social Media Sheds Light on Feral Swine Disease Risks to Hunters.** Hunters are particularly vulnerable to zoonotic disease risks when harvesting feral swine. Management agencies inform the public about these risks and best practices for mitigating them, but it is unclear how effectively this guidance has reached hunters and influenced their practices. NWRC and Colorado State University researchers reviewed approximately 600 feral swine hunting videos on YouTube to shed light on current harvesting practices, such as handling, field dressing, and butchering, that impact the risk of disease transmission from feral swine to people. Analysis showed little evidence of behaviors and communications regarding disease risks and best practices for personal safety. In contrast, many videos showed behaviors that could increase the risk of disease transmission to the subjects and other animals. Researchers recommend integrating these social media findings with hunter survey research to generate a more complete picture of how the hunting community is responding to the issue of disease risk from feral swine and how agencies can intervene to improve that response.

Contact: Keith Carlisle

- **Antibiotic Resistance in Wildlife and Livestock.** Antibiotic-resistant microorganisms (ARMs) are widespread in natural environments, animals, and people, making it more difficult to control life threatening infectious disease. NWRC, University of Florida, and APHIS Veterinary Services researchers investigated the potential transmission of ARMs and antibiotic resistance genes (ARGs) between cattle and wildlife by comparing gut microbiota and ARG profiles of feral swine, coyotes, cattle (*Bos taurus*), and environmental microbiota. Unexpectedly, wildlife had more abundant ARMs and ARGs compared to grazing cattle. Gut microbiota of cattle was more like that of feral swine captured within the cattle grazing area where the home range of both species overlapped. In addition, ARMs against medically important antibiotics were more prevalent in wildlife than grazing cattle, suggesting that wildlife could be a source of ARMs for livestock.

Contact: Kim Pepin

NWRC, University of Florida, and APHIS-Veterinary Services researchers investigated the potential transmission of antibiotic resistant microorganisms between cattle and wildlife by comparing gut microbiota in feral swine, coyotes, and cattle.
Photo by USDA, Wildlife Services

- **Animal Movement and Disease Dynamics.** Livestock and wildlife movement data is becoming increasingly available to wildlife disease researchers and managers. Such data from global positioning system (GPS) collars, proximity loggers, camera traps, and audio monitors can be used to help determine how animal movements and interactions impact disease transmission risk. It provides useful insights into contact formation, contact duration, pathogen deposition potential, and pathogen acquisition risk. NWRC researchers worked with numerous university and agency partners to develop a novel model call MoveSTIR— movement-driven modelling of spatio-temporal infection risk—which leverages spatial and temporal data on animal movement and proximity to help determine disease transmission risk among animals on the landscape. Determining how and why disease transmission rates vary across the landscape helps scientists and others identify potential transmission hotspots, determine which individual animals are involved in their generation, and optimize disease control strategies.

  Contact: Kim Pepin

- **Detection of Distinct CWD Isolates in Captive Elk.** CWD continues to spread in both wild and captive cervid herds (deer, elk, moose, reindeer *(Rangifer tarandus)*) in North America. However, little is known about the prevalence and identification of distinctive CWD isolates or strains within and among species. Researchers from NWRC, APHIS Veterinary Services, the Agricultural Research Service, Case Western Reserve University, and Colorado State University evaluated brain samples and conducted a biochemical analysis of prion proteins from two captive elk herds that had differing prevalence, history, and timelines of CWD incidence. One herd had a 16-year history of CWD with a consistently low prevalence rate (between 5 and 10 percent). The other herd had a 40-year known history of CWD with a high prevalence rate (nearly 100 percent of naïve animals develop clinical CWD within 2 to 12 years). An analysis of the stability of the prion proteins' structural conformations (i.e., their folded three-dimensional structure) found that the herd with low CWD prevalence rates had prion proteins with greater conformational stability. It has been hypothesized that prion isolates may change over time. Researchers suggest that a more infectious isolate may have emerged at the site with high CWD prevalence to become the dominant strain at the site over time. These findings suggest the prion isolates may influence the infectivity of the CWD prion and thus how the disease behaves in the landscape. They also provide insights to CWD

prion diversity and the potential evolution of CWD prions over time.

Contact: Kurt VerCauteren

- **Influenza A Virus and Snow Geese.** Avian influenza A viruses (IAVs) pose a potential threat to public, livestock, and wildlife health and can cause economic harm to the poultry industry. In general, most wild goose species are thought to pose little risk of IAV transmission to poultry and people. However, snow geese (*Anser caerulescens*) migrate between Eurasia and North America, exhibit a high infection prevalence for IAVs, and may play a role in IAV spillover to poultry. To evaluate whether snow geese significantly contribute to the circulation of IAVs, NWRC researchers estimated snow goose infection prevalence using more than 5,000 snow goose surveillance records. Surveillance data showed that IAV infection prevalence in snow geese was approximately 8 percent. This is higher than the infection rates found in other common North American goose species. Researchers also experimentally infected captive snow geese with a low pathogenic IAV to assess the species' susceptibility to the virus, infection dynamics, and long-term changes in antibodies. Only four of seven snow geese shed virus through their mouths and at moderate levels. All inoculated birds produced antibodies to the virus regardless of whether they shed virus at detectable levels. Antibody levels peaked at 10 days after exposure and then waned to undetectable levels by 6 months. While surveillance results showed comparatively high infection prevalence, the experimental infection study showed only moderate susceptibility and shedding. Researchers note that additional

NWRC researchers are assessing whether snow geese might exhibit higher levels of susceptibility and shedding rates than other waterfowl when exposed to influenza A viruses.
Photo by USDA, Wildlife Services, Clint Turnage

work is needed to assess whether snow geese might exhibit higher levels of susceptibility and shedding rates when exposed to other IAV strains.

Contact: Susan Shriner

Wildlife Damage Assessments

- **Spillover Delay Costs Associated with Wildlife Strikes at Airports.** Aircraft–wildlife collisions, or wildlife strikes, are rare events that pose safety and economic risks to the U.S. aviation industry. Damaging wildlife strikes often cause substantial repair costs as well as downtime for the aircraft and passengers directly involved. In the most severe and rare instances, wildlife strikes can cause injury and even loss of life. NWRC and Colorado State University researchers identified and quantified the spillover delay effects of damaging wildlife strikes for the U.S. commercial passenger airline industry during 1990 and 2019. Analyzing data from the National Wildlife Strike Database and the Bureau of Transportation Statistics Airline On-Time Statistics database, researchers discovered that the spillover delay effects of wildlife strikes are largely contained within the airline to which the strike occurred. The average damaging wildlife strike generated minimum delays of 570 aircraft minutes and roughly 40,000 passenger minutes. From this, researchers estimate that damaging wildlife strikes generate around $25 million in spillover delay costs each year—an external cost borne by airlines, passengers, and the economy at large.

  Contact: Stephanie Shwiff

- **Unreported Feral Swine Impacts to Agriculture.** Of all the negative feral swine impacts to people and resources, agricultural losses may be the costliest. To explore the full extent of feral swine impacts to agricultural producers, NWRC and Colorado State University researchers interviewed 23 producers in 16 Texas counties. Participants were asked to identify and describe all feral

An NWRC economic study showed the average damaging wildlife-airplane strike generated minimum delays of 570 aircraft minutes and roughly 40,000 passenger minutes. Researchers estimate that damaging wildlife strikes generate around $25 million in spillover delay costs each year.
Photo by Adobe Stock

swine-related costs and benefits they incurred in 2018. Researchers also compared the participants' estimates of total costs to an itemized total to determine whether producers were more likely to underestimate or overestimate their overall costs. Twenty discrete categories of negative and positive impacts were identified. Many, like additional time and fuel costs associated with reduced tractor speeds in damaged fields, reduced yields following replanting, and loss of livestock weight, have not figured into any published feral swine damage estimates to date. Other costs, such as those associated with feral swine management and control, may have been only partially accounted for in published reports. While previous studies have found that producers' estimates of direct crop damage tend to be fairly accurate, this study found that when participants were asked to estimate their total costs associated with feral swine, they initially underestimated their costs by a factor of nearly three, on average. More accurate feral swine damage and cost estimates can help ensure that adequate resources are directed at mitigating impacts on producers.

Contact: Keith Carlisle

- **Feral Swine Impacts to Forestry.** Most of Alabama consists of forested land but little is known about the impacts of feral swine on Alabama's forest resources. To guide forest management and associated feral swine control, NWRC researchers partnered with Auburn University School of Forestry to determine feral swine damage to Alabama's privately owned forests. Researchers sent surveys to 1,160 private landowners with more than 20 acres of land in Alabama. Results showed that feral swine caused damage to 34 percent and 13 percent of forest acres in longleaf pine (*Pinus palustris*) and loblolly pine (*Pinus taeda*) plantations, respectively. However, the costs of replanting longleaf seedlings were double those for loblolly seedlings. Results also suggested the southern half of Alabama holds the largest feral swine populations and sustained the most damage to forest stands. Consequently, landowners in this region invested the most on control methods (average cost per control technique ranged from $12 to $2,750). Landowners who did not have feral swine on their property were willing to pay about $14 per acre more for eradication than those with feral swine. Most surveyed landowners favored efforts to remove feral swine and were willing to pay for eradication and prevention.

  Contact: Stephanie Shwiff

- **Feral Swine Impacts to Native Wildlife.** Invasive species may negatively impact ecosystems to the detriment of native species, and often contribute to the decline and even extinction of local species through direct predation, competition, and habitat destruction. Feral swine are an invasive species introduced

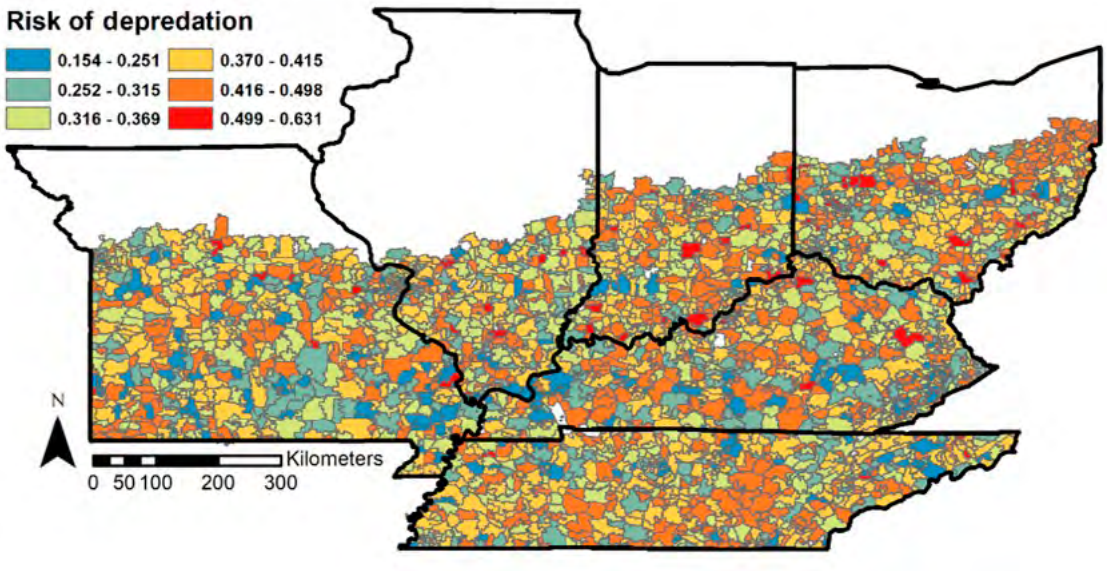
Feral swine cause damage to about a third of Alabama's acres of longleaf pine (Pinus palustris) forests on private plantations. *Photo by USDA, Wildlife Services, Gail Keirn*

to the United States and other parts of the world because of globalization. Auburn University and NWRC researchers conducted a comprehensive literature review on the impacts of invasive feral swine to native wildlife in North America, Australia, New Zealand, and South America. Researchers note that although there are some ways in which feral swine positively impact native species, such as serving as a prey source for large predators, most of the scientific literature indicates that invasive feral swine are a threat to native species. Additional research is needed to quantify the degree to which feral swine may be affecting native species populations. Such information is necessary to better inform the public and lawmakers and improve resources available to reduce the impacts of invasive feral swine.

Contact: Kurt VerCauteren

- **Modeling Black Vulture Depredation to Cattle.** As black vultures expand their range northward, concerns regarding potential attacks on livestock have increased. Using spatial risk modeling, NWRC and Purdue University researchers and partners identified landscape features associated with reported black vulture attacks on cattle across six States (IL, IN, KY, MO, OH, and TN). This information was used to predict potential livestock depredation in the Midwest. Researchers hypothesized that livestock depredation would be greatest in areas with intensive beef cattle production close to preferred black vulture habitat (e.g., areas with fewer old fields and early successional vegetation adjacent to older forests and agricultural lands). Models estimated depredation risks to be between 15 and 63 percent across the entire study area. The areas of greatest predicted risk corresponded to locations suitable for vultures and with increased opportunities for vulture-livestock encounters. Although intuitive, these relationships have not been previously quantified. Relative risks are presented by zip code to aid wildlife managers and livestock owners with mitigating vulture-livestock conflicts.

Contact: Bryan Kluever



NWRC and Purdue University researchers and partners used models to predict vulture depredation risks to cattle across six States.
Image by USDA, Wildlife Services

Wildlife Management Methods and Evaluations

- **Effects of Feral Swine Removal on Water Quality.** Feral swine can negatively impact ecosystems. Their rooting and wallowing limits water infiltration and nutrient cycling as well as increases erosion. Large groups of feral swine can deposit significant amounts of fecal material in concentrated areas, contaminating water sources and resulting in increased disease risks for people, wildlife, and livestock. NWRC and Auburn University researchers evaluated the effect of feral swine removal on water quality in streams in Alabama that were known to be significantly polluted by feral swine activity. They compared *Escherichia coli* and fecal coliform concentrations and loads in streams prior to and following feral swine removal efforts. *E. coli* infections in people can cause severe stomach cramps, vomiting, fever, diarrhea, and even death. Results suggest that *E. coli* and fecal coliform concentrations were reduced by 75 percent and 50 percent, respectively through pig removal efforts. Researchers note that the reduction in fecal contamination of streams depends on several factors, such as stream order (i.e., branching of a river system), the number of feral swine, and stream hydrology and physical characteristics. Continued monitoring may be necessary to observe changes in water quality.

  Contact: Kurt VerCauteren

- **Feral Swine Ecology Drives Best Management Practices.** Effective wildlife damage management requires insights into how animals move across landscapes, interact with resources, and respond to changing weather. These insights help managers make real-time decisions regarding where and when to implement trapping, aerial operations, toxicants, or other management approaches. A modeling effort using global positioning system (GPS) data from 49 collared feral swine, as well as habitat, landscape, and meteorological data, quantified the effects of biotic and abiotic factors on feral swine movements and home range sizes. From those results, NWRC and University of Georgia researchers were able to identify best management practices for feral swine removal. For example, when managing feral swine near streams, tools, such as traps, should be distributed along stream corridors (when regulations allow) to efficiently target feral swine movements. Additionally, placing more traps and bait stations in high quality feral swine habitats, such as bottomland hardwoods, where feral swine home range sizes are smaller may be necessary to ensure access by multiple sounders and individual boars. Modeling also showed that managers may increase their success and reduce costs by adjusting for weather conditions, such as low pressures and temperatures. For example, model simulations showed that feral swine in South Carolina tended to be more active when temperatures were low and pressures were high. This suggests that feral swine in South Carolina are more likely to visit traps under these climatic conditions. Such information is important for designing feral swine monitoring studies, identifying high risk zones for disease transmission, planning response to disease emergence events, and allowing more effective and efficient short-term management planning.

  Contact: Kim Pepin

- **Deterring Birds from Feral Swine Baiting Sites.** Toxic baiting is a potential new method for controlling feral swine populations and reducing damage. Field trials for a new toxic bait containing 5 percent sodium nitrite (SN)

Toxic baiting is a potential new tool for feral swine population control in the United States. To avoid nontarget species, such as songbirds, from eating toxic bait meant for feral swine, NWRC researchers recommend the use of inflatable scare devices* (pictured) *placed near baiting stations.
Photo by USDA, Wildlife Services, Nathan Snow

have revealed that feral swine often spill small particles of bait outside of bait stations which can be hazardous to nontarget species, primarily songbirds. NWRC researchers tested the efficacy of four possible deterrents (i.e., a methyl anthranilate repellent, metal grate, inflatable scarecrow, and scare dancer) to discourage birds from eating spilled bait at mock bait sites (i.e., baited with bird seed) in Colorado. The programable, inflatable scare dancer was the most effective, reducing bird visitation on average by 96 percent. Researchers also evaluated the inflatable scare dancer at SN toxic bait sites in Texas, where the devices were activated the morning after SN-toxic baits were deployed for feral swine. After one night of baiting, researchers estimated 91 percent of the swine that visited the bait sites succumbed to the toxic bait. They also found that the scare dancer was 100 percent effective at discouraging birds from visiting the toxic bait sites. Researchers recommend using the scare dancer and similar deterrent devices (i.e., novel, programmable, battery operated, continuous and erratic movement, and snapping sounds) to reduce hazards to nontarget birds at SN toxic bait sites. They also recommend baiting during seasons when migrating birds are not as abundant.

Contact: Nathan Snow

- **Beaver-Related Restoration and Water Quality.** Beaver-related restoration (BRR) is gaining popularity as a possible method for improving stream ecosystems in the western United States, but the effects are not fully understood. In general, BRR leads to increased pond surface area by creating conditions favorable to North American beaver (*Castor canadensis*) dam building or by mimicking beaver dam building through habitat modification. A premise of BRR is that water quality in and around beaver or beaver-like ponds will be favorable to native fishes, especially salmonids, although studies of water quality in beaver ponds are highly variable and inconclusive. A potential factor for the differing results is timing and methodology used in sampling. NWRC, Oregon State University, U.S. Geological Survey, and U.S. Forest Service researchers examined water quality related to beaver ponds in the Umpqua River Basin in Oregon from June through September of 2019. Water temperatures were monitored at eight beaver ponds and at every 100 meters (m) up to 400 m above and below the ponds. Dissolved oxygen (DO) was monitored at pond surfaces and pond bottoms. Downstream warming was greatest in June and July and best predicted by pond bottom temperatures. DO at pond surfaces and bottoms were hypoxic (≤5 mg/L)

for more than half of the monitoring period. Water temperatures increased for short distances below the ponds and oxygen conditions within the ponds were largely unsuitable for salmonid fishes. These findings contrast with some commonly stated expectations of BRR, and researchers recommend that managers consider these expectations prior to implementing BRR. In some cases, project goals may override water quality concerns but in streams where temperature or DO restoration are objectives, managers should consider using BRR techniques with caution.

Contact: Jimmy Taylor

- **Fladry for Ferrets**. Fladry is a nonlethal tool used to prevent livestock predation. It consists of a line of brightly colored flags hung around a pasture. Because of its novelty in the environment, predators such as coyotes are cautious of crossing the fladry barrier. NWRC researchers evaluated the effectiveness of fladry to control coyote access to endangered black-footed ferret (*Mustela nigripes*) reintroduction sites in Badlands National Park and Buffalo Gap National Grasslands in South Dakota. Coyotes can kill ferrets and compete with them for food. Camera traps were used to collect coyote detection data in and around fladry-protected sites for approximately 4,000 trap nights. Overall, coyote use of areas inside the fladry barrier declined by 60 percent after 60 days and coyotes avoided some previously used areas both within and outside the barriers. Interestingly, coyotes were attracted to previously unused areas surrounding the fladry and increased their activity around the fladry by 170 percent immediately after installation. Researchers suggest that coyotes actively explored these areas and responded to fladry in a way that is counterintuitive. The simplicity of the tool and these promising results encourage future studies on the use of fladry for conservation purposes.

Contact: Stewart Breck

NWRC researchers evaluated the effectiveness of fladry to prevent coyote access to endangered black-footed ferret reintroduction sites. Fladry is typically used to protect livestock from wolf predation.
Photo by USDA, Wildlife Services

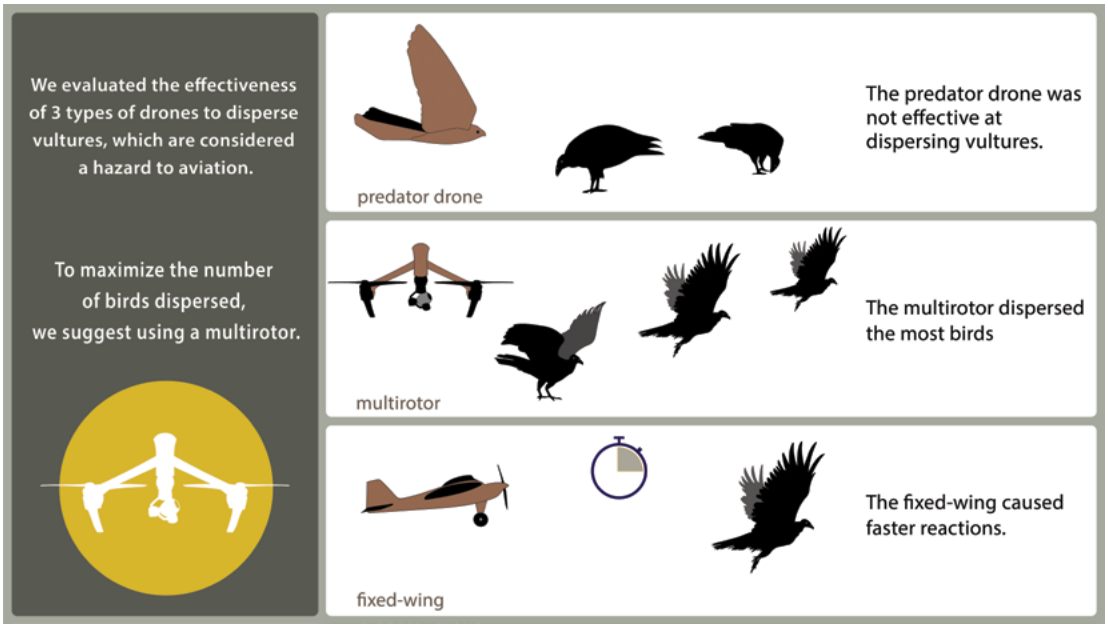
- **Effects of Public Perception on the Success of Wildlife Management.** Public perception can influence the success of wildlife management initiatives. Public perception is defined as the attitudes, beliefs, and values that influence individual behavior and support. Few social science studies have investigated rapid shifts in public perception and what drives those shifts. Colorado State University and NWRC researchers examined the factors that caused a shift in support and public perception in the year leading up to a 2020 gray wolf (*Canis lupus*) reintroduction ballot measure in Colorado. Multiple surveys in Colorado found high levels of support for wolf reintroduction in the State, but the conservation initiative only passed narrowly in November 2020. Researchers conducted a follow-up public survey immediately after the 2020 election and compared it to the 2019 pre-election survey. Results showed significant changes in beliefs between the pre- and post-election surveys, such as an increase in beliefs about negative outcomes of wolf reintroduction. The findings indicate these changes may have been influenced by media coverage, public outreach campaigns, and information about the cost of the conservation initiative. Researchers note the need for continual observance of public perception and suggest sharing scientific information, along with outreach and engagement strategies, to help inform public opinion about conservation initiatives.

  Contact: Stewart Breck

- **Palatability of Brodifacoum Bait for Invasive Mice.** The Midway Atoll National Wildlife Refuge encompasses nearly 600,000 acres of land and water in the North Pacific Ocean and provides habitat for millions of seabirds. Unfortunately, these seabirds are impacted by invasive mice that inhabit the sandy beaches and brushy habitats of Sand Island, the largest of three islands that make up Midway Atoll. To help protect seabirds, the U.S. Fish and Wildlife Service is planning a mouse eradication effort on Sand Island in 2023. To aid in the Sand Island effort, NWRC researchers and their partners conducted a series of bait acceptance and efficacy cage trials using a standard formulation of brodifacoum-based rodenticide on wild-caught mice from Sand Island. Some mice were only offered brodifacoum pellets, while others were offered a choice between brodifacoum pellets or alternative foods (i.e., either a low-palatability challenge diet or a high-palatability mixture of local grass seeds, pet food, mealworms, crickets). All the mice that were fed only brodifacoum pellets died, while only 40 percent of those offered a choice between brodifacoum pellets and alternative diets died. This suggests that mice may avoid the brodifacoum bait if other options are available. Researchers note that a successful mouse eradication on Sand Island will require a highly diligent and effective application of bait that errs on the side of ensuring that more bait is delivered into every potential mouse home range on the island. All variables (e.g., alternative foods such as garbage and foodstuffs, applying and monitoring of the bait) need to be managed with the highest degree of attention to detail.

  Contact: Steve Hess

- **Using Drones To Disperse Vultures.** When turkey vultures (*Cathartes aura*) gather in large groups in urban areas, their abundant fecal droppings and possible collisions with air traffic can cause safety concerns. NWRC researchers evaluated the use of unmanned aircraft systems (UAS) or drones to disperse turkey vultures by conducting field trials to observe how the birds reacted to three UAS



NWRC researchers evaluated the use of unmanned aircraft systems (UAS; also known as drones) to disperse turkey vultures. Targeted vultures dispersed in 63 percent of the UAS trials.
Image by USDA, Wildlife Services

types: a robotic falcon UAS that resembled a predator, a fixed-wing UAS, and a multirotor UAS. Targeted vultures flushed (dispersed) in 63 percent of the UAS trials. The likelihood of a vulture flushing was influenced by UAS type and angle of approach. Vultures were 2½ times more likely to flush when approached directly versus overhead. Additionally, vultures were twice as likely to flush when approached by a fixed-wing UAS versus the robotic falcon UAS. More vultures also dispersed when approached by the multirotor UAS versus the robotic falcon UAS. Given that the multirotor UAS can take-off and land vertically and access obstructed areas, researchers recommend that future efforts focus on enhancing its effectiveness by testing more approach patterns and adding select, onboard lighting to make it more visible to vultures.

Contact: Morgan Pfeiffer

- **Evaluating the Effectiveness of Aerial Toxic Bait Delivery for Eradicating Brown Treesnakes.** Few methods exist to manage invasive reptile damage, and little is known about their overall effectiveness in reducing and eradicating reptile populations. The brown treesnake is an invasive species that causes major ecological and economic harm to the island of Guam. The snakes have been the subject of intensive research on the effectiveness of control techniques, including the first automated aerial delivery system for the distribution of toxic acetaminophen baits for brown treesnake control. To evaluate the effectiveness of the aerial delivery system and predict how long it would take to eradicate brown treesnakes on Guam using the system, NWRC researchers partnered on a U.S. Geological Survey-led test of toxic aerial bait cartridges applied to a contained study population over 3 years. Researchers also tested the effects of adding live trapping to accelerate eradication timelines. Treatment of the population resulted in an immediate reduction followed by a gradual population decline that suggested eradication was possible but would require decades. Adding live trapping reduced the predicted time required to achieve eradication by more than half. These findings suggest that

***Recent studies suggest that invasive brown treesnake eradication in Guam is possible using aerial toxic baits* (pictured).**
Photo by USDA, Wildlife Services, Shane Siers

brown treesnake eradication is possible using aerial toxic baits, but adding live traps reduces the overall treatment time. Researchers note that tools effectively targeting large female brown treesnakes (greater than 1,000 mm snout-vent length) may have the greatest effect on reducing overall eradication timelines.

Contact: Shane Siers

Wildlife Population Monitoring Methods and Evaluations

- **Impacts of Migration on Red-Winged Blackbird Reproductive Success.** Many birds migrate south to avoid harsh conditions at their breeding grounds during the winter. However, energetically demanding migrations may delay the birds' spring reproductive development and negatively impact their overall reproductive success. NWRC, North Dakota State University, and University of Regina researchers explored the relationship between migration distance and reproductive status in red-winged blackbirds (*Agelaius phoeniceus). Researchers predicted that individual* birds that travel shorter distances will have higher levels of reproductive hormones upon arrival given they are able to invest less in migration and more in reproduction. Results from blood samples confirmed that baseline hormone levels were related to migration distance. In males, the baseline testosterone was elevated in shorter distance migrants. In females, the baseline estradiol was elevated in shorter distance migrants, but there was no relationship between migration distance and baseline testosterone. The findings indicate that, in a short-distance migrant, such as a red-winged blackbird, a few hundred kilometers difference in overwinter location may make a difference in how prepared these individuals are to breed.

  Contact: Page Klug

- **Diets of Black Vultures and Turkey Vultures.** Scavenging by vultures is an important ecosystem service because it limits the spread of disease. However, when vultures occur in high densities near people, they can cause problems such as property damage, aircraft collisions, and human health concerns. Human land-use changes and increased food resources may be contributing to the recent increases in vulture populations. NWRC and university researchers analyzed 176 pellets collected at black vulture and turkey vulture roost sites in coastal South Carolina and conducted a literature review of 14 pellet-based studies for both species. The pellet analysis identified 12 mammal species eaten by vultures. White-tailed deer were found in 65 percent of the samples and made-up 35 percent of the pellet volume overall. Other commonly consumed species included striped skunks and raccoons. Anthropogenic items (garbage) were found in 47 percent of the pellets. The literature review revealed a wide variability in diets across study sites, with large mammals (greater than 33

Human land-use changes and increased food resources may be contributing to the recent increases in vulture populations.
Photo by Adobe Stock

pounds/15 kilograms) typically making up most of the species eaten. Researchers note that increasing deer populations provide an important source of carrion for vultures in coastal South Carolina and likely throughout eastern North America. Ungulate populations, roadkill, and garbage appear to contribute considerably to turkey vulture and black vulture diets. As such, mitigation of human–vulture conflict will require effective garbage and roadkill management.

Contact: Bryan Kluever

- **Monitoring Coyote Populations with DNA.** Traditional methods for monitoring coyote populations often require costly capturing and handling of the animals. However, new noninvasive genetic sampling approaches do not require animal handling and use DNA in coyote scat (i.e., fecal material) to determine population densities and food habits. Because the efficacy of such approaches under different environmental conditions is not well understood, NWRC, University of Florida, and U.S. Geological Survey researchers examined the accumulations and degradation of DNA in scat from both rural and urban coyotes in Florida. Analysis of coyote scat showed that scat accumulation rates (0.02 scats/km/day) did not vary between rural and urban sites. The ability to amplify and genotype fecal DNA was negatively impacted as the scat was exposed to increased levels of sun and precipitation. After using fecal DNA to identify unique individuals, researchers estimated the urban coyote population density to be 8 coyotes per 100 km^2 (a lack of adequate scat samples in the rural area precluded a density estimation).

Researchers also analyzed DNA in the scat to identify the plant and animal species in the coyotes' diets. In total, 7 and 14 vertebrate animal species were detected in the diets of rural and urban coyotes, respectively. Feral swine were the most frequently detected prey item and were found in scat from both rural and urban sites. Other animal species detected included (but not limited to) several domestic species (cats, chickens, cows, sheep, horses), cottontail rabbits, white-tailed deer, and wood storks (*Mycteria americana*). Researchers also detected 11 orders of invertebrates and 50 plant families. The diversity of plant material in coyote scat was likely the result of plant material being intentionally eaten, indirectly eaten as a component of prey items (i.e., plant material within the digestive system of a prey item), unintentionally eaten (e.g., pollen), or the result of scat being contaminated by seeds, pollen, or spores after it was deposited. The results suggest that coyote scat sampling in Florida should occur during the winter, when rainfall is minimal. Sampling should also be spaced about 7 days apart to reduce potential DNA degradation and support optimal scat accumulation. Developing more robust sampling methods and using scat detection dogs to enhance detection may increase scat collection rates.

Contact: Bryan Kluever

- **Mountain Lion Habitat and Prey Selection.** Deer and other ungulates in urban areas have the potential to attract large carnivores that may impact the safety of people and domestic animals. NWRC, Utah Division of Wildlife Resources, Utah State University, and Colorado State University researchers placed radio-telemetry collars on 79 mountain lions in the Oquirrh Mountains near Salt Lake City, Utah, to monitor the lions' habitat use, diet, and causes of mortality in wildlands and at the urban-wildland interface (UWI). UWI is where urban areas and wildlands come together and often includes agricultural, military, and industrial activities. Results indicate that mountain lions primarily selected wildland habitats with seasonal mule deer populations. However, contrary to expectations, they also selected habitats closer to urban and mined areas. Mountain lion diets in the UWI did not differ from those in wildland habitats. Domestic ungulates represented only 2 percent of the 540 recovered prey items and were found primarily in wildlands. Native ungulates comprised more than 90 percent of the total kill, irrespective of season or land-use, suggesting that use of UWI habitats was linked to the presence of mule deer. Mountain lion mortality was disproportionately due to natural causes in wildlands, but individuals that died of human causes in UWI habitats were more likely to be inexperienced hunters, supporting young kittens, or compromised by physical handicaps. In general, the presence of mule deer was the key predictor of mountain lion habitat use, even in highly disturbed, human-altered landscapes. As such, researchers recommend that management designed to reduce mountain lion conflicts and ensure conservation focus on urban deer, land-use planning, and targeted education campaigns to reduce access to supplemental foods, such as roadkill and domestic animals.

Contact: Eric Gese

- **Mongoose Densities and Trapping Success.** The small Indian mongoose is an invasive species across the Caribbean and a rabies reservoir on at least four islands in the region. NWRC researchers and international partners from St. Kitts and Canada quantified differences in mongoose densities across

four habitat types (i.e., grassland, tropical dry forest, suburban habitat, and tropical rainforest) on St. Kitts, an island in the Caribbean free of mongoose rabies and where mongoose densities have not been quantified previously. High capture and recapture rates resulted in detailed estimates of mongoose densities across the habitats, with nearly six mongooses per hectare (2.4 mongooses per acre) in tropical dry forests versus 0.5 mongooses per hectare (0.2 mongooses per acre) in suburban habitats. Differences in activity patterns between male and female mongooses related to breeding and habitat quality also resulted in differences in trapping success. Researchers recommend that land cover and season be considered when estimating and comparing mongoose densities on St. Kitts to other islands with mongoose rabies, such as Puerto Rico, to better understand the population biology of this species across the Caribbean region.

Contact: Are Berentsen

Registration Updates

- **GonaCon Registered for Prairie Dogs.** In 2022, the EPA registered "GonaCon–Prairie Dogs" (EPA Reg. No. 56228-64)— APHIS' GnRH immunocontraceptive vaccine for managing fertility in sub-adult or adult female black-tailed, white-tailed, and Gunnison's prairie dogs. Previous NWRC laboratory and field studies showed that GonaCon–Prairie Dogs controlled female fertility for at least 1 year. This product must be hand injected and may only be used in prairie dog colonies that occur in urban/suburban areas, open spaces and natural areas, parks, campgrounds, airports, roadway medians, and other non-crop use sites. The vaccine provides an alternative non-lethal management tool for prairie dog population management at these use sites where trapping and relocation activities are relatively expensive, suitable habitat for transplants has become increasingly difficult to find, or relocation of prairie dogs is prohibited. The product can be administered by WS employees or state wildlife management agency personnel, or persons working under their authority.

  Contact: Emily Ruell

Technology Transfer

- **New Inventions, Patents, and Licenses.** In FY 2022, NWRC scientists were awarded three U.S. patents and four foreign patents. In addition, NWRC scientists submitted two utility patent applications. See the following tables (pages 46-47) for details on issued patents and patent applications. NWRC scientists also submitted two U.S. provisional patent applications and one invention disclosure to the NWRC Technology Transfer Office. In addition, patent licensees submitted a total of $75,311.29 in royalty payments.

  Contact: John Eisemann

- **Technology Transfer Agreements.** WS partners with universities, private companies, and others to promote research and development for new products that help manage wildlife damage. WS formalizes these partnerships through a variety of intellectual property agreements. In FY 2022, NWRC entered into 36 intellectual property agreements, 6 confidentiality agreements, 3 data sharing agreements, 15 material transfer agreements, 9 material transfer research agreements, and 3 cooperative research and development agreements. Technology transfer services were provided to the NWRC, several WS national programs, and WS Operations.

  Contact: John Eisemann

Patents Issued

INVENTION TITLE	NWRC INVENTORS AND *COOPERATOR CO-INVENTORS*	COUNTRY	PATENT/APPLICATION NUMBER
System and method for collision prevention	DeVault, T., Blackwell, B., and Seamans, T.	United States	11,142,173
Rotary manifold for paper-based immunoassays	Franklin, A., *Henry, C., Feeny, R., Carrell, C. (Colorado State University)*	United States	11,291,997
Adjuvanted rabies vaccine with improved viscosity profile	Miller, L., Fry, T., Hurley, J. *Maki, J. (Merial Inc.)*	United States	9,216,213
Trapping method and apparatus	Humphrey, J.	United States	8,407,931
Use of GnRH and analogs in the prevention and treatment of pet ferret adrenocortical hyperplasia	Miller, L. *Wagner, B. (University of Pittsburg)*	United States	8,927,495
Container apparatus brown treesnake	Pitt, W., Savarie, P. *Messaros, M. (Applied Design Corporation)*	United States	9,730,438
Microfluidized mycobacterium avium fragments as an adjuvant and carrier for mucosal vaccine delivery	Mauldin, R., Eckery, D., Miller. L.	United States	10,434171
Ultraviolet strategy for avian repellency	Werner, S.	United States African Regional Intellectual Property Organization Canada South Africa China India New Zealand Philippines South Africa Patent Cooperation Treaty	9,131,678 AP/P/2017/009720 2,954,333 2017/01198 ZL 2014 8 0080504.7 PCT/US2014/048119 728465 1/2017/500045 2017/01198 PCT/US2014/048119
Use of visual cues to enhance bird repellent compounds	Werner, S. *Ballinger, K. (Arkion Life Sciences)*	Australia Brazil Indonesia New Zealand	AU2015294513C1 BR122021017566-7 IDP000070772 2017/01198
Repellent and attractant composition for dichromatic animals	Werner, S. *Ballinger, K. (Arkion Life Sciences)*	United States United States ARIPO	10,638,745 11,252,953 IDP000079290
Method for repelling rodents	Werner, S. *Ballinger, K. (Arkion Life Sciences)*	United States Brazil Canada	9,999,220 B2 BR 112016016183-1 2,036,508

In 2013, the U.S. Patent and Trademark Office issued a patent to WS for a live snake trap that uses two trip pans to capture large, heavy snakes such as the invasive Burmese python. The trap was developed in conjunction with Tomahawk Live Trap, LLC.
Photo by USDA, Wildlife Services

Patent Applications

INVENTION TITLE	NWRC INVENTORS AND *COOPERATOR CO-INVENTORS*	COUNTRY	PATENT/APPLICATION NUMBER
Electromechanical pest animal suppression trap	Shiels, A. *Fragoso, J., Messaros, M. (Applied Design Corporation)*	United States	17/394,052
Selectively accessible feeder	Lavelle, M., Halseth, J., Snow, N. and *Staples, L., Lake, B. (Animal Control Technologies, Australia)*	United States PCT	17/270,855 PCT/AU2019/050903
Intelligent dual sensory species-specific recognition system	Vercauteren, K., Snow, N., Halseth, J. *Azimi-Sadjadi, M., Hall, J., Robbiano, C. (Information Systems Technologies, Inc.)*	United States	17/230,453
Repellent and attractant compositions for dichromatic animals	Werner, S. Ballinger, *K. (Arkion Life Sciences)*	United States	20200221684 A1
Deterrence of birds from treated seeds	Werner, S. *Ballinger, K. (Arkion Life Sciences)*	United States	62/796,051
Vaccine compositions and adjuvant	Miller, L., Rhyan, J., and Eckery. D.	United States	16/933,157 Application Withdrawn

Awards

- **2022 NWRC Publication Award.** Each year, the NWRC Publication Awards Committee, composed of NWRC scientists, reviews over 125 publications generated by NWRC colleagues. The resulting peer-recognized award honors outstanding contributions to science and wildlife damage management. In 2022, the committee presented the award to Drs. Jeffrey Chandler, Sarah Bevins, Jeff Root, and Susan Shriner for their work on SARS-CoV-2 in white-tailed deer.

  Chandler, J.C., S.N. Bevins, J.W. Ellis, T.J. Linder, R.M. Tell, M. Jenkins-Moore, J.J. Root, J.B. Lenoch, S. Robbe-Austerman, T.J. DeLiberto, T. Gidlewski, M.K. Torchetti, and S.A. Shriner. 2021. SARS-CoV-2 exposure in wild white-tailed deer (Odocoileus virginianus). Proceedings of the National Academy of Sciences 118(47):e2114828118. doi: 10.1073/pnas.2114828118

  For this study, researchers prioritized samples from white-tailed deer among other archived wildlife samples based on a predicted binding affinity of SARS-CoV-2 to angiotensin-converting enzyme 2 receptor and potential for human interaction with this species. Diagnostic tests were used to demonstrate that 40 percent of sampled wild white-tailed deer had been exposed to SARS-CoV-2, with strong evidence for exposure beginning in 2020 from samples spanning 2011-2021. As multiple activities bring white-tailed deer into direct contact with people (e.g., captive cervid operations, field research, conservation work, wildlife tourism, wildlife rehabilitation, supplemental feeding, hunting), these findings have human health and safety, wildlife health, and wildlife management implications. The findings of the study underscore the need for continued and expanded surveillance to determine the significance of SARS-CoV-2 in free-ranging deer and other wildlife. NWRC and NWDP employees are co-authors on this paper. WS Operations personnel were invaluable toward sample collection.

- **NWRC Employee of the Year Awards.** The winners of this award are nominated by their peers as employees who have clearly exceeded expectations in their contributions to the NWRC mission. The winners this year are:
  - Dr. Toni Piaggio
    research grade scientist
    Wildlife Genetics Project
    Fort Collins, CO
  - Dr. Jeff Chandler
    support scientist
    Laboratory Support Services Unit
    Fort Collins, CO
  - Andalyn Billings
    biological science technician
    Predator Project
    Fort Collins, CO
  - Kerry Haller
    supervisory budget analyst
    Administration Unit
    Fort Collins, CO

- **Kurt VerCauteren Receives Caesar Kleberg Award for Excellence in Applied Wildlife Research.** NWRC project leader and supervisory research wildlife biologist Dr. Kurt VerCauteren is the 2022 recipient of The Wildlife Society's (TWS) Caesar Kleberg Award. The Caesar Kleberg Award recognizes those who have distinguished themselves in applied wildlife research. It is focused on those whose body of work, in both inquiry and discovery, has resulted in the application of management and conservation "on the ground." VerCauteren and his teams were recognized for their years of work related to the development of new tools and techniques for mitigating wildlife conflict and disease. Over the years, their efforts have focused on deer, elk, feral swine, raccoons, bovine tuberculosis, chronic wasting disease, and more. In addition to the award plaque and commemorative medal, the recipient receives a complimentary TWS annual conference registration, travel expenses, and a $2,000 check.

- **Brad Blackwell Receives McAtee-Burger Award.** NWRC Ohio Field Station Leader Brad Blackwell and associate editor for the *Wildlife Society Bulletin*, is a 2021 recipient of the W. L. McAtee and G. V. Burger Award for Outstanding Service as Associate Editors. Blackwell received the award along with Bill Block, the associate editor for the *Journal of Wildlife Management*. The McAtee-Burger Award recognizes the outstanding work of an associate editor for TWS' two peer-reviewed journals. Blackwell "distinguished himself as a fair, supportive, and optimistic associate editor who consistently engages with authors to identify and present rigorous scientific information as part of the manuscript publication process in the *Wildlife Society Bulletin (WSB)*," wrote former WSB editor Dave Haukos and current WSB editor Brett Collier.

NWRC supervisory research wildlife biologist Dr. Kurt VerCauteren is the 2022 recipient of The Wildlife Society's Caesar Kleberg Award for Excellence in Applied Wildlife Research.
Photo by USDA Wildlife Services

2022 Publications

The transfer of scientific information is an important part of the research process. NWRC scientists and other WS experts publish in a variety of peer-reviewed journals that cover a wide range of disciplines, including wildlife management, genetics, analytical chemistry, ornithology, and ecology. (Note: 2021 publications that were not included in the 2021 NWRC accomplishments report are listed here.)

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Appendix 1

List of 2022 NWRC Research Projects

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

Project Leader: Fred Cunningham

Developing Control Methods, Evaluating Impacts, and Applying Ecology To Manage Carnivores

Project Leader: Dustin Ranglack

Developing Methods To Manage Damage and Disease of Feral Swine and Other Ungulates

Project Leader: Kurt VerCauteren

Evaluation, Development, and Assessment of Agents and Technologies Designed To Control Wildlife Populations

Project Leader: Jason Bruemmer

Economics, Operations Research, and Social Dimensions of Wildlife Management

Project Leader: Stephanie Shwiff

Evaluation and Development of Wildlife Repellents and Repellent Application Strategies

Project Leader: Scott Werner

Methods Development and Implementation of Genetic Approaches at the Livestock-Wildlife Interface

Project Leader: Antoinette Piaggio

Improving Methods To Manage Healthy Forests, Wetlands, and Rangelands

Project Leader: Jimmy Taylor (Acting)

Methods and Strategies for Wildlife Rabies Control and Elimination

Project Leader: Amy Gilbert

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

Project Leader: Steven Hess

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

Project Leader: Aaron Shiels

Methods Development and Damage Management of Depredating Birds and Invasive Wildlife

Project Leader: Bryan Kluever

Methods Development To Reduce Bird Damage to Agriculture: Evaluating Methods at Multiple Biological Levels and Landscape Scales

Project Leader: Page Klug

Understanding and Exploiting Wildlife Behavior To Mitigate Wildlife Collisions With Aircraft, Other Vehicles, and Structures

Project Leader: Brad Blackwell

Wildlife-Borne Pathogens Affecting Food Safety and Security: Developing Methods To Mitigate Effects

Project Leader: Alan Franklin

Wildlife Disease Dynamics, Epidemiology, and Response

Project Leader: Susan Shriner

Human Dimensions

Unit Leader: Keith Carlisle

Regulatory Support Services

Unit Leader: John Eisemann

Laboratory Support Services

Unit Leader: Jeffrey Chandler

Information Services

Unit Leader: Mary Foley

Animal Care

Unit Leader: Michael McBride

More information about these projects is available on the NWRC web page at:

www.aphis.usda.gov/wildlifedamage/nwrc

Appendix 2

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Berentsen, Are	(970) 266-6221 are.r.berentsen@usda.gov	Rabies
Bevins, Sarah	(970) 266-6211 sarah.n.bevins@usda.gov	Wildlife disease
Blackwell, Bradley	(419) 625-0242 ext. 15 bradley.f.blackwell@usda.gov	Aviation safety, lighting systems
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Cunningham, Fred	(662) 325-8215 fred.l.cunningham@usda.gov	Project Leader: Aquaculture, fish-eating birds
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DeLiberto, Shelagh	(970) 266- 6121 shelagh.t.deliberto@usda.gov	Repellents
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NAME	CONTACT INFORMATION	AREAS OF EXPERTISE
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NAME	CONTACT INFORMATION	AREAS OF EXPERTISE
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Pepin, Kim	(970) 266-6162 kim.m.pepin@usda.gov	Modeling, feral swine
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Smith, Benjamin	(970) 266-6091 benjamin.smith4@usda.gov	Feral swine, ungulates
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Snow, Nathan	(970) 266-6041 nathan.p.snow@usda.gov	Feral swine
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Tillman, Eric	(352) 448-2132 eric.a.tillman@usda.gov	Invasive species
VerCauteren, Kurt	(970) 266-6093 kurt.c.vercauteren@usda.gov	Project Leader: Feral swine, ungulates
Volker, Steve	(970) 266-6170 steven.f.volker@usda.gov	Chemistry
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Werner, Scott	(970) 266-6136 scott.j.werner@usda.gov	Project Leader: Repellents

Appendix 3

Acronyms and Abbreviations

ARG	antibiotic resistance genes
ARM	antibiotic-resistant microorganisms
APHIS	Animal and Plant Health Inspection Service
ARP	American Rescue Plan
ASF	African swine fever
BLM	Bureau of Land Management
BMP-15	bone morphogenetic protein-15
BRR	beaver-related restoration
CONARE	Corporation of the Basins of the Rivers Negro and Nare
CWD	chronic wasting disease
DNA	deoxyribonucleic acid
eDNA	environmental DNA
EPA	U.S. Environmental Protection Agency
FEAR	flush early and avoid the rush
GDF-9	growth differentiation factor-9
GnRH	gonadotropin releasing hormone
GPS	global positioning system
HPAI	highly pathogenic avian influenza
IAV	influenza A virus
LPD	livestock protection dog
LSSU	Laboratory Support Services Unit
NRMP	National Rabies Management Program
NWDP	National Wildlife Disease Program
NWRC	National Wildlife Research Center
ORV	oral rabies vaccine
SIA	stable isotope analysis
SN	sodium nitrite
TWS	The Wildlife Society
UAS	unmanned aircraft system
USDA	U.S. Department of Agriculture
USVI	U.S. Virgin Islands
UWI	urban-wildland interface
VIDOH	Virgin Islands Department of Health
WS	Wildlife Services
WSB	Wildlife Society Bulletin

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