



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



Wildlife Services

Innovative Solutions to Human-Wildlife Conflicts

National Wildlife Research Center • Accomplishments, 2024

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

National Wildlife Research Center

4101 LaPorte Ave.
Fort Collins, CO 80521-2154

www.aphis.usda.gov/national-wildlife-programs/nwrc

PHONE: (970) 266-6000
Email: nwrc@usda.gov

NWRC Management Team

Jason Suckow
Director

Doug Eckery
Assistant Director

Jimmy Taylor
Assistant Director

Natalie Erhart
Administrative Officer

NWRC Field Stations

Fargo, ND
(701) 231-5190

Gainesville, FL
(352) 448-2130

Hilo, HI
(808) 932-4750

Millville , UT
(435) 245-6091

Sandusky, OH
(419) 625-0242

Starkville, MS
(662) 325-8612

WS Pocatello Supply Depot

Pocatello, ID
(208) 236-6922

Cover & page 1: In 2024, WS employees located at the NWRC celebrated the 25th anniversary of the opening of the Center's Wildlife Science Building, signifying the completion of the Center's relocation from the Denver Federal Center to Fort Collins, Colorado, in 1999. Photo by USDA Wildlife Services

Message from the Director

In 2024, WS NWRC marked the 25th anniversary of the opening of its Wildlife Science Building at its headquarters office in Fort Collins, Colorado. Prior to its opening, most employees were scattered across offices and facilities at the Denver Federal Center. The move to Fort Collins signified a commitment to WS' continued growth in research. Situated on 43 acres at Colorado State University's (CSU) Foothills Campus, the NWRC is a national hub for wildlife damage research. Its unique laboratories and animal holding facilities support diverse partnerships and collaborations with universities; other Federal, State, and local agencies; and private institutions.

As we continue to grow our expertise, we are also focusing on the future—discovering, evaluating, and leveraging new technologies for use in wildlife disease and damage management, working with new and nontraditional stakeholders, and thinking about potential opportunities and challenges.

The WS program overall is using strategic foresight to integrate future-thinking principles into its culture and planning. Strategic foresight is a method for exploring plausible future scenarios, identifying the opportunities and challenges they present, and leveraging that information to make



Jason Suckow
NWRC Director

*Photo by USDA Wildlife Services,
Gail Keirn*



strategic decisions now that will better position us for the future.

WS' parent agency—the Animal and Plant Health Inspection Service—identified ten future trends most likely to impact the way the agency does business. Many of those trends, such as a changing and unpredictable climate, scientific and technological advances, evolving perceptions of animal welfare and wildlife, global health threats, and a changing workforce, speak directly to issues WS currently recognizes and is planning for in the years ahead. For example, we've invested in disease and diagnostics laboratories to research and address new and emerging zoonotic disease risks. NWRC's new Wildlife Disease Diagnostics Laboratory is designated a National Animal Health Laboratory Network (NAHLN) Affiliate Laboratory, allowing us to provide surge

capacity for NAHLN laboratory testing during disease outbreaks. The establishment of NWRC's Human Dimensions Unit in 2022 helps to inform wildlife policy and management by studying how people value wildlife and their wildlife management preferences. These and other advances ensure WS remains a leader in wildlife damage management and research, while positioning us to better address the challenges and opportunities of the future.

It is with pleasure that I present to you WS NWRC's 2024 research accomplishments.

Jason Suckow
Director
National Wildlife Research Center

Contents

Innovative Solutions to Human-Wildlife Conflicts

National Wildlife Research Center Accomplishments, 2024

Research Spotlights	5
Celebrating 25 Years of Research in Fort Collins	5
Collaborations	8
Update on Chronic Wasting Disease Research	12
2024 Accomplishments in Brief	16
Devices	17
Pesticides and Repellents	18
Other Chemical and Biological Methods	18
Disease Diagnostics, Surveillance, Risk Assessment, and Management	20
Wildlife Damage Assessments	27
Wildlife Management Methods and Evaluations	32
Wildlife Population Monitoring Methods and Evaluations	38
Registration Updates	43
Technology Transfer	44
Awards	46
2024 Publications	48
Appendix 1. List of 2024 NWRC Research Projects and Support Units	62
Appendix 2. NWRC Research Contacts	64
Appendix 3. Acronyms and Abbreviations	67

Research Spotlights



An endangered black-footed ferret (*Mustela nigripes*) pokes its head out from a prairie dog burrow in Montana. WS is part of the multi-agency Black-footed Ferret Recovery Implementation Team and helps to conduct plaque mitigation in black-footed ferret recovery areas.

Photo by USDA Wildlife Services, Kelsey Weir

NWRC can trace its roots back to 1885 and USDA's Division of Economic Ornithology.

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

SPOTLIGHT

Celebrating 25 Years of Research in Fort Collins

In June 2024, the NWRC celebrated the 25th anniversary of the opening of its Wildlife Science Building in Fort Collins, Colorado. The facility serves as the main office and laboratory building for the Center and is one of several buildings on its 43-acre headquarters campus.

"The start of what was to become today's NWRC began much, much earlier than just 25 years ago," states NWRC Director Jason Suckow. "NWRC can trace its roots back to 1885 and USDA's Division of Economic Ornithology. This pioneering research group focused on methods to control wildlife damage to agriculture. Over time, names and departments changed, groups merged, and NWRC's mission expanded."

In 1959, the Center was called the Denver Wildlife Research Center (DWRC), a name it kept until 1990. By the late 1980s, the DWRC had outgrown its facilities at the Denver Federal Center and needed a new home. In 1990, APHIS and CSU signed a Memorandum of Understanding to develop a new research facility on the CSU Foothills Campus. Due to the expanding national and international scope of its research,

a new name was chosen—the National Wildlife Research Center. In 1995, NWRC's first building on campus—the Animal Research Building—was completed and the first few employees from offices at the Denver Federal Center started moving to Fort Collins. In 1999, the 82,000 ft² Wildlife Science Building opened for business.

"Many changes have occurred since 1999. Our staff and mission have evolved and expanded. We started with approximately 135 employees and now have close to 200 employees. Our research focus in 1999 centered on bird damage to agriculture, predation damage management, and product development. It now encompasses these areas and more, such as wildlife disease, aviation safety, economics, wildlife genetics, and invasive species," continues Suckow. "Now, the Center houses staff for two WS national programs—the National Wildlife Disease Program and the National Feral Swine Damage Management Program. Both support crucial, mission-critical areas of expertise and operations within APHIS and WS. I am excited to see what the next 25 years holds."

During the recent celebration, NWRC and collocated national program employees were joined by USDA APHIS Administrator Dr. Mike Watson, Associate Administrator Dr. Donna Lalli, Associate Administrator Michelle Wenberg, and WS Deputy Administrator Janet Bucknall. The day's activities included a tour of the Center's unique laboratories and animal holding facilities, an employee town hall, a picnic lunch, the placement of a time capsule celebrating NWRC's first 25 years in Fort Collins, and a ribbon cutting ceremony for WS' new Bio-Archive Storage facility.

APHIS Administrator Dr. Mike Watson does the honors of cutting the ribbon at NWRC's grand opening of the new WS Bio-Archive Storage Facility. At capacity, the facility will maintain over 5 million blood, tissue, and other biological samples for wildlife research. Photo by USDA Wildlife Services, Gail Keirn



Supporting Future Research Through Sample Archives

In addition to celebrating the Wildlife Science Building's 25th anniversary, NWRC employees hosted a ribbon cutting ceremony for its newest building, the WS Bio-Archive Storage (BAS) facility. The BAS will likely become one of the largest wildlife tissue archives of its kind in the United States. It will include more than 100 ultra-low temperature (-80°F) freezers with the capacity to maintain over 5 million archived blood, tissue, and other biological samples. Many of the samples to be archived in the BAS were originally part of other WS collections and were collected from wildlife species throughout the United States, Puerto Rico, Guam, and the U.S. Virgin Islands. Most were collected by WS employees and Federal and State partners for research or disease monitoring efforts and surveillance of severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2), rabies, chronic wasting disease, plague, tularemia, and avian influenza in wildlife populations. The BAS will continue to expand its

collection as new samples are taken and other collections are incorporated.

"The samples stored in the BAS have great historical and scientific value to WS, as well as to conservationists, epidemiologists, and researchers around the world," concludes Suckow. "They are an important source of specimens for retrospective studies related to wildlife disease, genetics, and populations. We're looking forward to seeing what new discoveries WS and our collaborators will make with the help of this new facility."

NWRC Employees Prepare for the Future While Commemorating Current Research

As part of the 25th anniversary celebration, NWRC employees commemorated the Center's recent accomplishments by burying a time capsule to be opened again in 2049. The time capsule included summary cards highlighting NWRC's current research projects and units, as well as collocated WS national programs. It also included

TIME CAPSULE ARTIFACT	SUBMITTED BY
SARS-CoV-2 sample collection kit	WS National Wildlife Disease Program
“Squeal on Pigs” baseball cap and “Do Not Move Feral Swine” signage	WS National Feral Swine Damage Management Program
Vulture wing tags used to monitor black vulture and turkey vulture movements	NWRC Florida Field Station
Solar-powered, flashing light-emitting diode (LED) ear tag for livestock (called a flashtag) used to prevent livestock depredation	NWRC Utah Field Station
Oral contraceptive bait (pellets) called Ovocontrol-G used to contracept Canada geese and Muscovy ducks; a factsheet, registrations, and labeled syringe for GonaCon, an injectable contraceptive vaccine registered for deer, feral horses and burros, and prairie dogs	NWRC Population Management Project
Radio telemetry equipment for tracking raccoons (LOTEK unit and antenna)	NWRC Rabies Project
Goodnature A24 Rat + Stoat Trap	NWRC Rodent Project
NWRC Accomplishments Reports from the years 1999 and 2023	Director’s Office

artifacts representing current wildlife damage management tools and research equipment.

“Though no one really knows what the future holds, I am confident NWRC employees will meet future challenges with the same energy, determination, adaptability, and thoughtfulness as they have in the past,” states NWRC Director Jason Suckow. “They have already proven how valuable their research is by bettering our understanding and management of costly zoonotic diseases, such as rabies, highly pathogenic avian influenza, and SARS-CoV-2. They have harnessed new technologies, such as genome sequencing and other genetic approaches, unmanned aircraft systems, and nanoparticles, to develop new methods for use in wildlife damage management.”

Recently, APHIS leaders used a technique called “strategic foresight” to explore plausible future scenarios and identify associated opportunities and challenges. They identified ten trends and key drivers that have the potential to impact APHIS in the next 20 to 30 years. These included a future where change is the only constant,



where technology and science advance quickly, and stakeholder networks expand and shift. As challenging as this future may sound, NWRC’s expertise and skills as a research organization make APHIS better prepared to address it.

WS employees located at the NWRC review summaries and artifacts collected for a time capsule. The time capsule commemorates NWRC’s recent accomplishments and will be opened again in 2049.

Photo by USDA Wildlife Services, Gail Keirn

SPOTLIGHT

Collaborations

Conflicts between people and wildlife are inherently difficult to resolve. They require a strong understanding of animal behavior and ecology, creativity to adapt and explore new tools and techniques, and a sensitivity to social values and concerns. To successfully address these complex problems, institutions need to establish collaborative partnerships involving experts from a wide range of scientific disciplines, management organizations, and interested stakeholder groups.

As an organization, the NWRC exemplifies this core collaborative strategy. Last year, 83 percent of all NWRC studies included at least one outside partner. In all, NWRC worked with hundreds of State and Federal government agencies, non-governmental organizations, universities, foreign institutions, and private sector companies or other groups. Each collaboration leveraged assets, which together helped to improve the success of our research and development efforts.

“Our most important collaborative relationship is with our own WS Operational program,” states NWRC Director Jason Suckow. “Each year, over 45 percent of NWRC’s studies are conducted in cooperation with WS’ State and national programs.”

These collaborations are valuable for several reasons. First, they draw on the diverse and practical experience of WS’ knowledgeable field biologists and specialists. Second, WS is well connected to its regional stakeholders, and as a result, offers important recommendations about field study locations and local contacts to enhance the success of our research efforts. Third, these collaborations allow researchers to test their ideas under practical wildlife management scenarios, thus tying the research and development process to its ultimate goal—to

produce practical, economical, feasible, and effective information, methods, and tools for use in wildlife damage management.

WS Research and Operations Team Collaboration Award

In 2024, WS announced the winners of its first WS Research and Operations Team Collaboration Award. Two winning teams were selected. Both used advanced genetic approaches to gain knowledge about wildlife populations and inform operational activities. The collaborations included WS professionals at multiple levels from WS NWRC’s Wildlife Genetics and Rabies Projects, multiple WS Operations State offices, the WS National Rabies Management Program (NRMP), and WS National Feral Swine Damage Management Program (NFSDMP).

The first collaboration—comprised of the NWRC Rabies Project, NRMP, and WS Operations in 23 States—established a raccoon (*Procyon lotor*) genetic archive and rapid genotyping method as part of enhanced rabies surveillance activities. Since the 1990s, the NRMP has worked to prevent the spread of the raccoon variant of rabies virus (RV) in the Eastern United States. Understanding the spatial movement of raccoon RV and target reservoir populations is important for monitoring and refining strategies supporting the landscape-level control and local elimination of this lethal pathogen. In partnership with the NRMP, NWRC researchers established a raccoon genetic archive to assist in identifying regional raccoon populations in the Eastern United States. NRMP wildlife biologists collected over 4,000 tissue samples across and in proximity to oral rabies vaccination (ORV) zones, while partners in Quebec and Ontario also contributed samples to the raccoon genetic archive along the northern edges of shared international borders, to extend the identification and assignment

Resolving wildlife conflicts requires collaborative partnerships with diverse experts.

of raccoon populations and movements and inform raccoon RV management without borders in the Eastern United States.

“We use these samples to identify management units and migration corridors, as well as to infer the geographic origin of rabid animals associated with NRMP contingency actions,” states NWRC supervisory research biologist and project leader Dr. Amy Gilbert.

Researchers developed a rapid, high-throughput, and cost-effective method for genotyping the archive samples and created a database representing 1,300 raccoons from across North America. The method supports the NRMP’s contingency planning and management actions by identifying the geographic origins of rabid animals that breach ORV zones, saving valuable time and resources. For instance, a rabid raccoon collected on Cape Cod, Massachusetts, in 2021 was associated with a NRMP contingency action and NWRC researchers used the newly established raccoon genetic archive to identify the animal as a translocation from mainland Massachusetts. The ability to efficiently assess the genetic origin of this and other high priority rabid animals can inform real-time management decisions and reduce emergency response operations and costs.

The second collaboration included experts with NWRC’s Wildlife Genetics Project, NFSDMP, and WS Operations in Missouri and Iowa. In 2016, NWRC initiated the development of a nationwide feral swine genetic archive to determine the origin of feral swine (*Sus scrofa*) located in Missouri. Analysis showed that feral swine populations within Missouri were being supplemented



by the translocation of individuals from other States. This knowledge informed legislation, direct management actions, and prioritizations of regional action in Missouri intended to curtail feral swine movements into and within the State. Since then, the WS Missouri/Iowa program has removed feral swine from two-thirds of the watersheds that were once invaded by feral swine. Removal efforts continue aided by the development of Missouri-specific environmental DNA (eDNA) criteria for determining the presence or absence of feral swine on the landscape. The NFSDMP continues to prioritize investing in genetic research and the development of such operational tools to help verify feral swine presence/absence and combat illegal translocation of feral swine.

Collaborating with University Experts

NWRC often collaborates with university partners to develop or improve upon existing wildlife damage and disease management tools.

In 2024, WS announced the winners of its first WS Research and Operations Team Collaboration Award. Two winning teams were selected. Pictured: Representatives from one of the winning teams including the National Feral Swine Damage Management Program and NWRC Wildlife Genetics Project.

Photo by USDA Wildlife Services, Gail Keirn



NWRC partnered with Purdue University researchers to study how Canada geese respond to LED lights of different wavelengths and pulse frequencies. Findings could help modify onboard lighting systems to help birds detect and avoid approaching aircraft.

Photo by USDA Wildlife Services

For 18 years, researchers with NWRC's Aviation Safety Project have partnered with visual and behavioral ecologists at Purdue University to better understand how birds and other wildlife detect and respond to aircraft and provide insights into the development and use of visual deterrents. Their primary goal is to develop new tools and strategies for preventing collisions between wildlife and aircraft. Using their knowledge of bird visual systems, the team has conducted a variety of experiments to determine how the Canada goose (*Branta canadensis*) and other bird species see various wavelengths of light or respond to the approach of an aircraft. Modifications to onboard lighting systems might help to increase the distance at which birds detect and move away from an approaching aircraft, ultimately reducing the likelihood of collision.

"Birds see so much differently than humans do," states NWRC project leader Dr. Bradley Blackwell. "So, we can't translate our own perceptual understanding to the problem of birds avoiding aircraft. Instead, we think about birds' anti-predatory behavior and how we might apply the visual and behavioral information to better understand how birds respond to approaching aircraft and different lighting treatments."

In their most recent study, NWRC and Purdue University researchers partnered with Rensselaer Polytechnic Institute to develop a light stimulus

of high chromatic contrast to the eyes of Canada geese. Researchers then evaluated the birds' avoidance or attraction responses to specific LED lights of different wavelengths or pulse frequencies (blue 483 nanometers (nm) versus red 631 nm and steady versus pulsing at 2 Hertz (Hz), respectively). Overall, Canada geese tended to avoid the blue light and move towards the red light; however, these responses depended heavily on the number of light exposures.

"At the beginning of the experiment, geese tended to avoid the red light. However, after further exposure, the birds developed an attraction to the red light," explains Blackwell. "The response to the blue light generally followed a U-shape relationship of avoidance, then attraction, then avoidance again as the number of exposures increased."

Lights pulsing at 2 Hz enhanced avoidance responses under high natural light conditions, whereas steady lights enhanced avoidance responses under dim natural light conditions.

Researchers conclude that LED lights with specific wavelengths of blue light might be good candidates for deterring Canada geese. Additionally, deterrent systems that automatically modify the pulsing of the LED lights based on the intensity of the natural light might also increase bird avoidance behavior.

Sharing Knowledge and Expertise Internationally

WS is known worldwide for its wildlife damage management knowledge and expertise. Its experts are often invited to speak internationally on topics related to wildlife disease and One Health, and rodent, feral swine, and predator management. The NWRC also cooperates with international organizations to develop, test, and implement various tools and techniques to reduce wildlife damage around the world.

Detecting and preventing wildlife disease, increasing agricultural production, protecting native ecosystems, and eradicating invasive species are a few of the many challenges facing scientists and natural resource managers across the globe. NWRC researchers share their expertise with international colleagues by providing technical assistance and training. Past efforts have included:

- Avian influenza surveillance training in Asia
- Canine distemper and rabies studies in Africa
- Beaver (*Castor canadensis*) damage mitigation efforts in South America

More recent collaborations with a variety of institutions and colleagues in Australia have focused on the development of a sodium nitrite toxic bait for use on feral swine and the evaluation of an oral bait vaccine to prevent a transmissible cancer, known as devil facial tumor disease, in endangered Tasmanian devils (*Sarcophilus harrisii*).

Sodium Nitrite Toxicant

Since 2009, NWRC has been working with Australian scientists and a private company to evaluate the use of a microencapsulated form of sodium nitrite to control invasive feral swine in Australia, the United States, and other countries. Sodium nitrite is a meat preservative commonly used to cure meats, such as sausage and bacon. When eaten in high doses over a short period of time, it is toxic to feral swine.

Initial research focused on studies with captive feral swine to determine the toxicant's effectiveness and humaneness. Scientists were also interested in the toxicant's potential impact to other species that could be accidentally exposed to the bait. Tests showed that sodium nitrite degrades quickly when exposed to environmental elements, such as microorganisms, sunlight, heat,

and moisture. Furthermore, most sodium nitrite is broken down within the animal's body before it dies, making their carcasses safe for scavengers, such as coyotes and vultures.

In 2018, the U.S. Environmental Protection Agency (EPA) granted an Experimental Use Permit for a field trial of the sodium nitrite bait called HOGGONE®. Feral swine are messy eaters, and during the field trial they spilled toxic bait on the ground near bait stations. Researchers noticed that bait crumbs left outside bait stations by feral swine posed a risk to nontarget species, mainly seed-eating birds.

"We worked with our Australian colleagues to reformulate the bait to reduce nontarget risks by increasing its palatability to feral swine and reducing spillage," explains NWRC supervisory research wildlife biologist and project leader Dr. Kurt VerCauteren. "We also reassessed our baiting strategies and designed a durable, lightweight, and reusable bait station that reduced spills and prevented access to bait by nontarget species."

Although sodium nitrite is registered for use in Australia and approved under permit in Canada for emergency disease suppression, NWRC research on methods to reduce secondary hazards from sodium nitrite to nontarget species in the United States continues.

"It's been rewarding to work with our Australian counterparts on this challenging invasive species issue," concludes VerCauteren. "Their expertise and unique perspectives helped us to improve the product for use in our unique habitats and wildlife communities in the United States."

Rabies-style Oral Bait Vaccine

The Tasmanian devil is the largest carnivorous marsupial. Since 1996, its population has declined by about 80 percent, mainly due to a

transmissible cancer known as devil facial tumor (DFT1) disease. In 2014, a second transmissible devil facial tumor (DFT2) was discovered. DFT1 and DFT2 are nearly 100-percent fatal. Australian scientists partnered with NWRC to evaluate a potential rabies-style oral bait vaccine (OBV) program for DFTs.

Rabies OBVs have a long safety record. The WS NRMP, which works closely with NWRC researchers and other Federal, State, and local partners, has been using an OBV approach to control the spread of rabies virus in terrestrial wildlife in the United States since 1997.

After evaluating the benefits and limitations of various management options, the international team recommended the development and regional distribution of an OBV to limit the impact of DFT1 and prevent DFT2 from spreading.

“An oral vaccine to combat DFT1 and DFT2 in Tasmanian devils is currently under development in Australia,” states NWRC Rabies Project Leader Dr. Amy Gilbert. “However, the success of an OBV program to reduce or eliminate DFT in devil populations will depend not only on the effectiveness of the vaccine, but also the oral

bait formulation, field distribution and delivery strategies, and continuous monitoring of DFT prevalence in target populations and regions.”

Since 2021, NWRC and Australian collaborators have been collecting preliminary data on bait palatability, biomarkers, and bait uptake among Tasmanian wildlife, including pilot testing an automated bait station for devils.

The team tested placebo versions of commercially available oral baits used for controlling wild canids and invasive feral swine on mainland Australia. They first offered baits to captive devils to determine if devils would eat the bait and learn more about their feeding behaviors. Researchers then conducted limited field trials in select habitats in southern Tasmania to assess bait uptake by wild devils and nontarget species, such as brushtailed possums (*Trichosurus vulpecula*).

Results showed that captive devils ate all types of placebo baits but ate more of the ruminant meat- and fish-based baits than cereal-based baits. Captive devils also ate inert vaccine capsules inserted into placebo baits. Field trials showed that 53 percent of baits were removed from bait stations, with 76 percent of the removals occurring on the first night.

“Unfortunately, devils were suspected or confirmed via trail cameras of removing only about 7 percent of the baits, compared with 93 percent being removed by nontarget species,” states Gilbert.

To improve upon these numbers, the team conducted additional trials with an automated bait dispenser designed to limit access by nontarget species. This resulted in over 50 percent of the baits being removed by devils.

“The outcomes of this study are promising and lay the foundation for an OBV delivery system for Tasmanian devils if an effective vaccine can be developed. It’s rewarding to leverage our

NWRC researchers are leveraging their knowledge about rabies oral bait vaccines to help Australian colleagues develop an oral bait vaccine for devil facial tumor disease in Tasmanian devils. Photo by Adobe Stock



OBV expertise to help this critically endangered species,” concludes Gilbert.

Next Steps—With funding from the Australian Research Council and Ceva Wildlife Foundation, NWRC continues to partner with the University of Tasmania, government scientists, and industry to advance studies on the captive experimental immunogenicity and safety testing of oral vaccine baits for Tasmanian devils and limited field trial evaluations in Tasmania for control of DFT disease.

SPOTLIGHT

Update on Chronic Wasting Disease Research

Chronic wasting disease (CWD) is a fatal, transmissible neurological disease of cervids, including deer, elk, moose, and reindeer. It presents a significant challenge to wildlife managers and conservationists in the United States and Canada, as well as Norway, Sweden, and Finland. It also has ecological, economic, and cultural impacts, affecting numerous stakeholders and costing the U.S. economy tens of millions of dollars each year. Concerns about these impacts drive research that aims to reduce the spread of CWD and facilitate the management of healthy cervid populations.

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 CWD transmission. Results from this research helped to inform management and guide additional studies, such as those underway today.

NWRC’s CWD efforts were renewed in 2023 with the creation of a new CWD research project and the establishment of a state-of-the-art prion laboratory. This spotlight describes the Center’s ongoing efforts to develop new tools and techniques to aid in CWD management.



WS’ Attending Veterinarian encourages a white-tailed deer fawn into a weighing chute at NWRC’s Outdoor Animal Research Facility. Researchers are investigating the potential for CWD transmission via natural exposure to a previously contaminated environment. Photo by USDA Wildlife Services, Gail Keirn

Investigating Prion Persistence

CWD is caused by prions, which are misfolded, infectious forms of normal proteins. In infected animals, these prions accumulate in the central nervous system over time, leading to progressive neurodegeneration, loss of coordination and body condition, and eventually death. CWD is not known to infect people.

“CWD prions can remain infectious in the environment for many years, though the exact period of persistence is unknown,” states NWRC CWD Project Leader Dr. Jennifer Malmberg.

NWRC’s headquarters campus in Fort Collins is located within the CWD endemic region of northeastern Colorado and includes a double-fenced enclosure from which cervids have been excluded for approximately 20 years. Malmberg and her team obtained four newborn CWD-negative white-tailed deer (*Odocoileus virginianus*) fawns for a study in the outdoor enclosure that investigates the duration of prion persistence and the potential for transmission through environmental exposure.

Over the next several years, the deer will be sampled and tested for CWD every 6 months via rectal biopsy. Animals will also be tested at the



Researchers collect tissue and blood samples and place GPS collars on mule deer as part of a multi-year CWD study in Nebraska.

Photo by USDA Wildlife Services,
Jennifer Malmberg

onset of observable clinical signs consistent with CWD. The goal is to assess the risk of environmental transmission after roughly two decades of cervid exclusion. Findings from this study will address a critical knowledge gap pertaining to CWD transmission and prion persistence.

“Multiple factors influence the probability of environmental transmission, including clay content of the soil and level of exposure over time. This study will help characterize the risk of transmission through natural routes of exposure in CWD endemic regions,” states Malmberg.

Tracking CWD in Wild Deer Populations

As of December 2024, CWD has been detected in free-ranging cervids in 35 U.S. States and 4 Canadian provinces and continues to spread in North America, Europe, and Asia. Tracking and understanding the spread of the disease in America’s elk and deer is critical for effective management.

The NWRC CWD Project conducts both field and laboratory studies focused on the development of new tools and techniques to aid in CWD detection and management. As part of a multi-year study, NWRC researchers are partnering with the

Nebraska Game and Parks Commission and CSU to investigate the causes of mule deer (*Odocoileus hemionus*) mortality in Nebraska, as well as mule deer movement, behavior, and resource selection to optimize CWD detection tools.

“Nebraska is home to an estimated 100,000 to 140,000 mule deer that are highly valued as a natural resource and as a vital source of State revenue,” states NWRC CWD Project Leader Dr. Jennifer Malmberg. “This study will help us to better understand mule deer survival in the State and determine the impact of CWD on mule deer populations. We also hope to learn more about CWD’s impact on other sources of mule deer mortality, such as predation, vehicle collisions, and winterkill. For instance, research in Colorado has shown that mountain lions (*Puma concolor*) selectively prey on CWD infected deer.”

Starting in 2024, researchers live-captured 60 mule deer in the Nebraska Panhandle where CWD prevalence rates in mule deer are approximately 16 to 30 percent. This year, they hope to capture an additional 80 deer for the study. Global positioning system (GPS) collars were placed on the deer and tissues were collected for CWD testing. Over the next couple of years, data from the collars, as well as direct observations and trail cameras, will be analyzed to assess how deer movement and behavior impact the risk of CWD transmission among deer. Deer mortalities will be investigated to determine cause of death and carcasses will be tested for CWD.

“We hope to unravel some of the mystery around the disease and its impact on deer populations. Are infected deer more susceptible to other forms of mortality? Are there mortality “hotspots” on the landscape? Do infected deer select resources, such as habitats, differently? Do they behave differently?” states Malmberg. “Knowing the answers to these questions can help wildlife managers optimize CWD monitoring and surveillance.”

NWRC's CWD research focuses on the development of new tools for detecting infectious prions and identifying the underlying mechanisms influencing CWD transmission.

Improving Early Detection of CWD in Deer

In 2023, NWRC opened a new state-of-the-art prion laboratory. The lab is equipped with specialized instruments that facilitate research and development of prion detection methods.

“We can run CWD tissues, such as brain and lymph nodes,” states NWRC research biologist and lab manager Dr. Lindsay Parrie. “But we are really interested in developing more sensitive live tests that can detect prions as early as possible in other deer tissues, blood, or nasal swabs. CWD monitoring efforts would also benefit from new tools and techniques that identify and measure CWD prions in the environment, such as in soil and plants.”

Current CWD surveillance techniques are limited to diagnostic immunoassays, such as the enzyme-linked immunosorbent assay (ELISA) and immunohistochemistry, that require samples collected from a deer's obex (brainstem), medial retropharyngeal lymph node, and in limited instances the recto-anal mucosa-associated lymphoid tissue (rectum).

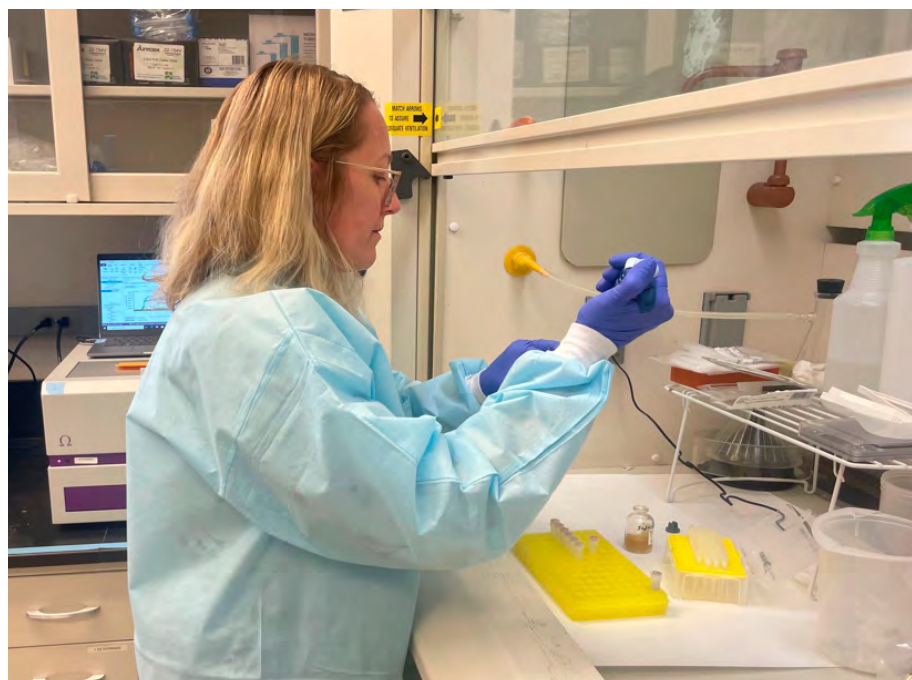
Parrie and others in NWRC's prion lab are exploring ways to optimize prion amplification assays, such as the real-time quaking-induced (RT-QuIC) assay which is amenable to a variety of biological and environmental samples. RT-QuIC allows for the massive amplification of the prion protein in a sample making the test approximately 10,000 to 10 million times more sensitive than the ELISA. RT-QuIC is also much faster (1-2 days) than immunohistochemistry, which can take weeks, making RT-QuIC more practical for research.

NWRC researchers have used RT-QuIC to detect CWD prions in mule deer ear tissues, nasal swabs, rectal biopsies, and fecal samples. Ongoing work is focused on further optimizing each sample type for maximum sensitivity and specificity.

Next Steps—The CWD Project will build on existing studies and continue to investigate CWD across different scales, from the protein level to population and landscape levels. An influx of tissue samples from deer and elk harvested by hunters in late 2024 will add to the team's tissue archive and support current and future research. In early 2025, researchers plan to live-capture, sample, and collar additional mule deer in Nebraska as part of their long-term deer population study. Researchers are also planning to obtain a transgenic mouse colony for use in bioassays.

In NWRC's new prion laboratory, researchers are exploring ways to optimize methods for amplifying and detecting CWD prions in various biological and environmental samples.

Photo by USDA Wildlife Services



2024 Accomplishments in Brief

A WS disease biologist prepares to collect samples from captured mallards (*Anas platyrhynchos*) in Alaska as part of WS' annual avian influenza surveillance effort.

Photo by USDA Wildlife Services, Kelsey Weir



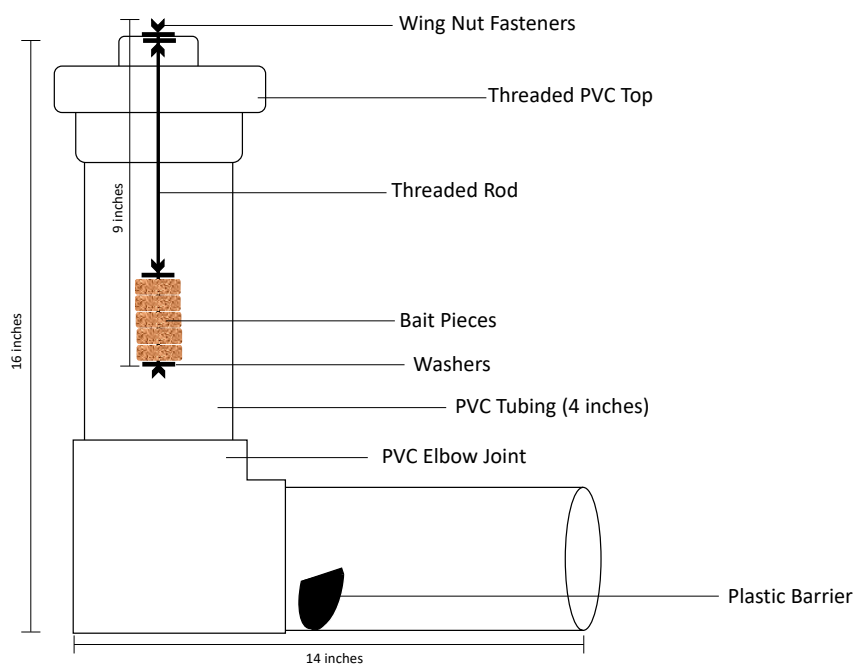
Resolving wildlife conflicts requires collaborative partnerships with diverse experts.

NWRC employs about 200 scientists, technicians, and support staff who are currently devoted to 16 research projects and 6 support units (see Appendix 1). Below are additional summaries of select findings and accomplishments from 2024.

Devices

- **Mongoose Bait Station.** Small Indian mongooses (*Urva auropunctata*) are an invasive predator impacting native species in Hawaii and other parts of the world. To aid in mongoose control efforts, NWRC researchers at the Hawaii Field Station developed and evaluated three prototype bait stations for use with mongooses that encourage bait consumption in place and restrict bait access by nontarget species. The bait station prototypes

were constructed with polyvinyl chloride (PVC) drainage pipes to keep costs low and improve their durability in tropical environments. A commercially available tamper-resistant rodenticide bait station was also evaluated for comparison. Researchers used a nontoxic formulation of an experimental fish-based toxicant bait and monitored bait station use, visitation rates, bait uptake, and spillage by captive and free-ranging mongooses in Hawaii. All four bait station prototypes were used by captive mongooses in the laboratory. One PVC bait station prototype and the commercial bait station were used by multiple free-ranging mongooses with minimal bait spillage in the field. Nontarget species captured on camera at bait station sites during the field trials were all nonnative species. Only one individual,



A new PVC bait station has been approved for use during field efficacy trials of a toxicant bait for invasive small Indian mongooses on Hawaii. The bait station design restricts access by nontarget animals.

Photo by USDA Wildlife Services

In 2024, NWRC researchers published a comprehensive review of chemical bird repellents used for crop and resource protection.

*Photo by USDA Wildlife Services,
Scott Werner*



a Polynesian rat, accessed the bait station. The PVC bait station design and commercial bait station have been approved for bait delivery during field efficacy trials of the toxic fish-based bait for mongooses under an EPA Experimental Use Permit.

Contact: *Steve Hess*

Pesticides and Repellents

- **New Publication Summarizes Chemical Bird Repellents.** More than 1,400 chemicals have been evaluated for use as bird repellents since 1948. Today, there are 17 registered bird repellent products in the United States for five active ingredients: anthraquinone, capsaicin, methiocarb, methyl anthranilate, and polybutene. To help aid in the future discovery and development of active ingredients and repellent products, NWRC researchers conducted a comprehensive review of chemical bird repellents used for crop and resource protection. The publication titled *Applications of chemical bird repellents for crop and resource protection: a review and synthesis*, includes results for all bird repellent tests published in English, current U.S. patents, and current

U.S. registrations. Researchers also rated each repellent's relative effectiveness to allow for comparison among repellent chemicals. Future research and development of chemical bird repellents will likely include biopesticides (i.e., pesticides derived from natural materials) and pesticides that are already registered for human food use.

Contact: *Scott Werner*

Other Chemical and Biological Methods

- **Measuring the Distribution of Nanoparticles in Tissues and Organs.** A nanoparticle or ultrafine particle is a particle of matter that is 1 to 100 nanometers in diameter (a strand of human hair is approximately 80,000 to 100,000 nanometers wide). Nanoparticles occur widely in nature and are objects of study in many sciences, such as chemistry, physics, geology, and biology. They are used in medicine to encase therapeutic agents and can deliver and release drugs or other compounds to specific tissues. NWRC and Kansas State University researchers recently developed a method for measuring

the distribution of magnetic iron nanoparticles in the tissues and organs of mice. The nanoparticles were injected intravenously or intraperitoneally (within the abdomen) or fed orally to mice. The magnetic nanoparticles allowed collection of branched amphiphilic peptide-coated magnetic nanobeads (BAPc-MNBs) from multiple organs by magnetic bead sorting, followed by a high-throughput screening for iron content. When injected intravenously, nanoparticles were distributed widely to various organs before they were eliminated from the system via the intestines in feces. The spleen accumulated the highest amount of BAPc-MNBs in mice when administered intravenously and intraperitoneally using nanoparticles. Long-term goals of this and similar research are to develop methods for using nanoparticles in wildlife damage management, such as to deliver toxicants or fertility control agents. Because toxicants and fertility control agents are often delivered in an oral bait, they need to be protected from the harsh environment of the digestive tract. Nanoparticles can achieve this by physically encasing the compounds or chemically making them resistant to breakdown.

Contact: Katherine Horak

- **Using Genetics to Combat Illegal**

Movement of Feral Swine. The illegal movement of feral swine (also known as wild pigs) for hunting purposes has contributed to their rapid expansion across the United States over the past 40 years. Feral swine are now reported in at least 35 States. To help curb the spread of these invasive animals, multiple States have passed laws prohibiting their possession or transport. However, the similarities between domestic pigs and invasive feral swine pose a challenge to the enforcement of these regulations. It can be difficult to distinguish

a domestic pig from an invasive feral swine just by looking at them. Genetic analysis has shown that most invasive feral swine (about 97 percent) in the United States are wild boar-domestic pig hybrids. NWRC researchers and partners are exploiting the wild boar ancestry found in most invasive feral swine to differentiate them from domestic pigs. Approximately 1,400 samples from 33 domestic breeds and 16 wild boar populations were genotyped and sorted into five genetically cohesive reference groups: mixed-commercial breeds, Durocs, heritage breeds, primitive breeds, and wild boar. Then, researchers used well-established genetic clustering techniques to evaluate the likelihood that any given genotype descended strictly from one of the domestic pig reference groups. The technique allows wildlife managers and law enforcement officials to collect a genetic sample from a captured pig, genotype it, and determine how likely it is that the pig descended from one of the domestic breed lineages, a pure wild boar lineage, or a hybrid of the two. Researchers evaluated the discriminatory power of this approach using simulated genotypes and real data from an additional 29 breeds of domestic pigs and more than 6,500 invasive feral swine samples. All the simulated and real data from domestic pigs fell within the statistical distribution of the domestic pig reference groups, while 74 percent of the feral swine data exceeded the maximum threshold for the domestic pig reference groups and could be statistically classified as having wild boar ancestry. This new genetic and statistical approach will help curtail illegal translocations of invasive feral swine which is an important part of reducing their spread and damage to the economy and the environment.

Contact: Tim Smyser

- **Genetic Tracking of a Rabid Coyote.** In May 2022, a coyote (*Canis latrans*) infected with the raccoon rabies virus variant (RRV) was collected in Lewis County, West Virginia, an area free from RRV. To help the NRMP to determine where the coyote contracted rabies and inform emergency response management decisions, NWRC collaborated with Princeton University researchers to apply coyote population genomics, and independently with the U.S. Centers for Disease Control and Prevention on the RRV phylogenetic analyses to determine the most likely geographic origin of the rabies virus infecting the coyote. When responding to outbreaks of RRV in naïve areas, it is important to determine if the rabid animal was locally infected or if it recently immigrated to the area because of natural movements or human translocation. The coyote genomic analyses leveraged information collected by Princeton University from populations across multiple eastern States bordering West Virginia, with the probable origin of the rabid coyote being the local county of collection. The RRV phylogenetic analyses included cases detected

from West Virginia and neighboring States, with most similar RRV sequences collected in a county 80 kilometers (50 miles) to the northeast, within the ORV zone. The combined results suggested that the coyote was infected with RRV in a management area and may have naturally dispersed to Lewis County, consistent with coyote ecology. Cross-species transmission and movement of RRV to a naïve area generally presents a low risk for onward transmission in local raccoon populations. The host and virus source tracking and estimation from this event helped with emergency response decision making, thereby saving the NRMP time and resources given the low risk for spread in raccoon populations within Lewis County.

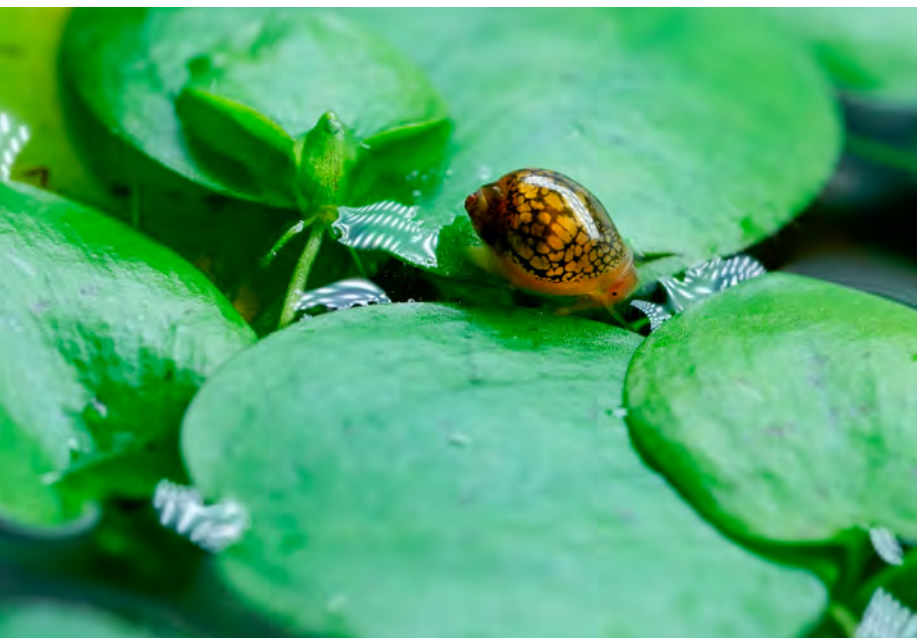
Contact: Matt Hopken

Disease Diagnostics, Surveillance, Risk Assessment, and Management

- **Influenza A Virus in Freshwater Snails—Risks to Waterfowl?** Waterfowl infected with avian influenza A viruses (IAVs) shed infectious virus into ponds, lakes, and other water bodies, exposing not only waterfowl to the virus but also other aquatic creatures. For example, aquatic invertebrates, such as freshwater snails, likely encounter IAVs in the water and sediment. Because snails are prey for many waterfowl species, NWRC and CSU researchers conducted a series of captive studies to determine if snails accumulate IAVs in their tissues and potentially spread them to waterfowl. In laboratory experiments, tadpole snails (*Physa* spp.) were exposed to a low pathogenic H3N8 virus to determine whether snails accumulate the virus and, if so, how long the virus persists

NWRC and Colorado State University researchers found that although snail tissues can contain avian influenza A viruses, the probability of the viruses being transmitted to waterfowl when they eat infected snails is short-lived.

Photo by Adobe Stock



in their tissues. Results showed that tadpole snails accumulate IAV ribonucleic acid (RNA) in their tissues for at least 4 days. The level of IAV RNA detected in snail tissues declined over time. Researchers conclude that although snail tissues can contain IAV, the probability of the virus being transmitted to waterfowl when they eat infected snails is short-lived. Direct exposure to infectious IAV through water is more likely. In habitats with flowing water, such as rivers and streams, researchers hypothesize that IAV concentrations may be higher in aquatic invertebrates and sediment versus the surrounding water.

Contact: Jeff Root

- **Environmental Transmission of IAVs to Mallards.** Wild birds are the natural reservoir hosts of IAV. Highly pathogenic strains of IAVs pose risks to wild birds, poultry, and human health. Understanding how these viruses are transmitted between birds is critical. NWRC researchers experimentally infected mallards with IAV then exposed several naïve mallard contact ducks to the experimentally infected ducks. The goal was to estimate the probability that a contact duck would become infected from either exposure to the virus shed directly from an infected duck or via shared water contaminated with the virus from an infected duck. Findings showed that environmental transmission from contaminated water best predicted the probability of transmission to naïve contact ducks. Relatively low levels of virus in the water were sufficient to cause infection and the probability of a naïve duck becoming infected varied over time. These results highlight the need to consider environmental sampling in IAV surveillance.

Contact: Kim Pepin



The WS National Wildlife Disease Program and its state partners continue to conduct SARS-CoV-2 surveillance in white-tailed deer across the species' range and examine the virus' evolutionary patterns.

Photo by USDA Wildlife Services

- **SARS-CoV-2 in White-tailed Deer.** The emergence of SARS-CoV-2 (the virus that causes COVID-19) in free-ranging white-tailed deer poses a unique public health risk due to the potential for the virus to persist, evolve, and spillback to humans. Starting in 2020, SARS-CoV-2 was found in white-tailed deer. By 2021, there was evidence of regional transmission in deer through a combination of ongoing deer-to-deer and human-to-deer transmissions. The WS National Wildlife Disease Program (NWDP) and its State partners continue to conduct SARS-CoV-2 surveillance in white-tailed deer across the species' range and examine the virus' evolutionary patterns. To aid in the development of future pathogen prevention and response plans, NWRC and university researchers partnered with NWDP experts to identify factors that influenced local and regional SARS-CoV-2 outbreak sizes and timing in white-tailed deer populations between October 2021 and March 2022 in the United States. Researchers discovered that deer SARS-CoV-2 outbreaks were characterized by a single epidemic peak followed by fade out. Outbreaks peaked early in the northeast and mid-Atlantic. The expected number of subsequent deer infection cases directly

generated by one infected deer (also known as reproduction ratio) was between 1 and 2.5, and infection trends in humans may have contributed to about 10 percent of infections in deer. This, together with the similar peak infection prevalence times across many counties and single-peak outbreak dynamics followed by fade out, suggest that widespread transmission via human-to-deer spillover may have been an important driver of the patterns and persistence. This research provides a framework for inferring population-level disease processes from landscape-scale surveillance data comprised of sparsely observed local outbreaks.

Contact: Kim Pepin

- **Experimental Infection of SARS-CoV-2 in Elk and Mule Deer.** Natural infections and experimental studies by researchers across the country have shown that a variety of mammal species can be infected with SARS-CoV-2. The implications to human and animal health could be substantial if these species are able to serve as maintenance hosts for the virus. Research by NWRC and partnering agencies has already shown white-tailed deer to be susceptible to the virus (see *SARS-CoV-2 in White-Tailed Deer* above). Evaluating the susceptibility of other cervid species to SARS-CoV-2 will help inform wildlife surveillance efforts which are key to understanding the epidemiology of SARS-CoV-2 and implementing control measures. NWRC and CSU researchers performed experimental infections to assess the susceptibility of elk (*Cervus canadensis*) and mule deer to the Delta variant of SARS-CoV-2. Nasal, oral, and rectal swabs, and blood and tissue samples were collected from animals for up to 21 days following inoculation. Elk did not shed infectious virus and showed low levels of antibodies in blood samples. Mule

deer, however, shed and transmitted the virus and showed high levels of antibodies in blood samples. These studies revealed that although elk are minimally susceptible to infection, mule deer become infected, shed infectious virus, and can infect naïve contacts. Mule deer are less widely distributed than white-tailed deer but still represent a population of cervids that is frequently in contact with humans and domestic animals. Therefore, susceptibility of mule deer provides yet another potential source for SARS-CoV-2 spillover or spillback. At this time, there is no evidence that wildlife is a significant source of SARS-CoV-2 exposure for humans, but the potential for this virus to become established in novel host species could lead to virus evolution in which novel variants may arise. Therefore, continued surveillance of species at risk, such as white-tailed and mule deer, is needed to detect any variants quickly and prevent transmission.

Contact: Jeff Root

- **CWD Surveillance Using Deer Scrapes.** White-tailed deer have a unique breeding season behavior called scraping, where they deposit urine and saliva at shared sites. Since both these fluids can contain CWD prions (infectious misfolded proteins), scrape sites could be targeted for environmental surveillance of CWD. To examine this potential, NWRC and university researchers monitored deer behavior and collected environmental samples from 105 scrape sites at the center of the CWD zone in southwestern Tennessee, where CWD prevalence is approximately 50 percent. They also sampled scrapes in northern Mississippi at the leading edge of the same CWD distribution zone to test the potential for early CWD detection. Findings showed 218 unique buck visits to 105 scrape sites with individual bucks visiting an average

of approximately 6 scrapes each. Analysis of environmental samples collected at scrape sites showed prion seeding activity in 20 percent of the soil and 41 percent of the licking branches at the sites within the CWD study area. Twenty-five percent of the soil and 11 percent of the licking branches at scrape sites sampled at the edge of the known CWD range were positive for prion seeding. Researchers concluded that white-tailed deer scrapes could serve as early warning sentinel sites for CWD surveillance by testing soil and licking branches for prion seeding activity, especially in areas with limited access to harvested deer samples.

Contact: Kurt VerCauteren

- **Vaccination Strategies for Eliminating Bovine Tuberculosis in Deer.** Globally, varying wildlife species serve as reservoirs for bovine tuberculosis (bTB) and can transmit the disease to cattle and humans. In the United States, bTB is endemic in white-tailed deer in northeastern lower Michigan and occasionally spills over to cattle. Using a disease transmission model, NWRC researchers worked with Michigan State University, Michigan Department of Natural Resources, and WS Michigan Operations experts to evaluate the effects of varying vaccination and harvest strategies to reduce and eliminate bTB from deer populations in Michigan. The model showed that vaccination using an oral bTB vaccine bait effectively reduced disease prevalence, especially when combined with increased harvest. Vaccination was effective even with low (30 percent) to moderate (60 percent) vaccine coverage of the susceptible and exposed deer population. Key vaccine properties for reducing and eliminating disease in the local deer population were vaccine coverage and efficacy. While complete elimination

is challenging, sustained vaccination and improved vaccine effectiveness are crucial for long-term disease management.

Contact: Kurt VerCauteren

- **Breaking the Brucellosis Cycle Through Contraception.** Every winter when snow levels are deep, hundreds of bison (*Bison bison*) migrate out of Yellowstone National Park in search of milder conditions and food. Their movement out of the park, and subsequent efforts to manage it, are controversial. Livestock producers and landowners near Yellowstone National Park are concerned about the spread of brucellosis and property damage. Bison, elk, and cattle can carry and spread *Bison brucellosis*, a bacterial disease cause by *Brucella abortus*. It is primarily spread through contact with tissues and fluids associated with abortions and infectious calving events. The disease can decrease milk production and animal weight and cause spontaneous abortion or infertility. The National Park Service, APHIS, and other State, Tribal and non-profit groups have historically limited bison expansion outside of the park and subjected animals to capture-and-quarantine, hazing, or lethal removal. To find new ways to reduce the spread of brucellosis in bison, NWRC researchers partnered with APHIS Veterinary Services and CSU to assess whether reducing pregnancy using GonaCon, a gonadotropin-releasing hormone (GnRH)-based immunocontraceptive, could reduce *B. abortus* shedding in treated bison herds. In a multi-year study, researchers discovered that naturally infected *B. abortus*-positive female bison that were treated with a single dose of the immunoncontraceptive produced fewer offspring than nontreated female bison over 5 reproductive years. Successful contraception of these bison also prevented the shedding

Bison brucellosis is primarily spread among bison, elk, and cattle through contact with tissues and fluids associated with abortions and infectious calving events.

Photo by Adobe Stock



of *B. abortus* by individual animals. However, it was also found that a single breakthrough pregnancy could result in shedding events with the potential to transmit *B. abortus* to many other susceptible individuals. This means that to significantly reduce disease prevalence, managers will need a longer-lasting contraceptive with high efficacy. Researchers note the results were promising and indicate that contraception could potentially be used to manage brucellosis in affected herds.

Contact: Doug Eckery

- **Management of Raccoon Rabies in Rural Versus Urban Environments.** ORV programs have successfully controlled and eliminated RRV in rural areas but remain challenging in urban areas likely due to higher raccoon densities, smaller home ranges, and fragmented habitats. NWRC researchers partnered with the WS NRMP and the University of Vermont to study the proportion of raccoons in the population that have rabies virus neutralizing antibodies (RVNA) during a 3-year ORV field trial across low, medium, and high development intensity areas of Burlington, Vermont. During the study, more than 2,200 animals, including 902 raccoons and 275 nontarget opossums (*Didelphis virginiana*), were trapped and sampled. Raccoon population RVNA

seroprevalence decreased with increasing raccoon abundance but increased as the average age of the raccoon population increased. In the low development areas, raccoon RVNA seroprevalence decreased as the number of nontarget opossum captures increased, suggesting that opossums may be competing with raccoons for ORV baits in these areas. The target bait density across the entire study area was 150 baits/km², which is commonly used in urban areas with higher raccoon densities. Bait distribution was planned across a 219 km² area within six grids (each averaging approximately 37 km²) and concentrated along roadway access, which resulted in spatially uneven baiting densities across the study area. Researchers conclude that increasing the ORV bait density and using smaller grids for hand distribution in developed areas may result in greater bait uptake by raccoons and population immunity.

In a simulation modeling study, NWRC worked with university and agency partners to evaluate the effectiveness of different rabies vaccination strategies (i.e., ORV hand baiting, helicopter bait drops, and bait stations compared to trap-vaccinate-release (TVR)) for raccoons in urban environments in Canada. NWRC and Southern Illinois University researchers simulated 560 vaccination strategy

designs that combined different ORV and TVR approaches based on the RRV control program of the Ontario Ministry of Natural Resources and Forestry. They also explored how varying levels of intervention impacted the success of the different approaches. Baiting data were overlaid with simulated raccoon population movements to estimate the proportions of the raccoon population immunized through the various vaccination strategy designs. Efficiency and costs were also calculated for the different designs. Estimated raccoon seroprevalence across different vaccination strategies varied widely, ranging from less than 5 percent to more than 70 percent. Increasing ORV bait densities led to a negligible increase in raccoon seroprevalence. Helicopter ORV was the most efficient and TVR was the least efficient strategy. However, helicopter-only based ORV resulted in lower seroprevalence (6 to 12 percent) than strategies which included some TVR effort (17 to 70 percent). The simulations and cost comparisons indicated that a mixed strategy operation including TVR may be the most efficient approach for raccoon rabies control and elimination in developed areas of eastern North America.

Contact: Amy Gilbert

- **Natural Exposure to Rabies and Population Densities of Small Indian Mongooses.** In the continental United States, ORV is used to control and eliminate specific rabies virus variants naturally maintained by small to medium-sized carnivores (e.g., raccoons, skunks, foxes). ORV is also being considered as a potential tool to mitigate and control rabies virus circulation and spillover exposures associated with small Indian mongooses in Puerto Rico. NWRC researchers worked with the WS NRMP and WS Operations staff in Puerto Rico to live-trap free-ranging

mongooses to estimate population densities across different habitats and sample for RVNA.

RVNA can be used to measure natural exposure to rabies virus or post-vaccination seroconversion rates in targeted wildlife populations. Researchers collected blood samples from 464 mongooses across six habitat types: dry grasslands and pastures, mangrove forest and shrubland, mature primary Tabonuco and secondary montane wet non-calcareous evergreen forest, hay and row crops, seasonally flooded herbaceous non-saline wetlands, lowland dry limestone shrubland, and moist grasslands and pastures. Overall, 17 percent of the mongooses tested seropositive for RVNA, with the greatest proportion of those collected from moist grasslands and pastures, seasonally flooded herbaceous non-saline wetlands, and mature primary Tabonuco and secondary montane wet noncalcareous evergreen forests. Interestingly, the grassland and pasture habitat comprised 68 percent of the total samples, but

Seventeen percent of the invasive small Indian mongooses captured and tested for rabies virus-neutralizing antibodies on Puerto Rico were positive.
Photo by USDA Wildlife Services, Mel Rivera-Rodriguez



mongoose RVNA seroprevalence in this habitat was among the lowest estimated. Sixty-eight percent of RVNA seropositive mongooses were male. This may be influenced by the larger home range sizes of male mongooses, which likely impacts contact rates and the potential for rabies virus transmission and exposures. The results shed light on natural rabies virus exposures in mongoose populations across habitats and furthers our understanding of the spatial variability of mongoose rabies virus transmission.

For population density estimates, mongoose habitats were grouped into four categories: broad-leaved evergreen forest, flooded shrub/herbaceous cover, grassland, and agriculture. Mean mongoose population densities were greater in broad-leaved evergreen forest habitat (205 mongooses/mi²; 79 mongooses/km²) compared to the other categories. No seasonal variation in mongoose population densities was documented between the wet (May–November) and dry (December–April) seasons. Findings suggest that mongoose population densities may vary across habitats and multiple ORV applications may be needed every year to reach population immunity thresholds for control, particularly in forested habitats with high population densities and rapid population turnover.

Contact: Are Berentsen

- **Home Range Overlap between Small Indian Mongooses and Free Roaming Domestic Dogs in Puerto Rico.** The first laboratory confirmed case of rabies in mongooses in the Western Hemisphere was in Puerto Rico in 1950. Following this initial mongoose case, several cases of rabies in domestic animals, including dogs, were reported across the island. In 2021, mongooses accounted for more than 70 percent of the reported animal

rabies cases in Puerto Rico, whereas domestic dogs represented 18 percent of positive cases. To gain insights about the potential for rabies virus transmission between the two species, NWRC collaborated with University of Montreal researchers to estimate home range sizes and space-use overlap from GPS-collared mongooses and free roaming domestic dogs (FRDD) in Puerto Rico. Home range estimates for male and female mongooses were 1.45 ± 0.21 km² and 0.60 ± 0.14 km², respectively. Mongooses favored dry forests and shrublands, and tended to avoid brackish water vegetation, salt marshes, barren lands, and developed areas. FRDD home ranges varied widely from 0.13 to 2.85 km² and were likely impacted by the availability of human provided food and other resources. Home ranges among mongooses overlapped extensively, whereas overlap between the mongoose and FRDD home ranges varied. Researchers observed more limited movements of FRDD near human residences, which may lessen the chance for interactions with mongooses and potential exposures to rabies virus. Feral FRDD may have greater home ranges and risks of exposure to mongoose rabies, yet these dogs also avoided areas near human residences. Responsible dog ownership, including restricting the movements and maintaining up to date rabies vaccination of owned animals, remains the best ways to mitigate human risks of exposure to mongoose rabies from dogs in Puerto Rico.

Contact: Are Berentsen

- **African Swine Fever and Feral Swine.** African swine fever (ASF) causes significant illness and death in both domestic and feral swine, and disease outbreaks result in high economic costs to impacted industries due to loss of animals, the cost of culling exposed/



University of Montreal (left) and NWRC researchers prepare to place a GPS collar on an anesthetized free roaming domestic dog in Puerto Rico as part of a rabies study. Photo by USDA Wildlife Services, Steven Llanos

infected animals, and trade restrictions. The co-occurrence of domestic and feral swine significantly complicates ASF management given the potential for wild populations to serve as persistent sources for disease spillover into domestic herds. The introduction of ASF into domestic swine herds in the United States would require a response focused on containment, culling, and contact tracing. However, detection of ASF among invasive feral swine would require a far more complex and intensive response given the challenges of detection, containment, and ultimately elimination among wild populations. NWRC researchers partnered with NFSDMP and APHIS Veterinary Services experts to describe the state of the science available to inform preparations for an ASF response among invasive feral swine, describe knowledge gaps and the associated studies needed to fill those gaps, and call for an integrated approach for preparedness that incorporates the best available science and acknowledges the importance of public education and outreach and policy solutions.

Contact: Kim Pepin

Wildlife Damage Assessments

- **Cost of Feral Swine Damage to Crops.**

Invasive feral swine damage agricultural crops by eating them or by their rooting, trampling, and wallowing behaviors. In their most recent assessment, NWRC economists found that the annual economic burden of feral swine damage to producers of 6 key crops in 11 States was close to \$700 million. Economists surveyed more than 11,000 producers of corn, soybeans, wheat, rice, peanuts, and sorghum from Alabama, Arkansas, California, Florida, Georgia, Louisiana, Mississippi, Missouri, North Carolina, South Carolina, and Texas. This study builds on the growing body of literature about feral swine damage to agricultural commodities and property, as well as opportunity costs, replanting, harvest, and control costs.

Contact: Stephanie Shwiff

- **Do the Benefits of Feral Swine Hunting Outweigh the Costs of Damage?**

Feral swine hunting is a culturally significant recreational and commercial activity in Texas, but do the benefits of hunting outweigh the costs of their damage? Recent studies have documented the



NWRC economists found that the annual economic burden of feral swine damage to producers of 6 key crops in 11 states was close to \$700 million (damage to corn pictured).

Photo by USDA Wildlife Services

annual value of damage inflicted by feral swine to the Texas economy as \$204.7 million to producers of corn, soybeans, wheat, rice, peanuts, and sorghum; \$135.2 million in production loss of hay, pecans, melons, sugarcane, sweet potatoes, and cotton; and \$477.2 million in predation, disease, and other livestock deaths, as well as veterinary and medical treatment costs, property damage and the rooting of pasture. NWRC researchers analyzed a survey of resident and non-resident hunting license holders in Texas about various topics related to their feral swine hunting activities, including expenditures. From the 37,317 responses received, researchers estimated that the marginal annual direct benefit of feral swine hunting to the Texas economy ranged between \$68.5 million and \$188.0 million. Although hunting is an important consideration in the

discussion of feral swine management, this estimate is dwarfed by the estimated total feral swine damage costs to agricultural producers and others in Texas.

Contact: Stephanie Shwiff

- Feral Swine-Vehicle Collisions.** Most people are familiar with the dangers and costs associated with deer-vehicle collisions. In fact, a recent analysis of more than 1 million animal-vehicle collisions by University of Washington researchers showed that deer were responsible for more than 90 percent of the collisions in the United States between 1994 and 2021. But what about other large animals, such as feral swine? To better understand the frequency and cost of feral swine-vehicle collisions in the United States, NWRC economists partnered with experts in the NFSDMP and the Savannah River National Laboratory. Using data from State Farm®, the researchers estimated the number of vehicle collisions with feral swine by State from 2015 to 2022. In 2022 alone, they estimated that a total of 16,714 feral swine-vehicle collisions occurred, resulting in \$103.8 million in vehicle repair costs. Texas bore the highest burden with \$56.2 million in damages, followed by Florida at \$12.4 million. Furthermore,

Using data from State Farm®, NWRC economists and partners estimated the number and cost of vehicle collisions with feral swine by state during 2015 to 2022.

Photo by USDA Wildlife Services, Gail Keirn



researchers found that the ratio of collisions with feral swine to vehicle miles traveled increased with feral swine density. Surprisingly, this ratio was more than seven times higher in Hawaii and Texas than would be expected based on the States' feral swine densities. Researchers discovered that the frequency of feral swine-vehicle collisions was much less than that for deer in the 30 States surveyed. However, feral swine-vehicle collisions were still very costly and represented the second most common type of wildlife-vehicle collision in the study.

Contact: Stephanie Shwiff

- **Alabama Farmers' Experiences and Management Preferences for Feral Swine.**

Government agencies and landowners use a variety of lethal methods to reduce invasive feral swine populations and resulting agricultural damages. To provide decision makers with information about Alabama farmers' experiences with feral swine and their preferences for management actions, NWRC, CSU, and Auburn University researchers surveyed members of the Alabama Farmers Federation. Survey responses showed that feral swine were often present on livestock, timber, and crop production acreage, but their damage was more common on crop acreage. Respondents had a low acceptance of feral swine, and all lethal control methods, particularly those performed by landowners, were considered acceptable. While most Alabama farmers agree that feral swine numbers need to be reduced, State managers should continue to build support by working closely with crop producers and by addressing potential concerns regarding the use of methods by government agencies in future initiatives and outreach.

Contact: Keith Carlisle



- **Feral Swine Impacts to Amphibians.** Feral swine are known nest predators of ground-nesting birds and reptiles and likely pose a threat to amphibians given their extensive use of wetland habitats and generalist diet. NWRC researchers used DNA metabarcoding to determine the diet of 222 adult feral swine in South Carolina using fecal samples. Results showed a diverse diet dominated by plant material (166 plant genera from 56 families) and 18 vertebrate species. Diet composition varied seasonally with plant availability and was consistent between male and female feral swine. Amphibians, such as barking tree frogs (*Dryophytes gratiosus*), were the most frequently eaten vertebrate group, occurring in 71 percent of samples with vertebrate DNA. This suggests that amphibians are potentially vulnerable to predation by feral swine in South Carolina. Mammal, reptile, and bird species were also detected infrequently in feral swine diets. Results highlight the need for research on feral swine impacts to the management and conservation of amphibians.

Contact: Toni Piaggio

- **Bird Use of Industrial Hemp Crops.**

Industrial hemp (*Cannabis sativa* L.; hemp) is an emerging crop in the United States but little is known about bird use or damage to hemp. Depending upon the type of crop (i.e., oilseed versus cannabinoid (CBD)), hemp fields may be attractive to birds as a food

Diet analyses of invasive feral swine in South Carolina show they eat barking tree frogs (*Dryophytes gratiosus*; shown) and other amphibians as part of their diverse diet.

Photo by Adobe Stock

Industrial hemp (*Cannabis sativa* L.) is an emerging crop in the US but little is known about bird use or damage to it. Photo by USDA Wildlife Services, Page Klug



resource, or as roosting habitat or shelter. In an observational study, NWRC and North Dakota State University researchers conducted bird surveys in seven oilseed fields and four CBD fields in North Dakota and Florida. Researchers observed 10 bird species in hemp, 12 species flying over hemp, and 11 species both foraging in and flying over hemp fields in North Dakota. In Florida, researchers observed four bird species in hemp, five species flying over hemp, and four species exhibiting both behaviors. Birds observed in hemp were either perched in the canopy or foraging on the ground. Counts were highest in oilseed and lowest in CBD varieties. The Florida sites were mainly CBD varieties, which explains lower species diversity and raw counts of birds given the lack of seeds produced. Maximum raw counts of the most common birds included 116 mourning doves (*Zenaida macroura*), 53 house finches (*Haemorhous mexicanus*), and 40 American goldfinches (*Spinus tristis*) using very small fields (139–388 yard²/116–324 meter²) in North Dakota suggest oilseed hemp could suffer depredation losses but potentially benefit bird conservation and act as a decoy crop to protect other commodities, such as sunflower crops.

Contact: Page Klug

• **Possible Wildlife Attractant Implications of Growing Industrial Hemp Near Airports.**

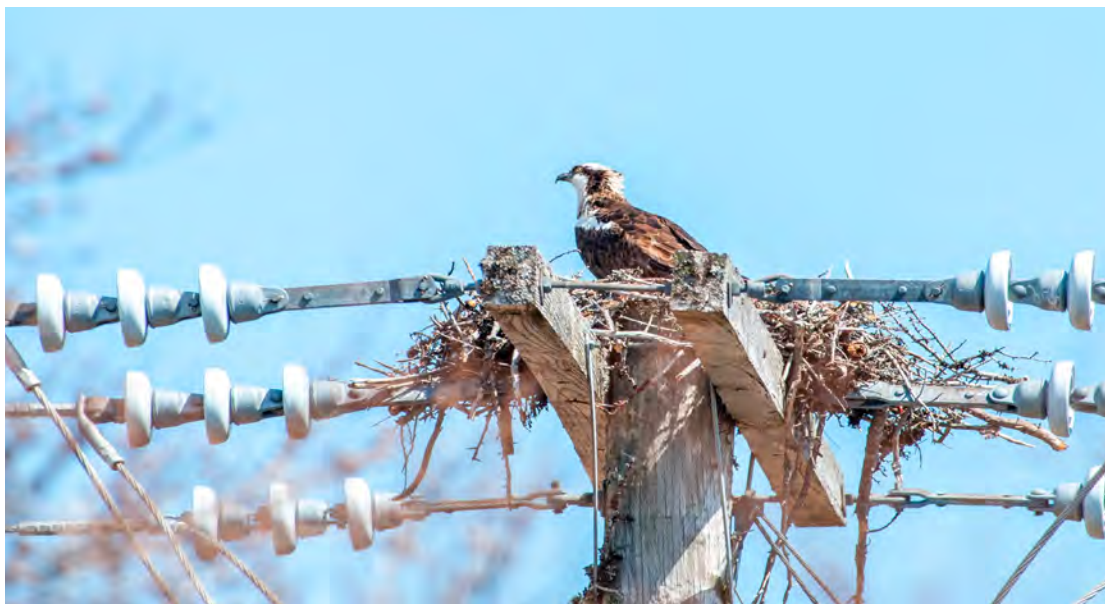
When planning possible land uses on and near airports, airport managers consider revenue from land covers, associated maintenance costs, and the potential for various land covers to attract wildlife species recognized as hazardous to aviation safety. The U.S. Federal Aviation Administration has expressed an interest in better understanding the potential impacts of cultivating industrial hemp as a revenue-producing land cover on or near airports. NWRC, WS Operations, and University of Florida researchers and experts conducted an initial literature review to understand the potential production value of hemp as well as its possible role in affecting aviation safety if cultivated on or near airports. Findings showed that hemp cultivation offers potential revenue opportunities in the areas of animal feed as well as medicinal and industrial products. Thus, hemp production on and near airports for purposes of revenue remains a possibility. However, much of what was learned in the review relates to U.S. land covers and wildlife populations from decades past, and little pertained to the use of hemp by species known to directly pose hazards to

aviation safety or those that might serve as prey resources for species frequently struck by aircraft. Therefore, researchers note that prior to cultivation on or near airport properties, wildlife use of hemp should be quantified relative to species aviation hazard scores. Also, researchers recommend a holistic approach that considers not only how hemp contributes to revenue and wildlife strike risk, but also land cover maintenance requirements (e.g., irrigation, pest control), harvest regimens, and the ecology of local wildlife populations relative to use of crops.

Contact: Brad Blackwell

- **Identifying Key Mitigation Areas for Human-Osprey Conflicts.** Raptor nests on structures, such as powerlines, can result in bird deaths, fires, and/or power outages due to falling nest materials or animals touching energized conductors. Power companies typically try to lessen these conflicts to avoid service disruptions. Performing mitigation measures across all potentially problematic power infrastructure is often not practical given logistical, time, or budgetary constraints.

Power companies need tools to help identify risks and prioritize mitigation. Researchers with the NWRC, Mississippi State University, and Kentucky Department of Fish and Wildlife Resources examined the influence of habitat and infrastructure distribution on the potential risk of osprey (*Pandion haliaetus*) nesting conflicts on the Tennessee Valley Authority's power infrastructure in Tennessee, Alabama, Georgia, Kentucky, Mississippi, North Carolina, and Virginia. Data from 1990 to 2020 on osprey nesting and conflict records were used to model risk. Osprey preferred habitats on or near open water and closer to developed areas. Transmission line density was determined to be low (0.14 ± 0.29 lines/km² or 0.05 ± 0.11 lines/miles²) and mixed across the service area with more lines within urban centers and near power facilities. By combining osprey habitat preferences with transmission infrastructure information, researchers revealed that areas of very low to low osprey-power infrastructure conflict risk comprised 99 percent of the service area. Less than 1 percent of the service area was considered moderate, high, or very high risk, and these sections were



NWRC researchers and partners are working on new approaches to mitigate damage to and from nesting osprey on transmission towers and powerlines.

Photo by Adobe Stock

mostly concentrated along major rivers and lakes, and around urban centers. Risk was more prevalent in the northeastern portion of the service area. This work presents a new approach for mitigating osprey–power infrastructure conflicts by helping to prioritize areas for mitigation and facilitating coexistence with this protected species.

Contact: Brian Dorr

- **Scavenging Behaviors of Vultures and Implications for Livestock Depredation.**

Little is known about the early stage scavenging signatures of vultures on livestock. The ability to distinguish between scavenging and predatory feeding signs on carcasses eaten by vultures is crucial to identifying criteria for evaluating livestock depredation. NWRC researchers partnered with WS Operations and university experts to monitor turkey and black vulture consumption and scavenging effort on neonatal calf carcasses. Twenty carcasses were placed periodically in a pasture at Purdue University's Southern Indiana Purdue Agricultural Center between February and May, consistent with local spring calving season. The carcasses were monitored using a live-feed game camera. After vulture exposure, carcasses were collected and necropsied to document and measure scavenging effort. Scavenging black vultures targeted the perineum and tongue, while turkey vultures targeted the eyes, perineum, and tongue. These findings indicate that criteria commonly used to identify livestock depredation by vultures only document vulture presence and not predation. Researchers conclude that new and more definitive criteria are needed to distinguish between scavenging and predatory feeding signs by vultures.

Contact: Bryan Kluever

Wildlife Management Methods and Evaluations

- **Measuring the Impacts of Feral Swine**

Removal. Feral swine are managed throughout their invasive range in the United States. In many States, recreational hunting of feral swine is popular and assumed to help control their populations. But there is little evidence to support recreational hunting as a long-term management tool, and, in many cases, it may be counterproductive. Recreational hunting typically removes about 23 percent of a population, on average. This is far below the number needed to reduce populations. Recreational hunting also provides financial incentives for keeping pigs on the landscape, which is counter to the goal of control efforts. Instead, successful feral swine population control is more likely achieved through coordinated and adaptive strategies by wildlife professionals. NWRC and University of Georgia researchers aimed to measure the effects of a 3-year coordinated feral swine trapping removal effort. Researchers measured changes in feral swine relative abundance and their associated damages using data combined from feral swine population surveys, damage assessments, and environmental rooting surveys before and after feral swine removal across 19 privately owned properties in South Carolina. Following control efforts by WS, both the number of feral swine detections and estimated abundances decreased significantly. Within 24 months, relative abundance was reduced by an average of 70 percent. This resulted in a corresponding decline in environmental rooting damage by about 99 percent. Within fragmented agricultural landscapes, feral swine home ranges often spread across multiple properties. Thus, surrounding landowners who did not participate

in the study may also have benefited from the removal efforts. The key is coordination. While individual landowners may not have the resources to continually support intensive removal efforts, groups of landowners who cooperate may be able to reduce feral swine damage across more extensive areas.

Contact: Kurt VerCauteren

- **Reducing Nontarget Hazards Associated with Feral Swine Toxicant Baiting.** In 2018, an experimental sodium nitrite-based toxic bait for invasive feral swine was evaluated to determine its effectiveness in reducing local feral swine populations in Texas. Local populations were reduced by more than 70 percent, but spillage of bait outside of feral swine-specific feeders (bait stations) caused by feeding feral swine resulted in the death of some nontarget animals. To evaluate risks to nontarget animals, NWRC researchers and partners recently tested whether bait presentation (i.e., crumbled, extruded, or compacted in trays) influenced the total amount of bait

spilled by feral swine. They also estimated the associated risk to nontarget species through a series of experimental baiting trials with wild caught feral swine. Results showed that bait spilled outside of bait stations could be reduced by more than 90 percent when it is compacted in trays, as opposed to being manually crumbled into pieces or extruded. Researchers documented a mean spill rate of 0.913 grams of bait per feral swine. Using this spill rate estimate, researchers conducted risk assessments for nine nontarget species for which sodium nitrite toxicity data exist. Findings indicate that there is a relatively low risk of lethal exposure to these nontarget species except for nonnative zebra finches and laboratory white mice. Researchers estimate there may be enough spilled bait per feeding feral swine to kill 9.5 zebra finches or 3.5 white mice. Other species assessed range from 0.002 to 0.406 potential mortalities per feral swine. Researchers recommend that baits be tightly compacted and secured in bait stations



To help reduce non-target species hazards, NWRC researchers and partners recently tested whether bait presentation (i.e., crumbled, extruded, or compacted (shown) in trays) influenced the total amount of toxic bait spilled by feral swine.

Photo by USDA Wildlife Services, Nathan Snow

to minimize risks to nontarget animals from spilled bait by feral swine.

Contact: *Nathan Snow*

- **Limitations of Brown Treesnake Baiting.**

In October 2020, a new population of invasive brown treesnakes (*Boiga irregularis*) was discovered on Cocos Island, a 33-hectare (82 acre) island located about 2.5 kilometers (1.5 miles) off the south coast of Guam. Cocos Island is a refuge for many lizards and birds, including endangered species, which were extirpated from mainland Guam by invasive predators including brown treesnakes. Several tools and techniques, including baiting and trapping, have been developed and continue to be improved for managing invasive brown treesnakes on mainland Guam. NWRC researchers worked with WS Guam and other partners to evaluate the usefulness of toxic baiting with acetaminophen-treated carrion baits and cage trapping on Cocos Island. Multiple bait types and bait presentations (i.e., on the ground, suspended in the canopy, and

in four plastic-tube bait station configurations) were evaluated over thousands of nights. All baits were monitored with time-lapse cameras. None of the baits were taken by brown treesnakes. Only one brown treesnake was captured using a trap with a live mouse lure. This low level of effectiveness is not a result of low snake density. Ongoing visual searching and hand capturing efforts have resulted in snake captures and sightings. Researchers hypothesize that the low success rates are due to an extremely high abundance of preferred live prey, primarily large geckos, and birds. Findings do not bode well for managing future island invasions by brown treesnakes. If snakes were to become established in other prey-rich environments, current baiting and trapping methods may be similarly ineffective. Future work on Cocos Island will include the continuation of visual searching and manual removal of snakes, the only method that has been effective. Researchers plan to evaluate whether the use of live bird lures is more effective than carrion or live rodents. Preventing the

A bait station and trail camera hang from trees on Cocos Island off the south coast of Guam. NWRC researchers evaluated the use of toxic baiting and cage traps to reduce a newly discovered population of invasive brown treesnakes on the island. Photo by USDA Wildlife Services, Shane Siers





Researchers from NWRC's Mississippi Field Station and Mississippi State University evaluated the effectiveness of six commercial nonlethal deterrents, including Hypertough™ Zip ties (pictured), to prevent cormorant use of floating oyster cages.

Photo by USDA Wildlife Services

accidental translocation of snakes from Guam remains a critical management strategy.

Contact: *Shane Siers*

- **Reducing Cormorant Use of Oyster**

Cages. In 2023, the United States produced approximately 45 million pounds of oysters worth about \$221 million. Oysters are produced either naturally or farmed. Oyster farmers often use floating cages to facilitate the management of the shellfish. Oysters grown in floating cages grow faster and have higher survival rates than those cultured in bottom cages. When birds, such as double-crested cormorants (*Nannopterum auratus*), gather on floating oyster cages to loaf or roost, their feces can impact water quality and spread pathogens. Researchers from NWRC's Mississippi Field Station and Mississippi State University evaluated the effectiveness of six commercial nonlethal deterrents (Gullsweep Bird and Seagull Deterrent® Bird B Gone; Bird B Gone Spinning Bird Deterrent®; Bird Spikes TANGTEA; Hypertough™ Zip ties, 11-inch black; a float-mounted triangle Ketcham Supply; and Scarem Kite® Flyonte) to prevent cormorant use of floating oyster cages. All deterrents except the Scarem Kite significantly reduced or halted cormorant use of oyster floats. The Scarem Kite was the only deterrent that required consistent wind to

operate effectively, and the study location did not experience consistent wind. It is possible that in the right location the kite would have produced significant reductions in bird use. Overall, the results show that these simple nonlethal deterrent applications to oyster cage floats can help to reduce impacts to water quality and the potential spread of pathogens by cormorants.

Contact: *Fred Cunningham*

- **Modern-day “Scarecrows” for Bird**

Damage. Two modern-day “scarecrows”—the University of Rhode Island (URI) Laser Scarecrow and an inflatable scarecrow—were evaluated by NWRC researchers to help reduce damage from European starlings (*Sturnus vulgaris*) and vultures, respectively. Lasers are a promising deterrent to reduce bird damage to agricultural crops and property. Visible lasers emit a focused, steady beam of light at a single wavelength. They appear to frighten birds and elicit escape responses like other frightening devices. In a controlled pen study, NWRC researchers from the Florida and North Dakota field stations tested the effectiveness of the URI Laser Scarecrow to reduce European starling damage to milk-stage corn. Sweet corn is especially suitable for laser deterrent use because it has a narrow, 2-week window of susceptibility to damage during its milk stage (i.e., when the

An inflatable scarecrow called the Scare Dancer® was used by NWRC researchers to reduce vulture abundance by as much as 82 percent in some areas.

Photo by USDA Wildlife Services



kernels are mostly yellow with a white milky fluid inside that is rich in sugars and protein). This shorter time window could limit a bird's ability to habituate to the laser. Researchers presented 18 captive flocks of free-ranging starlings with fresh sweet corn ears in plots with and without laser treatments. Damage to corn was reduced by at least 20 percent in areas protected by URI Laser Scarecrows, particularly those plots that mimicked natural crop situations. Damage increased over time and as the distance from lasers increased. This was the first controlled pen study where free-flying birds had access to fresh sweet corn and could choose to feed in either laser-treated or untreated plots, allowing researchers to see how birds respond to repeated laser exposure and document how bird damage increases as the distance from a laser increases. These insights will help guide how best to use lasers as bird deterrents.

Visual frightening devices that mimic the presence of humans, predators, or a novel object are used to cause fear responses in birds. One visual frightening device in particular—the inflatable scarecrow—has been used to reduce songbirds at feral swine feeders, but little is known about its effectiveness with other species and at other

locations. NWRC researchers at the Florida Field Station tested the effectiveness of Scare Dancer®, an inflatable scarecrow, to disperse black vultures (*Coragyps atratus*) and turkey vultures (*Cathartes aura*) from areas, such as parking lots, hydroelectric dams, baseball fields, small-scaled farms, and waste management sites, in five States. The devices reduced vulture abundance by as much as 82 percent. Researchers also observed an increase in vulture abundance as distance to the device increased (> 50 meters/164 feet). This finding suggests that inflatable deterrents may not be as effective at larger sites with widespread vulture damage issues. More information is needed to determine if the use of more inflatable scarecrows or the combined use of the devices with other management strategies (i.e., pyrotechnics) may be more effective at discouraging widespread vulture damage at these sites. Researchers recommend inflatable scarecrows as a tool to reduce vulture-human conflicts at sites where the conflicts are spatially restricted (e.g., parking lots or recreation areas), conducive to scarecrow use (e.g., flat stable surfaces), and where human tolerance for vultures is limited.

Contact: Bryan Kluever

- **Fertility Control for Free-Ranging Prairie Dogs.** In 2022, GonaCon-Prairie Dogs, an injectable contraceptive vaccine, was registered by the EPA (EPA Reg. No. 56228-64) for managing fertility in sub-adult or adult female black-tailed, white-tailed, and Gunnison's prairie dogs (*Cynomys* spp.). Prior to this registration, NWRC and CSU researchers tested the field efficacy of the vaccine in black-tailed prairie dogs in six urban and suburban areas of Colorado under an EPA Experimental Use Permit. Female prairie dogs were live trapped and treated with 0.4 milliliters of either GonaCon or a sham vaccine. Juveniles and adults were counted at each field site to estimate the juvenile-to-adult ratio and juvenile density. Researchers determined the juvenile-to-adult ratio was significantly reduced in the first year following treatment. Juvenile density was also lower in the GonaCon-treated sites versus the sham sites. However, both the GonaCon and sham sites produced similar numbers of offspring during the second year following treatment. Researchers concluded that GonaCon is highly effective during the

first year but not in the second year if only a small area (0.6–2.8 ha/1.5–7 acres) or small proportion of females in a colony is treated. A follow up study is underway involving NWRC's Rodents Project and Population Management Project, as well as WS Colorado, to test GonaCon over whole colonies, males and females, and in the presence and absence of pre-treatment prairie dog removals from colonies.

Contact: Aaron Shiels

- **Using Prescribed Fires and Biosolids Applications to Manage Wildlife.** Birds and other wildlife can pose significant threats to both human safety and property when they appear near airports. Biologists with WS Airport Wildlife Hazards Program (AWHP) provide airport operators across the Nation with advice and recommendations on how to keep runways and flight paths clear of wildlife. NWRC and AWHP experts investigated whether the application of prescribed burning and/or long-term biosolid applications alter plant communities and wildlife use in



Prescribed burns and biosolid applications, used alone and in combination, might be viable grassland management tools for altering wildlife use of grassland areas on and near airports.

Photo by USDA Wildlife Services

A Mexican wolf is released back into its territory following a capture during the 2019 helicopter count and capture operation with a new radio tracking collar.

Photo by Arizona Game and Fish Department



grassland areas at the Marine Corps Air Station Cherry Point in North Carolina. Researchers monitored vegetation growth, plant species diversity, and wildlife activity over 3 years in plots with and without annual prescribed burns and/or the application of a biosolid (i.e., treated and stabilized sewage sludge). Prescribed burning reduced the amount of litter, increased bare ground during spring, and altered the plant community composition relative to areas that were not burned. Overall, prescribed burning did not alter bird use of the airfield grasslands, while the long-term application of biosolids resulted in higher bird use. Few species-specific differences in bird use of prescribed burned and unburned grasslands were found. In contrast, white-tailed deer use of areas that were burned in winter, as well as the adjacent unburned areas, was drastically reduced. Winter prescribed burning appeared to remove forage plants at the time of year deer would use them the most. Findings suggest that prescribed burning and biosolid applications, used alone and in combination, might be viable grassland management tools for altering wildlife use of grassland areas, specifically white-tailed deer; however, similar research at additional locations should be conducted.

Contact: Brian Washburn

Wildlife Population Monitoring Methods and Evaluations

- **Factors Affecting Endangered Mexican Wolf Recovery.** The Mexican wolf (*Canis lupus baileyi*) is an endangered wolf subspecies being recovered in the Southwest United States and Mexico on shared landscapes where people occupy and use the land. When human-carnivore conflict occurs, one management option is to remove individual carnivores (i.e., management removal) involved in the conflict. However, some studies have found that when too many individuals are removed, it can negatively affect the carnivore population. To gain a better understanding of these impacts, NWRC, U.S. Fish and Wildlife Service, and Arizona Department of Game and Fish researchers investigated the growth of Mexican wolf populations in response to management removals, illegal killings, and several other factors, such as natural mortalities, natural reproduction, translocations, and releases. From 1998 to 2019, the wolf population grew about 12 percent per year. Removal of wolves for conflict management was higher from 1998 to 2007 than for 2008 to 2019, with rates of 25 percent and 5 percent, respectively. Illegal killing was a consistent source of Mexican wolf

mortality, accounting for 28 percent of deaths from 1998 to 2007 and 50 percent of deaths from 2008 to 2019. Wolves released from captivity and translocated into new territories are more susceptible to purposeful and accidental illegal killing. Captive-reared animals could be more vulnerable because they have been influenced by human presence (e.g., feeding in captivity) on a regular basis and thus do not have the flight response to humans often seen in wild wolves. Translocated wolves could be more vulnerable because they initially travel more without extensive knowledge of the landscape, thus creating more opportunity to cross paths with humans. The relationship between illegal killings and release/translocations was significant, with the highest illegal killing rates doubling during periods with high numbers of reintroductions and translocations. If the growth rate remains at 12 percent in the future, modeling predicts the Mexican wolf population will reach a minimum of 320 wolves in 2026. Researchers conclude that management removal to reduce human-carnivore conflict can have negative population impacts if not used carefully.

Contact: Stewart Breck

- **Coyote Response to Removal of Human-provided Water Sources in the Desert.**

The spread of coyotes into desert ecosystems has led some scientists and land managers to question whether human-provided water sources contributed to their expansion. NWRC and Utah State University researchers gathered and analyzed movement data from 31 radio-collared coyotes in the Dugway Proving Ground, a U.S. Army installation in Tooele County, Utah, before and after the removal of artificial water sources (guzzlers) on the landscape. Following the removal of guzzlers, coyotes in treated areas did not shift their

movement patterns to remain closer to water. In fact, coyotes in treated areas spent more time in areas further away from water than those whose artificial water sources remained in place. Vegetation was an important factor in habitat selection, with coyotes selecting more riparian and agricultural areas. Coyotes also selected areas where hunting and trapping was prohibited. Researchers hypothesize that the cause of increased coyote abundance in the Dugway Proving Ground was not due to the introduction of human-provided water sources but rather the end of regional lethal predator control programs. These two management decisions both occurred in the 1970s and their influences on the subsequent increase of coyote abundance may be conflated. These results, in combination with previous studies, provide evidence that coyotes are desert-adapted carnivores that do not rely on human-provided water sources.

Contact: Dustin Ranglack

- **Ancestry of U.S. Feral Swine Led to Increased Invasiveness.** Feral swine are one of the most destructive invasive species in the world, with populations established on all continents except Antarctica. Ancestry analyses of feral swine throughout invaded regions within the contiguous United States show that current populations are hybrids of domestic pigs and wild boar. NWRC and international researchers hypothesize that such hybridization enriches genetic diversity and increases the adaptive potential of U.S. feral swine populations. To test this hypothesis, researchers genotyped 881 feral swine captured within the Great Smoky Mountains National Park, which represent a hybrid population that descended from one of the first European wild boar introductions in the United States. Researchers discovered that several of the genes of these

hybrid swine related to traits, such as skull and nerve cell formation and skin pigmentation, that affect feralization. Researchers note that the unique combination of wild and domestic swine genes within the U.S. feral swine population, plus natural selection, have shaped feral swine adaptability and made them a more destructive invasive species.

Contact: Tim Smyser

- **Human-mediated Movement of Feral Swine.** Purposeful movement (i.e., translocation) of feral swine by people for hunting or other purposes has contributed to the species' rapid range expansion in the United States over the past 30 years. NWRC geneticists used machine learning and network analyses to leverage genomic data from thousands of feral swine captured across the United States to describe feral swine movement patterns. Machine learning uses algorithms to analyze large amounts of data, identify patterns, and create predication models. Researchers were able to differentiate between natural range expansion and human-mediated movement of feral swine that has contributed to the species' expansion. Findings showed extensive movement of feral swine well beyond their dispersal capabilities, including individuals with predicted origins greater than 620 miles (1,000 km) away from their sampling locations. Researchers found that feral swine were translocated across the United States, with many States receiving animals from just a few States while other States received feral swine from more than 10 States. Areas in Georgia, southern Oklahoma, central Texas, southern Louisiana, and central Florida were hotspots for the origination of translocations. For long-distance translocations, the main sources of feral swine were central and northern Texas, as

well as Florida. Analyses showed Texas had a disproportionate impact on the spread of feral swine, serving as a source to 26 of the 38 States investigated. This information will aid in feral swine management, as well as legislation and enforcement of human activities.

Contact: Tim Smyser

- **Feral Swine Establishment of Home Ranges After Translocation.** The rapid expansion of feral swine in North America is mainly attributed to the intentional and illegal translocation of the animals to create hunting opportunities. To learn more about feral swine movement and establishment following translocation, NWRC and University of Georgia researchers conducted experimental trials with 38 collared feral swine released either in social groups or individually. Results showed feral swine translocated with their social group made less extensive movements away from the release location and established a stable home range about 5 days faster than those translocated individually. Habitat quality also impacted the home range sizes of translocated animals. Animals released in lower-quality habitats established larger home ranges. Findings suggest that translocated feral swine are more likely to establish a viable population near their release site when the habitat quality is high, and they are released with members of their social group. However, all the animals translocated in this study made extensive movements from their release location, highlighting the potential for single translocation events of either individuals or groups to have far-reaching consequences within a much broader landscape beyond the location where they are released. This information will aid managers in developing appropriate response strategies for containing and eliminating



new source populations following feral swine translocations.

Contact: Kim Pepin

- **Potential Expansion of Feral Swine from Canada to the Northern United States.**

Understanding the connectiveness of habitats across landscapes is an essential part of invasive species management since habitat connectivity can increase a species' invasion potential. Invasive feral swine were introduced to Canada in the 1980s. NWRC, WS Operations, APHIS Veterinary Services, and university experts examined the potential for Canadian feral swine to invade across the northern prairies from western Canada into currently feral swine-free northern U.S. States. Researchers used data from 22 GPS-collared feral swine in Canada to determine feral swine movements and habitat preferences. Analysis showed feral swine in Canada preferred deciduous forests, crops, and wetlands. Using data from the Commission for Environmental Cooperation North American landcover map, researchers determined such intermixed habitats are found throughout southern Saskatchewan and Manitoba, north-eastern Montana, North and South Dakota, and western portions of Minnesota, making these areas particularly vulnerable to feral swine invasion. Researchers note that deciduous forest, wetlands, water, and agricultural crops are

easier to traverse, given that they are relatively flat, provide food, hiding, and thermoregulatory cover, while reducing the risk to predation, hunting, and human disturbance. Results show the potential for rapid expansion of feral swine in the northern prairies of North America and help guide efforts to monitor the species as it continues to expand its range.

Contact: Kurt VerCauteren

- **Raccoon Movement in the Southeastern United States and Impacts of Sex, Season, and Habitat.** The movement behavior of raccoons varies widely across habitats with important implications for the management of zoonotic diseases, such as rabies. To better understand the movement behavior of raccoons in the southeastern United States, WS NRMP personnel and NWRC and University of Georgia researchers investigated the roles of sex, season, and habitat on monthly raccoon home range and core area sizes across three representative rural habitats (bottomland hardwood, upland pine, and riparian forest) in South Carolina. Forty-six raccoons captured during 2018 and 2022 were collared with GPS telemetry data-logging transmitters and monitored. Males maintained home range and core areas about 2 to 5 times larger than females in upland pine and riparian habitats throughout the year, but their home range and core areas

NWRC, WS Operations, APHIS-Veterinary Services, and university experts examined the potential for Canadian feral swine to invade across the northern prairies from western Canada into currently feral swine-free northern U.S. States. *Photo by Adobe Stock*

NWRC researchers and partners found the overall average survival rate for turkey vultures in North and South America is greater than 75 percent, but mortality risk increases with road density.

Photo by Adobe Stock



in bottomland hardwood were only larger than females during the breeding season. The home range and core areas of females did not vary across habitats. Male raccoons had larger home range and core areas in upland pine and riparian habitats compared to bottomland hardwood throughout much of the year. The home ranges for male raccoons in upland pine and riparian habitats were among the largest recorded for raccoons in the United States. Such large and variable home ranges likely contribute to the spread of zoonotic disease by male raccoons in these habitats. Even though upland pine and riparian habitats appeared to offer more limited resources for raccoons in this area, these populations remain important to bait efficiently for landscape level raccoon rabies control. These results can be used to inform and design disease mitigation strategies customized to rural areas of the southeastern United States.

Contact: Amy Gilbert

- **Space Use and Resource Selection by Black Vultures.** Black vulture populations have increased and expanded their distribution in the Southern and Eastern United States. In conjunction with these patterns has been a rise in human-vulture conflicts. To better understand

vulture space use patterns in Florida, Georgia, and South Carolina, NWRC researchers evaluated the movements of 23 black vultures equipped with GPS transmitters between 2006 and 2020. Results showed that the size of vulture home ranges did not differ between breeding and non-breeding seasons. However, there were differences across geographical locations, with the largest home ranges located in Florida. Overall, black vultures avoided homogeneous landscapes regardless of season or activity and exhibited a strong selection for areas with a diversity of resources, such as food, water, roosting and perch sites, and thermals for energy-efficient flight. The importance of factors such as percent urban cover and road density varied by site. Researchers stress the importance of using site-specific studies to understand and manage local vulture populations and associated human-vulture conflicts.

Contact: Bryan Kluever

- **Turkey Vulture Survival and Road Density.** Turkey vultures are the most widely distributed vulture in the Western Hemisphere, but little is known about their survival rates. NWRC researchers and partners combined turkey vulture mortality and movement data with updated geographic information layers to

model yearly and seasonal survival in relation to several environmental factors (i.e., nighttime light, human population density, road density, and landcover types). Overall average survival was greater than 75 percent, but mortality risk increased with road density. Mortality risk was also greater during the nonbreeding and return migration seasons. Road networks across the Americas appear to create ecological traps for turkey vultures where road densities are high, increasing the number of vulture-vehicle collisions and potential human-wildlife conflicts. In regions with high road density, researchers suggest increasing the removal of roadkill that likely attracts vultures and leads to vulture-vehicle collisions.

Contact: Bryan Kluever

Registration Updates

- **Alpha-chloralose.** Immobilizing birds with alpha-chloralose baits is an effective capture method for bird removal projects when other capture methods are impractical, dangerous for personnel, or may be injurious to target birds. In 2022, the U.S. Food and Drug Administration (FDA) announced a new enforcement discretion for certain compounded bulk drug substances used as sedatives for free-ranging wildlife species when prescribed by State-licensed veterinarians (FDA Guidance #256). In January 2024, FDA reviewed and accepted nominations from WS and the International Crane Foundation to allow alpha-chloralose to be added to the [List of Bulk Drug Substances for Compounding Drugs for Use in Free-Ranging Wildlife Species](#) for the immobilization and live capture of Canada geese, American coots, mallards (including feral domestic and hybrid ducks), and sandhill cranes (www.fda.gov/animal-veterinary/animal-drug-compounding/list-bulk-drug-substances-compounding-drugs-use-food-producing-animals-or-free-ranging-wildlife). In August 2024, WS submitted a second nomination to FDA for alpha-chloralose to add common ravens, pigeons, wild and feral turkeys, nonnative and feral geese, ducks, chickens, and swans. FDA listed them as “Under Review” (www.fda.gov/animal-veterinary/animal-drug-compounding/bulk-drug-substances-currently-under-review). WS personnel can now use alpha-chloralose for these bird species with the assistance of a State-licensed consulting veterinarian and in accordance with Guidance #256 and WS training requirements.

Contact: Emily Ruell

- **Bromethalin.** In July 2024, EPA approved label amendments for Bromethalin-100 Conservation Blocks (EPA Reg. No. 56228-65) and Bromethalin-100 Conservation Place Packs (EPA Reg. No. 56228-66) to allow these products to be used on any island by Federal agencies for conservation purposes as long as the Federal agencies had met their Endangered Species Act Section 7 consultation requirements beforehand. These bromethalin baits are formulated as blocks and place packs (chewable polyglassine sachets containing pellets) and are identical in formulation to Bell Laboratories’ Fastrac® products. Bromethalin is an “acute” rodenticide with a different mechanism of action from the anticoagulant rodenticides registered for island conservation. These new island product labels allow a variety of hand-baiting methods and can potentially be used as a primary bait for island projects conducted with hand-baiting methods only, in rotation with other baits, or used as a “mop up” bait for any survivors in an eradication project for rodents that did not consume sufficient quantities of the primary bait.

Contact: Emily Ruell



In July 2024, EPA approved a label amendment to allow GonaCon–Prairie Dogs (EPA Reg. No. 56228-64) to be used on both male and female prairie dogs.

Photo by Adobe Stock

- **GonaCon–Prairie Dogs.** In July 2024, EPA approved a label amendment to allow GonaCon–Prairie Dogs (EPA Reg. No. 56228-64) to be used on both male and female prairie dogs (sub-adult and adult black-tailed, white-tailed, and Gunnison’s prairie dogs). GonaCon–Prairie Dogs can be applied by WS employees or State wildlife management agency personnel.

Contact: *Emily Ruell*

Technology Transfer

- **Pocatello Supply Depot.** In 2024, the administrative oversight of the Pocatello Supply Depot (PSD) was transferred from the WS Deputy Administrator’s Office to the NWRC. The PSD is the manufacturing entity of the WS program and has been in operation in Pocatello, Idaho, since 1936. The PSD has laboratory, manufacturing, and storage facilities. PSD products are available for sale to Federal and non-federal agencies, organizations, commercial businesses, and individuals. The goal of the PSD is to ensure WS employees and others engaged in wildlife damage management have access to specialized products and services that are not available on the commercial market. This is accomplished through:

- Producing specialized wildlife damage management equipment and supplies
- Coordinating and maintaining pesticide registrations
- Formulating APHIS-registered vertebrate pesticides
- Providing technical assistance and coordinating testing and development of existing control methods and other WS services
- Disseminating technical information concerning production, shipment, storage, and disposal of materials provided by the depot

- **New Inventions, Patents, and Licenses.**

In fiscal year (FY) 2024, NWRC scientists were awarded three patents (1 U.S., 2 foreign), converted four provisional patents to full patent applications, and filed five provisional patents. See the following table for details on issued patents. NWRC scientists also disclosed new inventions to the NWRC Technology Transfer Office. Patent licenses paid approximately \$119,000 in royalties in FY 2024.

An example of one of NWRC’s recently filed provisional patents involves the development of a new nonlethal predator damage management tool called a flashtag. Researchers with NWRC’s



Predator Project partnered with WS Operations and a private inventor to create the novel LED light deterrent that protects cattle and sheep from predation by large carnivores, such as wolves. Producers can attach the flashtags to the ears of their livestock using standard ear-tag equipment. The device only activates when it is dark, and the animal is in rapid motion. The light emitted from these low cost, solar-powered tags likely confuses predators when

they pursue the tagged livestock. Researchers are working with the USDA Agricultural Research Service and multiple private ranching operations across Arizona, Colorado, Idaho, Montana, Nebraska, Oregon, Utah, Wisconsin, Wyoming, and Chihuahua, Mexico, to further test the effectiveness of the flashtags to protect cattle and sheep from predation.

Contact: Sarah Hibbs-Shipp

APHIS filed a provisional patent with the U.S. Patent and Trademark Office for a new nonlethal predator damage management tool called a flashtag. The device was created by NWRC researchers with the help of a private inventor and WS Operations field specialists.

Photos by USDA Wildlife Services

INVENTION TITLE	NWRC INVENTORS AND COOPERATOR CO-INVENTORS	COUNTRY	PATENT/APPLICATION NUMBER
Rotary manifold for paper-based immunoassays	Franklin, A., Henry, C., Feeny, R., Carrell, C. (Colorado State University)	United States	US11291997B2
Preventing birds from ingesting pesticide-treated substances	Werner, S., Ballinger, K. (Arkion Life Science)	China	CN113329625A CN113329625B
Repellent and attractant composition for dichromatic animals	Werner, S., Ballinger, K. (Arkion Life Science)	Egypt Indonesia United States China United States	30898 IDP000079290 US11252953B2 CN108601346B US10638745B2
Ultraviolet strategy for avian repellency	Werner, S.	Canada China Australia United States Vietnam	CA2954333C CN106793770B AU2014400622B2 US9131678B1 37148

List of NWRC-issued patents.

**List of NWRC-issued patents
(continued.)**

INVENTION TITLE	NWRC INVENTORS AND COOPERATOR CO-INVENTORS	COUNTRY	PATENT/APPLICATION NUMBER
Method for repelling rodents	Werner, S., Ballinger, K. (Arkion Life Science)	Canada Australia United States	CA2936508C AU2015204488B2 US9999220B2
Use of visual cues to enhance bird repellent compounds	Werner, S., Ballinger, K. (Arkion Life Science)	Japan Australia China	JP6641353B2 AU2015294513C1 CN106998674B
System and method for collision prevention	DeVault, T., Blackwell, B., and Seamans, T.	United States	US11142173B2
Microfluidized mycobacterium avium fragments as an adjuvant and carrier for mucosal vaccine delivery	Mauldin, R., Eckery, D., Miller, D.	United States	US10434171B2
Container apparatus brown treesnake	Pitt, W., Savarie, P., Messaros, M. (Applied Design Corporation)	United States	US9730438B2
Adjuvanted rabies vaccine with improved viscosity profile	Miller, L., Fry, T., Hurley, J., Maki, J. (Merial Inc.)	United States	US9216213B2
Use of gonadotropin-releasing hormone (GnRH) and analogs in the prevention and treatment of pet ferret adrenocortical hyperplasia	Miller, L., Wagner, B. (University of Pittsburgh)	United States	US8927495B1
Trapping method and apparatus	Humphrey, J.	United States	US8407931B1
Vaccine compositions and adjuvant	Miller, L., Rhyan, J.	United States	US7731939B2
Selectively accessible feeder	Lavelle, M., Halseth, J., Snow, N. and Staples, L., Lake, B. (Animal Control Technologies, Australia)	United States	US20210204509A1

- 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 2024, NWRC entered into 43 new technology transfer agreements: 7 confidentiality agreements, 3 data sharing

agreements, 16 material transfer agreements, 13 material transfer research agreements, and 6 cooperative research and development agreements. Of the 43 agreements, 9 of them are with international cooperators. Technology transfer services were provided to the NWRC, several WS national programs, and WS Operations.

Contact: Sarah Hibbs-Shipp

Awards

- **2023 NWRC Publication Award.** Each year, the NWRC Publication Awards Committee, composed of NWRC scientists, reviews more than 100 publications generated by NWRC colleagues. The resulting peer-recognized award honors outstanding contributions to science and wildlife damage management. In 2024, the committee reviewed 119 publications published in 2023 and presented the award to Drs. Stewart Breck, Amy Davis, and Kim Pepin for their paper evaluating factors affecting the recovery of endangered Mexican wolves in the United States. Co-authors included WS Arizona State director Dave Bergman and experts from the U.S. Fish and Wildlife Service and Arizona Game and Fish Department.

Breck, S.W., A.J. Davis, J.K. Oakleaf, D.L.

Bergman, J. deVos, J.P. Greer, and K. Pepin.

2023. [*Factors affecting the recovery of Mexican wolves in the Southwest United States*](#). *Journal of Applied Ecology* 60(10): 2199-2209. doi: 10.1111/1365-2664.14483

See summary of the study on page 38 of this report. The NWRC Publication Awards Committee selected this publication because of its impactful research, reliable data analysis, complexity, and innovative use of data.

- **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. Jennifer Malmberg**
research grade scientist; Chronic Wasting Disease Project; Fort Collins, CO
 - **Dr. Hayden Hamby**
support scientist; Laboratory Support Services Unit; Fort Collins, CO



NWRC supervisory research wildlife biologist Dr. Alan Franklin was honored with The Wildlife Society's Fellows Award for exceptional service to the wildlife profession.
Photo by USDA Wildlife Services

- **Caitlyn Clifford**
biological science technician; Aquaculture Project; Fort Collins, CO
- **Talia Bogaard**
administrative support; Administration Unit; Fort Collins, CO
- **The Wildlife Society's Fellows Award.**
NWRC supervisory research wildlife biologist Dr. Alan Franklin was honored with The Wildlife Society's (TWS) Fellows Award on October 20, 2024, during TWS' 2024 conference in Baltimore, Maryland. This award recognizes current TWS members who have distinguished themselves through exceptional service to the wildlife profession. TWS Fellows serve as ambassadors of TWS and are encouraged to engage in outreach and other activities that will benefit and promote both TWS and the wildlife profession. Fellows are appointed for life.
Dr. Franklin is Project Leader for the NWRC's Wildlife Pathogens, Agriculture, and One Health Project. His expertise is primarily on the ecology and dynamics of wildlife populations, particularly in integrating quantitative analysis of empirical data with ecological theory and integrating wildlife population ecology with wildlife disease ecology. He currently works on avian influenza surveillance and monitoring in wildlife, and ecology of pathogenic and antimicrobial resistant bacteria in wildlife populations at the wildlife-agricultural interface.

2024 Publications



A black bear is released from a culvert trap in Wisconsin. The bear was captured and moved to a new location after it preyed on domestic poultry. Photo by USDA Wildlife Services, Cody Knapp

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: 2023 publications that were not included in the 2023 NWRC accomplishments report are listed here.)

During FY24, NWRC had 185 active studies, produced 100 publications, collaborated with more than 155 entities, and had over 123,000 downloads from Digital Commons.

Ahlstrom, C.A., M.K. Torchetti, J.K. Lenocho, K.B. Beckmen, M.B. Boldenow, E.J. Buck, B.D. Daniels, K. Dilione, R. Gerlach, K. Lantz, A. Matz, R.L. Poulson, L.C. Scott, G. Sheffield, D. Sinnett, D.E. Stallknecht, R. Stimmelmayer, E. Taylor, A.R. Williams, and A.M. Ramey. [Genomic characterization of highly pathogenic H5 avian influenza viruses from Alaska during 2022 provides evidence for genotype-specific trends of spatiotemporal and interspecies dissemination](#). Emerging Microbes & Infections 13(1), 2406291. doi: 10.1080/22221751.2024.2406291

Ammar, S., T.J. Dawant, J. Kelly, G. Hickling, J. Brown, K. Van Why, R. Poulson, C. Su, and R. Gerhold. 2024. [Toxoplasma gondii survey in waterfowl and gulls from eight US states](#). Journal of Wildlife Diseases 60(2): 542-545. doi: 10.7589/JWD-D-22-00132

Antaky, C.C., R.T. Sugihara, I.L. Leinbach, S.R. Siers, E.W. Ruell, and S.C. Hess. 2023. [Development and evaluation of prototype toxicant-delivery bait stations for the control of the small Indian mongoose](#). Management of Biological Invasions 14(4): 775-791. doi: 10.3391/mbi.2023.14.4.12

Arneson, J.R., D.A. Peloquin, T.G. Prestby, and S.P. Saunders. 2024. [Common Grackle \(Quiscalus quiscula\) predation of a Great Lakes Piping Plover \(Charadrius melodus\) nest and its conservation implications](#). Waterbirds 47(1): 1-6. doi: /10.1675/063.047.0111

Azeem, S., J. Baroch, D. Tewari, K.L. Pabilonia, M. Killian, B. Bradel-Tretheway, D. Sun, S. Ghorbani-Nezami, and K.-J. Yoon. 2024. [Molecular Characterization of Non-H5 and Non-H7 Avian Influenza Viruses from Non-Mallard Migratory Waterbirds of the North American Flyways, 2006–2011](#). Pathogens 13(4): 333. doi: 10.3390/pathogens13040333

Baker, E., A. Jensen, D. Miller, K.B. Garrett, C.A. Cleveland, J. Brown, K. Van Why, and R. Gerhold. 2023. [Hepatozoon spp. infection in wild canids in the eastern United States](#). Parasites & Vectors 16: 372. doi: 10.1186/s13071-023-05968-x

Barmentlo, N.W.G., P.G. Meirmans, W.H. Stiver, J.G. Yarkovich, B.E. McCann, A.J. Piaggio, D. Wright, T.J. Smyser, and M. Bosse. 2024. [Natural selection on feralization genes contributed to the invasive spread of wild pigs throughout the United States](#). Molecular Ecology 33: e17383. doi: 10.1111/mec.17383

- Bastille-Rousseau, G., N.T. Gorman, K.M. McClure, L. Nituch, T. Buchanan, R.B. Chipman, A.T. Gilbert, K.M. Pepin. 2023. [Assessing the efficiency of local rabies vaccination strategies for raccoons \(*Procyon lotor*\) in an urban setting](#). Journal of Wildlife Diseases 60(1): 26-38. doi: 10.7589/JWD-D-23-00059.
- Beasley, E.M., K.M. Nelson, D. Slate, A.T. Gilbert, F.E. Pogmore, R.B. Chipman, A.J. Davis. 2023. [Oral rabies vaccination of raccoons \(*Procyon lotor*\) across a development intensity gradient in Burlington, Vermont, USA, 2015-2017](#). Journal of Wildlife Diseases 60(1): 1-13. doi: 10.7589/JWD-D-22-00117
- Berentsen, A.R., C.C. Suave, M.J. Rivera-Rodriguez, F.B. Torres-Toledo, R.B. Chipman, and A.T. Gilbert. 2023. [Population density of the small Indian mongoose \(*Urva auropunctata*\) across multiple habitat types and seasons in Puerto Rico](#). Caribbean Journal of Science 53(2): 358-373. doi: 10.18475/cjos.v53i2.a17
- Berentsen, A.R., M.J. Rivers-Rodriguez, F.B. Torres-Toledo, A.J. Davis, R.B. Chipman, and A.T. Gilbert. 2023. [Rabies virus serosurvey of the small Indian mongoose \(*Urva auropunctata*\) across multiple habitats in Puerto Rico, 2014-21](#). Journal of Wildlife Disease 59(4): 577-589. doi: 10.7589/JWD-D-22-00148
- Bernasconi, D.A., M.L. Miller, J.E. Hill, P. Gupta, R.B. Chipman, A.T. Gilbert, O.E. Rhodes, Jr., and G. Dharmarajan. 2023. [Raccoons \(*Procyon lotor*\) show higher trypanosoma cruzi detection rates than Virginia opossums \(*Didelphis virginiana*\) in South Carolina, USA](#). Journal of Wildlife Diseases 59(4): 673-683. doi: 10.7589/JWD-D-22-00174
- Blackwell, B.F., M.B. Pfeiffer, J.L. Hoblet, and B.N. Buckingham. 2024. [Use of nest boxes by European Starlings \(*Sturnus vulgaris*\): Effects of perceived nest predation risk](#). The Wilson Journal of Ornithology 136(1): 17-35. doi: 10.1676/23-00006
- Blackwell, B.F., P.E. Klug, L.A. Humberg, Z.T. Brym, B.M. Kluever, and J.M. Edwards. 2023. [Cultivation of industrial hemp on and near airports: implications for wildlife use and risk to aviation safety](#). Human-Wildlife Interactions 16(3): 373-383. doi: 10.26077/9721-9c7d
- Bleke, C.A., E.M. Gese, J.J. Villalba, S.B. Roberts, and S.S. French. 2024. [Temporal and spatial influences on fawn summer survival in pronghorn populations: Management implications from noninvasive monitoring](#). Animals 14, 1468. doi: 10.3390/ani14101468
- Bowden, C.F., J.N. Kiser, R.S. Miller, A.C. Buckley, P.M. Boggiato, R.M. Giglio, V.R. Brown, D. Garrick, H.L. Neibergs, A.J. Piaggio, S.E. Speidel, and T.J. Smyser. 2023. [Genomic regions associated with pseudorabies virus infection status in naturally infected feral swine \(*Sus scrofa*\)](#). Frontiers in Genetics 14: 1292671. doi: 10.3389/fgene.2023.1292671
- Breck, S.W., A.J. Davis, J.K. Oakleaf, D.L. Bergman, J. deVos, J.P. Greer, and K. Pepin. 2023. [Factors affecting the recovery of Mexican wolves in the Southwest United States](#). Journal of Applied Ecology 60(10): 2199-2209. doi: 10.1111/1365-2664.14483
- Brown, V.R., J.B. Lenocho, and C.F. Bowden. 2023. [African swine fever](#). pgs 198-213. In: D.A. Jessup and R.W. Radcliffe, editors. Wildlife disease and health in conservation. John Hopkins University Press, Baltimore, Maryland. 468 pp.

- Brown, V.R., R.S. Miller, K.M. Pepin, K.M. Carlisle, M.A. Cook, C.F. Vanicek, L.K. Holmstrom, L.T. Rochette, and T.J. Smyser. 2024. [African swine fever at the wildlife-livestock interface: challenges for management and outbreak response within invasive wild pigs in the United States](#). *Frontiers in Veterinary Science* 11: 1348123. doi.org/10.3389/fvets.2024.1348123
- Canright V.R., Piaggio A.J., Beasley J.C. 2024. [Invasive wild pig \(*Sus scrofa*\) diets on barrier islands in the southeastern United States](#). *Pest Management Science* 80: 3901-3911. doi: 10.1002/ps.8093
- Cartright, V.R., A.J. Piaggio, S.M. Chinn, R.M. Giglio, J.M. Craine, and J.C. Beasley. 2023. [DNA metabarcoding reveals consumption of diverse community of amphibians by invasive wild pigs \(*Sus scrofa*\) in the Southeastern United States](#). *Scientific Reports* 13: 20889. doi: 10.1038/s41598-023-48139-9
- Claunch, N.M., C.M. Goodman, B.M. Kluever, N. Barve, R.P. Guralnick, and C.M. Romagosa. 2023. [Commonly collected thermal performance data can inform species distributions in a data-limited invader](#). *Scientific Reports* 13: 15880. doi: 10.1038/s41598-023-43128-4
- Cleveland, C.A., E. Haynes, K.C. Callaghan, A. Fotjik, S. Coker, E. Doub, V.R. Brown, A.A. Majewska, and M.J. Yabsley. 2023. [Distribution and prevalence of antibodies to *Trichinella* spp. and *Toxoplasma gondii* in wild pigs \(*Sus scrofa*\) in the United States](#). *Veterinary Parasitology* 325: 110090. doi: 10.1016/j.vetpar.2023.110090
- Clontz, L.M., A. Yang, S.M. Chinn, K.M. Pepin, K.C. VerCauteren, G. Wittemyer, R.S. Miller, and J.C. Beasley. 2023. [Role of social structure in establishment of an invasive large mammal after translocation](#). *Pest Management Science* 79(10): 3819-3829. doi: 10.1002/ps.7567
- Crompton, J., M.B. Pfeiffer, S. Samiappan, J.A. Elmore, L.R. Jones, B.S. Krishnan, R.B. Iglay, E. Fernandez-Juricic, and B.F. Blackwell. 2024. [Relief displacement of airborne objects](#). *Remote Sensing Letters* 15(9): 872–882. doi: 10.1080/2150704X.2024.2387131
- Cunningham, F.L., Burr, P., Glover, J., Tappa, J., Redd, M., and Wang, G. 2023. [The effectiveness of commercially available Double-Crested Cormorant \(*Nannopterum auritus*\) deterrent methods in reducing loafing time on floating oyster cages](#). *Diversity* 16(1): 5. doi.org/10.3390/d16010005
- Davis A.J., R.B. Chipman, K.M. Nelson, B.S. Haley, J.D. Kirby, X. Ma, R.M. Wallace, and A.T. Gilbert. [Evaluation of contingency actions to control the spread of raccoon rabies in Ohio and Virginia](#). *Preventative Veterinary Medicine*. 2024 Feb 9; 225: 106145. doi: 10.1016/j.prevetmed.2024.106145. PMID: 38354432
- DeLiberto, S.T. and Werner, S.J. 2024. [Applications of chemical bird repellents for crop and resource protection: a review and synthesis](#). *Wildlife Research* 51, WR23062. https://doi.org/10.1071/WR23062
- Dempsey, S., R.J. Pye, A.T. Gilbert, N.M. Fountain-Jones, J.M. Moffatt, S. Benson-Amram, T.J. Smyser, A.S. Flies. 2022. [Evaluation of oral baits and distribution methods for Tasmanian devils \(*Sarcophilus harrisii*\)](#). *Wildlife Research* 50(10): 807-819. doi: 10.1071/WR22070
- Ditmer, M.A., G. Wittemyer, K.A. Zeller, S.W. Breck, R.J. Fletcher, Jr., and K.R. Crooks. 2023. [Predicting dispersal and conflict risk for wolf recolonization in Colorado](#). *Journal of Applied Ecology*. 60(22): 2327-2339. doi: 10.1111/1365-2664.14504

- Dooley, J.L., P.F. Doherty, D.L. Otis, G.C. White, D.R. Taylor, D.L. Griffin, S.C. Chandler, S.M. Catino, K.K. Fleming, R.V. Raftovich, and A.J. Piaggio. 2024. [Discrimination among similarly colored goose species in federal harvest surveys](#). *Journal of Wildlife Management* e22591. doi: 10.1002/jwmg.22591
- Dorr, B.S., F.L. Cunningham, P. Burr, S. Barras, K.C. Godwin, and L. Roy. 2024. [Avian predators and their management at aquaculture facilities in the Southeastern United States](#). Southern Regional Aquaculture Center publication 400.
- Dressel, D., K.C. VerCauteren, M.J. Lavelle, N.P. Snow, and H. Campa, III. 2024. [Use of rhodamine B as a biomarker in a simulated oral vaccine deployment against bovine tuberculosis in white-tailed deer](#). *Frontiers in Veterinary Science* 11: 1354772. doi: 10.3389/fvets.2024.1354772
- Dubey, J.P., P.C. Thompson, L.S. de Araujo, A. Gupta, S. Kay, O.C.H. Kwok, J. Battle, K. Van Why, J.D. Brown, and B.M. Rosenthal. 2024. [Trichinella murrelli identified in red foxes \(*Vulpes vulpes*\) in Pennsylvania, USA](#). *Veterinary Parasitology: Regional Studies and Reports* 54, 101086. doi: 10.1016/j.vprsr.2024.101086
- Dugger, K.M., A.B. Franklin, D.B. Lesmeister, R.J. Davis, et al. 2023. [Estimating northern spotted owl \(*Strix occidentalis caurina*\) pair detection probabilities based on call-back surveys associated with long-term mark-recapture studies, 1993-2018](#). 2023. US Geological Survey Open-File Report 2023-1012: 1-25. doi: 10.3133/ofr20231012
- Ellis, H.E., L.M. Jaebker, A.D. Bright, M.D. Smith, and K.M. Carlisle. 2023. [Alabama agricultural producers' experiences with wild pigs \(*Sus scrofa*\) and their preferences concerning wild pig management](#). *Human Dimensions of Wildlife*, 1-5. doi: 10.1080/10871209.2023.2273506
- Engeman, R.M., E.A. Tillman, B.A. Evans, J.C. Griffin, G. Grobaski, B.S. Smith, J. Stark, and B.M. Kluever. 2024. [Eradication of feral swine from a barrier island in Florida, USA: an examination of effort and multi-method, multi-species population indexing](#). *NeoBiota* 93: 91-116. doi: 10.3897/neobiota.93.112647
- Evans, B.A., J.S. Humphrey, E.A. Tillman, M.L. Avery, and B.M. Kluever. 2023. [Site-specific space use and resource selection by black vultures \(*Coragyps atratus*\) in the Southeastern USA](#). *Ibis* 166: 129-145. doi: 10.1111/ibi.13244
- Feuka, A., A. Pandey, M. Cosgrove, M. Moriarty, A. Duffiney, H. Campa, III, K. VerCauteren, and K.M. Pepin. 2024. [Estimating landscape spread of a low-prevalence disease using multiple surveillance methods](#). *Journal of Applied Ecology* 61: 575-587. doi: 10.1111/1365-2664.14574
- Feuka, A.B., A. Duffiney, K.C. VerCauteren, K.M. Pepin, A. Pandey, M. Cosgrove, M. Moriarty, and H. Campa. 2024. [Wildlife vaccination strategies for eliminating bovine tuberculosis in white-tailed deer populations](#). *PLOS Computational Biology* 20(1): e1011287. doi.org/10.1371/journal.pcbi.1011287
- Foster, J.A., J.C. Kinsey, M.J. Lavelle, K.C. VerCauteren, and N.P. Snow. 2024. [Low secondary risks for turkey vultures from a sodium nitrite toxic bait for wild pigs](#). *Wildlife Society Bulletin* 48:e1539. doi: 10.1002/wsb.1539
- Freeman, S.M., J.L. Catrow, J.E. Cox, A. Turano, M. Rich, H.P. Ihrig, N. Poudyal, C-W.T. Chang, E.M. Gese, J.K. Young, and A.L. Olsen. 2024. [Binding affinity, selectivity, and pharmacokinetics of the oxytocin receptor antagonist L-368,899 in the coyote \(*Canis latrans*\)](#). *Comparative Medicine* 74(1): 3-11. doi: 10.30802/AALAS-CM-23-000044

- Frey, R.K., M.E. Wehtje, P. Nol, P.R. Clarke, J.C. Rhyan, M.P. McCollum, L.A. Miller, and D.C. Eckery. 2024. [Effects of the immunocontraceptive Gonacon on pregnancy in Brucella-seropositive American bison \(*Bison bison*\)](#). *Journal of Wildlife Diseases* 60(2): 339-345. doi: 10.7589/JWD-D-21-00168
- Garrett, K., J. Brown, R.K.A. Grunert, J. Hunte, M.G. Ruder, K. Van Why, M.J. Yabsley, and C.A. Cleveland. 2023. [Echinococcus species infections among wild canids in Pennsylvania, USA](#). *Journal of Wildlife Diseases* 59(2): 332-336. doi: 10.7589/JWD-D-22-00042
- Gese, E.M., P.A. Terletzky, C.A. Bleke, E.T. Stevenson, and S.S. French. 2023. [Changes in fecal glucocorticoid metabolites in captive coyotes \(*Canis latrans*\): influence of gender, time, and reproductive status](#). *Animals* 13: 3596. <https://doi.org/10.3390/ani13233596>
- Gese, E., L.M. White, S.J. Gifford, G. Kaufman, M.A. Peyton, R.R. Parmenter, and J.W. Cain. 2024. [Seroprevalence, blood chemistry, and patterns of canine parvovirus, distemper virus, plague, and tularemia in free-ranging coyotes \(*Canis latrans*\) in northern New Mexico, USA](#). *Journal of Wildlife Diseases*, 60(1). doi.org/10.7589/JWD-D-22-00079
- Giglio, R.M., C.F. Bowden, R.K. Brook, A.J. Piaggio, and T.J. Smyser. 2024. [Characterizing feral swine movement across the contiguous United States using neural networks and genetic data](#). *Molecular Ecology* 33, e17489. doi: 10.1111/mec.17489
- Gilbert, A.T., L.I. Van Pelt, L.A. Hastings, C.M. Gigante, L.A. Orciari, S. Kelley, K. Fitzpatrick, R.E. Condori Condori, Y. Li, S. Brunt, A. Davis, M.W. Hopken, C.P. Mankowski, R.M. Wallace, C.E. Rupprecht, R.B. Chipman, and D.L. Bergman. 2024. [Reemergence of a big brown bat *Lyssavirus* rabies variant in striped skunks in Flagstaff, Arizona, USA, 2021-2023](#). *Vector-Borne and Zoonotic Diseases* 24(8): 552-562. doi: 10.1089/vbz.2023.0126
- Hall, D.B., B.A. Kimball, J.M. Germano, E.M. Gese, and J.A. Perry. 2023. [Differential canid predation of translocated juvenile desert tortoises \(*Gopherus agassizii*\) using chemical signature differences](#). *Herpetological Conservation and Biology* 18(3): 488-499.
- Hastings, L.A., C.L. Chambers, D.L. Bergman, and T.C. Theimer. 2024. [Increased bat activity at urban water sources: implications for cross-species transmission of bat rabies to mesocarnivores](#). *Urban Ecosystems* 27: 75–84. doi: 10.1007/s11252-023-01413-0
- Herbert, A.M., P.A. Zollner, L.R. Jones, M.L. Wahl, G.N. Burcham, B.M. Kluever, L.A. Humberg, and B.M. Quinby. 2024. [Competitive behaviors between Black Vultures \(*Coragyps atratus*\) and Turkey Vultures \(*Cathartes aura*\) during scavenging](#). *Journal of Raptor Research* 58(4): 1-13. doi: 10.3356/jrr2378
- Hewitt, J., G. Wilson-Henjum, D.T. Collins, J.M. Ringenberg, C.A. Quintanal, R. Pleszewski, J.C. Chandler, T.J. DeLiberto, and K.M. Pepin. 2024. [A method for characterizing disease emergence curves from paired pathogen detection and serology data](#). *Methods in Ecology and Evolution*, 15, 1677-1690. DOI: 10.1111/2041-210X.14370

- Hewitt, J., G. Wilson-Henjum, D.T. Collins, T.J. Linder, J.B. Lenocho, J.D. Heale, C.A. Quintanal Segarra, R. Pleszewski, D.S. McBride, A.S. Bowman, J.C. Chandler, S.A. Shriner, S.N. Bevins, D.J. Kohler, R.B. Chipman, A.L. Gosser, D.L. Bergman, T.J. Deliberto, and K.M. Pepin. 2024. [Landscape-scale epidemiological dynamics of SARS-CoV-2 in white-tailed deer](#). *Transboundary and Emerging Diseases* 2024: 1-11. doi: 10.1155/2024/7589509
- Hill, J.E., D.A. Bernasconi, R.B. Chipman, A.T. Gilbert, J.C. Beasley, O.E. Rhodes, Jr., and G. Dharmarajan. 2024. [Home range and resource selection of Virginia opossums in the rural southeastern United States](#). *Mammal Research* 69: 193–204. doi: 10.1007/s13364-023-00733-y
- Hill, J.E., J.L. Helton, D.A. Bernasconi, W.C. Dixon, M.T. Hamilton, R.B. Chipman, A.T. Gilbert, J.C. Beasley, G. Dharmarajan, and O.E. Rhodes, Jr. 2023. [Raccoon densities across four land cover types in the southeastern United States](#). *Journal of Wildlife Management* 87:e22480. doi: 10.1002/jwmg.22480
- Hill, J.E., M.L. Miller, J.L. Helton, R.B. Chipman, A.T. Gilbert, J.C. Beasley, G. Dharmarajan, O.E. Rhodes, Jr. 2023. [Raccoon spatial ecology in the rural southeastern United States](#). *PLoS ONE* 18(11):e0293133. doi: 10.1371/journal.pone.0293133
- Hill, J.E., M.L. Miller, R.B. Chipman, A.T. Gilbert, J.C. Beasley, G. Dharmarajan, and O.E. Rhodes. [Influence of habitat and baiting strategy on oral rabies vaccine bait uptake by raccoons in the southeastern United States](#). 2024. *Applied Animal Behaviour Science* 277: 106320. doi: 10.1016/j.applanim.2024.106320
- Hoag, D.L., J. Burkhardt, B. Ghasemi, S. Breck, R. Niemiec, and K. Crooks. 2023. [Willingness to pay for reintroducing wolves in a divided voting base](#). *Global Ecology Conservation* 46:e02576. doi: 10.1016/j.gecco.2023.e02576
- Holthuijzen, W.A., C.C. Antaky, E.N. Flint, J.H. Plissner, C.A. Wolf, and H.P. Jones. 2023. [A next-generation sequencing study of arthropods in the diet of Laysan Teal *Anas laysanensis*](#). *Wildfowl* 73: 118-133. <https://wildfowl.wwt.org.uk/index.php/wildfowl/article/view/2787>
- Hopken, M.W., A.J. Piaggio, Z. Abdo, R.B. Chipman, C.P. Mankowski, K.M. Nelson, M. Samsel Hilton, C. Thurber, M.T.N. Tsuchiya, J.E. Maldonado, and A.T. Gilbert. 2023. [Are rabid raccoons \(*Procyon lotor*\) ready for the rapture? Determining the geographic origin of rabies virus-infected raccoons using RADcapture and microhaplotypes](#). *Evolutionary Applications* 16: 1937-1955. doi: 10.1111/eva.13613
- Hopken, M.W., C. Gigante, A.T. Gilbert, R.B. Chipman, J.D. Kirby, R.E. Condori, S. Mills, C. Hartley, J. Forbes, L. Dettinger, D. Xia, Y. Li, and B. vonHoldt. 2024. [Genetic tracking of a rabid coyote \(*Canis latrans*\) detected beyond a rabies enzootic area in West Virginia, USA](#). *Journal of Wildlife Diseases* 60(3): 745–752. doi: 10.7589/JWD-D-23-00158
- Huang, M.H.J., S. Demarais, B.K. Strickland, A. Houston, A. Banda, and K.C. VerCauteren. 2024. [Chronic wasting disease effects on a breeding season behavior in White-tailed Deer \(*Odocoileus virginianus*\)](#). *Journal of Mammalogy* 105(5): 1175–1181. doi: 10.1093/jmammal/gyae050
- Igley, R.B., L.R. Jones, J.A. Elmore, K.O. Evans, S. Samiappan, M.B. Pfeiffer, and B.F. Blackwell. 2024. [Wildlife monitoring with drones: A survey of end users](#). *Wildlife Society Bulletin* 48:e1533. doi: 10.1002/wsb.1533

- Jareb, C., K.M. Pepin, R.S. Miller, S.A. Shwiff, and S.C. McKee. 2024. [Agricultural and ecological resources safeguarded by the prevention of wild pig population expansion](#). *Biology* 13, 670. doi: 10.3390/biology13090670
- Jarvi, S.I., L.M. Kaluna, S.C. Hess, L. Hamilton, C. Antaky, R.T. Sugihara, I.L. Leinbach, Y. Tagami, A. Steel, K. Howe, S. Jacquier, F. Cookman, J. Diaz, J. Jacob, and P. Follett. 2024. [Efficacy of x-ray phytosanitary irradiation on the infectivity and reproduction of *Angiostrongylus cantonensis* in experimentally infected rats](#). *The American Journal of Tropical Medicine and Hygiene* 110(4): 691-699. doi: 10.4269/ajtmh.23-0570
- Johnson, S.R., C.K. Ellis, C.K. Wickham, M.R. Selleck, and A.T. Gilbert. 2023. [Comparison of ketamine-xylazine butorphanol-azaperone-medetomidine, and nalbuphine-medetomidine-azaperone for raccoon \(*Procyon lotor*\) immobilization](#). 2023. *Journal of Wildlife Diseases* 60(1): 95-104. doi: 10.7589/JWD-D-23-00060
- Jones, L.R., C. Mensah, J.A. Elmore, K.O. Evans, M.B. Pfeiffer, B.F. Blackwell, and R.B. Iglay. 2024. [Heating decoys to mimic thermal signatures of live animals for drones](#). *MethodsX* 13, 102933. doi: 10.1016/j.mex.2024.102933
- Jones, D., P.S. Stock, E. Lefoulon, M.V. Mazzamuto, W.E. Hall, D.L. Bergman, and J.L. Koprowski. 2024. [Unraveling parasite identification in invasive and endangered squirrel species: potential for parasite spillover](#). *Biological Invasions* 26: 829–844. doi: 10.1007/s10530-023-03212-2
- Kennedy, A.C., W.S. Winter, A.L. Gardner, N. Woodman, S.A. Shifflett, S. Redus, J.R. Newcomer, and R.P. Eckerlin. 2024. [Records of fleas \(*Siphonaptera*\) from Delaware](#). *Journal of Medical Entomology* 61(4): 959-964. doi: 10.1093/jme/tjae069
- Kennedy, S.M., P. Thomas, S.S. Ditchkoff, V.R. Brown, G.W. Raithel, M.F. Chamorro, P.H. Walz, C.S. Kyriakis, and S.M. Falkenberg. 2024. [Seroprevalence of bovine viral diarrhea virus in wild pigs \(*Sus scrofa*\) in 17 states in the USA](#). *Journal of Wildlife Diseases* 60(3): 647-659. doi: 10.7589/JWD-D-23-00066
- Kinsey, J.C., J.A. Foster, N.P. Snow, J.D. Wishart, L.D. Staples, J.K. Bush, and K.C. VerCauteren. 2023. [Assessment of spilled toxic bait by wild pigs and potential risk to non-target species](#). *Pest Management Science* 79(11): 4589-4598. doi: 10.1002/ps.7658
- Kluever, B.M., B.A. Evans, N.M. Osterhoudt, and E.A. Tillman. 2024. [Efficacy of an inflatable deterrent for reducing New World vulture human-wildlife conflict](#). *Scientific Reports* 14(1): 6622. <https://doi.org/10.1038/s41598-024-56941-2>
- Koriakin, K., D.B. Jolley, B. Smith, K.C. VerCauteren, and N.P. Snow. 2024. [Effects of ungulate-proof fencing on space use by wild pigs](#). *Journal of Wildlife Management* e22592. doi: 10.1002/jwmg.22592
- Koriakin, K.J., K.C. VerCauteren, N.P. Snow, and D.B. Jolley. 2024. [Spatiotemporal partitioning of two invasive ungulates in Guam \(Abstract\)](#). *Proceedings of the Vertebrate Pest Conference* 31. Paper No. 10, 2 pp. <https://escholarship.org/uc/item/2q635133>
- Kotten, E.A., I. Hennessy, B.M. Kluever, Z.T. Brym, B.F. Blackwell, L.A. Humberg, and P.E. Klug. 2023. [Industrial hemp as a resource for birds in agroecosystems: human-wildlife conflict or conservation opportunity?](#) *Human-Wildlife Interactions* 16(3): 384–398. doi: 10.26077/c340-6745

- Kramer, C.J., M.R. Boudreau, R. Powers, K.C. VerCauteren, R.S. Miller, and R.K. Brook. 2024. [Potential landscape connectivity for invasive wild pigs \(*Sus scrofa*\) across the northern prairies of North America](#). doi: 10.1007/s10530-024-03326-1
- La, T.H.A., I.A. McMillan, P. Dahal, A.H. Burger, M. Belcaid, D.M. Phelps, S.M. Goldstein, V.R. Brown, and M.H. Norris. 2024. [Tracking sero-molecular trends of swine brucellosis in Hawai'i and the central Pacific](#). *Frontiers in Public Health* 12:1440933. doi: 10.3389/fpubh.2024.1440933
- Li, X., B.M. Parker, R.K. Boughton, J.C. Beasley, T.J. Smyser, J.D. Austin, K.M. Pepin, R.S. Miller, K.C. VerCauteren, and S.M. Wisely. 2024. [Torque teno sus virus 1: A potential surrogate pathogen to study pig-transmitted transboundary animal diseases](#). 2024. *Viruses* 16, 1397. doi: 10.3390/v16091397
- Lorch, J.M., A.J. Piaggio, and D.R. Taylor. 2024. [Analysis of mitochondrial DNA sequence data demonstrates that monophyly of *Myotis occultus* is complicated by greater sampling of *Myotis lucifugus*](#). *The Southwestern Naturalist*, 67(4): 255-262. doi: 10.1894/0038-4909-67.4.255
- Lunn, R., P.E. Baumhardt, B.F. Blackwell, J.P. Freyssonier, and E. Fernandez-Juricic. 2023. [Light wavelength and pulsing frequency affect avoidance responses of Canada geese](#). *PeerJ* 11e:16379. doi: 10.7717/peerj.16379
- Manz, S.T., K.E. Sieving, R.N. Brown, P.E. Klug, B.M. and Kluever. 2024. [Experimental assessment of laser scarecrows for reducing avian damage to sweet corn](#). *Pest Management Science* 80: 1547-1556. doi: 10.1002/ps.7888
- Margenau, E.L., N.W. Cooper, D.J. Brown, D.M. Donner, P.P. Marra, and P. Ryan. 2022. [Spatially structured brown-headed cowbird control measures and their effects on Kirtland's warbler long-term population sustainability](#). *Wildlife Research* 50(10): 771-781. doi: 10.1071/WR22037
- McDonough, M.T., S.J. Zenas, R.A. Gitzen, M.D. Smith, K.C. VerCauteren, and S.S. Ditchkoff. 2024. [Population response of eastern wild turkey to removal of wild pigs](#). *Journal of Wildlife Management* 88:e22662. doi: 10.1002/jwmg.22662
- McKee, S., K. Carlisle, J. Tomeček, S. Shwiff, R. Connally, M. Frank, M. Bodenchuk, and N. Didero. 2024. [An estimate of the marginal annual economic contribution of wild-pig hunting in Texas](#). *Wildlife Research* 51(4): WR23063. doi: 10.1071/WR23063
- McKee, S.C., D. Mooney, and R.S. Miller. 2023. [Type and frequency of wild pig-domestic livestock contacts and operator concern for disease spread](#). *Q Open* 3(2) qoad027. doi: 10.1093/qopen/qoad027
- McKee, S.C., J.J. Mayer, and S.A. Shwiff. 2024. [Comprehensive Economic Impacts of Wild Pigs on Producers of Six Crops in the South-Eastern US and California](#). *Agriculture* 14(1): 153. doi: 10.3390/agriculture14010153
- McKee, S.C., J.L. Psiropoulos, and J.J. Mayer. 2024. [Frequency and vehicle damage costs of wild pig-vehicle collisions in the United States, 2015–2022](#). *European Journal of Wildlife Research* 70: 44. doi: 10.1007/s10344-024-01792-5
- Medeiros, M.J., W.P. Haines, C.E. Aslan, A.B. Shiels, A. Aue, and C.T. Liang. 2024. [Understory arthropod diversity in a mixed dryland ecosystem, Hawai'i](#). *Pacific Science* 77(4): 363-382. doi: 10.2984/77.4.1

- Murphy, N.K., M.R. Boudreau, B.S. Dorr, K. Slankard, and S.A. Rush. 2024. [Identifying priority mitigation areas for human–osprey conflict](#). *Journal of Wildlife Management* 88(3): e22540. <https://doi.org/10.1002/jwmg.22540>
- Natarajan, P., K. Horak, J. Rowe, S. Yoon, J. Lingo, J.M. Tomich, and S.D. Fleming. 2024. [Biodistribution Analysis of Peptide-Coated Magnetic Iron Nanoparticles: A Simple and Quantitative Method](#). *Molecular Pharmaceutics* 21(2): 970–981. doi.org/10.1021/acs.molpharmaceut.3c01080
- Naveda-Rodríguez, A., K.L. Bildstein, D.R. Barber, J.-F. Therrien, M.L. Avery, B.M. Kluever, S.A. Rush, and F.J. Vilella. 2023. [Turkey Vulture survival is reduced in areas of greater road density](#). *Ornithological Applications* 125(4): duad024. doi: 10.1093/ornithapp/duad024
- Nol, P., R. Frey, M. Wehtje, J. Rhyan, P.R. Clarke, M. McCollum, C. Quance, D. Eckery, and S. Robbe- Austerman. 2024. [Effects of pregnancy prevention on *Brucella abortus* shedding in American bison \(*Bison bison*\)](#). *Journal of Wildlife Diseases* 60(2): 327–338. doi: 10.7589/JWD-D-21-00167
- Oesterle, P.T., J.J. Root, D.S.O. Mora, H. Schneider, A.B. Franklin, and K.P. Huyvaert. 2023. [Limited accumulation and persistence of an influenza A virus in tadpole snails \(*Physa* spp.\)](#). *Journal of Wildlife Disease* 59(4): 694–701. doi: 10.7589/JWD-D-22-00149.
- Ogawa, R., G. Wang, L.W. Burger, B.K. Strickland, J.B. Davis, and F.L. Cunningham. 2024. [Bayesian integrated species distribution models for hierarchical resource selection by a soaring bird](#). *Ecological Informatics* 82, 102787. doi: 10.1016/j.ecoinf.2024.102787
- Pandey, A., C. Wojan, A. Feuka, M.E. Craft, K. Manlove, and K.M. Pepin. 2024. [The influence of social and spatial processes on the epidemiology of environmentally transmitted pathogens in wildlife: implications for management](#). *Philosophical Transactions of the Royal Society B*. 379: 20220532. doi: 10.1098/rstb.2022.0532
- Pantin-Jackman, M.J., E. Spackman, C. Leyson, S. Youk, S.A. Lee, L.M. Moon, M.K. Torchetti, M.L. Killian, J.B. Lenocho, D.R. Kapczynski, D.E. Swayne, and D.L. Suarez. 2023. [Pathogenicity in chickens and turkeys of a 2021 United States H5N1 highly pathogenic avian influenza clade 2.3.4.4b wild bird virus compared to two previous H5N8 clade 2.3.4.4 viruses](#). *Viruses* 15(11): 2273. doi: 10.3390/v15112273
- Parker, M.R., E.A. Tillman, L.A. Nazaraian, M.L. Barlowe, J.M. Lincoln, and B.M. Kluver. 2023. [Skin lipids alone enable conspecific tracking in an invasive reptile, the Argentine black and white tegu lizard \(*Salvator merianae*\)](#). *PLoS One*. 2023 Oct 31;18(10): e0293591. doi: 10.1371/journal.pone.0293591.
- Pepin, K.M., C.B. Leach, N.L. Barrett, J.W. Eillis, K.K. VanDalen, C.T. Webb, and S.A. Shriner. 2023. [Environmental transmission of influenza A virus in mallards](#). *mBio* 14(5). doi: 10.1128/mbio.00862-23
- Pepin, K.M., K. Carlisle, D. Anderson, M.G. Baker, R.B. Chipman, J. Benschop, et al. 2024. [Steps towards operationalizing One Health approaches](#). *One Health* 18: 100740. doi: 10.1016/j.onehlt.2024.100740

- Pepin, K.M., K.C. VerCauteren, M.H.J. Huang, S. Demarais, A. Banda, B.K. Strickland, A.G. Welch, S. Hearst, S. Lichtenberg, and A. Houston. 2024. [Expanding CWD disease surveillance options using environmental contamination at deer signposts](#). *Ecological Solutions and Evidence* 5(1): e12298. doi.org/10.1002/2688-8319.12298
- Pepin, K.M., T. Borowik, M. Frant, K. Pils, and T. Podgorski. 2023. [Risk of African swine fever virus transmission among wild boar and domestic pigs in Poland](#). *Frontiers in Veterinary Science* 10: 1295127. doi: 10.3389/fvets.2023.1295127
- Pershyn, N.A., E.M. Gese, E.F. Stuber, and B.M. Kluever. 2024. [Kit foxes demonstrate adaptive compromise characteristics under intraguild predation pressure by coyotes in the Great Basin desert](#). *Scientific Reports* 14: 14446. doi: 10.1038/s41598-024-61692-1
- Pershyn, N.A., E.M. Gese, E.F. Stuber, and B.M. Kluever. 2024. [Coyotes in the Great Basin desert do not exhibit a spatial response following the removal of anthropogenic water sources](#). *Journal of Arid Environments*, 220: 105097. doi: 10.1016/j.jaridenv.2023.105097
- Piaggio, A.J., E. Lanners, D.R. Taylor, A.B. Shiels, M. Matocq, and J. Eisemann. 2024. [Discovery of a novel invasive rodent species on Wake Atoll with a desert southwest USA origin](#). *BiolInvasions Records* 13(3): 675–683. doi: 10.3391/bir.2024.13.3.09
- Pipkin, D.R., B.R. Leland, K. Garwood, L. Tschirhart-Hejl, M.J. Bodenchuk, and J.M. Tomecek. 2024. [The Texas Feral Swine Eradication and Control Pilot Program](#). *Proceedings of the Vertebrate Pest Conference* 31. Paper No. 12, 4 pp. <https://escholarship.org/uc/item/0cx2v202>
- Porter, S.M., A.E. Hartwig, H. Bielefeldt-Ohmann, J.M. Marano, J. Root, and A.M. Bosco-Lauth. 2024. [Experimental SARS-CoV-2 Infection of Elk and Mule Deer](#). *Emerging Infectious Diseases* 30(2): 354-357. doi: 10.3201/eid3002.231093
- Pratyosh, K., J.F. Suter, and S.C. McKee. 2024. [Measuring changes in pork demand, welfare effects, and the role of information sources in the event of an African swine fever outbreak in the United States](#). *Food Policy* 126: 102672. doi: 10.1016/j.foodpol.2024.102672.e
- Preckler-Quiquater, S., E.M. Kierepka, D.M. Reding, A.J. Piaggio, and B.N. Sacks. 2023. [Can demographic histories explain long-term isolation and recent pulses of asymmetric gene flow between highly divergent grey fox lineages?](#) *Molecular Ecology* 32(19): 5211-5449. doi: 10.1111/mec.17105
- Psiropoulos, J.L., E. Howe, J.J. Mayer, and S.C. McKee. 2023. [Characterization of recent wild pig-vehicle collisions in Georgia, USA](#). *Mammal Research* 69: 131-144. doi: 10.1007/s13364-023-00724-z
- Pye, R., D. Nichols, S.A. Nofs, A.T. Gilbert, and A.S. Flies. 2023. [Ethyl-lophenoxic acid as a serum marker for oral baiting of Tasmanian devils](#). *Australian Journal of Zoology* 71: ZO23017. doi: org/10.1071/ ZO23017
- Reding, D.M., B.N. Sacks, E.K. Latch, and A. Piaggio. 2023. Genetics for furbearer management and conservation. Pages 16.1–16.24. In: T.L. Hiller, R.D. Applegate, R.D. Bluett, S.N. Frey, E.M. Gese, and J.F. Organ, editors. [Wild furbearer management and conservation in North America](#). Wildlife Ecology Institute, Helena, Montana, USA. doi: 10.59438/BZWM9451

- Ringenberg, J.M., K. Weir, L. Humberg, C. Voglewede, M. Oswald, J.J. Root, K. Dillione, E. Casey, M. Milleson, T. Linder, and J. Lenocho. 2024. [Prevalence of avian influenza virus in atypical wild birds host groups during an outbreak of highly pathogenic strain EA/AM H5N1](#). *Transboundary and Emerging Diseases*, 4009552. doi: 10.1155/2024/4009552
- Ringenberg, J.M., K. Weir, T. Linder, and J. Lenocho. 2024. [Detections of rabbit hemorrhagic disease virus 2 \(RHDV2\) following the 2020 outbreak in wild lagomorphs across the western United States](#). *Viruses* 16(7): 1106. doi: 10.3390/v16071106
- Rockweit, J.T., K.M. Dugger, D.B. Lesmeister, R.J. Davis, A.B. Franklin, J.M. Higley. 2024. [Changing fire regimes and nuanced impacts on a critically imperiled species](#). *Biological Conservation* 296: 110701. doi: 10.1016/j.biocon.2024.110701
- Root, J.J., S.M. Porter, J.B. Lenocho, J.W. Ellis, and A.M. Bosco-Lauth. 2024. [Susceptibilities and viral shedding of peridomestic wildlife infected with clade 2.3.4.4b highly pathogenic avian influenza virus \(H5N1\)](#). *Virology* 600, 110231. doi: 10.1016/j.virol.2024.110231
- Root, J.J., and T. Gidlewski. 2023. Rabbit hemorrhagic disease. pgs 259-272. In: D.A. Jessup and R.W. Radcliffe, editors. [Wildlife disease and health in conservation](#). John Hopkins University Press, Baltimore, Maryland. 468 pp.
- Rosenblatt, E., J.D. Cook, G.V. DiRenzo, E.H.C. Grant, F. Arce, K.M. Pepin, F.J. Rudolph, M.C. Runge, S. Shriner, D.P. Walsh, and B.A. Mosher. 2024. [Epidemiological modeling of SARS-CoV-2 in white-tailed deer \(*Odocoileus virginianus*\) reveals conditions for introduction and widespread transmission](#). *PLoS Computational Biology* 20(7): e1012263. doi: 10.1371/journal.pcbi.1012263
- Rosypal von Dohlen, A., S. Randall, J. Grays, M.A. Dugo, B.J. Hunt, J. Brown, K. Van Why, S. Ammar, and R. Gerhold. 2024. [Rapid point-of-care testing for detection of antibodies to *Toxoplasma gondii* in black vultures and ring-billed gulls from Pennsylvania](#). *Journal of Parasitology* 110(3): 206-209. doi: 10.1645/24-24
- Sauve, C.C., A.R. Berentsen, S.F. Llanos, A.T. Gilbert, and P.A. Leighton. 2023. [Home range overlap between small Indian mongooses and free roaming domestic dogs in Puerto Rico: implications for rabies management](#). *Scientific Reports* 13: 22944. doi: 10.1038/s41598-023-50261-7
- Seetahal, J.F.R., M.F. Millien, A. Berentsen, S. Cheetham, M.S. Núñez-Novas, K. Douglas, J. Gonzales, and C.E. Rupprecht. 2024. [Origins and contemporary epidemiology of rabies in the Insular Caribbean](#). Pages 133-172 In: C. E. Rupprecht, editor. *History of Rabies in the Americas: From the Pre-Columbian to the Present*, Volume II. Fascinating Life Sciences. Springer, Cham. doi: 10.1007/978-3-031-25405-5_6
- Selleck, M.R., S.R. Johnson, and A.T. Gilbert. 2024. [Serological response to canine distemper vaccination in wild caught raccoons \(*Procyon lotor*\)](#). *Journal of Zoo and Wildlife Medicine*, 55(2): 462-465. doi: 10.1638/2023-0078
- Sherbrooke, W.C. and B.A. Kimball. 2024. [Antipredator blood-squirting defense in horned lizards \(*Phrynosoma*\): Chemical isolation of plasma component\(s\), *Pogonomyrmex* ant dietary origin, and evolution](#). *Ichthyology & Herpetology* 112(1): 106-116. doi: 10.1643/h2021139

- Shiels, A.B., E.W. Ruell, and J.E. Bruemmer. 2024. [Efficacy of GonaCon fertility control against prairie dogs and potential for uses on other rodent species](#). Proceedings of the Vertebrate Pest Conference 31. Paper No. 6, 5 pp. <https://escholarship.org/uc/item/2xr915qh>
- Shiels, A.B., J. Runte, E.W. Ruell, D.C. Eckery, G.W. Witmer, and D.J. Salked. 2023. [Treatment with the immunocontraceptive vaccine, GonaCon, induces temporary fertility control in free-ranging prairie dog populations in Colorado, USA](#). Wildlife Research 51: WR22135. doi: 10.1071/WR22135
- Siers, S.R., M.G. Nafus, J.E. Calaor, R.M. Volsteadt, M.S. Grassi, M. Volsteadt, A.F. Collins, P.D. Barnhart, L.T. Huse, A.A. Yackel Adams, and D.L. Vice. 2024. [Limitations of invasive snake control tools in the context of a new invasion on an island with abundant prey](#). NeoBiota 90: 1-33. doi: 10.3897/neobiota.90.103041
- Smyser, T.J., M.A. Hardy, A.J. Davis, W.L. Preston, and W.D. Tietje. 2024. [Downed wood removal effects on survival and site fidelity of woodrats in a California oak woodland](#). Journal of Wildlife Management 88: e22590. doi: 10.1002/jwmg.22590
- Smyser, T.J., P. Pfaffelhuber, R.M. Giglio, M.G. DeSaix, A.J. Davis, C.F. Bowden, M.A. Tabak, A. Manunza, V.A. Bâlteanu, M. Amills, et al. 2024. [Probabilistic genetic identification of wild boar hybridization to support control of invasive wild pigs \(*Sus scrofa*\)](#). Ecosphere 15(2): e4774. doi: 10.1002/ecs2.4774
- Snow, N.P., B. Smith, M.J. Lavelle, M.P. Glow, K. Chalkowski, B.R. Leland, S. Sherburne, J.W. Fischer, K.J. Kohen, S.M. Cook, H. Smith, K.C. VerCauteren, R.S. Miller, and K.M. Pepin. 2024. [Comparing efficiencies of population control methods for responding to introductions of transboundary animal diseases in wild pigs](#). Preventive Veterinary Medicine 233, 106347. doi: 10.1016/j.prevetmed.2024.106347
- Snow, N.P., M.P. Glow, J.A. Foster, and K.C. VerCauteren. 2024. [Seasonal efficacy and risks from a sodium nitrite toxic bait for wild pigs](#). Pest Management Science 80: 3227-3237. doi: 10.1002/ps.8025
- Streiker, D.G., M.E. Griffiths, R. Antia, L. Bergner, P. Bowman, M.V.D.S. de Moraes, K. Esvelt, M. Famulare, A. Gilbert, et al. 2024. [Developing transmissible vaccines for animal infections](#). Science 384: 275-277. doi: 10.1126/science.adn3231
- Treichler, J.W., K.C. VerCauteren, C.R. Taylor, and J.C. Beasley. 2023. [Changes in wild pig \(*Sus scrofa*\) relative abundance, crop damage, and environmental impacts in response to control efforts](#). Pest Management Science 79(12): 4765-4773. doi: 10.1002/ps.7671
- Turano, A., S.P. Brummer, J.T. Schultz, J.K. Young, and S.M. Freeman. 2024. [Internal and external factors affect pair mate proximity in captive coyotes, *Canis latrans*](#). Animal Behaviour 212: 49-62. doi: 10.1016/j.anbehav.2024.03.022
- VerCauteren, K.C. and S.W. Breck. 2024. [Overview of global wildlife-livestock interfaces: the array of conflicts and strategies to mitigate them](#). Animal Frontiers 14(1): 30-39. doi: 10.1093/af/vfad075

- VerCauteren, K.C., Pepin, K.M., Cook, S.M., et al. 2024. [What is known, unknown, and needed to be known about damage caused by wild pigs](#). *Biological Invasions* 26: 1313-1325. doi: 10.1007/s10530-024-03263-z
- Wahl M.L., G.N. Burcham, A.M. Herbert, L.A. Humberg, P.A. Zollner, L. R. Jones, B.M. Quinby, and B.M. Kluever. 2024. [Taphonomic signatures of early scavenging by black and turkey vultures](#). *PLoS ONE* 19(8): e0307610. doi: 10.1371/journal.pone.0307610
- Washburn, B.E. 2024. [Evaluation of mitigation translocation as a management tool to reduce conflicts between humans and American kestrels](#). *Wildlife Society Bulletin* 48:e1540. doi: 10.1002/wsb.1540
- Washburn, B. and M. Begier. 2024. [Using prescribed fire and biosolids applications as grassland management tools: Do wildlife respond?](#) *Fire*. 7(4):112. doi.org/10.3390/fire7040112
- Wolfson, D.W., P.E. Schlichting, R.K. Boughton, R.S. Miller, K.C. Vercauteren, and J.S. Lewis. 2023. [Comparison of daily activity patterns across seasons using GPS telemetry and camera trap data for a widespread mammal](#). *Ecosphere* 14(12): e4728. doi:10.1002/ecs2.4728
- Yang, A., R. Boughton, R.S. Miller, N.P. Snow, K.C. Vercauteren, K.M. Pepin, and G. Wittemyer. 2023. [Individual-level patterns of resource selection do not predict hotspots of contact](#). *Movement Ecology* 11: 74. doi: 10.1186/s40462-023-00435-9
- Youk, S., M.K. Torchetti, K. Lantz, J.B. Lenocho, M.L. Killian, C. Leyson, S.N. Bevins, K. Dilione, H.S. Ip, D.E. Stallknecht, R.L. Poulson, D.L. Suarez, and M.J. Pantin-Jackwood. 2023. [H5N1 highly pathogenic avian influenza clade 2.3.4.4b in wild and domestic birds: Introductions into the United States and reassortments, December 2021–April 2022](#). *Virology* 587: 109860. doi: 10.1016/j.virol.2023.109860
- Young, J.K., A.M. Mast, J.A. Walton, T. Rodgers, A.J. Piaggio, D.R. Taylor, and K.E. Mock. 2023. [Straight from the coyote's mouth: genetic identification of prey through oral swabs of predators](#). *Wildlife Biology* e01155. doi: 10.1002/wlb3.01155
- Zichello, J.M., S.T. DeLiberto, P. Holmes, A.A. Pierwola, and S.J. Werner. 2023. [Recent beak evolution in North American starlings after invasion](#). *Scientific Reports* 14: 140. doi: 10.1038/s41598-023-49623-y
- Zubiria Perez, A., K.F. Kellner, D.M. MacFarland, J.L. Price Tack, D.B. Ruid, G.E. Stauffer, and J.L. Belant. 2024. [Effects of lethal management on gray wolf pack persistence and reproduction in Wisconsin, USA](#). *Scientific Reports* 14: 9895. doi: 10.1038/s41598-024-60764-6

Appendix 1

List of 2024 NWRC Research Projects and Support Units

Developing and Evaluating Tools and Strategies
for CWD Detection and Management

Project Leader: Jennifer Malmberg

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

Management of Ungulate Damage and Disease:
Emphasis Feral Swine

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

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 in
Island Ecosystems

Project Leader: Steven Hess

Methods and Strategies To Manage Semi-
Aquatic and Terrestrial Rodent Damage 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 Pathogens, Agriculture, and One Health

Project Leader: Alan Franklin

Wildlife Disease Dynamics, Epidemiology,
and Response

Project Leader: Jeff Root

Human Dimensions

Unit Leader: Keith Carlisle

Regulatory Support Services

Unit Leader: Sarah Hibbs-Shipp

Laboratory Support Services

Unit Leader: Jeffrey Chandler

Information Services

Unit Leader: Mary Foley

Animal Care

Unit Leader: Elizabeth Falendysz

Administration

Unit Leader: Natalie Erhart

More information about these projects and units is available online: :

www.aphis.usda.gov/wildlifedamage/nwrc

Appendix 2

NWRC Research Contacts

NAME	CONTACT INFORMATION	AREAS OF EXPERTISE
Altringer, Levi	(970) 266-6060 levi.altringer@usda.gov	Economics
Blackwell, Bradley	(419) 625-0242 ext. 15 bradley.f.blackwell@usda.gov	Project Leader: Aviation safety, lighting systems
Breck, Stewart	(970) 559-8805 stewart.w.breck@usda.gov	Predator-prey relationships
Bruemmer, Jason	(970) 266-6035 jason.bruemmer@usda.gov	Project Leader: Population management, fertility control
Carlisle, Keith	(970) 266-6047 keith.m.carlisle@usda.gov	Unit Leader: Human dimensions
Chandler, Jeffrey	(970) 266-6090 jeffrey.c.chandler@usda.gov	Unit Leader: Laboratory support services
Christiansen, Jeffrey	(970) 266-6314 jeffrey.christiansen@usda.gov	Chronic wasting disease
Claunch, Natalie	(352) 448-2145 natalie.claunch@usda.gov	Invasive birds and reptiles
Cunningham, Fred	(662) 325-8612 fred.l.cunningham@usda.gov	Project Leader: Aquaculture, fish-eating birds
Davis, Amy	(970) 266-6313 amy.j.davis@usda.gov	Rabies, modeling
Dorr, Brian	(662) 325-8216 brian.s.dorr@usda.gov	Aquaculture, fish-eating birds
Drabik-Hamshare (Pfeiffer), Morgan	(419) 625-0242 morgan.b.drabik-hamshare@usda.gov	Aviation safety, drones, vultures
Erhart, Natalie	(970) 266-6033 natalie.erhart@usda.gov	Unit Leader: Administration; Administrative Officer
Falendysz, Elizabeth	(970) 266-6364 elizabeth.falendysz@usda.gov	Unit Leader: Animal care; Supervisory Attending Veterinarian
Foley, Mary	(970) 266-6023 mary.f.foley@usda.gov	Unit Leader: Library, web, archives
Franklin, Alan	(970) 266-6137 alan.b.franklin@usda.gov	Project Leader: Emerging infectious diseases, food safety

NAME	CONTACT INFORMATION	AREAS OF EXPERTISE
Gilbert, Amy	(970) 266-6054 amy.t.gilbert@usda.gov	Project Leader: Rabies
Goetz, Scott	(970) 266-6008 scott.goetz@usda.gov	Emerging infectious diseases, food safety
Haller, Kerry	(970) 266-6134 kerry.l.haller@usda.gov	Budget Supervisor
Hamby, Hayden	(970) 266-6230 hayden.hamby@usda.gov	Formulation chemistry
Hess, Steven	(808) 932-4751 steven.hess@usda.gov	Project Leader: Island invasives
Hibbs-Shipp, Sarah	(970) 266-6048 sarah.hibbs-shipp@usda.gov	Unit Leader: Regulatory Support Services; Technology Transfer
Horak, Katherine	(970) 266-6168 katherine.e.horak@usda.gov	Toxicology, pesticides
Kluever, Bryan	(352) 448-2130 bryan.kluever@usda.gov	Project Leader: Invasive species, birds, reptiles
Klug, Page	(701) 231-5190 page.e.klug@usda.gov	Project Leader: Bird damage to agriculture
Malmberg, Jennifer	(970) 266-6286 jennifer.malmberg@usda.gov	Project Leader: Chronic wasting disease
Maybon, Larry	(970) 266-6029 larry.maybon@usda.gov	Facilities Supervisor
Milholland, Matthew	(662) 325-8314 matthew.milholland@usda.gov	Aquaculture, fish-eating birds
Nicholas, Kellie	(970) 266-6065 kellie.r.nicholas@usda.gov	Bioarchivist
Parrie, Lindsay	(970) 266-6156 lindsay.parrie@usda.gov	Chronic wasting disease
Pepin, Kim	(970) 266-6162 kim.m.pepin@usda.gov	Modeling, quantitative ecology
Phillips, Aaron	(970) 266-5752 aaron.phillips@usda.gov	Wildlife Disease Diagnostic Laboratory Manager

NAME	CONTACT INFORMATION	AREAS OF EXPERTISE
Piaggio, Toni	(970) 266-6142 toni.j.piaggio@usda.gov	Project Leader: Genetics
Ranglack, Dustin	(435) 245-6091 dustin.ranglack@usda.gov	Project Leader: Predators
Robinson, Stacie	(970) 266-6134 stacie.robinson@usda.gov	Semi-aquatic rodents
Root, Jeff	(970) 266-6050 jeff.root@usda.gov	Wildlife diseases
Ruell, Emily	(970) 266-6161 emily.w.ruell@usda.gov	Registration Manager
Shiels, Aaron	(970) 266-6374 aaron.b.shiels@usda.gov	Project Leader: Rodents
Shwiff, Stephanie	(970) 266-6150 stephanie.a.shwiff@usda.gov	Project Leader: Economics
Siers, Shane	(671) 686-1334 shane.r.siers@usda.gov	Island invasives, brown treesnakes, Guam
Smith, Peter	(970) 266-6082 peter.smith2@usda.gov	Fertility control
Smyser, Timothy	(970) 266-6365 timothy.j.smyser@usda.gov	Genetics
Snow, Nathan	(970) 266-6041 nathan.p.snow@usda.gov	Feral swine
Sutliff, Aimee	(970) 266-6153 aimee.sutliff@usda.gov	Toxicology
Towner, Clint	(208) 236-6920 ws.psd@usda.gov	Pocatello Supply Depot Manager
VerCauteren, Kurt	(970) 266-6093 kurt.c.vercauteren@usda.gov	Project Leader: Feral swine, ungulates
Washburn, Brian	(419) 625-0242 ext. 12 brian.e.washburn@usda.gov	Aviation safety, bird movements, raptors
Werner, Scott	(970) 266-6136 scott.j.werner@usda.gov	Project Leader: Repellents

Appendix 3

Acronyms and Abbreviations

AIV	avian influenza virus	IAV	influenza A virus
APHIS	Animal and Plant Health Inspection Service	LED	light-emitting diode
ASF	African swine fever	NFSDMP	National Feral Swine Damage Management Program
AWHP	Airport Wildlife Hazards Program	NRMP	National Rabies Management Program
BAPs-MNBs	branched amphiphilic peptide-coated magnetic nanobeads	NWDP	National Wildlife Disease Program
BAS	Bio-Archive Storage	NWRC	National Wildlife Research Center
bTB	bovine tuberculosis	OBV	oral bait vaccine
CBD	cannabinoid	ORV	oral rabies vaccine
CSU	Colorado State University	PVC	polyvinyl chloride
CWD	chronic wasting disease	RNA	ribonucleic acid
DFTD	devil facial tumor disease	RRV	raccoon rabies virus variant
DNA	deoxyribonucleic acid	RT-QuIC	real-time quaking-induced assay
DWRC	Denver Wildlife Research Center	RV	rabies virus
eDNA	environmental DNA	RVNA	rabies virus neutralizing antibodies
ELISA	enzyme-linked immunosorbent assay	SARS-CoV-2	severe acute respiratory syndrome coronavirus 2
EPA	U.S. Environmental Protection Agency	TV	transmissible vaccine
FDA	U.S. Food and Drug Administration	TVR	trap-vaccinate-release
FRDD	free roaming domestics dog	TWS	The Wildlife Society
GnRH	gonadotropin-releasing hormone	URI	University of Rhode Island
GPS	global positioning system	USDA	U.S. Department of Agriculture
		WS	Wildlife Services



In accordance with Federal civil rights law and U.S. Department of Agriculture (USDA) civil rights regulations and policies, the USDA, its Agencies, offices, and employees, and institutions participating in or administering USDA programs are prohibited from discriminating based on race, color, national origin, religion, sex, disability, age, marital status, family/parental status, income derived from a public assistance program, political beliefs, or reprisal or retaliation for prior civil rights activity, in any program or activity conducted or funded by USDA (not all bases apply to all programs). Remedies and complaint filing deadlines vary by program or incident.

Persons with disabilities who require alternative means of communication for program information (e.g., Braille, large print, audiotape, American Sign Language, etc.) should contact the responsible Agency or USDA's TARGET Center at (202) 720-2600 (voice and TTY) or contact USDA through the Federal Relay Service at (800) 877-8339. Additionally, program information may be made available in languages other than English.

To file a program discrimination complaint, complete the USDA Program Discrimination Complaint Form, AD-3027, found online at [How to File a Program Discrimination Complaint](#) and at any USDA office or write a letter addressed to USDA and provide in the letter all of the information requested in the form. To request a copy of the complaint form, call (866) 632-9992. Submit your completed form or letter to USDA by: (1) mail: U.S. Department of Agriculture, Office of the Assistant Secretary for Civil Rights, 1400 Independence Avenue, SW, Washington, D.C. 20250-9410; (2) fax: (202) 690-7442; or (3) email: program.intake@usda.gov.

USDA is an equal opportunity provider, employer, and lender.

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

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

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

