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

Wildlife Services

Innovative Solutions to Human-Wildlife Conflicts

National Wildlife Research Center • Accomplishments, 2023

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/wildlifedamage/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

Cover: Animal research at the NWRC adheres to the highest standards in accordance with Federal and State laws, regulatory guidelines, and humane principles. *Photo by USDA Wildlife Services*

Message From the Director

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

Growing up in a rural area in Wisconsin, the great outdoors was my playground. I spent most of my free time tracking animals through the snow and mud, catching frogs in the farm pond and exploring the bird sounds in the woods behind our home. This love for nature grew into a lifelong career in natural resources and wildlife damage management.

Every Wildlife Services (WS) employee I know shares this passion and stewardship for wildlife. Whether they grew up in the city or a rural town, they are committed to protecting the health and sustainability of America's native wildlife and ecosystems.

In the United States, wildlife is a public trust resource. This means the government holds and manages wildlife, fish, and waterways for the benefit of the resources and the public. Our work is not always easy. WS is tasked with resolving human-wildlife conflicts, and our employees must seek a balance among a variety of priorities, including wildlife and environmental conservation, human health and safety, economic considerations, and social factors. We recognize the importance of careful decision-making, especially in the development, selection, and use of various wildlife damage management tools and methods.

WS-NWRC supports efforts to resolve wildlife damage issues by developing new tools and techniques that are environmentally safe, practical, cost effective, and socially acceptable. To do this, NWRC researchers conduct both field and laboratory studies. Some of these involve housing wild or laboratory animals in captive settings.

Our passion and stewardship for wildlife extends to those under our care. Our attending veterinarian and animal care specialists work with NWRC researchers and the Institutional Animal Care and Use Committee to ensure the safe care, handling, and study of research animals in the field and in captivity. Their efforts adhere to the highest standards in accordance with Federal and State laws, regulatory guidelines, and humane principles. You can learn more about our animal care activities and training in the Spotlight titled "Commitment to Animal Care" (page 5).

I'm proud of the work WS does every day. Not only does it ensure the long-term health of our Nation's valuable natural resources but also resolves issues that arise when wildlife and people come into conflict. It is a difficult balancing act, but a challenge for which our employees are well suited.

It is with pleasure that I present to you NWRC's 2023 research accomplishments.

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

This year's accomplishments report is dedicated in memory of NWRC's Attending Veterinarian Dr. Michael McBride and animal care specialist Adam Mitchell.

A black bear cub is sampled for SARS-CoV-2 in Wisconsin as part of WS' disease surveillance and research.
Photo by USDA Wildlife Services, Anna Schneider

Contents

Innovative Solutions to Human-Wildlife Conflicts

National Wildlife Research Center Accomplishments, 2023

Research Spotlights

NWRC's Animal Care Unit ensures the health and wellbeing of the captive animals housed at the Center for research purposes. This includes preparing food for hundreds of animals each day. *Photo by USDA Wildlife Services, Gail Keirn*

NWRC's Animal Care Unit is responsible for the feeding, housing, and overall health and wellbeing of captive animals at the Center's headquarters and field stations.

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

SPOTLIGHT

Commitment to Animal Care

NWRC supports WS' efforts to resolve wildlife damage management issues by developing new tools and techniques for use by Operations employees, stakeholders, and others. To do this, NWRC researchers conduct both field and laboratory studies. Some of which involve housing wild or laboratory animals in captive settings.

"On any given day, NWRC's headquarters campus and field stations may house several hundred individual animals for research purposes," states NWRC Supervisory Attending Veterinarian and Animal Care Unit Leader Dr. Michael McBride. "The Animal Care Unit is responsible for the feeding, housing, and overall health and well-being of these animals at our facilities."

To date, the NWRC headquarters campus has housed more than 90 different animal species ranging from acorn woodpeckers (*Melanerpes formicivorous*) to black-tailed prairie dogs (*Cynomys ludovicianus*) to Burmese pythons (*Python bivittatus*). In total, it's housed 37 species of birds, 30 species of mammals, 17 species of reptiles and amphibians, and 6 species of fish and invertebrates. That level of diversity requires McBride and his team to stay up to date on the latest information and practices related to animal care, welfare, and enrichment. The team is also trained in laboratory animal science and many team members are certified by the American Association for Laboratory Animal Science.

NWRC adheres to the Animal Welfare Act and works with the APHIS Animal Care Program to ensure the safe and humane handling and study of research animals. NWRC's Institutional Animal Care and Use Committee (IACUC) oversees the use of animals in research and is responsible for ensuring that the facility remains in compliance with the Animal Welfare Act.

NWRC also supports the "3Rs" philosophy regarding the use of animals in scientific experiments (Balls 2009[1]). The 3Rs stand for:

1. Refinement: Make refinements to minimize discomfort, distress, and pain to animals whenever possible.
2. Reduction: Use the minimum number of animals necessary to obtain valid results.
3. Replacement: Whenever feasible, replace animal experiments with non-animal experiments (e.g., mathematical models, computer simulations, and in vitro biological systems).

[1] Balls, M. 2009. T*he Three Rs and the Humanity Criterion: An abridged version of The Principles of Humane Experimental Technique* by WMS Russell and, RL Burch (1959). Published by The Fund for the Replacement of Animals in Medical Experiments, Russell & Burch House, 96-98 North Sherwood Street, Nottingham NG1 4EE, UK. 131 pp.

NWRC's animal care specialists are trained in laboratory animal science, and many are certified by the American Association for Laboratory Animal Science.
Photo by USDA Wildlife Services, Gail Keirn

"Working closely with NWRC researchers and IACUC, the Animal Care Unit ensures that captive animals are well cared for, and the animal research at the Center adheres to the highest standards in accordance with federal and state laws, regulatory guidelines, and humane principles," states McBride.

The following sections highlight the NWRC Animal Care Unit's animal enrichment and employee training activities.

Enrichment for Black Rats

The Animal Care Unit has an extensive enrichment program designed to encourage natural and problem-solving behaviors in NWRC's captive animals," notes animal care specialist Kirsten Bird. "We provide the animals with unique foods, puzzles, natural materials for manipulation and nest building, and appropriate social housing to ensure they are not only healthy, but also remain alert and engaged with their surroundings. We provide quality care to the animals so that we have quality animals for research."

The black rat (*Rattus rattus*) is one of the most damaging invasive species to agriculture and natural ecosystems. Due to numerous human-wildlife conflicts involving the black rat, NWRC maintains a small population of captive black rats for research purposes.

NWRC's Animal Care Unit constructed playpen enclosures for the black rat breeding colony based on scientific literature suggesting that the domesticated laboratory rat (*Rattus norvegicus*) had significant benefits and improvements in their welfare when the animals were offered time to explore, exercise, and socialize in recreational secondary enclosures.

Animal Care technicians converted commercially available caging into six playpens for the black rats. Large plastic cement mixing tubs were inserted into the bottom of each playpen as a barrier to contain a layer of substrate within the playpen. Various boxes, nesting materials, hides, wooden bird perches, and other items were added to each playpen as additional enrichment. A feeding station was incorporated into each setup to ensure unlimited food and water were available.

"Unlike domesticated laboratory rats, the black rats at NWRC are descended from wild-caught individuals and generally do not tolerate human interaction or handling," states McBride. "Over time, however, the rats became habituated and accustomed to entering and exiting a 'transfer box' which consisted of a plastic box with a small sliding door."

The goal for the enclosure-to-playpen transfer process was to allow the rats to voluntarily choose to enter the transfer box when it was placed next to them. Once a rat entered the transfer box, the door on the box was securely closed and the rat was moved into the playpen. The same technique was applied when retrieving a rat from a playpen.

Offering the rats time to explore within a large, enrichment-filled playpen allows them to express natural behaviors, such as jumping, running, climbing, creating multiple food caches, and interacting with and manipulating large, moveable objects, which may not be achievable within a standard enclosure. Increasing opportunities for captive animals to express natural behaviors improves their overall mental and physical fitness and supports more accurate and dependable research findings.

Immobilization and Euthanasia Training for WS Employees

In his role as Attending Veterinarian, McBride works with experts at the WS National Training Academy to provide animal immobilization and euthanasia (I&E) training to WS researchers and Operations employees. Most of the substances used to immobilize and euthanize wildlife are regulated by Federal and State laws because of the potential hazards to animals and humans and the potential for substance abuse. Only properly trained WS personnel are certified to possess and use WS-approved I&E drugs.

WS recognizes chemical immobilization as an important tool for wildlife management. It can be a very effective and safe tool for:

- Handling potentially dangerous species, such as large carnivores and ungulates;
- Reducing stress during lengthy procedures, such as radio-collaring or sample collection;
- Minimizing pain and suffering to an injured animal; and
- Capturing and moving free-ranging animals.

Chemical immobilization also provides humane options for euthanasia. When euthanasia is necessary to resolve a wildlife damage management problem, the primary goal is to alleviate or prevent the animal's pain and suffering.

"We are responsible for handling each captured animal with care and respect," states McBride. "Immobilizing drugs add one more variable to an already challenging field operation. They introduce additional physiological challenges to the animal, such as decreased ability to thermoregulate and slower respiration when oxygen demands may be high. Therefore, our personnel must know and shoulder the added responsibilities of patient monitoring and care."

WS I&E training includes an overview of legal responsibilities, policies, and WS-approved I&E drugs. It also provides instruction on the use of personal protective equipment and drug delivery systems, as well as how to calculate drug dosages, handle immobilized animals, and dispose of biohazardous materials.

Next Steps—NWRC's Animal Care Unit continues to work with NWRC researchers and WS leadership to identify new and innovative animal care and veterinary approaches for use in wildlife damage management and research.

SPOTLIGHT

Supporting Wildlife Disease Research and Surveillance

The NWRC Laboratory Support Services Unit provides laboratory expertise and services related to analytical chemistry, microbiology, and product formulation to researchers, as well as WS Operations employees and stakeholders. Examples of this work include analyzing and measuring pesticide residues in animals and the environment; detecting and characterizing pathogens of wildlife; and developing and producing products, such as toxicants and vaccines.

In 2023, the Unit expanded its disease diagnostic capabilities with the founding of the Wildlife Disease Diagnostics Laboratory. This state-of-the-art laboratory provides a wide range of diagnostic services and expertise to WS, partnering agencies, stakeholders, and academia.

Its cooperative agreements with the University of Wyoming allows for additional diagnostic testing surge capacity and wildlife-focused disease diagnostics.

Below are recent accomplishments related to the NWRC Laboratory Support Services Unit's wildlife disease research, diagnostics, and associated infrastructure.

Protecting Deer from Bovine Tuberculosis

In North America, bovine tuberculosis (bTB, caused by *Mycobacterium bovis*) is recognized as a disease of cattle and deer. The Cooperative State-Federal Tuberculosis Eradication Program comprised of the USDA, State animal health agencies, and livestock producers has nearly eliminated *bTB* from cattle in the United States. However, wild white-tailed deer (*Odocoileus virginianus*) remain a maintenance host for *M.*

USDA Deputy Secretary Torres Small tours NWRC's new Wildlife Disease Diagnostics Laboratory.
Photo by USDA Wildlife Services, Gail Keirn

Advances in technology and infrastructure are helping NWRC researchers to develop systems and tools for detecting, monitoring, and managing wildlife disease.

bovis in some locations, and thus represent a barrier for bTB eradication.

"Efforts to eradicate bTB from the United States would be enhanced by optimizing the delivery of the bTB vaccine to wild white-tailed deer," states formulation chemist Dr. Hayden Hamby. "Currently, vaccine delivery to wild deer is impractical as it requires capturing and handling the animal."

Hamby worked closely with other NWRC researchers and the USDA National Animal Disease Center to develop a novel approach for delivering the bTB vaccine to wild deer. Rather than direct administration, the team encapsulated the vaccine in an edible polymer (*provisional patent filed*) which is coated with a mixture of alfalfa. This product can be deployed in the field as an edible bait, eliminating the need for animal handling. Initial studies found that deer receiving the vaccine via the edible polymer had comparable immunological responses to those receiving the vaccine directly.

"Next steps are to deploy encapsulated vaccine baits in a large field study and monitor bait uptake using camera traps. This study will serve as a proof of concept for operational bTB vaccine deployment," states Hamby.

Animal Reservoirs of SARS-CoV-2

Multiple studies have detected severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2, the virus that causes COVID in people) in farmed, domestic, zoo, and wild animals. It is possible that multiple animal species could become reservoirs of the virus resulting in the potential evolution of novel virus variants.

NWRC formulation chemists developed a novel approach for delivering the bTB vaccine to wild deer. Rather than direct administration, the vaccine is encapsulated in an edible polymer.
Photo by USDA Wildlife Services, Abigail Feuka

"It is not practical or feasible to use animal models to assess SARS-CoV-2 infectivity with all potential hosts. This requires the development of alternative strategies to evaluate host susceptibility of SARS-CoV-2 in wildlife," states Laboratory Support Services Unit Leader and microbiologist Dr. Jeffrey Chandler. "NWRC is partnering with the University of Missouri to explore the molecular mechanisms that allow SARS-CoV-2 to infect the host cells of multiple high-priority wildlife species. A better understanding of these mechanisms allows us to rapidly screen a variety of species and predict whether they will be susceptible to a particular SARS-CoV-2 variant."

Previous studies identified that the host cellular surface receptor ACE2 and protease TMPRSS2 are key mediators of the SARS-CoV-2 infection process. The structure and composition of host receptors and proteases varies between animal species and tissue types, resulting in different

binding affinities and activation potentials of SARS-CoV-2 variants.

To date, the research team has evaluated the binding interactions of host receptors from 11 priority wildlife species with six SARS-CoV-2 variants. Additionally, studies are underway to identify new characteristics of host animal species that could impact SARS-CoV-2 infection.

Results from this effort will be used to inform SARS-CoV-2 surveillance strategies in targeted wildlife populations. The information and laboratory processes produced in this effort will also aid in host susceptibility screening efforts for other existing and emerging pathogens.

NAHLN Affiliation and ISO Accreditation

The National Animal Health Laboratory Network (NAHLN) is a group of approximately 60 Federal, State, and university laboratories specializing in animal disease diagnostics. The NAHLN is essential to protecting animal health, public health, and the Nation's food supply from microbial pathogens by supporting animal disease surveillance, response to emerging events, and facilitating communication of diagnostic outcomes to decision makers.

NWRC's Wildlife Disease Diagnostic Laboratory is in the process of becoming a NAHLN Affiliate Laboratory. Affiliate laboratories are publicly funded laboratories that perform testing which is synergistic with NAHLN objectives. Additionally, these laboratories may provide surge capacity for NAHLN laboratory testing. WS' participation in the NAHLN further advances APHIS' One Health approach.

"NAHLN serves as a vital system for monitoring and surveillance of animal diseases, such as highly pathogenic avian influenza and SARS-CoV-2," states Chandler. "Wildlife Services has a vast reach and a unique capability to assess infectious diseases of wildlife. Support of this critical mission is enhanced through the integration of our laboratory into the NAHLN."

In conjunction with NAHLN application, NWRC's Wildlife Disease Diagnostic Laboratory is pursuing ISO 17025 accreditation. This accreditation is an internationally recognized standard for laboratory proficiency and data quality. Obtaining this credential will provide added assurance to WS partners and stakeholders in the robustness of the laboratory's results.

Bioarchive Storage Facility

In addition to expanding its collaborations, staffing, and laboratory capabilities for microbial diagnostics and infectious disease research, NWRC broke ground on a new bioarchive storage facility in 2023 to house wildlife tissue and serum samples.

"In 2005, Wildlife Services established a wildlife tissue and serum archive. The collection is unique in its quantity, diversity, and broad geographic range of samples and reached its capacity at its current location," states NWRC bioarchivist Kellie Nicholas. "The new 7,300 square foot bioarchive storage facility with a capacity for 110 ultracold freezers incorporates the existing collection and serves as a national storage and clearinghouse for future wildlife tissue, blood, and other biological samples for research purposes."

The 2020 SARS-CoV-2 pandemic brought to focus the need to maintain and expand WS' bioarchive capabilities. At that time, NWRC researchers were able to analyze archived blood samples from white-tailed deer in Illinois, Michigan, New York, and Pennsylvania from 2011 to 2020, before SARS-CoV-2 was detected in the United States. They quickly determined that deer in the United

NWRC broke ground on a new bioarchive storage facility in 2023. It serves as a national storage and clearinghouse for wildlife tissue, blood, and other biological samples for research purposes.
Photo by USDA Wildlife Services, Kellie Nicholas

States had not been exposed to the virus prior to the pandemic. The archived samples were invaluable in this retrospective study and helped experts determine when U.S. deer were first exposed.

The bioarchive includes hundreds of thousands of samples from many species from across the United States, Puerto Rico, Guam, and the U.S. Virgin Islands. Examples include serum and tissue samples from animals, including waterfowl, carnivores, and invasive species, such as feral swine (*Sus scrofa*), as well as samples collected for surveillance of SARS-CoV-2, chronic wasting disease, plague, tularemia, and avian influenza in wildlife populations.

Agencies and organizations that are interested in contributing to or using the samples in the bioarchives can contact NWRC at nwrc@usda.gov.

Next Steps— The NWRC Laboratory Support Services Unit will continue to expand the diversity, scope, and scale of its analytical and microbiological testing services. Key areas include developing analytical workflows to detect and quantify multiple toxicants in various mediums and expanding testing capabilities for avian influenza virus and African swine fever virus. Other research efforts include the development of new microbial diagnostic tools for APHIS-priority pathogens; supporting basic research and assessing environmental risks associated with rodenticides; and formulating baits for vaccine, biomarker, and toxicant delivery to wildlife.

SPOTLIGHT

Human Dimensions of Wildlife Damage Management

Human dimensions of wildlife damage management is an applied social science that arose from social psychology. It helps to inform wildlife policy and management by studying how people value wildlife and their preferences for how wildlife is managed. Human dimensions researchers also study how people are impacted by management decisions and if efforts by the government, non-profit organizations, the private sector, and others create opportunities or barriers when addressing a particular wildlife damage management issue.

"Although WS-NWRC's Human Dimensions Unit was formally created in 2022, the Center has been collaborating for years with universities, State and Federal agencies, and others to better understand people's perceptions and values associated with wildlife and wildlife damage management," states NWRC supervisory social scientist and Human Dimensions Unit Leader Dr. Keith Carlisle.

Wildlife value orientations are described as people's basic beliefs and relationships to wildlife. They are expressions of our fundamental

In the United States, the number of citizens who believe wildlife should be managed for the benefit of people is decreasing. This will shape the future of wildlife damage management.
Photo by Adobe Stock

values that are formed early in our lifetimes and tend to be stable throughout our lives. Human dimensions researchers classify people into one of four value orientations. They include the following:

1. Traditionalists – People who believe wildlife should be managed for the benefit of people.
2. Mutualists – People who believe wildlife is part of our extended family with the same rights as people.
3. Pluralists – People who may express more traditionalist or mutualist views depending upon the issue or situation.
4. Distanced – People who are disengaged from and disinterested in wildlife.

A 2004-2018 collaborative effort called the "America's Wildlife Values" project led by researchers at Colorado State University found that mutualists make up the largest segment of the U.S. population at 35 percent. Between 2004 and 2018, they determined that the percentage of mutualists in 19 western states increased by 5 percent, while traditionalists decreased by 6 percent.

"As society moves away from more rural and agrarian lifestyles to more urban lifestyles, we are seeing a shift away from traditionalists towards more mutualists," states Carlisle. "Such trends are important for us to understand as they will shape the future of wildlife damage management."

NWRC's Human Dimensions Unit researchers use both quantitative and qualitative methods, such as surveys, interviews, and focus groups, (under the guidance of the Paperwork Reduction Act of 1980) to collect information and gather a deeper understanding of an issue.

The following highlights recent NWRC studies related to human dimensions and wildlife damage management.

Livestock Producer Perceptions of Nonlethal Management Methods

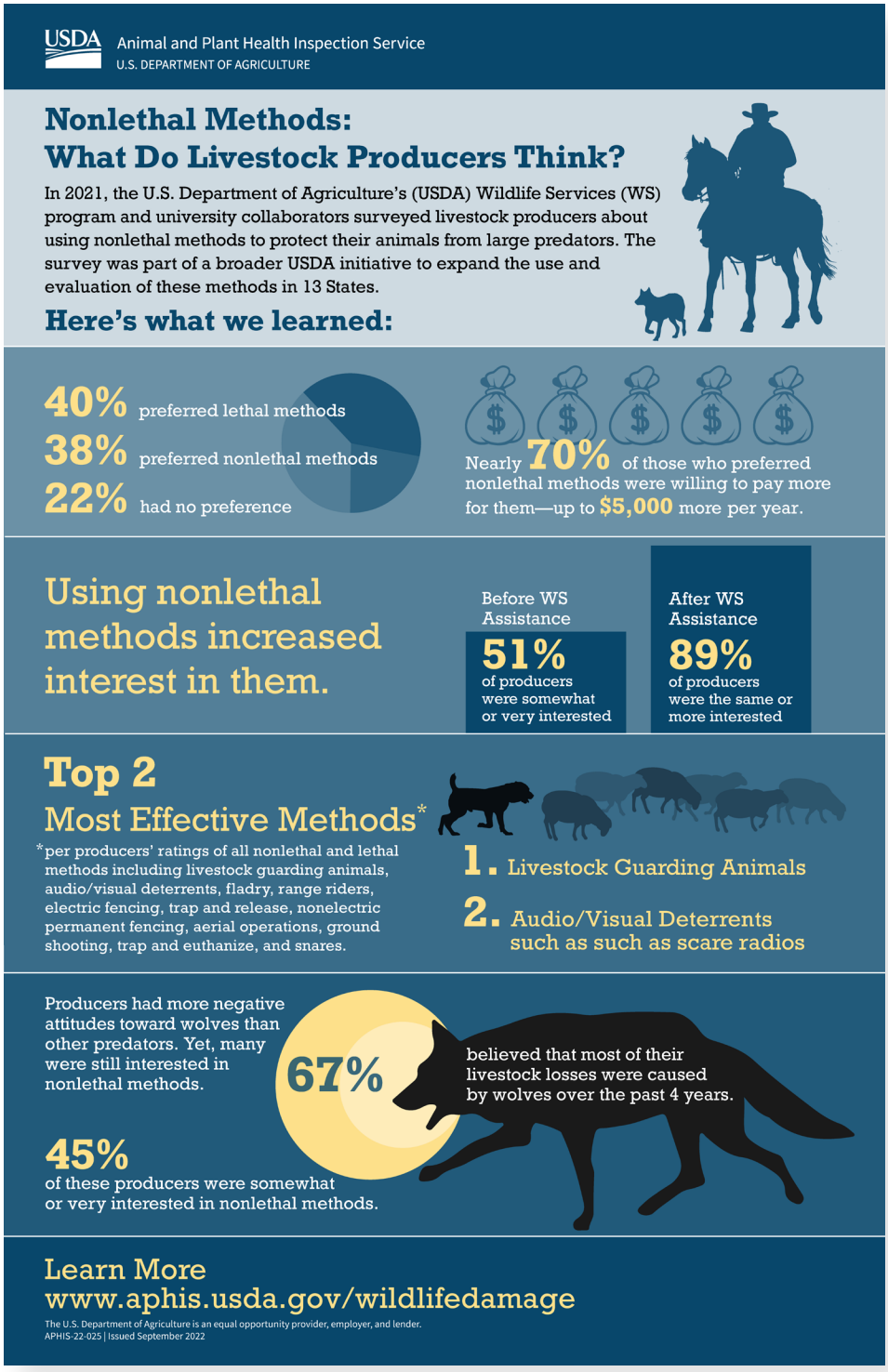
In the United States, predator-livestock conflict is a concern for livestock producers. While coyotes (*Canis latrans*) are responsible for most predator-related losses of livestock, producers also worry about impacts to their animals' health and wellbeing by other larger carnivores, such as wolves (*Canis lupus*), bears and mountain lions (*Puma concolor*).

Since 2020, WS has received Congressional funding to expand its research and increase the implementation of nonlethal livestock protection projects in multiple States. Informally called the "WS Nonlethal Initiative," these funds support the increased use and evaluation of a variety of methods and tools, such as range riding, fladry, guard dogs, and electric fencing. More recently, Congress has increased the Initiative's funding and expanded its activities to include beaver damage management and research.

"To increase WS' understanding of our cooperators' perceptions of nonlethal predator control methods, we worked with university partners to survey livestock producers in participating States," notes Carlisle. "What we found was surprising."

Results from surveys in 2021 showed that 40 percent of producers preferred lethal methods,

Effective wildlife damage management requires an understanding of how people perceive and value wildlife and associated management practices.



A 2022 infographic summarizing livestock producers' thoughts and perceptions regarding the use of nonlethal predator control methods.
USDA Wildlife Services

compared to 38 percent who preferred nonlethal, and 22 percent who had no preference. Nearly 70 percent of producers who preferred nonlethal methods were willing to pay up to $5,000 more per year to use those methods. Producers also rated livestock guarding animals and audio/visual deterrents as the most effective methods out of all nonlethal and lethal methods listed.

WS continues to learn from livestock producers who are receiving assistance as part of the WS Nonlethal Initiative. In 2023, producers in 11 States in the West and Midwest were identified for more in-depth interviews. Through these conversations, researchers are gathering detailed information about producers' personal experiences, beliefs, and attitudes towards large predators and their management, particularly the methods and tools livestock producers have deployed in cooperation with WS Operations. Results will improve the efficacy of nonlethal tools used by WS staff and livestock producers seeking to protect livestock and livelihoods from conflict with large predators.

Hunter Acceptability of Feral Swine Management Methods

Management of invasive feral swine may be controversial. It sometimes involves conflicts among stakeholders and wildlife agencies, who may have differing attitudes toward the topic. This can often create a barrier to effectively address the problem.

"Federal, State, and private entities have developed management tools and methods to control feral swine populations and reduce their damage," states Carlisle. "These include nonlethal methods, such as fencing, and lethal methods, such as trapping and aerial operations. People's thoughts and attitudes about these methods vary. For example, hunters, farmers, and the public all typically hold negative attitudes toward feral swine, yet hunters may have greater tolerance for the species and less acceptance of elimination strategies because hunters enjoy hunting feral swine, and some may profit from the activity."

NWRC, Colorado State University, and Texas A&M University human dimensions researchers investigated the acceptability of various feral swine control methods by registered hunters in Texas and whether their acceptability varied according to their affiliation with agriculture, hunting, conservation, or no natural resource organization.

Results from more than 37,000 survey respondents revealed that most hunters were accepting of all control actions except toxicants and nonlethal deterrents. This suggests that most hunters accept the need for feral swine control in Texas and would be supportive of most control actions. Hunters affiliated with agricultural organizations were the most accepting of control actions, while hunters with no organizational affiliations were least accepting. Notably, however, most hunters preferred that feral swine populations be reduced but not eliminated in Texas, with a small segment of hunters preferring that feral swine populations increase.

Findings suggested that while the type of organization with which a hunter affiliates provides some basis for predicting acceptability of control actions, the association is likely not significant enough to warrant differentiating feral swine outreach messaging based on affiliation.

Benefits of Social Networks in Feral Swine Management

Collaboration among various stakeholders is crucial to solving challenging wildlife damage management issues. Missouri has successfully generated the political will and resources to mount a sustained campaign towards eliminating invasive feral swine in the State.

To help understand and learn from the State's success, NWRC and Colorado State University human dimensions researchers partnered with the WS National Feral Swine Damage Management Program (NFSDMP) to conduct a social network analysis of feral swine policy, research, and management in Missouri. A social network analysis is a method used to measure, map, and analyze the attributes of individuals, groups, or organizations within a network.

"In Missouri, there are numerous people and organizations involved in feral swine management issues," states Colorado State University research social scientist Hailey Ellis. "We wanted to identify which individuals and organizations serve as major communication hubs on feral swine issues and determine patterns of communication and collaboration within the network. Understanding these links helps us to identify effective ways for generating collective action among stakeholders."

The study identified a total of 20 organizations and 141 individuals, representing State and Federal government, nonprofit, academia, and industry sectors. Among respondents, nearly all agreed (91 percent) that feral swine should be eliminated in Missouri, and a large majority (72 percent) felt that their organizations had a significant amount of influence on feral swine management decisions in the State. All respondents agreed that feral swine management in the State had achieved some level of success. This indicates that members of the network have a unity of purpose and agreement and may be able to focus more of their efforts on developing and implementing strategies rather than negotiating conflicts.

In addition, the study identified 15 "information brokers" who linked organizations on feral swine management issues that otherwise may not have been in communication with one another.

Of those 15 individuals, 7 were employed by WS, and 3 were employed by the Missouri Department of Conservation. Researchers note it is likely that having relatively few brokers in the network may lead to network fragmentation if these individuals no longer hold these roles and that it is valuable to have and maintain brokers from multiple organizations.

Results from the social network analysis lay the foundation for the current phase of this research. NWRC's Human Dimensions Unit researchers are interviewing wildlife managers and decision-makers in Missouri to determine whether there are practices, policies, or processes in Missouri that can benefit other States in their approaches to feral swine policy and management.

Next Steps—Ongoing Human Dimensions Unit studies include a survey of hunters and members of the public in five States to measure awareness of State restrictions on transporting and releasing feral swine, a practice that has led to expansion of feral swine populations. Researchers are also collaborating with multiple universities to learn how the SARS-CoV-2 virus has been able to spill over from people to white-tailed deer populations. The researchers plan to use both qualitative and quantitative methods to identify how people are interacting with white-tailed deer in selected urban, exurban, and rural locations and to model the risk of SARS-CoV-2 transmission. Another collaboration with the University of Minnesota plans to develop a hunter-based chronic wasting disease surveillance program on the White Earth Native American Reservation in northwestern Minnesota.

To solve challenging wildlife damage management issues, collaboration is crucial. Numerous organizations in Missouri work on feral swine management and hold group training sessions. Such collaborations may be key to Missouri's efforts to eliminate feral swine in the State. *Photo by Adobe Stock*

2023 Accomplishments in Brief

WS biologists collect fish samples on Midway Atoll as part of an environmental monitoring effort. The information will be used to assess the effects of a multi-agency rodent eradication on the island's native species.

Photo by USDA Wildlife Services, Carmen Antaky

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

WS NWRC employs about 150 scientists, technicians, and support staff who are currently devoted to 16 research projects and 6 support units (see Appendix 1). Below are additional summaries of select findings and accomplishments from 2023.

Devices

- **Novel Feeder for Delivering Chemical Agents to Invasive Parakeets.** Monk parakeets (*Myiopsitta monachus*) are among the most invasive bird species worldwide. In their introduced range, their populations have caused negative impacts on native species and habitats, economies, and human safety. Chemical agents, such as toxicants and contraceptives, are being explored as possible methods to control invasive monk parakeet populations but they must be delivered in a way that prevents access by nontarget animals. NWRC and Texas A&M University-Kingsville researchers designed and tested a parakeet-selective feeder. The feeder allows access to bait by parakeets and limits access by nontarget species by lowering a wire exclusion curtain around the feeder. Only birds with a zygodactyl toe arrangement (two toes facing forward and two toes facing backward) can maneuver under the curtain and access the bait. The feeder was tested in a series of trials with captive and free-ranging monk parakeets and nontarget bird species in Florida. Monk parakeets successfully accessed food from the parakeet-selective feeder throughout the study. The mean number of daily feeder uses

NWRC and Texas A&M University-Kingsville researchers designed and tested a parakeet-selective feeder. The feeder allows access to bait by invasive parakeets and limits access by nontarget species by lowering a wire exclusion curtain around the feeder.
Photo by USDA Wildlife Services, Eric Tillman

by nontarget species decreased from a high of nearly 16 uses per day when the exclusion curtain was not used to less than 1 use per day when the curtain was in place. Findings suggest the parakeet-selective feeder is a promising tool for delivering bait treated with chemical control agents to manage monk parakeets and other nonnative parakeet populations, but its success may vary by target species, location, local animal diversity, and availability of alternative forage.

Contact: Bryan Kluever

Pesticides

- **Development of a New Toxicant for Invasive Mongoose.** Small Indian mongooses (*Urva auropuncta*) are invasive to the United States and currently established on Hawaii, Puerto Rico, and the U.S. Virgin Islands. Mongooses pose a threat to the eggs and nestlings of native ground-nesting birds and other native species. Mongooses also pose a health risk to people. They carry leptospirosis in Hawaii and the Caribbean, and they are a rabies reservoir in the Caribbean. Trapping is the primary method for mongoose control but has limitations. In addition to trapping, toxicants can improve ongoing mongoose control programs and enhance rapid response to new invasions. Since 2018, NWRC researchers and Regulatory Support Services Unit experts have worked to develop and register a new toxic bait for mongooses. Efforts have included the following activities.

STUDY	RESULTS
Evaluated the efficacy and palatability of 10 commercially available rodenticide baits, as well as fresh minced chicken formulations of technical diphacinone powder and two other acute toxicants.	Overall, consumption of the 10 commercial rodenticide products was low while consumption of the toxicants mixed with fresh minced chicken was high by captive mongooses.
Conducted a feasibility assessment comparing the registration potential of four efficacious active ingredients: bromethalin, diphacinone, para-aminopropiophenone (PAPP), and sodium nitrite.	Of the four active ingredients, diphacinone has the most registration potential for use with mongooses because it is a registered active ingredient in rodenticides, is registered for use in bait stations for mongooses, has the lowest risk to nontarget species, and has an antidote (vitamin K).
Evaluated the palatability of four potential bait matrices that were previously developed or are in development for other carnivore and omnivore pest species.	A fish-based bait matrix was selected for use with mongooses because of its palatability, stability, and ease-of-use.
Tested the fish-based bait matrix combined with 0.005% diphacinone in trials with wild-caught mongooses.	Eighty-five percent of the mongooses that ate the diphacinone bait died. In January 2022, APHIS submitted an Experimental Use Permit application to the U.S. Environmental Protection Agency (EPA) for a product performance field study in Hawaii to support the registration of a new toxic bait called Fish-based Bait for Mongooses. EPA approved the permit in 2023.
Testing the efficacy of Fish-based Bait for Mongooses on free-ranging mongooses in Hawaii and safety for non-target species to support national registration of the product.	Ongoing. Field trials under an Experimental Use Permit are planned for 2024 at three sites on the Hawaii Island and Oahu.

In addition to their bait formulation, development, and registration efforts, NWRC experts are evaluating bait station designs to better target mongooses, reduce bait consumption by rodents, and exclude other nontarget species, such as native Hawaiian birds.

Contact: Steve Hess

Other Chemical and Biological Methods

- **Evaluating a Novel RHDV2 Vaccine.** In 2010, a new *Lagovirus* named rabbit hemorrhagic disease virus 2 (RHDV2) emerged in France and has since been detected in many European countries, North America, the Middle East, North Africa, Australia, and New Zealand. It is fatal to European rabbits (*Oryctolagus cuniculus*). Previous NWRC studies with captive eastern cottontails (*Sylvilagus floridanus*) showed the species is susceptible to RHDV2 and can shed viral RNA, thereby suggesting this North American species could be involved in the epidemiology of this virus. NWRC and Colorado State University researchers partnered with Medgene Labs to test a novel vaccine against RHDV2 in domestic rabbits. Twenty-six New Zealand white rabbits were vaccinated with either a placebo or an inactivated (killed) baculovirus-derived recombinant subunit vaccine, directed at eliciting an immune response to the immunogenic VP60 protein of RHDV2 (*patent pending*). After 35 days, a total of 22 rabbits were challenged orally with RHDV2 and monitored for 10 days. None of the vaccinated animals exhibited clinical disease or mortality following infection with RHDV2 while 69 percent of the placebo animals succumbed to lethal disease following infection. Outside of emergency use, there are currently no licensed vaccines against RHDV2 on the market in the United States. This vaccine candidate would provide an option for controlling this disease.

  Contact: Jeff Root

- **Identifying Vulture Species and Individuals from Pellets.** NWRC geneticists have developed a novel method for identifying vulture species and individuals at roost sites from regurgitated vulture pellets. Like owls, vultures regurgitate (spit up) a pellet of indigestible material, such as bones and fur. The pellet also contains deoxyribonucleic acid (DNA) from the vulture. By analyzing the DNA in the pellet, researchers can gather critical population data and conduct mark-recapture, population structure, relatedness, and movement studies. The method adds to a suite of tools for vulture management. It also encourages the use of pellets for noninvasive

Vulture pellets (pictured) contain valuable DNA that is being used to determine vulture species and individuals at roosts and other locations.
Photo by USDA Wildlife Services

Nutria are an invasive, semiaquatic rodent species in the United States. NWRC geneticists validated a new method for detecting nutria DNA in water samples which aids in locating the animals for removal.
Photo by USDA Wildlife Services, Daniel Dawson Jr.

genetic sampling of other species that regurgitate pellets, such as raptors, water birds, and shorebirds.

Contact: Toni Piaggio

- **Development of a Gene Drive to Suppress Invasive Mice.** Invasive rodents pose a significant threat to global biodiversity, contributing to countless extinctions, particularly on islands. Genetic biocontrol (i.e., techniques used to alter the genetic material of an organism), has potential to control invasive populations, but has not been developed in vertebrates. A NWRC geneticist collaborated with scientists in Australia, at several universities, and non-governmental organizations to develop a suppression gene drive strategy (tCRISPR) in laboratory mice. The strategy uses a modified naturally occurring genetic element (t haplotype) to spread faulty copies of a female fertility gene that decreases the number of fertile females in a population. Researchers used complex simulation modeling of the strategy with island mice populations and showed that population eradication can occur. This work marks a significant laboratory development of a gene drive for the suppression of invasive wild mice. Although genetic biocontrol strategies including gene drives have considerable potential, their development must proceed with utmost caution; be informed by comprehensive risk assessments; have phased testing with a step-by-step approach; and have respectful engagement with stakeholders, publics, and the general community, as well as with regulatory authorities.

  Contact: Toni Piaggio

- **Validating an eDNA Assay for Invasive Nutria.** Nutria (*Myocastor coypus*) are an invasive, semiaquatic rodent species in the United States. NWRC geneticists validated the specificity, generality, and sensitivity of a quantitative polymerase chain reaction (qPCR) assay previously described for use in Japan using two environmental DNA (eDNA) sampling methodologies for application in the United States. These methods included field filtration of large volumes of water and direct sampling of small volumes of water. Researchers also successfully tested the assay

on a known wild nutria population in Oregon. Results showed that the filtration method required fewer samples for eDNA detection than the direct sampling. However, the choice of methods should consider specific field conditions, as well as time and budget tradeoffs. Researchers conclude the assay can be applied to eDNA monitoring of nutria throughout the United States.

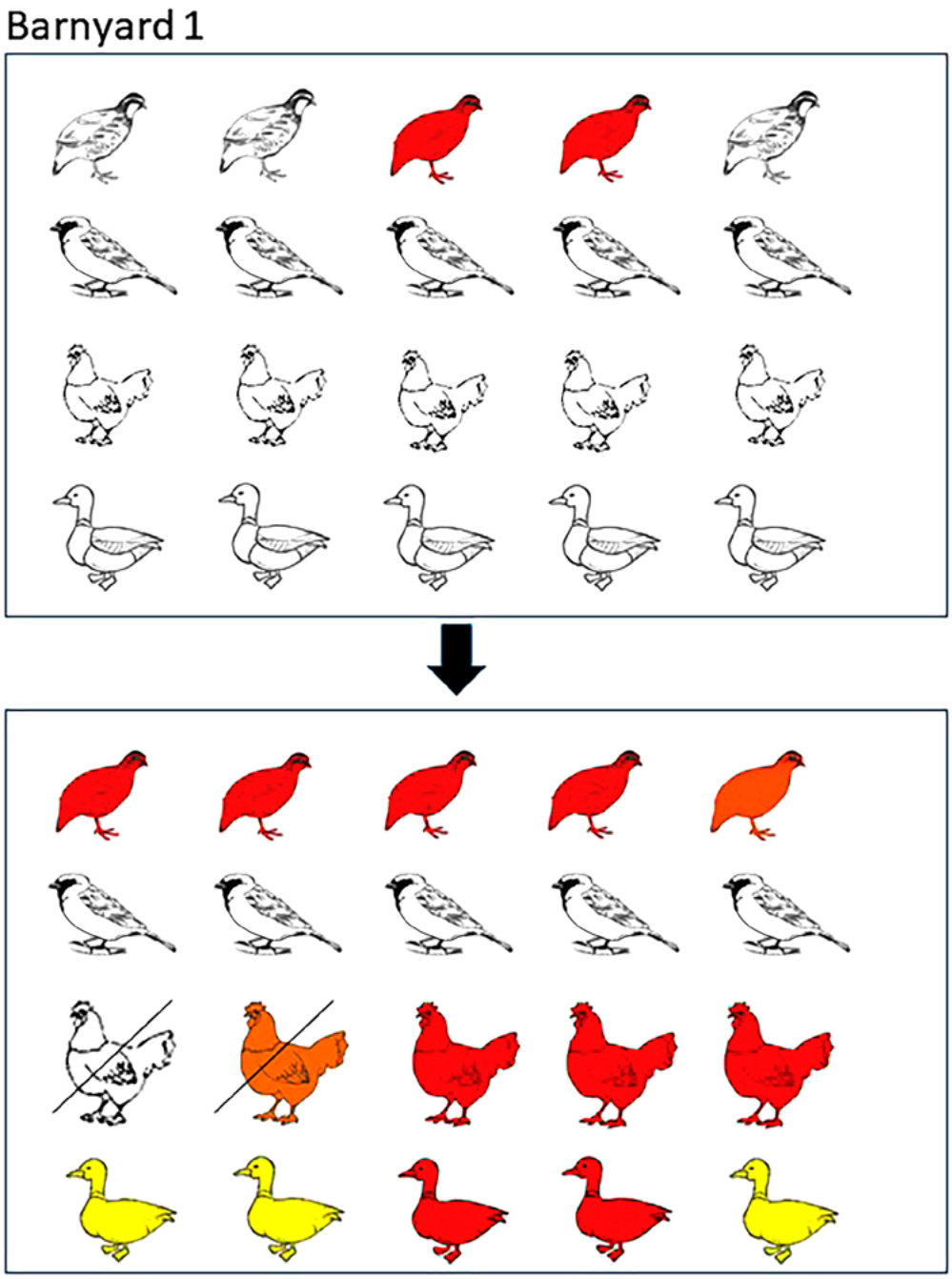
Contact: Toni Piaggio

Disease Diagnostics, Surveillance, Risk Assessment, and Management

- **Intercontinental Movement of Highly Pathogenic Avian Influenza (HPAI) H5N1.** Influenza A viruses are found worldwide, and wild birds are the primary wildlife reservoir. Many wild ducks are often repeatedly exposed to and infected with these viruses (hereafter referred to as avian influenza viruses or AIV) often with little to no sign of clinical disease. Wild bird samples are routinely collected by the WS program and screened for AIV in conjunction with the National Animal Health Laboratory Network and with the National Veterinary Services Laboratories as part of a targeted AIV surveillance program in wild birds. As part of these routine surveillance efforts, WS detected Gs/GD lineage clade 2.3.4.4b HPAI H5N1 viruses in multiple wild birds sampled in North Carolina and South Carolina during December 2021 and January 2022. Genetic analyses showed that all virus segments were of Eurasian origin and are closely related to the December 2021 HPAI H5N1 findings in Newfoundland, Canada. Although there has been intense focus on intercontinental movement of HPAI from Asia to the North American Pacific Flyway, this suggests that U.S. wild bird surveillance captured the introduction of a Eurasian-origin HPAI into wild birds in the Atlantic Flyway. These findings show that targeted AIV surveillance in wild bird populations can detect newly introduced or emergent AIVs before spillover to domestic poultry. Advanced warnings from wild bird surveillance helps poultry producers enhance or alter biosecurity measures in the face of increased AIV risk.

  Contact: Jeff Root

- **Transmission Potential of H7N9 Influenza Among Common Birds.** Influenza A viruses are a diverse group of pathogens that have been responsible for millions of human and avian deaths throughout history. To better understand the transmission potential of H7N9 influenza A virus among common bird species, NWRC and Colorado State University researchers co-housed Coturnix quail (*Coturnix* sp.), domestic ducks (*Anas platyrhynchos domesticus*), chickens (*Gallus gallus domesticus*), and house sparrows (*Passer domesticus*) in an artificial barnyard setting. In a series of experiments, individuals from a single species were infected with the virus and all birds were sampled daily for 5 days and again on day 7, 9, 12 and 21. Results showed quail shed virus orally and were a source of infection for both chickens and ducks. Infected chickens transmitted the virus to quail but not to ducks or house sparrows. Infected ducks transmitted to chickens, resulting in seroconversion (antibodies to the virus) without viral shedding. House sparrows did not shed virus sufficiently to transmit to other species. These results show that transmission varies by species, and that quail and chickens are more likely to maintain H7N9 than ducks or passerines (songbirds). Limiting the interactions and co-housing of species may aid in minimizing



To understand the transmission potential of H7N9 influenza A virus among common bird species, Coturnix quail, domestic ducks, chickens, and house sparrows were co-housed in an artificial barnyard setting. In the trial, birds shown in red in the upper box were inoculated with H7N9. In the lower box, red indicates animals that shed infectious virus and seroconverted, yellow indicates animals that seroconverted but did not shed infectious virus, and orange indicates animals that shed infectious virus but did not seroconvert. Animals with a strikethrough line were removed prior to the end of the study.
Graphic by USDA Wildlife Services, Jeff Root

the spread of the virus and the opportunity for viral reassortment.

Contact: Jeff Root

- **Transmission and Evolution of SARS-CoV-2 in Free-ranging Deer.** The emergence of SARS-CoV-2 in free-ranging white-tailed deer poses a unique public health risk due to the potential for the virus to persist, evolve, and spillback into humans. Between November 2021 and October 2022, WS worked with numerous partners to collect and analyze nasal swab and blood samples from over 11,000 free-ranging white-tailed deer across Washington, D.C. and 29 States. Genetic analyses of deer-associated isolates resulted in 391 sequences and identified 34 Pango lineages (a nomenclature system used to track global transmission lineages of SARS-CoV-2) including the Alpha, Gamma, Delta, and Omicron variants. Analyses showed these white-tailed deer viruses originated from

at least 109 independent spillovers from people, were transmitted from deer-to-deer in at least 39 instances, and that 3 cases of potential spillover from white-tailed deer back to people occurred. Overall, the findings suggest that multiple SARS-CoV-2 lineages were introduced, became established, and co-circulated in white-tailed deer. Additional research demonstrated the SARS-CoV-2 virus evolved three times faster in white-tailed deer compared to humans. The driver for this evolution in deer was different mutational biases and selection pressures. Efficient deer-to-deer transmission and changes in the virus could facilitate establishment of white-tailed deer as a reservoir of SARS-CoV-2, presenting potential risks for zoonotic transmission back to people and to other animals.

Contact: Jeff Chandler

- **Coyote and Red Fox Susceptibility to SARS-CoV-2.** Throughout the COVID-19 pandemic, veterinarians detected multiple instances of natural SARS-CoV-2 infections in domestic dogs, likely from exposure to infected people. NWRC researchers conducted a series of experimental inoculations to see if common wild canids, such as coyotes and red foxes (*Vulpes vulpes*), could become infected and shed infectious SARS-CoV-2 virus. Results showed red foxes became infected and shed infectious virus through their noses and mouths for at least 3 days after inoculation. Each fox also showed mild clinical signs including tiredness and sneezing. On the other hand, none of the coyotes became infected or shed detectable virus. If red foxes were to become a maintenance host for the virus, impacts may include not only negative effects on animal health, but also the development of new viral variants and the potential for spillback of the virus to people.

Contact: Jeff Root

- **Using Fecal Microbiomes to Determine Vaccination Status in Skunks.** In wildlife disease surveillance and monitoring, it is often difficult to determine the amount of infection,

NWRC researchers conducted a series of experimental inoculations that showed red foxes can become infected with SARS-CoV-2 and shed infectious virus through their noses and mouths.
Photo by Adobe Stock

vaccination, or immunity in wildlife populations. Biomarkers are one tool managers use to estimate vaccination rates. A biomarker is a measurable substance in an animal that indicates it has been exposed to something such as a vaccine bait. In addition to various chemical biomarkers, NWRC researchers are exploring whether an animal's fecal microbiome is an effective biomarker for predicting rabies virus vaccination and infection status. Researchers collected fecal samples from 22 striped skunks (*Mephitis mephitis*) that were given an oral rabies vaccine, a sham vaccine, and/or infected with rabies virus. Using DNA extraction and sequencing techniques, researchers identified and compared the skunks' fecal microbiome communities before and after treatment. The microbiome analysis determined that alpha diversity (a measure of microbiome diversity within a sample) did not differ among treatment groups; however, beta diversity (a measure of microbiome diversity between samples) did differ. Researchers also identified 13 operational taxonomic units (groups of closely related microorganisms) indicative of vaccination in the skunk fecal samples. Each matched closely to fecal volatile organic compounds associated with vaccination status in skunks. This research is the first to highlight striped skunk microbiome biodiversity as a vaccination biomarker and may lead to alternative methods for vaccination and disease surveillance and monitoring in wildlife populations.

Contact: Matt Hopken

A trail camera shows a raccoon investigating a placebo ORV bait deployed for a study on bait uptake by target and nontarget species.
Photo by USDA Wildlife Services

- **Competition for Oral Rabies Baits in the Southeastern United States.** WS' National Rabies Management Program (NRMP) has coordinated the use of oral rabies vaccination (ORV) to control the spread of raccoon (*Prycon lotor*) rabies virus variant west of the Appalachian Mountains since 1997. Working with State and local partners, the NRMP deploys ORV baits containing a rabies vaccine, primarily targeting raccoon populations. Bait competition between raccoons and non-target species may limit the effectiveness of ORV programs, but the extent of bait competition remains poorly quantified, particularly in the southeastern United States. In collaboration with the University of Georgia, researchers placed placebo ORV baits in bottomland hardwood and upland pine habitats in South Carolina between August and December 2019 and used remote cameras to examine bait competition between raccoons and non-target species. The estimated proportion of bait eaten by raccoons was approximately 19 percent in bottomland hardwood and 12 percent in upland pine habitats. Researchers estimated that raccoons were the primary consumer of baits in bottomland hardwood, whereas invertebrates were the primary consumer of baits in upland pine, eating approximately 27 percent of the baits. Vertebrate competition appeared to have little effect on raccoon uptake and cumulatively only accounted for 8 percent of bait uptake.

Results indicate a need to consider the effects of invertebrates on bait consumption to minimize their potential impact on ORV bait uptake by raccoons.

Contact: Amy Davis

- **Regional Cross-Border Raccoon Rabies Elimination.** Wildlife rabies is intensively managed in the northeastern United States and several southeastern Canadian provinces to control the spread of and locally eliminate raccoon rabies virus. Researchers studied and modeled the occurrence of raccoon rabies across the northeastern United States and southeastern Canada from surveillance data collected between 2008 and 2018. They examined the probability of raccoon rabies occurrence on the landscape and relationships with management activities (e.g., ORV and trap-vaccinate-release), habitat types and other factors. They also compared raccoon rabies detection probabilities between different surveillance samples (e.g., strange acting animals, road-kills, public health surveillance). Results showed that ORV management was the greatest driver in reducing raccoon rabies occurrence on the landscape. Additionally, raccoon rabies occupancy declined with increasing duration of ORV baiting programs across years. Raccoon rabies detection probabilities varied, with samples from strange acting animals and public health surveillance having the highest detection rates. These results support the movement of the ORV zone south within the United States due to high elimination probabilities along the shared border with Québec. However, enhanced rabies surveillance is still needed to ensure elimination is maintained.

  Contact: Amy Davis

- **Raccoon Movement Following Translocation.** Raccoons are routinely translocated (i.e., captured from one area and released to another) both legally and illegally to mitigate conflicts with people. However, translocation has also contributed to the spread of raccoon rabies virus in eastern North America. The NRMP partnered with researchers at the University of Georgia and NWRC to track the movements of collared racoons before and after experimentally translocating individual animals 10 miles (16 kilometers (km)) between habitats at the Savannah River Site in South Carolina. Translocated raccoons showed a 13-fold increase in home range area compared to pre-translocation movements. Most raccoons established new home ranges and resumed pre-translocation movement behavior around 36 days after translocation. However, 3 raccoons moved over 10 miles from their release point back to the original capture location. Four raccoons crossed a 328-foot-wide (100 meter) river following translocation. Raccoons were not observed crossing rivers prior to translocation. Researchers conclude that large increases in space use combined with more frequent crossing of geographic barriers, such as rivers, increases potential for raccoon contacts and heightens disease transmission risks from translocation. These results underscore the need to raise awareness and discourage raccoon translocations to prevent the spread of wildlife rabies.

  Contact: Amy Gilbert

- **Deer Scrapes and Chronic Wasting Disease (CWD) Transmission.** CWD is spread by infectious prions shed through bodily fluids, such as feces, urine, blood, and saliva. These prions may remain infectious in the environment for years. CWD not only spreads when deer or

One likely pathway of indirect CWD transmission in white-tailed deer is through their scraping behavior, such as licking low-hanging branches.
Photo by Adobe Stock

other cervids come in close contact with each other, but also indirectly from the environment during feeding or other activities in shared spaces. One likely pathway of indirect CWD transmission in white-tailed deer is through their scraping behavior. Scrapes are created primarily by bucks during the breeding season. Scrapes are communication signposts marked and visited by bucks and does. Scrapes are created when a deer uses its front hooves to clear a circular area on the ground of debris and duff (usually next to a tree). It then urinates on the area and rubs its face on and licks a low-hanging branch, depositing scented secretions from glands. Additional deer will visit the scrape and perform similar behaviors, potentially encountering or disseminating CWD prions. Scrapes represent an understudied part of deer social behavior that may impact the spread of CWD. NWRC, Southern Illinois University, and the University of Wisconsin-Stevens Point researchers recorded visits and behaviors by deer at scrapes throughout DeSoto National Wildlife Refuge in Iowa. More than 2,000 interactions by 169 unique, identifiable males and 75 females were recorded. Adult males performed the most scrape-related behaviors and spent the most time at scrapes, especially smelling the overhanging branch, smelling the scrape, licking/grasping the overhanging branch, and scraping. Researchers used this and other data to conduct a social network analysis to describe indirect contact patterns among deer at scrapes. Results showed scrapes may be effective targets for management to reduce indirect contact and potential spread of CWD prions among deer.

Contact: Kurt VerCauteren

- **Optimizing a Response to African Swine Fever (ASF) in Feral Swine.** ASF virus is a deadly pathogen of swine that threatens domestic swine industries globally and persists in wild boar populations in some countries. If ASF were introduced into feral swine in the United States, an immediate response would be key to containing its spread and protecting domestic swine industries. In foreign animal disease (FAD) outbreaks, managers typically establish a response zone—a physical location around an infected premises or animal that consists of a control area and surveillance zone. With the widespread distribution of feral swine in the United States, APHIS recognizes the importance of response planning in both domestic and feral swine. Effective response in feral swine involves unique planning considerations. A primary tool APHIS employs for FAD preparedness is scenario modeling. Scenario modeling is used to anticipate

If ASF were introduced into feral swine in the United States, an immediate response would be key to containing its spread and protecting domestic swine industries. NWRC researchers collaborated with the NFSDMP, APHIS-Veterinary Services, and WS Operations to develop a modeling platform to determine the optimal size of emergency response zones if the disease were to infect feral swine.
Graphic by APHIS

potential outcomes, test the impacts of different surveillance and control policies, and inform logistical readiness. Several tools have been developed for livestock but tools for feral swine have been lacking. To aid in response planning, NWRC researchers collaborated with NFSDMP, APHIS-Veterinary Services, and WS Operations to develop a modeling platform to determine the optimal size of response zones for ASF in feral swine. The platform leveraged ecological data from feral swine in the United States and ASF surveillance data from other countries. Optimal response zone sizes were defined as those that quickly eliminated the disease and resulted in the least amount of spatial spread of ASF. Modeling showed that the optimal response zone size was often larger than 6 miles (10 km) and depended strongly on the local movement of feral swine. Lower optimal response zones were possible when movement among feral swine was low, management culling capacity was high, and time to detection was short. Focusing control efforts near the most recent detection versus the outer edge of a response zone was optimal for containing and eliminating ASF. APHIS is using the modeling platform to evaluate alternative feral swine control practices, ASF surveillance strategies for early detection, and response readiness.

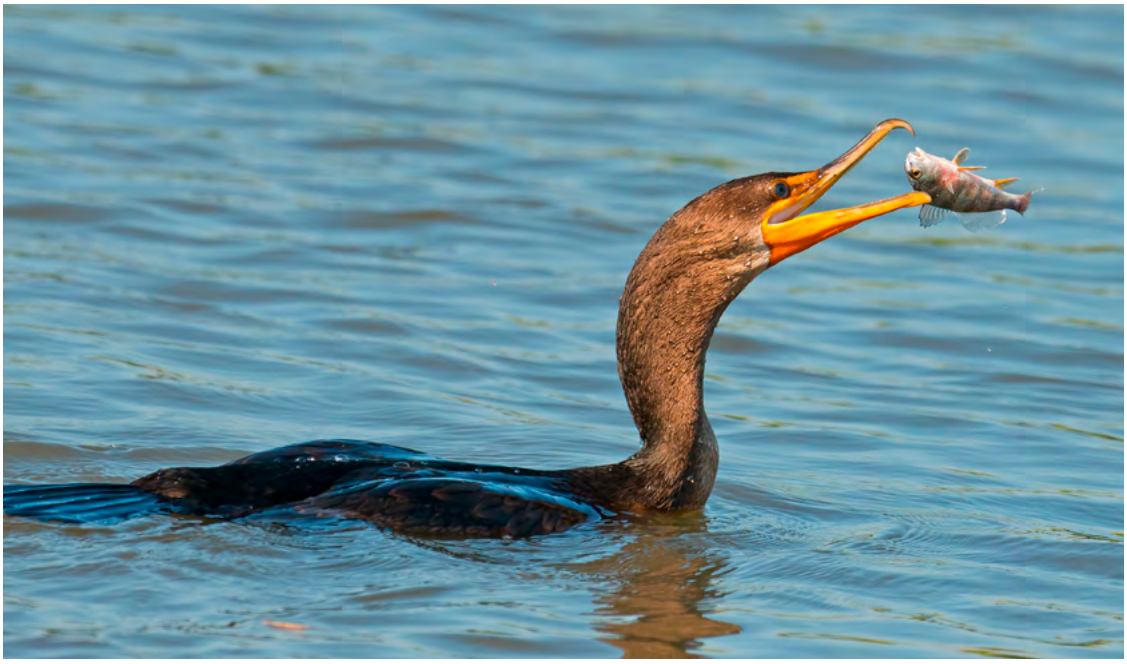
Contact: Kim Pepin

- **FAD Surveillance.** Surveillance is an important part of APHIS' efforts to protect animal agriculture and quickly identify introduced FADs. Once introduced, pathogens that are shared among domestic and wild animals are difficult to manage. Thus, early identification of FAD in wildlife is critical to minimize impacts on animal agriculture, wildlife, and biodiversity. To aid in FAD surveillance and address gaps in existing wildlife surveillance systems, NWRC researchers and other APHIS experts developed an adaptive surveillance approach. The approach is flexible, accounting for changes in disease risks through time, addressing outbreaks in varying sizes, and including numerical data or expert opinion. In a series of simulations, the new adaptive surveillance approach prioritized feral swine surveillance areas in the United States to maximize the detection and sampling for three FAD diseases: classical swine fever, ASF, and foot-and-mouth disease. Only 1.2 percent of counties in the United States were consistently in the upper 5 percent of risk ranking. Researchers note that opportunistic surveillance sampling is likely to miss or under sample these high-risk populations. However, this new framework improves upon traditional surveillance strategies that are largely opportunistic or use coarse risk factors that are static through time.

Contact: Kim Pepin

Wildlife Damage Assessments

- **Impacts of Cormorant Predation on Fish Populations.** Double-crested cormorants (*Nannopterum auritum*) have been linked to declines in wild fish populations in many locations across their breeding range. Researchers at the NWRC, Minnesota Department of Natural Resources, Michigan Department of Natural Resources, Cornell University, and U.S. Geological Survey conducted a meta-analysis of eight fisheries in the Great Lakes region to determine how female fish populations respond to changes in cormorant abundance. Fish species of interest included walleye (*Sander vitreus*), yellow perch (*Perca*



A double-crested cormorant eats a yellow perch. NWRC researchers and partners conducted a meta-analysis of eight fisheries in the Great Lakes region to determine how female fish populations respond to changes in cormorant abundance.
Photo by Adobe Stock

flavescens), smallmouth bass (*Micropterus dolomieu*), and northern pike (*Esox lucius*). Several biological performance indicators (BPIs), such as estimated age, maturity/egg development, age evenness, and total length at age 3, were used to track fish population densities. Analysis showed that mean total female fish length at age 3 most closely tracked cormorant abundance. As cormorant abundance increased, the length of female fish in this size category also increased which is an indicator of a reduced fish population. Researchers conclude that some BPIs, particularly those attributed to density-dependent responses, such as growth and maturation, can serve as supporting evidence of excessive cormorant predation on important sportfish populations.

Contact: Brian Dorr

- **Estimating Feral Swine Damage to Corn Using Unmanned Aircraft Systems (UAS).** Economic estimates for feral swine damage vary widely. To improve estimates, NWRC and Texas A&M University researchers integrated remotely sensed imagery from UAS (or drones) and crop harvest data to measure feral swine damage in corn fields in Texas. Drones with natural color (i.e., red, green, blue) cameras were used to monitor corn fields at different growth stages (i.e., establishment, vegetative, blister-milk, and dent-mature). Feral swine damage was classified into 18 drone image collections by combining manually digitized images and deep-learning algorithms. Researchers compared damage estimates from the drone imagery to those derived from ground-based transect surveys used to verify swine damage. All the drone imagery estimates were more than 80 percent accurate for all the corn growth stages. Most damage occurred in the latter growth stages, when corn ears were maturing, and the kernels were the most nutritious. In one case, feral swine damaged up to 9.2 percent of a single monitored field. The average yield of corn in areas with no feral swine damage was 6,200 pounds per acre (6,949 kilograms per hectare). In areas with feral swine damage, corn yields were reduced by 46 percent. Drone imagery, when combined with harvest yield data, provides an accurate assessment of crop damage and yield loss due to feral swine.

  Contact: Kurt VerCauteren

- **Feral Swine Preferences for Various Growth Stages of Corn.** Feral swine often feed upon agricultural crops. This damage may increase as feral swine populations expand, impacting the human food supply and increasing costs of food production. NWRC and Texas A&M University researchers evaluated movement behaviors of global positioning system (GPS)-collared feral swine relative to five growth stages of corn (i.e., pre-planting, establishment, vegetative, blister–milk, and dent–mature) and landscape features in Texas. Results showed feral swine movement and resource selection were dependent upon corn growth stages and landscape composition. For instance, feral swine use of corn fields increased as corn crops matured. It was also higher in crop fields that were closer to wooded areas. Most feral swine remained near corn fields while some moved long-distances to select for corn. This suggests that lethal control timed before and maintained during the greatest feral swine use could be the most effective. However, the timing of damage may not always align with seasonal effectiveness of aerial operations and trapping. If lethal control is not as effective or efficient before or during later growth stages of corn, managers should consider using nonlethal methods, such as

fencing, especially if corn fields are located near habitats used as shelter by feral swine.

Contact: Kurt VerCauteren

- **Criteria for Standardizing Economic Estimates of Feral Swine Damage.** Well-executed, economic estimates of wildlife damage can benefit wildlife research and management. Although attempts to measure the economic costs of feral swine in the United States have occurred since the late 1900s, little has been done to review and evaluate those estimates. NWRC and Colorado State University economists conducted a review of 235 publications providing economic estimates of direct damage caused by feral swine. Of those, 40 publications met review criteria and were further evaluated to identify knowledge gaps and criteria for improving future economic estimates. Seventy-four percent of the economic estimates in the publications described agricultural damage, such as non-consumptive, consumptive, disease, or unspecified damage to crops, livestock, and agricultural land, infrastructure, or equipment. Other estimates described damage to natural resources (13 percent), property (8 percent), and miscellaneous (5 percent). A lack of standardization among the publications makes it difficult to combine and leverage the data in support of a national economic estimate of feral swine damage in the United States. Researchers suggest using six criteria to ensure future feral swine economic estimates are consistent, shareable, and repeatable across studies (Table 1). If implemented, the criteria ensure study results can be extrapolated beyond their respective studies and benefit the greater feral swine management community.

  Contact: Stephanie Shwiff

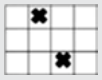
CRITERION		DESCRIPTION	EXAMPLE
1		Research methods for **quantifying** and **valuing** damage are vetted and clearly detailed	**Quantifying damage**: Survey questionnaire, field observation **Valuing damage**: Market prices, benefit-transfer, contingent valuation
2		Study sample or population is described	3 hectares of wetland, 5,000 head of dairy cattle
3		Damage units relative to the study sample or population are quantified and. clear	Hectares, head, plants/ acre, pounds/ acre, bushels/acre
4		As best as possible,. the damage is classified using the ''3D framework" (destruction, depredation, disease) (Shwiff et aL., 20 l 7b)	Corn trampiling (destruction) vs. c orn consumption (depredation)
5		A wild pig density (head/unit area)or proxy can be applied to the study area	~20 wild pigs per acre
6	$ (YEAR)	Currency estimate with year the estimate pertains to	$25 (in 2012 USD)

Table 1. NWRC and Colorado State University economists suggest researchers and managers use six criteria for ensuring feral swine economic estimates are consistent, sharable, and repeatable across studies.

NWRC and Colorado State University researchers, with the help of WS Operations personnel, took advantage of the unprecedented declines in air traffic during the COVID-19 pandemic to study the connection between air traffic volume and wildlife strike risk.
Photo by USDA Wildlife Services, Gail Keirn

- **Impact of COVID-19 Pandemic on Wildlife-Aircraft Collisions.** Wildlife-aircraft collisions, commonly referred to as wildlife strikes or bird strikes, are relatively rare events that pose considerable safety and economic risks within the aviation industry. One factor that is likely to impact wildlife strike risk and wildlife strike frequency at airports is air traffic volume, or the frequency at which aircraft are taking off and landing. Essentially, if aircraft movements act as a deterrent for wildlife, then air traffic volume levels are likely to affect the abundance and behavior of wildlife within the airport environment and, therefore, wildlife strike risk. Researchers from the NWRC and Colorado State University, with the help of WS Operations personnel, took advantage of the unprecedented declines in air traffic volume during the COVID-19 months of 2020 to study the hypothesized connection between air traffic volume and wildlife strike risk. During the COVID-19 pandemic in 2020, data from the 50 largest airports in the United States showed that the absolute number of wildlife strikes declined in response to reductions in air traffic volume. The net effect of these changes, however, was an increase in the wildlife strike rate, or the number of wildlife strikes per aircraft movement, from May 2020 through September 2020. Wildlife strike rates were particularly pronounced at airports with larger relative declines in air traffic volume. Drawing on evidence from a number of other scientific studies, the researchers hypothesize that the increase in wildlife strikes rates at these airports was likely due to wildlife becoming more abundant and active in response to less air traffic. The results of this study suggest that, while smaller airports may seemingly have less risk overall—i.e., lower traffic volume, less passengers per flight, and less expensive aircraft—wildlife managers should take note of how lower levels of air traffic volume might influence wildlife abundance and behavior at these airports.

  Contact: Levi Altringer

Wildlife Management Methods and Evaluations

- **Best Conditions for Baiting Feral Swine.** Feral swine are a highly destructive invasive species throughout North and South America, Australia, and many island nations. Controlling feral swine often involves baiting to draw them into traps or entice them to eat a toxic bait. Feral swine are generalist feeders and focus on food resources that are seasonally available. They are also dependent on the availability of water; therefore, it is unknown if baiting is most successful when food is limited (i.e., winter) or when water is limited (i.e., summer). To evaluate how environmental conditions (i.e., precipitation) and exposure to previous control efforts influence feral swine use of bait sites, NWRC, Texas A&M University, and Texas Parks and Wildlife researchers compared feral swine visits to bait sites during dry and wet years in Alabama and Texas. They also compared visitation rates between naïve feral swine and those that had been previously trapped and released. Results showed that feral swine use of bait sites increased by 119 to 136 percent in drier years and that bait site use was higher for feral swine that had not experienced previous control efforts. Researchers recommend that managers increase control efforts during drier periods and focus on eliminating the number of feral swine that experience near misses related to trapping and other management activities.

  Contact: Nathan Snow

- **Estimating Feral Swine Weight Using Body Measurements.** Monitoring feral swine populations not only helps WS gauge the success of its eradication and damage management efforts, but also feral swine population dynamics and the species' use of resources. Ecological indicators, such as body mass, can provide insights about population densities

To evaluate how environmental conditions and exposure to previous control efforts influence feral swine use of bait sites, NWRC, Texas A&M University, and Texas Parks and Wildlife researchers compared feral swine visits to bait sites during dry and wet years in Alabama and Texas. *Photo by USDA Wildlife Services*

and resource availability. Adult feral swine typically weigh between 150 to 220 pounds (68 to 90 kilograms), often making it difficult to measure their body mass (weight) when specialized equipment, access, or time is limited. Finding other body measurements that could be gathered without the aid of specialized equipment and that accurately predict body mass would benefit WS' monitoring efforts. NWRC and university researchers assessed whether body measurements, such as body length, chest girth, ear length, eye to snout length, hindfoot length, shoulder length, and tail length, could accurately predict feral swine body mass. They evaluated separate models for each body measurement and successfully developed equations using simple metrics for body length, chest girth, or shoulder height that accurately predict the body mass of feral swine. Researchers validated their findings from feral swine throughout the United States (including Guam) and Australia, but caution that body mass estimates may vary in other regions. Ultimately, though, it seems possible to accurately estimate body mass using simple measurements.

Contact: Nathan Snow

- **Evaluation of Goodnature A24 Self-resetting Traps.** A special issue of *Management of Biological Invasions*, co-edited by NWRC and University of Auburn researchers, highlights the effectiveness of Goodnature A24 self-resetting traps for removing invasive rodents. Goodnature A24 rat+stoat self-resetting traps (A24s) are used extensively for rat control in several countries and environments, especially on islands. Unlike traditional single-set kill traps, A24s trigger and reset up to 24 times. The devices use CO_2 gas cartridges to trigger a pneumatic striker that instantly kills rodents when they enter the chamber. The goal of the special issue was to evaluate and improve the efficiency of these automatic, non-toxic traps. The issue is made up of seven papers, including an introduction, studies on the use of A24s for house mice (*Mus musculus*) and black rats, and evaluations of trap excluders, height placement, and other modifications to prevent accidental trapping of non-target species. Researchers note that like other traps and rodent control devices, there are many factors that affect A24 performance and effectiveness, including rat density, the availability of alternative foods, seasonality, trap density and spacing, lure type and attractiveness, non-target species interference, and rat behavior, and provide recommendations for minimizing these factors.

  Contact: Aaron Shiels

- **Audio Recordings Used to Deter Monk Parakeets.** The monk parakeet is a gregarious parrot native to South America that has established populations worldwide and is considered an urban and agricultural pest in parts of its native and introduced ranges. NWRC and university researchers tested the effectiveness of audio recordings to repel or attract invasive monk parakeets for management purposes. Audio recordings designed to deter parakeets from an area included vocalizations from predatory red-tailed hawks. Audio recordings designed to attract parakeets included calls from other monk parakeets. Captive monk parakeets were repelled by predator vocalizations in 80 percent of the trials but were only attracted to other monk parakeet vocalizations in 10 percent of the trials. Results showed that predator playback calls may be useful for temporarily removing monk parakeets from an area.

  Contact: Bryan Kluever

NWRC researchers evaluated the effect of nonlethal harassment on Canada geese in the winter.
Photo by Adobe Stock

- **Canada Goose Response to Winter Harassment.** Wildlife harassment (i.e., intentional disturbance by people) is a common nonlethal management approach to reduce human-wildlife conflicts. NWRC researchers and partners evaluated the effect of harassment on Canada goose (*Branta canadensis*) behavior during the winter in urban greenspaces (e.g., parks, cemeteries, housing complexes) in Chicago, Illinois. Winter can be a challenging period for waterfowl given limited food and greater thermoregulatory and energetic costs; and it was expected that harassment in winter would be more effective than during other times of the year. Results showed that harassment caused geese to leave sites more often (3.5 times) than on days when they were not harassed, but geese returned more quickly after harassment than without harassment. Harassment affected goose foraging, resting, flying, and alert behaviors, but the effects were minimal compared to the effects of weather. Harassment resulted in short-term behavioral changes that likely did not affect the birds' energetic costs. Also, it also did not cause individual geese to leave the area or avoid a specific location for more than 48 hours. During periods of extreme cold, geese moved to areas (e.g., open water bodies) where they could rest and engage in other behaviors that limited their energetic demands. Researchers note that harassing geese in areas that provide sanctuary during extreme cold periods or using lethal management in coordination with targeted harassment might be more effective than harassment alone in greenspaces.

  Contact: Brian Washburn

- **Using UAS to Disperse Gulls.** Ring-billed *(Larus delawarensis*) and herring (*L. argentatus*) gulls are numerous and widespread in North America. Large gull populations near flight routes have the potential to increase the risk of gull-aircraft collisions. Experts with the NWRC's Ohio Field Station, WS Operations, and

Trail camera images show ring-billed gulls on a roof top at night, before (left) and during exposure to a flying UAS (drone) used to simulate a nocturnal predator.
Photo by USDA Wildlife Services, Morgan Drabik-Hamshare (Pfeiffer)

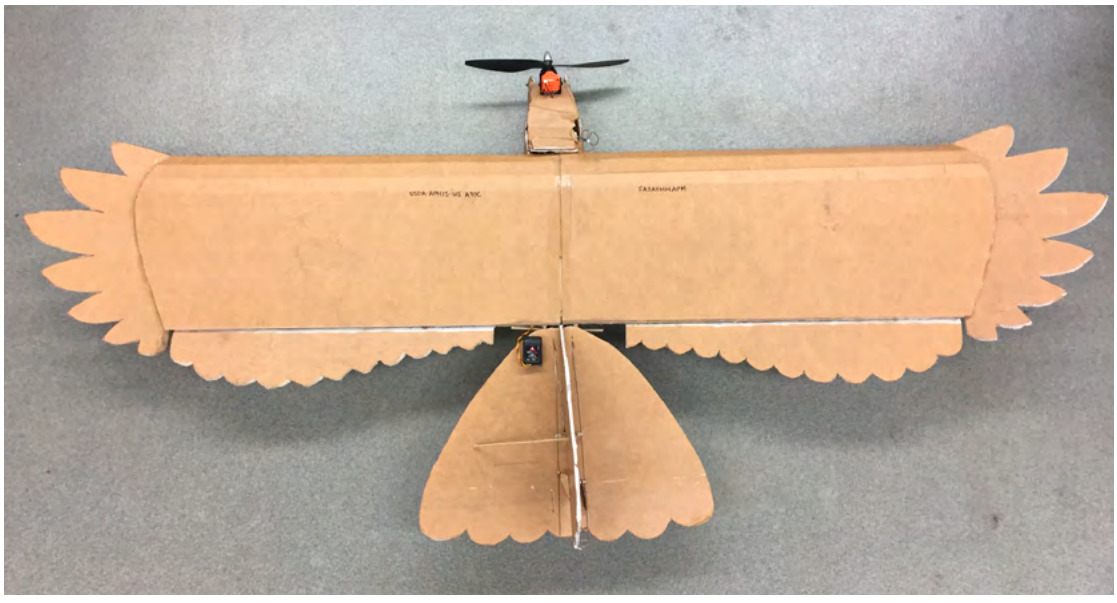
the Federal Aviation Administration, evaluated UAS use to simulate a nocturnal predator disturbance and disperse nesting gulls at night from rooftops in Ohio and Illinois. Gulls rely on predator-free nesting locations for protection against nocturnal predators. Results showed the first UAS treatment of the night generally caused the birds to disperse from the target roof. No gulls interacted with the UAS and most flushed within 6 minutes. Researchers note, however, that the nocturnal UAS hazing of gulls has the potential to move birds to other roofs which could be counterproductive for management of their presence within a flight route.

Contact: Morgan Drabik-Hamshare (Pfeiffer)

- **Using UAS to Disperse Blackbirds.** Throughout the prairie-pothole region of the Northern Great Plains, red-winged blackbirds (*Agelaius phoeniceus*), common grackles (*Quiscalus quiscula*), and yellow-headed blackbirds (*Xanthocephalus xanthocephalus*) gather in large mixed flocks that can number over 100,000 birds. NWRC, North Dakota State University, and Purdue University researchers investigated the effectiveness of UAS to deter foraging blackbirds from commercial sunflower fields in North Dakota. Three UAS models were tested: 1) a fixed-wing predator model that mimicked a hawk, 2) a fixed-wing airplane of similar size, and 3) a multirotor drone. Blackbird flocks reacted to every UAS by taking flight. Flocks took flight 1.6 times sooner for the fixed-wing predator model and 1.8 times sooner for the fixed-wing airplane compared to the multirotor drone. The use of UAS in smaller fields and/or on smaller flocks was more likely to result in birds abandoning the fields than the type of UAS used. Researchers conclude that the effectiveness of UAS as bird dispersal tools depends upon a combination of factors including the type of UAS, its trajectory and duration of use, the time of year, landscape features, and the behavior of the targeted species.

  Contact: Page Klug

- **Reducing Nest Debris Hazards to Aviation.** European starling (*Sturnus vulgaris*) nests pose debris hazards to airport hangars, and aircraft engines and flight surfaces. To investigate if



NWRC and university researchers tested the effectiveness of three UAS models (a fixed-wing predator model that mimicked a hawk (pictured), a fixed-wing airplane of similar size, and a multirotor drone) to deter foraging blackbirds in commercial sunflower fields. *Photo by USDA Wildlife Services, Page Klug*

European starling nests pose debris hazards to airport hangars, and aircraft engines and flight surfaces.
Photo by USDA Wildlife Services, Caroline Olson

consistent removal of nest material would decrease starling use of a nest site (measured by a reduction in material accumulation), NWRC researchers erected 120 wooden nest boxes on utility poles at a study site in Ohio. Nest boxes were checked, and nest materials were either repeatedly removed, completely removed (but only after nest construction and 1 or more starling eggs was laid), or not removed. Results showed starlings placed approximately 50 percent more nest material and eggs at nest boxes that experienced repeated nest material removal, indicating that consistent disturbance does not discourage starling use. Aside from covering moored aircraft and closing aircraft hangar doors which often are not feasible options, removing nest material more than twice a week is necessary to manage debris hazards that could affect aircraft function and safety.

Contact: Brad Blackwell

- **Predicting Brown Treesnake Suppression Thresholds for Reintroduction of Guam's Native Birds.** Predation by invasive brown treesnakes (*Boiga irregularis*) has led to the extirpation or extinction of nearly all of Guam's native forest birds. Recognizing that island-wide eradication of the snakes is currently unlikely, NWRC researchers collaborated with the University of Guam and U.S. Geological Survey's (USGS) Pacific Island Ecosystems Research Center to evaluate whether reintroduced native forest birds could withstand brown treesnake predation. Population models showed that all seven bird species evaluated could persist with some reduced level of predation. However, encounter rates between snakes and birds must be much lower than what are currently observed in experimental snake suppression areas. Bird species varied in their predicted abilities to withstand brown treesnake predation, with Chichirika (Rufous Fantail, *Rhipidura rufifrons*) being the most vulnerable, and Ko'ko' (Guam Rail, *Gallirallus owstoni*) being the most resistant.

  Contact: Shane Siers

- **Novel Technique for Capturing Ravens.** Soft-catch, padded foothold traps; net launchers and rocket nets; and walk-in/box traps have been used to capture common ravens (*Corvus corax*). However, all these techniques require pre-baiting or using traps at congregated foraging areas, such as landfills. To improve capture success and avoid

pre-baiting, NWRC and Oregon State University researchers designed a novel method for capturing ravens at nocturnal roosts. A 3-meter noose pole is used to secure the birds while strobe spotlights temporarily disorient them. When tested in eastern Oregon, the noose pole/strobe light method resulted in 37 captured ravens for 17.75 trap-hours (0.48 trap-hours per raven). The method was only used during the summer when communal roosts were observed. Foothold traps, on the other hand, resulted in 3 captured ravens for 229.25 trap-hours (76.4 trap-hours per raven) over the same time. Although components of this technique are well-known and commonly used for other species, this is the first time they have been combined and used to capture ravens.

Contact: Jimmy Taylor

- **Reducing Predation on Stocked Salmon and Trout.** Working with the Michigan Department of Natural Resources, U.S. Geological Survey, the University of Michigan, and Minnow Environmental Inc., Canada, NWRC researchers from the Mississippi Field Station evaluated migration and movement data of multiple predators of salmon and trout stocked in Lake Huron. Predation is one of the most influential variables affecting survival of these stocked fish. Researchers used telemetry of double-crested cormorants, walleye, and lake trout (*Salvelinus namaycush*) to show that most predation of stocked salmon and trout in Lake Huron could be avoided if stocking occurs before April 14. Dispersal of cormorants from stocking sites could also reduce predation of stocked fish and allow for further stocking up to April 30. Understanding predator movements can help managers increase the survival of stocked salmon and trout in Lake Huron and increase angler opportunity.

Contact: Brian Dorr

NWRC researchers collaborated with the University of Guam and U.S. Geological Survey to evaluate whether reintroduced native forest bird populations could withstand brown treesnake predation. Shown: Brown treesnake eating a white tern (Gygis alba). *Photo by U.S. Geological Survey, Nathan Sablan*

- **Assessing and Mitigating Human Exposure to Rodenticides.** Rodenticides are commonly used to eradicate invasive rodents from islands, with eradication projects increasingly being undertaken on inhabited islands or islands used by people for harvesting food. Such eradication projects on inhabited islands require that real and perceived human health risks are socially acceptable, or effectively lessened. Most concerns are related to rodenticide exposure to people, livestock, pets, game animals, and marine food sources. NWRC, Island Conservation, and Landcare Research experts conducted a literature and database review of rodent eradications from 153 inhabited islands. The review showed that secondary exposure to people through consumption of food products containing rodenticide residues was higher than primary exposure during rodent eradication programs on islands. The most common secondary pathways identified were livestock (goats, cattle), followed by land crabs and pigs. Primary pathways included bait handling, followed by bait dust generated during the bait loading process. Researchers did not find reports of any adverse effects from human

NWRC researchers collaborated with university, non-profit, and private partners to identify better ways for sharing knowledge among producers, researchers, and land managers about methods to reduce carnivore-livestock conflicts.
Photo by Adobe Stock

exposure resulting from rodent eradication programs on inhabited islands, including direct rodenticide bait consumption, inhalation, dermal absorption, secondary or tertiary exposure. Managers of future eradications on inhabited islands will benefit from proactively managing risks and perceptions through appropriate outreach and engagement with island communities.

Contact: Shane Siers

- **Rancher-to-Researcher Knowledge Exchange.** Across much of the western United States, recovering carnivore populations are creating new challenges for livestock producers. Fencing is an important mitigation practice that many ranchers, land managers, and conservationists implement to reduce carnivore-livestock conflict. While fencing strategies have been reviewed in the literature, research seldom incorporates knowledge from the people who use fencing the most (i.e., livestock producers). Incorporating producers and practitioners early in the process of producing scientific knowledge allows research priorities and expected outcomes to be set collaboratively, gives transparency to the agricultural community of the research process, provides a critical lens to evaluate efficacy and functionality of management tools, and informs the practicality of fencing as a conflict prevention tool. NWRC researchers collaborated with university, non-profit, and private partners to build a common understanding of the effectiveness of various fencing designs to reduce carnivore-livestock conflicts and provide a better mechanism for sharing this knowledge between producers, researchers, and land managers. The group was part of the Conflict on Workinglands project, supported by a Conservation Innovation Grant from the Natural Resources Conservation Service. Together, they created research priorities and an evaluation plan to inform standards on fencing as a preventative strategy. By co-producing research, the group successfully promoted the adoption of methods and sharing of research findings to others. Although this case study focused on fencing, the approach can be broadly applied to researchers and interest groups working on human-wildlife conflict mitigation tools.

  Contact: Stewart Breck

- **Producer Perceptions of Black Vulture Conflicts.** Black vulture (*Coragyps atratus*) populations and distributions are expanding in the midwestern United States. While most vulture species are obligate scavengers, the black vulture may attack weak or newborn livestock creating a novel problem for livestock producers. NWRC partnered with WS Operations and Purdue University to examine livestock producer experiences and perceived livestock losses in Indiana and Kentucky. Losses to black vultures were reported by 22 percent of goat producers, 24 percent of sheep producers, 38 percent of cattle producers, and 44 percent of mixed-livestock producers. The criteria used to determine a perceived predation event were presence of vultures on the carcass, followed by missing eyes or tongue, damage to the perineal area, reported visual observation of the kill, or presence of feathers around the carcass. Sixty-two percent of livestock producers used at least one mitigation technique. Common mitigation techniques included the removal of carcasses and afterbirth, followed by nonlethal harassment of vultures (i.e., pyrotechnics), modifying farm management practices, the use of guard animals or effigies, and lethal control. Except for nonlethal harassment, all mitigation techniques were considered effective by most respondents. Most respondents indicated a willingness to acquire a lethal control permit from either the Federal government, State government, or the State Farm Bureau, assuming the permit was free. Results provide insights into producer perceptions and aid in the development of strategies to address vulture-livestock conflicts.

Contact: Bryan Kluever

Wildlife Population Monitoring Methods and Evaluations

- **Social Grouping in Feral Swine.** Despite the widespread distribution and extensive ecological and economic impacts of invasive feral swine, their social organization is largely understudied and limited to observational data. NWRC, Savannah River Ecology Laboratory, and Texas A&M University researchers used genetic data from nearly 1,000 feral swine from South Carolina and Oklahoma to better understand and describe the composition of feral swine social groups. The most common social unit was sounders, which are characterized as the association of two or more breeding-aged feral swine with or without dependent offspring. In addition to sounders, pseudo-solitary females and male-dominated bachelor groups were observed more often than previously reported. Though primarily composed of close female kin, some sounders included unrelated females. Bachelor groups were predominantly composed of young, dispersal-aged males and usually included only close kin. Collectively, results suggest the social organization of feral swine in their invaded range is complex, dynamic, and likely variable across invaded habitats. This work reveals how feral swine may respond to management activities, demonstrating that single animals missed in whole sounder removal efforts may readily integrate into other sounders. It also informs feral swine dispersal patterns and management assumptions about distances that differentiate translocations versus natural dispersal, as some male siblings were sampled 60 to 100 miles (96 to 161 km) from source populations.

Contact: Tim Smyser

To better understand how feral swine respond to management, NWRC researchers used genetic data from nearly 1,000 feral swine from South Carolina and Oklahoma to describe the composition of feral swine social groups.
Photo by Adobe Stock

- **Factors Influencing Feral Swine Pregnancy and Litter Size.** Most of the feral swine in North America are genetic hybrids of feral domestic pigs and wild boar. They have the highest reproductive potential of any wild ungulate. NWRC researchers partnered with experts from the University of Georgia and Illinois Department of Natural Resources to study the impacts of genetic, physiological, and environmental factors on female feral swine pregnancy, litter size, and other reproductive traits. Data from more than 500 female feral swine in South Carolina showed the animals produced offspring throughout the year with peaks in conception matching seasonal pulses in food availability, such as acorns or fruits. The likelihood of pregnancy was influenced by female weight and nutritional condition and was greatest during years with abundant food resources. Similarly, litter size increased with female weight and age, implying larger and older females contributed the most to population increases. The proportion of wild boar ancestry in individuals did not significantly influence their productivity. Researchers suggest targeting reproductively mature females in early winter in the southeastern United States to maximize the impact of removal efforts on population growth rates and damage mitigation caused by feral swine. Allocating resources toward removal of adult females and entire sounders could have the largest impact on feral swine populations because larger and older females have the greatest reproductive potential.

  Contact: Tim Smyser

- **Invasive Frog Adjusts to Higher Elevations and Colder Temperatures.** The coqui frog (*Eleutherodactylus coqui*) was accidentally introduced to Hawaii in the 1980s on imported nursery plants and has since spread across much of the big island and other smaller islands. Beloved in their native Puerto Rico, invasive coqui frogs in Hawaii lack natural predators to keep their populations in check. They frequently hitchhike on cars from lower elevations and are already breeding at elevations higher than the highest point in their native habitats of Puerto Rico. There is concern that the species will continue to expand its range and invade higher elevation habitats potentially impacting many of Hawaii's endemic species, including endangered Hawaiian forest birds by competing with them for food. To determine whether coqui frogs can acclimate to colder temperatures, researchers from the NWRC, Utah State University, and the University of Brazil measured basal thermal tolerance and physiological responses of wild-caught coqui frogs collected from different elevations on Hawaii. Results from two acclimation experiments suggest that frogs collected from high elevation locations are more resilient to cold temperatures than ones collected from low elevations. Coqui frogs in Hawaii differ in their thermal tolerance according to elevation, helping them cope

with local temperatures and acclimate to new temperatures in less than 3 weeks. Researchers conclude that the lower temperatures typically found at higher elevations may not prevent future coqui frog invasions. Coqui frog invasions of higher elevation habitats may be inevitable unless more effective control strategies are developed.

Contact: Steve Hess

- **Improving UAS Imagery.** Researchers at the NWRC Ohio Field Station partnered with Mississippi State University to improve UAS imagery and identify best practices for conducting UAS-based wildlife surveys. Researchers combined visible and thermal imagery to help detect and classify animals. The added information from thermal images improved the detection and classification of white-tailed deer from 15 to 85 percent. Results suggest that combining visible and thermal images is ideal for surveying animals which are well camouflaged or difficult to discern from image backgrounds. Researchers also used a UAS to survey known numbers of animal decoy species, representing a range of body sizes and colors. Surveys were done at four flight altitudes (50, 100, 150, 200 feet), with two camera angles (45 and 90 degrees) and across a range of times of day (morning to late afternoon). Experienced observers identified and counted the animals in the UAS images. Increasing flight altitude resulted in decreased accuracy in animal counts overall. Accuracy was best at midday compared to morning and afternoon hours, when decoy and structure shadows were present or more pronounced. The 45 degree-camera enhanced accuracy compared to 90 degrees, but only when animals were most difficult to identify and count, such as at higher flight altitudes or during the early morning and late afternoon.

Contact: Brad Blackwell

Invasive coqui frogs in Hawaii lack natural predators to keep their populations in check. There is concern that the species will continue to expand its range and invade higher elevation habitats potentially impacting many of Hawaii's endemic species.
Photo by Adobe Stock

- **Improving GPS Data with Continuous-Time Movement Models.** Wildlife researchers and managers often use GPS to track collared animal movements and interactions through space and time. This information is especially useful for predicting the spatial spread of pathogens through wildlife populations. Although emerging tracking technologies can collect high-resolution movement data, many studies still rely upon GPS collars with relatively low resolution (e.g., gathering data

NWRC researchers and partners used data from GPS-collared feral swine and continuous-time movement models to predict unobserved feral swine movement patterns and interactions during tracking periods
Photo by USDA Wildlife Services

NWRC research suggests that ground-based surveys are more efficient at estimating prairie dog densities than UAS due to the extensive image collection and processing time associated with UAS-based estimates.
Photo by USDA Wildlife Services, Aaron Shiels

every 30 minutes or 1 hour). Continuous-time movement models (CTMM) offer a bridge to overcome limitations related to measuring animal interactions by predicting potential unobserved movements during tracking periods and simulating movement trajectories. NWRC researchers collaborated with multiple university and agency partners to develop a method to measure individual and spatial patterns of interactions among GPS-collared animals using CTMM fit to GPS tracking data. They evaluated the method's performance with simulations for two different species and diseases— feral swine that can host ASF and mule deer (*Odocoileus hemionus*) that can host CWD. Model simulations showed that estimates based on GPS movement data with greater than 30-minute intervals significantly underestimated animal interactions. However, CTMM were able to recover most of the interactions and improve estimations of animal interaction rates over space and time.

Contact: Kim Pepin

- **Estimating Prairie Dogs Using UAS.** Black-tailed prairie dogs are one of the most common and accessible native wildlife species along Colorado's Front Range, and their suburban populations expand and contract in response to urban planning and plague outbreaks. NWRC researchers tested the effectiveness of using small UAS to estimate prairie dog densities. They counted prairie dogs and burrows by video recording and merging still images taken using two types of drones (DJI Matric 210 and AutelEvo II) at altitudes of 100, 150, and 400 feet (burrows only). Researchers also compared UAS estimates to ground-based count surveys. Overall, video and still images both had similar accuracy in most prairie dog counts; however, video taken at 150 feet was more accurate than video taken at 100 feet. The greater field of view at 150 feet likely reduced the probability of counting the same prairie dog more than once. The use of drones for burrow and prairie dog counts was more time consuming than traditional on-the-ground counts that included repeated prairie dog counts in a day. Although UAS may accurately estimate large prairie dog colonies, findings suggest that ground-based surveys are more efficient due to the extensive image collection and processing time associated with UAS-based estimates.

  Contact: Aaron Shiels

- **Restoring Genetic Diversity in Allegheny Woodrats.** Allegheny woodrats (*Neotoma magister*) are distributed throughout high elevation areas in the Interior Highlands and Appalachian Mountains in the United States. Historically, Alleghany woodrat populations were relatively fluid networks, enabling gene flow between subpopulations and the recolonization of formerly extirpated regions. However, over the past 45 years, the abundance of Allegheny woodrats has declined throughout the species' range due to a combination of habitat destruction, declining food availability, and roundworm parasitism. To restore genetic diversity to a small, genetically poor subpopulation in New Jersey, six Alleghany woodrats were translocated from a genetically robust population in Pennsylvania. NWRC, State, and university researchers developed a 134 single nucleotide polymorphism (also known as SNP) panel to genotype the six translocated woodrats and 82 other woodrats from the New Jersey population captured before and after the translocation events. Genetic analysis showed that a minimum of two translocated individuals successfully produced at least 13 offspring, who reproduced as well. These results indicate that very small numbers of translocated individuals can successfully restore the genetic diversity of a threatened population.

  Contact: Tim Smyser

- **Influence of Human Resources on Raven Populations.** The common raven is native to North America and has increased in abundance, especially throughout the West, during the last century. Human development (i.e., power lines, agricultural irrigation structures, gas wells, billboards, landfills, campgrounds, etc.) has helped ravens to disperse into less suitable habitats and increase their annual survival and reproduction rates. Overabundant raven populations in the western United States are impacting other native at-risk species, such as the greater sage-grouse (*Centrocercus urophasianus*) and potentially the Gunnison sage-grouse (*C. minimus*). NWRC and Oregon State University researchers used Breeding Bird Survey data from 1995–2014 to describe changes in raven abundance and expansion into sagebrush (*Artemisia* spp.) ecosystems, specifically sage-grouse habitat. Results showed areas with higher densities of electric power transmission lines had higher raven population growth rates. Furthermore, ravens were observed at higher abundance as the amount of urban land cover and burned area increased near sage grouse management zones. As the distance to landfills and the amount of forest near sage-grouse management zones increased, raven abundance decreased. Researchers conclude that ravens have capitalized on human subsidies to increase their abundance and expand into sagebrush ecosystems that did not historically support high raven populations.

  Contact: Jimmy Taylor

- **Factors Influencing Vulture Roost Selection.** Roost locations can contribute to vulture conflicts with people. NWRC and university researchers used remote cameras to document the use of roost sites by black and turkey vultures (*Cathartes aura*) in South Carolina. The number of vultures at roost sites increased in less developed areas and in areas further from water. Roosts in more developed areas were used more often during the day likely because they provided food (e.g., roadkill, garbage) and more favorable soaring conditions due to thermal currents rising from paved surfaces. Roosts in less developed areas were more often used at night. Vultures tended to depart nocturnal roosts before sunrise and

Identifying and dispersing vulture roosts will be an important part of wildlife damage management as vulture populations continue to expand across North America. Turkey vulture (top), black vulture (bottom).
Photo by Adobe Stock

return within two hours of sunset. Researchers note this movement may increase the potential risk of collision with aircraft during those times. The identification and dispersal of major vulture roosts will be an important component of wildlife damage management as vulture populations continue to expand across North America.

Contact: Bryan Kluever

- **Impacts of Changing Aquaculture on the Abundance and Distribution of Cormorants.** The double-crested cormorant is a fish-eating bird that has a long history of depredating farmed catfish in Mississippi. A large-scale monitoring program began in 1989 to estimate the abundance and location of cormorants at every known roost in the primary catfish producing region of the State, regionally known as the Delta. An analysis of this dataset by NWRC and Mississippi State University researchers showed that the Midwest breeding population of cormorants is increasing, while the number of wintering cormorants in the Delta is decreasing. The decline closely follows the loss of aquaculture. Interestingly, the numbers of cormorants foraging on aquaculture remains close to historical levels. The amount of aquaculture land located near cormorant roosts was a significant predictor of both cormorant presence and abundance. However, the influence of aquaculture was seasonally dependent, with greater positive influences occurring in the winter prior to cormorant migration. The information gained from this analysis aids in cormorant damage management, furthers the understanding of cormorant ecology, and highlights that agricultural changes can influence migration, distribution, and abundance of bird species at large geographic scales.

Contact: Brian Dorr

- **Space Use and Movements of Double-Crested Cormorants.** Since the ban on dichlorodiphenyltrichloroethane (DDT) in the late 1970's, the number of breeding double-crested cormorants in the United States has increased substantially, particularly in the interior portion of North America. Studies have assessed cormorant movements during migration, wintering, and breeding seasons. However, little is known about how the birds use and move within their southern breeding sites in lake ecosystems. NWRC, Mississippi State University, and Tennessee Valley Authority researchers used movement data from eight cormorants fitted with backpack satellite transmitters to determine cormorant home range and core use areas from May through August on Guntersville Reservoir in Alabama. Compared to previous studies of home ranges of northern breeding cormorants, home ranges on Guntersville Reservoir were much

Double-crested cormorants were fitted with backpack satellite transmitters to determine their home range and core use areas on Guntersville Reservoir in Alabama. *Photo by USDA Wildlife Services, Lanna Rogers*

smaller (16 mi^2/41.8 km^2 and core use area of 2.5 mi^2/6.4 km^2). For instance, studies of cormorants tagged near aquaculture facilities in the Mississippi Delta region report a mean home range of 11,794 mi^2/30,547 km^2 during the summer. Differences in space used by cormorants breeding in Alabama relative to their northern breeding grounds may be explained by landscape characteristics and availability of prey. Compared to the Great Lakes, Guntersville Reservoir is a small aquatic system and therefore cormorants in this reservoir do not have to travel far for prey. Moreover, since cormorants tend to forage in waters less than 37 feet/10.6 meters in depth, cormorants in the Great Lakes must find appropriate prey on shorelines or areas of shallow depth. Guntersville Reservoir is shallow, with depths no deeper than 10.6 meters outside of the main channel. Managers in the southeast who are monitoring and controlling cormorant populations on reservoirs can use data derived from telemetered birds to determine bird movements and what habitat characteristics are present in their home ranges. Knowing that Guntersville Reservoir cormorants use smaller areas than northern birds nesting in the Great Lakes helps managers focus their activities on smaller and more precise areas.

Contact: Brian Dorr

Registration Updates

- **Section 3 Registrations for Island Conservation Bait Products.** The western Pacific Ocean coral atoll, known as Wake Atoll, is approximately 290 mi^2/751 km^2 and consists of 3 islands: Wake Island, Wilkes Island, and Peale Island. WS is collaborating with the U.S. Air Force and Island Conservation to complete an eradication project for two invasive rodent species— Pacific rats (*Rattus exulans*) and woodrats (*Neotoma* sp.)—on Wake Atoll in 2024. In preparation for the eradication, NWRC's Regulatory Support Services Unit worked with WS partners to receive EPA approval for new Section 3 registrations for two island conservation bait products containing the acute toxicant bromethalin (EPA Registration Nos. 56228-65 and 56228-66). The labels are currently limited to hand baiting methods only on Wake Atoll but may be expanded to other islands under supplemental labels or label amendments in the future.

  Contact: Emily Ruell

- **New Charcoal Source for Gas Cartridges.** In 2021, the WS Pocatello Supply Depot (PSD) lost the original manufacturing source of the active ingredient charcoal (carbon) for APHIS' four gas cartridge registrations. Sales

of these products to non-WS customers were suspended. Before a new source could be used in marketed gas cartridge products, the EPA required manufacturing process information, new analytical chemistry method development for carbon and impurities, and characterization data for five batches from the new source of charcoal. NWRC's Regulatory Support Services Unit worked with PSD to complete and submit these data submissions and new charcoal source applications to the EPA in March 2023. EPA approved the new charcoal source in August 2023.

Contact: Emily Ruell

- **Amended Compound DRC-1339 Concentrate Label.** Due to multiple years of reported juvenile and adult livestock losses from corvid predation, WS requested an amendment to the label for Compound DRC-1339 Concentrate–Livestock, Nest & Fodder Depredations (EPA Reg. No. 56228-29). The old label limited the product's use to the protection of newborn livestock. NWRC's Regulatory Support Services Unit submitted a label amendment application to the EPA in March 2023 and it was approved in June 2023. The new label allows the product to be used to protect livestock in any age class when they are being preyed upon by target corvid species (crows, ravens, and magpies).

Contact: Emily Ruell

Technology Transfer

- **4th International CWD Symposium.** The 4th International CWD Symposium was held in Denver, CO, May 29-June 2, 2023. The Symposium drew approximately 440 attendees from around the world to address and discuss the unique challenges associated with CWD and its impacts on wild and captive cervids. Participants included students, academics, Tribal representatives, State and Federal agency representatives, farmed cervid producers, other stakeholders, and renowned CWD experts. Focus areas included CWD surveillance, management, epidemiology, pathogenesis and transmission, human dimensions, environmental detection, and intervention/

WS was one of several hosts and sponsors for the 4th International CWD Symposium held in Denver, Colorado, in May 2023.
Photo by USDA Wildlife Services, Gail Keirn

prevention. The symposium was organized by USDA-APHIS, Colorado State University, USGS, U.S. Forest Service (USFS), U.S. Fish and Wildlife Service, National Park Service, Colorado Parks and Wildlife, and the Wyoming Game and Fish Department. Sponsors for the event included USDA-APHIS WS, Colorado State University, American Association of Wildlife Veterinarians, USGS, USFS, National Deer Association, North American Deer Farmers Association, Omni International, Responsible Hunting Scent Association, and the Theodore Roosevelt Conservation Partnership.

Contact: Jennifer Malmberg

- **New Inventions, Patents, and Licenses.** In FY 2023, NWRC scientists were awarded three foreign patents. See the following table for details on issued patents and patent applications. NWRC scientists also submitted five U.S. provisional patent applications and one invention disclosure to the NWRC Technology Transfer Office. In addition, patent licensees paid approximately $100,000 in royalties.

Contact: Sarah Hibbs-Shipp

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
Repellent and attractant composition for dichromatic animals	Werner, S., Ballinger, K. (Arkion Life Science)	Egypt Indonesia United States China United States	30898 IDP000079290 US11252953B2 (US16/833,860) CN108601346B US10638745B2
Ultraviolet strategy for avian repellency	Werner, S.	New Zealand	NZ728465B2, NZ728465A
		Canada	CA2954333C
		China	CN106793770B
		Australia	AU2014400622B2
		United States	US9131678B1 (US13/755,671)
Method for repelling rodents	Werner, S., Ballinger, K. (Arkion Life Science)	Canada Australia United States	CA2936508C AU2015204488B2 US9999220B2 (US14/595,718)
Use of visual cues to enhance bird repellent compounds	Werner, S., Ballinger, K (Arkion Life Science)	Japan Australia United States	JP6641353B2 AU2015294513C1 US14/910,099
System and method for collision prevention	DeVault, T., Blackwell, B., and Seamans, T.	United States	US11142173B2

Table of NWRC-issued patents, patent applications, and provisional applications.

INVENTION TITLE	NWRC INVENTORS AND *COOPERATOR CO-INVENTORS*	COUNTRY	PATENT/APPLICATION NUMBER
Microfluidized mycobacterium avium fragments as an adjuvant and carrier for mucosal vaccine delivery	Mauldin, R., Eckery, D., Miller. D.	United States	US10434171B2 (10,434171)
Container apparatus brown treesnake	Pitt, W., Savarie, P., Messaros, M. (Applied Design Corporation)	United States	US9730438B2 (9,730,438)
Adjuvanted rabies vaccine with improved viscosity profile	Miller, L., Fry, T., Hurley, J., Maki, J. (Merial Inc.)	United States	US9216213B2 (9,216,213)
Use of GNRH and analogs in the prevention and treatment of pet ferret adrenocortical hyperplasia	Miller, L., Wagner, B. (University of Pittsburg)	United States	US8927495B1 (8,927,495)
Trapping method and apparatus	Humphrey, J.	United States	US8407931B1 (8,407,931)
Vaccine compositions and adjuvant	Miller, L., Rhyan, J.	United States	US7731939B2

Applications

Trigeminal cue for wildlife repellents	Werner, S., Ballinger, K. (Arkion Life Sciences)	United States PCT	18/223,654 PCT/US2023/028116
Rodent repellent compositions	Werner, S., Ballinger, K. (Arkion Life Sciences)	United States PCT	18/223,659 PCT/US2023/028120
Selective bait delivery apparatus and method for rodent control	Shiels, A., Fragoso, J., Messaros, M. (Applied Design Corporation)	United States	63/453,553
Selective feeder for control of invasive psittacines	Tillman, E.,	United States	US20230240270A1 (18/101,160)
Electromechanical pest animal suppression trap	Shiels, A., Fragoso, J., Messaros, M. (Applied Design Corporation)	United States	17/394,052
Selectively accessible feeder	Lavelle, M., Halseth, J., Snow, N. and Staples, L., Lake, B. (Animal Control Technologies, Australia)	EPO Brazil WIPO United States Australia Canada PCT	EP3840572A4 BR112021003505A2 WO2020037381A1 US20210204509A1 (17/270,855) AU2019323945A1 EP3840572A1 CA3110648A1 PCT/AU2019/050903

Table of NWRC-issued patents, patent applications, and provisional applications (continued).

INVENTION TITLE	NWRC INVENTORS AND *COOPERATOR CO-INVENTORS*	COUNTRY	PATENT/APPLICATION NUMBER
Repellent and attractant compositions for dichromatic animals	Werner, S., Ballinger, K. (Arkion Life Sciences)	Brazil South Africa Ecuador Philippines South Korea Colombia Morocco Canada	BR112018013603B1 ZA201804136B ECSP18057724A PH12018550098A1 KR20180110667A CO2018008149A2 MA42867A1 CA3049200A1
Use of visual cues to enhance bird repellent compounds	Werner, S., Ballinger, K. (Arkion Life Science)	South Korea Brazil New Zealand China Malaysia South Africa Mexico Peru Philippines Colombia United States Canada	KR102556756B1 BR122021017566B1 (divisionals) NZ728476B2 CN106998674B MY184390A ZA201701198B MX2017001085A PE20170858A1 PH12017500117A1 CO2017001590A2 US20160157477A1 CA2955932A1
Method for repelling rodents	Werner, S., Ballinger, K. (Arkion Life Science)	New Zealand Brazil Mexico	NZ721804B2 BR112016016183B8 MX2016009126A
Ultraviolet strategy for avian repellency	Werner, S.	Brazil Chile Peru Mexico Philippines Colombia PCT	BR112017000459B1 CL2017000042A1 PE20170933A1 MX2017000298A PH12017500045A1 CO2017000617A2 PCT/US2014/048119
Deterrence of birds from treated seeds	Werner, S., Ballinger, K. (Arkion Life Sciences)	Japan EPA Japan EPO Mexico South Korea China Australia Canada WIPO (PCT) PCTs	JPWO2020154389A5 (divisional) EP3914074A4 (divisional) JP2022518038A EP3914074A1 MX2021008774A KR20210121099A CN113329625A AU2020211967A1 CA3126949A1 WO2020154389A1 PCT/US2020/014593
Intelligent dual sensory species-specific recognition system	Vercauteren, K., Snow, N., Halseth, J., Azimi-Sadjadi, M., Hall, J., Robbiano, C. (Information Systems Technologies, Inc.)	United States	17/230,453

INVENTION TITLE	NWRC INVENTORS AND *COOPERATOR CO-INVENTORS*	COUNTRY	PATENT/APPLICATION NUMBER
Provisional Applications			
Porous protein microcrystals as a scaffold for nucleic acids and proteins	Horak, K., Snow C. (Colorado State University)	United States	63/471,035
Encapsulated liquid product and process for encapsulating hydrophilic material	Hamby, H., Feuka, A.	United States	63/528,957
RNAi-based species-specific toxicants	Horak, K.	United States	63/413,329
Rodenticidal GABA receptor antagonists	Horak, K.	United States	63/413,333

Table of NWRC-issued patents, patent applications, and provisional applications (continued).

- **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 2023, NWRC entered into 5 confidentiality agreements, 2 data sharing agreements, 15 material transfer agreements, 15 material transfer research agreements, and 2 cooperative research and development agreements. 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 2023, the committee presented the award to Drs. Amy Davis and Kim Pepin for their paper describing the development of a new method to estimate changes in animal abundance over time. Co-authors included WS Operations employees from Missouri and Florida.

  Davis A.J., R. Farrar, B. Jump, P. Hall, T. Guerrant, and K.M. Pepin. 2022. An efficient method of evaluating multiple concurrent management actions on invasive populations. Ecological Applications 2022; 32(6):e2623. doi:10.1002/eap.2623.

A primary challenge with invasive species management is balancing the need to monitor change in abundance with the fundamental goal of reducing or eliminating invasive species. To address this challenge, a new method was developed to estimate changes in abundance over time using only data collected by management removal actions. The method allows for multiple removal methods, occurring non-systematically over a large spatial area and over time, and thus, also provides a method for evaluating the impact of management actions on populations over time.

This peer-reviewed research represents a novel use of WS management data. All co-authors are WS staff from both NWRC and Operations, and the research was funded through the WS NFSDMP.

- **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. Kim Pepin**
    research grade scientist; Management of Ungulate Damage and Disease Project; Fort Collins, CO
  - **Anna Mangan**
    support scientist; Wildlife Genetics Project; Fort Collins, CO
  - **Kaytlin Bohr**
    biological science technician; Disease Dynamics Project; Fort Collins, CO
  - **Jim Carlson**
    biosafety officer; Regulatory Support Services Unit; Fort Collins, CO

Dr. Antoinette Piaggio is the recipient of TWS' 2023 W.L. McAtee and G.V. Burger Award for Outstanding Service as Associate Editor.
Photo by USDA Wildlife Services, Gail Keirn

- **Dr. Antoinette Piaggio Awarded 2023 W.L. McAtee and G.V. Burger Award.** NWRC Wildlife Genetics Project Leader and supervisory research biologist Dr. Toni Piaggio received The Wildlife Society's (TWS) 2023 W.L. McAtee and G.V. Burger Award for Outstanding Service as Associate Editor for the organization's *Wildlife Society Bulletin*. TWS representatives noted Piaggio's dedication to scientific results that are useful and understandable by wildlife managers. The award was presented at TWS' 30th annual conference in Louisville, Kentucky.

2023 Publications

A WS wildlife disease biologist maneuvers a small field boat through the Alaskan wetlands as part of the program's surveillance for avian influenza in wild birds. *Photo by USDA Wildlife Services, Kelsey Weir*

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: 2022 publications that were not included in the 2022 NWRC accomplishments report are listed here.)

During FY23, NWRC had 204 active studies, produced 63 publications, collaborated with more than 150 entities, and had over 132,000 downloads from Digital Commons.

Altringer, L., S.C. McKee, J.D. Kougher, M.J. Begier, and S.A. Shwiff. 2023. The impact of the COVID-19 pandemic on wildlife–aircraft collisions at US airports. Scientific Reports 13(1):11602. doi: 10.1038/s41598-023-38451-9

Anderson, C.J., E.A. Tillman, W.P. Bukoski, S.C. Hess, L.A. Brennan, P.E. Klug, and B.M. Kluever. 2023. A novel parakeet-selective feeder for control of invasive psittacines. Wildlife Society Bulletin 47(3):e1483. doi: 10.1002/wsb.1483

Anderson, C.J., L.A. Brennan, W.P. Bukoski, S.C. Hess, C.D. Hilton, A.B. Shiels, S.R. Siers, B.M. Kluever, and P.E. Klug. 2023. Evaluation of roost culling as a management strategy for reducing invasive rose-ringed parakeet (*Psittacula krameri*) populations. Biological Invasions 25:1403-1419. doi: 10.1007/s10530-022-02984-3

Antaky, C.C., S.C. Hess, I.L. Leinbach, R.T. Sugihara, E.W. Ruell, and S.R. Siers. 2022. Development of a novel vertebrate pesticide for the invasive small Indian mongoose. Proceedings of the Vertebrate Pest Conference 30. Paper no. 1. 3 pp. https://escholarship.org/uc/item/3hv2t4nd

Askren, R.J., M.W. Eichholz, C.M. Sharp, B.E. Washburn, S.F. Beckernman, C.K. Pullins, A.M.V. Fournier, J.A. Vonbank, M.D. Weegman, H.M. Hagy, and M.P. Ward. 2022. Behavioral responses of Canada geese to winter harassment in the context of human-wildlife conflicts. Wildlife Society Bulletin 46(5):e1384. doi: 10.1002/wsb.1384

Baldwin, R.A., J.A. Smith, R. Meinerz, and A.B. Shiels. 2022. Managing roof rats in citrus orchards: initial efforts toward building an integrated pest management program. Proceedings of the Vertebrate Pest Conference 30. Paper no. 10. 4 pp. https://escholarship.org/uc/item/99m7008k

Baldwin, R.A., R. Meinerz, and A.B. Shiels. 2022. Efficacy of Goodnature A24 self-resetting traps and diphacinone bait for controlling black rats (*Rattus rattus*) in citrus orchards. Management of Biological Invasions 13(3):577-592. doi: 10.3391/mbi.2022.13.3.07

Baruzzi, C., N.P. Snow, K.C. VerCauteren, B.K. Strickland, J.S. Arnoult, J.W. Fischer, M.P. Glow, M.J. Lavelle, B.A. Smith, D. Steakley, and M.A. Lashley. 2023. Estimating body mass of wild pigs (*Sus scrofa*) using body morphometrics. Ecology and Evolution 13(3):e9853. doi: 10.1002/ece3.9853

Bechert, U.S., J.W. Turner, Jr., D.L. Baker, D.C. Eckery, J.E. Bruemmer, C.C. Lyman, T.M. Prado, S.R.B. King, and M.A. Fraker. 2002. Fertility control options for management of free-roaming horse populations. Human-Wildlife Interactions 16(2):179–216. doi: 10.26077/3f26-5f33

Bevins, S.N., S.A. Shriner, J.C. Cumbee, K.E. Dilione, K.E. Douglass, J.W. Ellis, M.L. Killian, M.K. Torchetti, and J.B. Lenoch. 2022. Intercontinental movement of H5 2.3.4.4 highly pathogenic avian influenza A(H5N1) to the United States, 2021. Emerging Infectious Diseases 28(5):1006-1011. doi: 10.3201/eid2805.220318

Blackwell, B.F., B.N. Buckingham, and M.B. Pfeiffer. European starling use of nest boxes relative to human disturbance. Human-Wildlife Interaction 16(1):84-96. doi: 10.26077/90e2-07b5

Bosco-Lauth, A., A. Rodriguez, R.M. Maison, S.M. Porter, and J.J. Root. 2023. H7N9 influenza A virus transmission in a multispecies barnyard model. Virology 582:100-105. doi: 10.1016/j.virol.2023.04.002

Bosco-Lauth, A.M., B. Cominsky, S. Porter, J.J. Root, A. Schueler, G. Anderson, S. VanderWal, and A. Benson. 2022. A novel vaccine candidate against rabbit hemorrhagic disease virus 2 (RHDV2) confers protection in domestic rabbits. American Journal of Veterinary Research 83(12). doi: 10.2460/ajvr.22.05.0095

Bowden, C.F., J. Grinolds, G. Franckowiak, L. McCallister, J. Halseth, M. Cleland, T. Guerrant, M. Bodenchuk, R. Miknis, M.C. Marlow, and V.R. Brown. 2023. Evaluation of the effect of hydrated lime on the scavenging of feral swine (*Sus scrofa*) carcasses and implications for managing carcass-based transmission of African swine fever virus. Journal of Wildlife Diseases 59(1):49-60. doi: 10.7589/JWD-D-22-00061

Brandell, E.E., M.K. Jackson, P.C. Cross, A.J. Piaggio, D.R. Taylor, D.W. Smith, B. Boufana, D.R. Stahler, and P.J. Hudson. 2022. Evaluating noninvasive methods for estimating cestode prevalence in a wild carnivore population. PLoS ONE 17(11):e0277420. doi: 10.1371/journal.pone.0277420

Breck, S.W., J.T. Schultz, D. Prause, C. Krebs, A.J. Giordano, and B. Boots. 2023. Integrating robotics into wildlife conservation: testing improvements to predator deterrents through movement. PeerJ 11:e15491. doi: 10.7717/peerj.15491

Brown, V.R., R.S. Miller, C.F. Bowden, T.J. Smyser, N.A. Ledesma, A. Hartwig, P. Gordy, A.M. Anderson, S.M. Porter, K. Alexander, Z. Gouker, T. Gidlewski, R.A. Bowen, and A.M. Bosco-Lauth. 2023. Disease progression and serological assay performance in heritage breed pigs following ***Brucella suis*** experimental challenge as a model for naturally infected feral swine. Pathogens 12(5):638. doi: 10.3390/pathogens12050638

Burr, P.C., B.S. Dorr, J.L. Avery, G.M. Street, and B.K. Strickland. 2023. Long term changes in aquaculture influence migration, regional abundance, and distribution of an avian species. PLoS ONE 18(4):e0284265. doi: 10.1371/journal.pone.0284265

Carlisle, K.M., H.E. Ellis, L.M. Jaebker, and A.D. Bright. 2022. Producers' perceptions of large carnivores and nonlethal methods to protect livestock from depredation: findings from a multistate federal initiative. Human Dimensions of Wildlife 28(4):392-395. doi: 10.1080/10871209.2022.2057624

Carver, C., J. Bruemmer, S. Coleman, G. Landolt, and T. Hess. 2023. Effects of corn supplementation on serum and muscle microRNA profiles in horses. Food Science & Nutrition 11(6):2811-2822. doi: 10.1002/fsn3.3259

Castaño, P.A., C.C. Hanson, K.J. Campbell, V. Carrión, P. Fisher, E. Ruell, D. Will, and S. Siers. 2022. Invasive rodent eradication on islands: assessment and mitigation of human exposure to rodenticides. Biological Invasions 25:653-671. doi: 10.1007/s10530-022-02940-1

Chinn, S.M., P.E. Schlichting, T.J. Smyser, C.F. Bowden, and J.C. Beasley. 2022. Factors influencing pregnancy, litter size, and reproductive parameters of invasive wild pigs. The Journal of Wildlife Management 86(8):e22304. doi: 10.1002/jwmg.22304

Chinn, S.M., T. Smyser, and J.C. Beasley. 2023. Variance in offspring sex ratio and maternal allocation in a highly invasive mammal. Ecology and Evolution 13(5):e10136. doi: 10.1002/ece3.10136

Chomphosy, W.H., D.T. Manning, S. Shwiff, and S. Weiler. 2023. Optimal R&D investment in the management of invasive species. Ecological Economics 221:107875. doi: 10.1016/j.ecolecon.2023.107875

Combs, M.A., A.J. Golnar, J.M. Overcash, A.L. Lloyd, K.R. Hayes, D.A. O'Brochta, and K.M. Pepin. 2023. Leveraging eco-evolutionary models for gene drive risk assessment. Trends in Genetics 39(8):609-623. doi: 10.1016/j.tig.2023.04.004

Crampton, L.H., M.K. Reeves, T. Bogardus, E.M. Gallerani, J. Hite, T.A. Winter, and A.B. Shiels. 2022. Modifications to prevent non-target lethality of Goodnature A24 rat traps - effects on rodent kill rates. Management of Biological Invasions 13(3):513-533. doi: 10.3391/mbi.2022.13.3.04

Cunningham, F.L., G. Wang, and D.T. King. 2022. Seasonal habitat selection by American white pelicans. Diversity 14(10):821. doi: 10.3390/d14100821

Cunningham, M.W., D.P. Wolf, K.A. Sayler, M. Milleson, B. Bankovich, P. Schueller, B.S. Haley, S. Stura, and M.J. Yabsley. 2023. Distribution of *Baylisascaris procyonis* in raccoons (*Procyon lotor*) in Florida, USA. Journal of Wildlife Disease 59(2):347-352. doi: 10.7589/JWD-D-22-00115

Davis, A.J., M. Gagnier, A. Massé, K.M. Nelson, J.D. Kirby, R. Wallace, X. Ma, C. Fehlner-Gardiner, R.B. Chipman, and A.T. Gilbert. 2023. Raccoon rabies control and elimination in the northeastern U.S. and southern Québec, Canada. Epidemiology & Infection 151:e62. doi: 10.1017/S095026882300047X

Davis, A.J. and S. Kay. 2023. Writing statistical methods for ecologists. Ecosphere 14(5):e4539. doi: 10.1002/ecs2.4539

Didero, N.M., K.H. Ernst, S.C. McKee, and S.A. Shwiff. 2023. A call and suggested criteria for standardizing economic estimates of wild pig damage. Crop Protection 165:106149. doi: 10.1016/j.cropro.2022.106149

Dinkins, J.B., L.R. Perry, J.L. Beck, and J.D. Taylor. 2021. Increased abundance of the common raven within the ranges of greater and Gunnison sage-grouse: influence of anthropogenic subsidies and fire. Human-Wildlife Interactions 15(3):270-288. doi: 10.26077/mv59-jy24

Dixon, W.C., J.E. Hill, R.B. Chipman, A.J. Davis, A.T. Gilbert, J.C. Beasley, O.E. Rhodes, Jr., and G. Dharmarajan. 2023. Interspecific oral rabies vaccine bait competition in the Southeast United States. applied Animal Behaviour Science 261:105897. doi: 10.1016/j.applanim.2023.105897

Dorr, B.S., D.G. Fielder, J.R. Jackson, J.F. Farquhar, D.W. Schultz, and R.M. Claramunt. 2022. Ontario's double-crested cormorant hunting season may be ineffective but that doesn't mean there are no conflict issues. Avian Conservation and Ecology 17(2):11. doi: 10.5751/ACE-02249-170211

Dykstra, A.M., C. Baruzzi, K. VerCauteren, B. Strickland, and M. Lashley. 2023. Biological invasions disrupt activity patterns of native wildlife: An example from wild pigs. Food Webs 34:e00270. doi: 10.1016/j.fooweb.2022.e00270

Egan, C.C., B.F. Blackwell, E. Fernández-Juricic, and P.E. Klug. 2023. Dispersal of blackbird flocks from sunflower fields: efficacy influenced by flock and field size but not drone platform. Wildlife Society Bulletin 47(3):e1478. doi: 10.1002/wsb.1478

Egan, M.E., K.M. Pepin, J.W. Fischer, S.E. Hygnstrom, K.C. VerCauteren, and G. Bastille-Rousseau. 2023. Social network analysis of white-tailed deer scraping behavior: Implications for disease transmission. Ecosphere 14(2):e4434. doi: 10.1002/ecs2.4434

Ellis, H.E., M.J. Grady, L.M. Jaebker, A.D. Bright, and K.M. Carlisle. 2023. A social network analysis of actors involved in wild pig (***Sus scrofa***) management in Missouri. Wildlife Society Bulletin 47(2):e1413. doi: 10.1002/wsb.1413

Elmore, J.A., E.A. Schultz, L.R. Jones, K.O. Evans, S. Samiappan, M.B. Pfeiffer, B.F. Blackwell, and R.B. Iglay. 2023. Evidence on the efficacy of small unoccupied aircraft systems (UAS) as a survey tool for North American terrestrial, vertebrate animals: a systematic map. Environmental Evidence 12:3. doi: 10.1186/s13750-022-00294-8

Estien, C.O., C.L. O'Connell, X. Francis, G. Smith-Vidaurre, B.M. Kluever, E.A. Hobson, and A. van der Marel. 2022. Temporary behavioral responses to playbacks by a pest parrot and implications for management. Animal Behavior and Cognition 9(4):363-384. doi: 10.26451/abc.09.04.01.2022

Evans, B.A., J.S. Humphrey, E.A. Tillman, and B.M. Kluever. 2022. Cannibalism by black vultures (*Coragyps atratus*). Journal of Raptor Research 56(4):498-500. doi: 10.3356/JRR-22-29

Feng, A., S. Bevins, J. Chandler, T.J. DeLiberto, R. Ghai, K. Lantz, J. Lenoch, A. Retchless, S. Shriner, C.Y. Tang, S.S. Tong, M. Torchetti, A. Uehara, and X.-F. Wan. 2023. Transmission of SARS-CoV-2 in free-ranging white-tailed deer in the United States. Nature Communications 14(1):4078. doi: 10.1038/s41467-023-39782-x

Ferguson, T.L., D.T. King, B.J. Rude, W. Baumgartner, C.L. Huston, B. Strickland, and F.L. Cunningham. 2023. Natural West Nile virus infections in captive raised American white pelicans (*Pelecanus erythrorhynchos*). Waterbirds 54(2):206-212. doi: 10.1675/063.045.0211

Fielder, D.G., T.A. Hayden, T.R. Binder, B.S. Dorr, and H.A. Currier. 2023. Predator telemetry informs temporal and spatial overlap with stocked salmonids in Lake Huron. Animal Biotelemetry 11:25. doi: 10.1186/s40317-023-00336-z

Foster, J.A., L.H. Williamson, J.C. Kinsey, R.L. Reitz, K.C. VerCauteren, and N.P. Snow. 2023. Alternatives to corn for baiting wild pigs. Wildlife Society Bulletin 47(3):e1480. doi: 10.1002/wsb.1480

Franklin, A.B. 2023. An ode to owls. Science 380(6651):1228. doi: 10.1126/science.adi4560

Friesenhahn, B.A., L.D. Massey, R.W. DeYoung, M.J. Cherry, J.W. Fischer, N.P. Snow, K.C. VerCauteren, and H.L. Perotto-Baldivieso. 2023. Using drones to detect and quantify wild pig damage and yield loss in corn fields throughout plant growth stages. Wildlife Society Bulletin 47(2):e1437. doi: 10.1002/wsb.1437

Friesenhahn, B.A, R.W. DeYoung, M.J. Cherry, H.L. Perotto-Baldivieso, K.C. VerCauteren, and N.P. Snow. 2023. Movements and resource selection of wild pigs associated with growth stages of corn. Crop Protection 163:106119. doi: 10.1016/j.cropro.2022.106119

Garcia, A.C., M.A. Parsons, and J.K. Young. 2022. Effects of early-life experience on innovation and problem-solving in captive coyotes. Behavioral Ecology and Sociobiology 76:141. doi: 10.1007/s00265-022-03251-0

Gierus, L., A. Birand, M.D. Bunting, G.I. Godahewa, S.G. Piltz, K.P. Oh, A.J. Piaggio, D.W. Threadgill, J. Godwin, O. Edwards, P. Cassey, J.V. Ross, T.A.A. Prowse, and P.Q. Thomas. 2022. Leveraging a natural murine meiotic drive to suppress invasive populations. Proceedings of the National Academy of Sciences 119(46):e2213308119. doi: 10.1073/pnas.2213308119

Goldade, D.A., S.R. Siers, S.C. Hess, R.T. Sugihara, and C.A. Riekena. 2023. Determination of residue levels of rodenticide in rodent livers offered novel diphacinone baits by liquid chromatography-tandem mass spectrometry. PLoS ONE 18(8):e0289261. doi: 10.1371/journal.pone.0289261

Guan, M., A.K. Olivier, X. Lu, W. Epperson, X. Zhang, L. Zhong, K. Waters, N. Mamaliger, L. Li, F. Wen, Y.J. Tao, T.J. DeLiberto, and X.-F. Wan. 2022. The Sialyl Lewis X Glycan Receptor Facilitates Infection of Subtype H7 Avian Influenza A Viruses. Journal of Virology 96(19):e01344-22. doi: 10.1128/jvi.01344-22

Guzy, J.C., B.G. Falk, B.J. Smith, J.D. Willson, R.N. Reed, N.G. Aumen, M.L. Avery, I.A. Bartoszek, E. Campbell, M.S. Cherkiss, N.M. Claunch, A.F. Currflow, T. Dean, J. Dixon, R. Engeman, S. Funck, R. Gibble, K.C. Hengstebeck, J.S. Humphrey, M.E. Hunter, J.M. Josimovich, J. Ketterlin, M. Kirkland, F.J. Mazzotti, R. McCleery, M.A. Miller, M. McCollister, M.R. Parker, S.E. Pittman, M. Rochford, C. Romagosa, A. Roybal, R.W. Snow, M.M. Spencer, J.H. Waddle, A.A. Yackel Adams, and K.M. Hart. 2023. Burmese pythons in Florida: A synthesis of biology, impacts, and management tools. NeoBiota 80:1-119. doi: 10.3897/neobiota.80.90439

Helton, J.L., J.E. Hill, D.A. Bernasconi, W.C. Dixon, R.B. Chipman, A.T. Gilbert, J.C. Beasley, G. Dharmarajan, and O.E. Rhodes, Jr. 2023. Assessment of habitat-specific competition for oral rabies vaccine baits between raccoons and opossums. Journal of Wildlife Management 87(5):e22398. doi: 10.1002/jwmg.22398

Hess, S.C., C.J. Anderson, E.A. Tillman, W.P. Bukoski, A.B. Shiels, P.S. Klug, and B.M. Kluever. 2023. Differences in feeder visitation by invasive rose-ringed parakeets (*Psittacula krameri*) between Hawaiian Islands. Pacific Science 77(1):111-123. doi: 10.2984/77.1.7

Hess, S.C., J. Sprague, and J. Muise. 2022. Evidence for irruptive fluctuation in axis deer of Hawai'i. Proceedings of the Vertebrate Pest Conference 30. Paper no. 14. 4 pp. https://escholarship.org/uc/item/5vz709dw

Hill, J.E., J.L. Helton, R.B. Chipman, A.T. Gilbert, J.C. Beasley, G. Dharmarajan, and O.E. Rhodes. 2023. Spatial ecology of translocated raccoons. Scientific Reports 13:10447. doi: 10.1038/s41598-023-37323-6

Hill, J.E., K.F. Kellner, A.E. Holland, B.M. Kluever, M.B. Pfeiffer, T.L. DeVault, and J.L. Belant. 2023. Urbanization influences spatiotemporal patterns of roost site selection by black vultures and turkey vultures. Urban Ecosystems 26:967–979. doi: 10.1007/s11252-023-01328-w

Hodge, A.E., E.M. Gese, and B.M. Kluever. 2002. Does water availability shift dietary preferences of coyotes in the west desert of Utah? Journal of Arid Environments 206:104833. doi: 10.1016/j.jaridenv.2022.104833

Hodge, A.E., E.M. Gese, and B.M. Kluever. 2023. Demographic and functional responses of kit foxes to changes in prey abundance. Canadian Journal of Zoology 101(2):65-74. doi: 10.1139/cjz-2022-0061

Hollinshead, F.K., M.K. Mehegan, A. Gunn, T. Nett, J.E. Bruemmer, and D.W. Hanlon. 2002. The correlation of endogenous progesterone concentration in diestrus on early pregnancy rate in thoroughbred mares. Journal of Equine Veterinary Science 118:104127. doi: 10.1016/j.jevs.2022.104127

Hopken, M.W., D. Gilfillan, A.T. Gilbert, A.J. Piaggio, M.S. Hilton, J. Pierce, B. Kimball, and Z. Abdo. 2023. Biodiversity indices and Random Forests reveal the potential for striped skunk (*Mephitis mephitis*) fecal microbial communities to function as a biomarker for oral rabies vaccination. PLoS ONE 18(8):e0285852. doi: 10.1371/journal.pone.0285852

Hyde, M., E. Payán, J. Barragan, D. Stasiukynas, S. Rincón, W.L. Kendall, J. Rodriguez, K.R. Crooks, S.W. Breck, and V. Boron. 2023. Tourism-supported working lands sustain a growing jaguar population in the Colombian Llanos. Scientific Reports 13:10408. doi: 10.1038/s41598-023-36935-2

Hyde, M., S.W. Breck, A. Few, J. Beaver, J. Schrecengost, J. Stone, C. Krebs, R. Talmo, K. Eneas, R. Nickerson, K.E. Kunkel, and J.K. Young. 2022. Multidisciplinary engagement for fencing research informs efficacy and rancher-to-researcher knowledge exchange. Frontiers in Conservation Science 3:938054. doi: 10.3389/fcosc.2022.938054

Jaebker, L.M., A.D. Bright, H.E. Ellis, J.M. Tomeček, M.G. Frank, R.L. Connally, S.A. Shwiff, and K.M. Carlisle. 2023. Texas hunters' attitudes toward wild pigs (***Sus scrofa***) and their management: an applied approach for wildlife managers. Wildlife Society Bulletin 47(3):e1472. doi: 10.1002/wsb.1472

Jaebker, L.M., T.L. Teel, A.D. Bright, H.E. McLean, J.M. Tomeček, M.G. Frank, R.L. Connally, S.A. Shwiff, and K.M. Carlisle. 2022. Social identity and acceptability of wild pig (*Sus scrofa*) control actions: A case study of Texas hunters. Human Dimensions of Wildlife 27(6):507-521. doi: 10.1080/10871209.2021.1967525

Jones, L.R., J.A. Elmore, B.S. Krishnan, S. Samiappan, K.O. Evans, M.B. Pfeiffer, B.F. Blackwell, and R.B. Iglay. 2023. Controllable factors affecting accuracy and precision of human identification of animals from drone imagery. Ecosphere 14(9):e4657. doi: 10.1002/ecs2.4657

Kading, R.C., E.M. Borland, E.C. Mossel, T. Nakayiki, B. Nalikka, J.P. Ledermann, M.B. Crabtree, N.A. Panella, L. Nyakarahuka, A.T. Gilbert, J.C. Kerbis-Peterhans, J.S. Towner, B.R. Amman, T.K. Sealy, B.R. Miller, J.J. Lutwama, R.M. Kityo, and A.M. Powers. 2022. Exposure of Egyptian rousette bats (*Rousettus aegyptiacus*) and a little free-tailed bat (*Chaerephon pumilus*) to alphaviruses in Uganda. Diseases 10(4):121. doi: 10.3390/diseases10040121

Kellner, A., T.C. Atwood, D.C. Douglas, S.W. Breck, and G. Wittemyer. 2023. High winds and melting sea ice trigger landward movement in a polar bear population of concern. Ecosphere 14(2):e4420. doi: 10.1002/ecs2.4420

Kent, C.M., A.M. Ramey, J.T. Ackerman, J. Bahl, S.N. Bevins, A.S. Bowman, W.M. Boyce, C.J. Cardona, M.L. Casazza, T.D. Cline, S.E. De La Cruz, J.S. Hall, N.J. Hill, H.S. Ip, S. Krauss, J.M. Mullinax, J.M. Nolting, M. Plancarte, R.L. Poulson, J.A. Runstadler, R.D. Slemons, D.E. Stallknecht, J.D. Sullivan, J.Y. Takekawa, R.J. Webby, R.G. Webster, and D.J. Prosser. 2022. Spatiotemporal changes in influenza A virus prevalence among wild waterfowl inhabiting the continental United States throughout the annual cycle. Scientific Reports 12(1):13083. doi: 10.1038/s41598-022-17396-5

Kent, E., S. Coleman, J. Bruemmer, R.R. Casagrande, C. Levihn, G. Romo, K. Herkelman, and T. Hess. 2023. Comparison of an antioxidant source and antioxidant plus BCAA in athletic performance and post exercise recovery of horses. Journal of Equine Veterinary Science 121:104200. doi: 10.1016/j.jevs.2022.104200

Kierepka, E.M., S. Preckler-Quisquater, D.M. Reding, A.J. Piaggio, S.P.D. Riley, B.N. Sacks. 2023. Genomic analyses of gray fox lineages suggest ancient divergence and secondary contact in the southern Great Plains. Journal of Heredity 114(2):110-119. doi: 10.1093/jhered/esac060

Kluever, B.M., M.L. Avery, D.E. Gawlik, P. Hall, J.S. Humphrey, T. Pernas, and F. Ridgley. 2023. Eradication of African sacred ibis (*Threskiornis aethiopicus*) from South Florida, USA: a collaborative early detection and rapid response case study. Management of Biological Invasions 14(1):123-132. doi: 10.3391/mbi.2023.14.1.01

Klug, P.E., A.B. Shiels, B.M. Kluever, C.J. Anderson, S.C. Hess, E.W. Ruell, W.P. Bukoski, and S.R. Siers. 2023. A review of nonlethal and lethal control tools for managing the damage of invasive birds to human assets and economic activities. Management of Biological Invasions 14(1):1-44. doi: 10.3391/mbi.2023.14.1.01

Kreuser, A.M., A.B. Shiels, C.A. Lepczyk, and L.H. Crampton. 2022. Bird and rat carcass persistence in a Hawaiian rainforest managed for rodents using Goodnature A24 self-resetting traps. Management of Biological Invasions 13(3):494-512. doi: 10.3391/mbi.2022.13.3.03

Krishnan, B.S., L.R. Jones, J.A. Elmore, S. Samiappan, K.O. Evans, M.B. Pfeiffer, B.F. Blackwell, and R.B. Iglay. 2023. Fusion of visible and thermal images improves automated detection and classification of animals for drone surveys. Scientific Reports 13:10385. doi: 10.1038/s41598-023-37295-7

Kunkel, A., G. Veytsel, S. Bonaparte, H. Meek, X. Ma, A.J. Davis, J. Bonwitt, and R.M. Wallace. 2023. Defining county-level terrestrial rabies freedom using the US national rabies surveillance system: surveillance data analysis. JMIR Public Health and Surveillance 9:e43061. doi: 10.2196/43061

Leivers, S.J., K.M. Carlisle, R.L. Connally, M.G. Frank, and J.M. Tomeĉek. 2023. The influence of income and loss on hunters' attitudes towards wild pigs and their management. Wildlife Society Bulletin 47(2):e1439. doi: 10.1002/wsb.1439

Leivers, S., T. Campbell, M. Bodenchuk, and J. Tomeĉek. 2023. Behavior of wild pigs toward conspecific carcasses: implications for disease transmission in a hot, semiarid climate. Transboundary and Emerging Diseases 2023:4195199. doi: 10.1155/2023/4195199

Livieri, T.M., S.C. Forrest, M.R. Matchett, and S.W. Breck. 2022. Conserving endangered black-footed ferrets: biological threats, political challenges, and lessons learned. pgs 458-470. In: D.A. Dellasala and M.I. Goldstein, editors. Imperiled: The Encyclopedia of Conservation. Elsevier Science. 2608 pp. doi: 10.1016/B978-0-12-821139-7.00061-1

Maison, R.M., M.R. Priore, V.R. Brown, M.J. Bodenchuk, B.R. Borlee, R.A. Bowen, and A.M. Bosco-Lauth. 2023. Feral swine as indirect indicators of environmental anthrax contamination and potential mechanical vectors of infectious spores. Pathogens 12(4):622. doi: 10.3390/pathogens12040622

Mangan, A.M., J.A. Kronenberger, I.H. Plummer, T.M. Wilcox, and A.J. Piaggio. 2023. Validation of a nutria (*Myocastor coypus*) environmental DNA assay highlights considerations for sampling methodology. Environmental DNA 5(3):391-402. doi: 10.1002/edn3.412

Marchetti, J.R., K.H. Beard, E.E. Virgin, E.L. Lewis, S.C. Hess, K.C. Ki, L.O. Sermersheim, A.P. Furtado, and S.S. French. 2023. Invasive frogs show persistent physiological differences to elevation and acclimate to colder temperatures. Journal of Thermal Biology 114:103590. doi: 10.1016/j.jtherbio.2023.103590

McBride, D.S., S.K. Garushyants, J. Franks, A.F. Magee, S.H. Overend, D. Huey, A.M. Williams, S.A. Faith, A. Kandeil, S. Trifkovic, L. Miller, T. Jeevan, A. Patel, J.M. Nolting, M.J. Tonkovich, J.T. Genders, A.J. Montoney, K. Kasnyik, T.J. Linder, S.N. Bevins, J.B. Lenoch, J.C. Chandler, T.J. DeLiberto, E.V. Koonin, M.A. Suchard, P. Lemey, R.J. Webby, M.I. Nelson, and A.S. Bowman. 2023. Accelerated evolution of SARS-CoV-2 in free-ranging white-tailed deer. Nature Communications 14:5105. doi: 10.1038/s41467-023-40706-y

McElderry, R.M., E.H. Paxton, A.V. Nguyen, and S.R. Siers. 2022. Predation thresholds for reintroduction of native avifauna following suppression of invasive brown treesnakes on Guam. Ecological Applications 32(8):e2716. doi: 10.1002/eap.2716

Meehan, T.D., S.P. Saunders, W.V. DeLuca, N.L. Michel, J. Grand, J.L. Deppe, M.F. Jimenez, E.J. Knight, N.E. Seavy, M.A. Smith, L. Taylor, C. Witko, M.E. Akresh, D.R. Barber, E.M. Bayne, J.C. Beasley, J.L. Belant, R.O. Bierregaard, K.L. Bildstein, T.J. Boves, J.N. Brzorad, S.P. Campbell, A. Celis-Murillo, H.A. Cooke, R. Domenech, L. Goodrich, E.A. Gow, A. Haines, M.T. Hallworth, J.M. Hill, A.E. Holland, S. Jennings, R. Kays, D.T. King, S.A. Mackenzie, P.P. Marra, R.A. McCabe, K.P. McFarland, M.J. McGrady, R.Melcer, Jr., D.R. Norris, R.E. Norvell, O.E. Rhodes, Jr., C.C. Rimmer, A.L. Scarpignato, A. Shreading, J.L. Watson, and C.B. Wilsey. 2022. Integrating data types to estimate spatial patterns of avian migration across the Western Hemisphere. Ecological Applications 32(7):e2679. doi: 10.1002/eap.2679

Miller, R.S., S.N. Bevins, G. Cook, R. Free, K.M. Pepin, T. Gidlewski, and V.R. Brown. 2022. Adaptive risk-based targeted surveillance for foreign animal diseases at the wildlife-livestock interface. Transboundary and Emerging Diseases 69(5):e2329-e2340. doi: 10.1111/tbed.14576

Moran, L.L.K., B.S. Dorr, K.C. Hanson-Dorr, R.J. Moore, and S.A. Rush. 2023. Space use and movements of southeastern breeding double-crested cormorants (*Nannopterum auritum*) in the United States. Diversity 15(3):453. doi: 10.3390/d15030453

Morehead, A.R., C.D. Carrillo, H. Hicks, W. Sanders, and D.L. Bergman. 2022. Abert's squirrel management in support of endangered Mount Graham red squirrel recovery in Arizona. Proceedings of the Vertebrate Pest Conference 30. Paper no. 19. 6 pp. https://escholarship.org/uc/item/7km15588

Muller-Girard, M., G. Fowles, J. Duchamp, S. Kouneski, C. Mollohan, T.J. Smyser, G.G. Turner, B. Westrich, and J.M. Doyle. 2022. A novel SNP assay reveals increased genetic variability and abundance following translocations to a remnant Allegheny woodrat population. BMC Ecology and Evolution 22(1):137. doi: 10.1186/s12862-022-02083-w

O'Brien, D.J., T.C. Thacker, L.C.M. Salvador, A.G. Duffiney, S. Robbe-Austerman, M.S. Camacho, J.E. Lombard, and M.V. Palmer. 2023. The devil you know and the devil you don't: current status and challenges of bovine tuberculosis eradication in the United States. Irish Veterinary Journal 76(1):16. doi: 10.1186/s13620-023-00247-8

Ogawa, R., J.B. Davis, D.T. King, L.W. Burger, B.K. Strickland, M.A. Sovada, G. Wang, and F.L. Cunningham. 2022. Migratory movements and home ranges of geographically distinct wintering populations of a soaring bird. Diversity 14(12):1109. doi: 10.3390/d14121109

Pepin, K.M., V.R. Brown, A. Yang, J.C. Beasley, R. Boughton, K.C. VerCauteren, R.S. Miller, and S.N. Bevins. 2002. Optimizing response to an introduction of African swine fever in wild pigs. Transboundary and Emerging Diseases 69(5):e3111-e3127. doi: 10.1111/tbed.14668

Perry, L.R., T.M. Owens, Z.T. Slick, J.D. Taylor, and J.B. Dinkins. 2021. A novel technique to improve capture success of common ravens. Human-Wildlife Interactions 15(3):447-454. doi: 10.26077/ac41-c60f

Pfeiffer, M.B., C.K. Pullins, S.F. Beckerman, J.L. Hoblet, and B.F. Blackwell. 2023. Investigating nocturnal UAS treatments in an applied context to prevent gulls from nesting on rooftops. Wildlife Society Bulletin 47(2):e1423. doi: 10.1002/wsb.1423

Podgórsk, T., K.M. Pepin, A. Radko, A. Podbielska, M. Łyjak, G. Woźniakowski, and T. Borowik. 2022. How do genetic relatedness and spatial proximity shape African swine fever infections in wild boar? Transboundary and Emerging Diseases 69(5):2656-2666. doi: 10.1111/tbed.14418

Porter, S.M., A.E. Hartwig, H. Bielefeldt-Ohmann, A.M. Bosco-Lauth, and J.J. Root. 2022. Susceptibility of wild canids to SARS-CoV-2. Emerging Infectious Diseases 28(9):1852-1855. doi: 10.3201/eid2809.220223

Rockweit, J.T., J.M. Jenkins, J.E. Hines, J.D. Nichols, K.M. Dugger, A.B. Franklin, P.C. Carlson, W.L. Kendall, D.B. Lesmeister, C. McCafferty, S.H. Ackers, L.S. Andrews, L.L. Bailey, J. Burgher, K.P. Burnham, T. Chestnut, M.M. Conner, R.J. Davis, K.E. Dilione, E.D. Forsman, E.M. Glenn, S.A. Gremel, K.A. Hamm, D.R. Herter, J.M. Higley, R.B. Horn, D.W. Lamphear, T.L. McDonald, J.A. Reid, C.J. Schwarz, D.C. Simon, S.G. Sovern, J.K. Swingle, J.D. Wiens, H. Wise, and C.B. Yackulic. 2023. Range-wide sources of variation in reproductive rates of northern spotted owls. Ecological Applications 33(1):e2726. doi: 10.1002/eap.2726

Rush, S.A., N.J. Buckley, P.A. Zollner, B.M. Kluever, B.L. McWherter, G.N. Burcham, Z. Ma, M.L. Wahl, and A. Naveda-Rodriguez. 2023. Science-driven guidelines needed to better manage and conserve black vultures in North America. Wildlife Letters 1(2):79-82. doi: 10.1002/wll2.12017

Schultz, D.W., B.S. Dorr, D.G. Fielder, J.R. Jackson, and R.L. DeBruyne. 2022. Indicators of fish population responses to avian predation with focus on double-crested cormorants. Journal of Great Lakes Research 48:1659-1668. doi: 10.1016/j.jglr.2022.08.022

Shiels, A.B., D.R. Spock, T. Cochran, and L. Baeten. 2022. Efficacy testing of Goodnature A24 self-resetting rat traps for wild house mice (*Mus musculus*). Management of Biological Invasions 13(3):557-576. doi: 10.3391/mbi.2022.13.3.06

Shiels, A.B., G.E. Ramirez de Arellano, and L. Shiels. 2022. Invasive rodent responses to experimental and natural hurricanes with implications for global climate change. Ecosphere 13(12):e4307. doi: 10.1002/ecs2.4307

Shiels, A.B., J.W. Fischer, D. Spock, and M. Allira. 2022. Improving efficiency of prairie dog surveys by using a small copter drone. Proceedings of the Vertebrate Pest Conference 30. Paper no. 21. 7 pp. https://escholarship.org/uc/item/04q7t6zk

Shiels, A.B., L.H. Crampton, D.R. Spock, A.L. Greggor, K. Earnest, L. Berry, and B. Masuda. 2022. Testing Goodnature A24 rat trap excluders and trap height placement to prevent non-target bird mortality. Management of Biological Invasions 13(3):534-556. doi: 10.3391/mbi.2022.13.3.05

Shiels, A.B., T. Bogardus, L.H. Crampton, M. Gronwald, A.M. Kreuser, R.A. Baldwin, and C.A. Lepczyk. 2022. An introduction to a special issue and review of the effectiveness of Goodnature A24 self-resetting rat traps. Management of Biological Invasions 13(3):466-478. doi: 10.3391/mbi.2022.13.3.01

Smith, M.M., C. Van Hemert, T.C. Atwood, D.R. Sinnett, J.W. Hupp, B.W. Meixell, D.D. Gustine, L.G. Adams, and A.M. Ramey. 2022. A serologic survey of *Francisella tularensis* exposure in wildlife on the arctic coastal plain of Alaska. Journal of Wildlife Diseases 58(4):746-755. doi: 10.7589/JWD-D-21-00162

Snow, N.P., M.P. Glow, M.J. Lavelle, J.W. Fischer, S.M. Cook, M.W. Lutman, J.A. Foster, and K.C. VerCauteren. 2022. Dry and unwary are best conditions for baiting wild pigs (*Sus scrofa*). Applied Animal Behaviour Science 257:105777. doi: 10.1016/j.applanim.2022.105777

Spraker, T.R., T. Gidlewski, J.G. Powers, T.A. Nichols, and M.A. Wild. 2023. Distribution of the misfolded isoform of the prion protein in peripheral tissues and spinal cord of Rocky Mountain elk (*Cervus elaphus nelsoni*) with naturally occurring chronic wasting disease. Veterinary Pathology 60(4):420-433. doi: 10.1177/03009858231173467

Stuart, K.C, R.J. Edwards, Y. Chang, W.C. Warren, D.W. Burt, W.B. Sherwin, N.R. Hofmeister, S.J. Werner, G.F. Ball, M. Bateson, M.C. Brandley, K.L. Buchanan, P. Cassey, D.F. Clayton, T. De Meyer, S.L. Meddle, and L.A. Rollins. 2022. Transcript- and annotation-guided genome assembly of the European starling. Molecular Ecology Resources 22(8):3141-3160. doi: 10.1111/1755-0998.13679

Taitingfong, R.I., C. Triplett, V.N. Vásquez, R.M. Rajagopalan, R. Raban, A. Roberts, G. Terradas, B. Baumgartner, C. Emerson, F. Gould, F. Okumu, C.E. Schairer, H.C. Bossin, L. Buchman, K.J. Campbell, A. Clark, J. Delborne, K. Esvelt, J. Fisher, R.M. Friedman, G. Gronvall, N. Gurfield, E. Heitman, N. Kofler, T. Kuiken, J. Kuzma, P. Manrique-Saide, J.M. Marshall, M. Montague, A.C. Morrison, C.C. Opsen, R. Phelan, A. Piaggio, H. Quemada, L. Rudenko, N. Sawadogo, R. Smith, H. Tuten, A. Ullah, A. Vorsino, N. Windbichler, O.S. Akbari, K. Long, J.V. Lavery, S.W.

Evans, K. Tountas, and C.S. Bloss. 2023. Exploring the value of a global gene drive project registry. Nature Biotechnology 41:9-13. doi: 10.1038/s41587-022-01591-w

Talmi-Frank, D., A.D. Byas, R. Murrieta, J. Weger-Lucarelli, C. Rückert, E.N. Gallichotte, J.A. Yoshimoto, C. Allen, A.M. Bosco-Lauth, B. Graham, T.A. Felix, A.C. Brault, and G.D. Ebel. 2023. Intracellular diversity of WNV within circulating Avian peripheral blood mononuclear cells reveals host-dependent patterns of polyinfection. Pathogens 12(6):767. doi: 10.3390/pathogens12060767

Taylor, D.R., B.M. Kluever, J.S. Humphrey, I.M. Hennessy, A. Sutton, W.E. Bruce, and A.J. Piaggio. 2022. Amplification of black vulture (*Coragyps atratus*) DNA from regurgitated food pellets. The Wilson Journal of Ornithology 134(3):546-551. doi: 10.1676/22-00001

Tillis, S.B., J.M. Josimovich, M.A. Miller, L.L. Hoon-Hanks, A.M. Hartmann, N.M. Claunch, M.E. Iredale, T.D. Logan, A.A. Yackel Adams, I.A. Bartoszek, J.S. Humphrey, B.M. Kluever, M.D. Stenglein, R.N. Reed, C.M. Romagosa, J.F.X. Wellehan, and R.J. Ossiboff. 2022. Divergent serpentoviruses in free-ranging invasive pythons and native colubrids in Southern Florida, United States. Viruses 14(12):2726. doi: 10.3390/v14122726

Titus, C.L., C.F. Bowden, T.J. Smyser, S.L. Webb, and J.C. Beasley. 2022. Genomic tools reveal complex social organization of an invasive large mammal (*Sus scrofa*). Biological Invasions 24(10):3199-3216. doi: 10.1007/s10530-022-02840-4

Turano, A., S.P. Brummer, J.K. Young, and S.M. Freeman. 2023. Can a traditional partner preference test quantify monogamous behavior in captive coyotes? Behavioural Processes 206:104832. doi: 10.1016/j.beproc.2023.104832

van der Marel, A., X. Francis, C.L. O'Connell, C.O. Estien, C. Carminito, V.D. Moore, N. Lormand, B.M. Kluever, and E.A. Hobson. 2023. Perturbations highlight importance of social history in parakeet rank dynamics. Behavioral Ecology 34(3):457-467. doi: 10.1093/beheco/arad015

Veals, A.M., J.L. Koprowski, K.C. VerCauteren, D.L. Bergman, and M.V. Mazzamuto. 2022. Gray fox (*Urocyon cinereoargenteus*) space use in southeastern Arizona. The Southwestern Naturalist 66(2):166-168. doi: 10.1894/0038-4909-66.2.166

Wahl, M.L., B. McWherter, P.A. Zollner, Z. Ma, G.N. Burcham, L.A. Humberg, and B.M. Kluever. 2023. Livestock producers' perceptions of the American black vulture conflict in the midwestern United States. Wildlife Society Bulletin 47(2):e1440. doi: 10.1002/wsb.1440

Wait, L.F., S.R. Johnson, K.M. Nelson, R.B. Chipman, F.E. Pogmore, A.P. Dobson, and A.L. Graham. 2023. Demographic, environmental and physiological predictors of gastrointestinal parasites in urban raccoons. International Journal for Parasitology: Parasite and Wildlife 21:116-128. doi: 10.1016/j.ijppaw.2023.04.011

Washburn, B.E., C.K. Pullins, A.M. Hoffman, S.F. Beckernman, and T.L. Guerrant. 2022. Sex determination of Eastern red-tailed hawks (*Buteo jamaicensis borealis*) using morphometrics. Journal of Raptor Research 56(4):466-470. doi: 10.3356/JRR-22-00004

Yang, A., M.Q. Wilber, K.R. Manlove, R.S. Miller, R. Boughton, J. Beasley, J. Northrup, K.C. VerCauteren, G. Wittemyer, and K. Pepin. 2023. Deriving spatially explicit direct and indirect interaction networks from animal movement data. Ecology and Evolution 13(3):e9774. doi: 10.1002/ece3.9774

Appendix 1

List of 2023 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

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

Project Leader: Kurt VerCauteren

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

Project Leader: Jason Bruemmer

Economics, Operations Research, and Social Dimensions of Wildlife Management

Project Leader: Stephanie Shwiff

Evaluation and Development of Wildlife Repellents and Repellent Application Strategies

Project Leader: Scott Werner

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

Project Leader: Antoinette Piaggio

Methods and Strategies for Wildlife Rabies Control and Elimination

Project Leader: Amy Gilbert

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

Project Leader: Steven Hess

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

Project Leader: Aaron Shiels

Methods Development and Damage Management of Depredating Birds and Invasive Wildlife

Project Leader: Bryan Kluever

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

Project Leader: Page Klug

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

Project Leader: Brad Blackwell

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

Project Leader: Alan Franklin

Wildlife Disease Dynamics, Epidemiology, and Response

Project Leader: 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: Michael McBride

Administration

Unit Leader: Natalie Erhart

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

www.aphis.usda.gov/wildlifedamage/nwrc

Appendix 2

NWRC Primary 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
Bruemmer, Jason	(970) 266-6035 jason.bruemmer@usda.gov	Project Leader: Fertility control, population management
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
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
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
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
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	Physiological modeling, pesticides, toxicology

NAME	CONTACT INFORMATION	AREAS OF EXPERTISE
Kluever, Bryan	(352) 448-2130 bryan.kluever@usda.gov	Project Leader: Invasive species, birds
Klug, Page	(701) 231-5190 page.e.klug@usda.gov	Project Leader: Bird damage to agriculture
Kohler, Allison	(970) 266-6121 allison.kohler@usda.gov	Repellents
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
Vacant	(970) 266-6364	Unit Leader: Animal care, Supervisory Attending Veterinarian
Nicholas, Kellie	(970) 266-6065 kellie.r.nicholas@usda.gov	Bioarchivist
Parrie, Lindsay	(970) 266-6156 lindsay.parrie@usda.gov	Chronic wasting disease
Phillips, Aaron	(970) 266-5752 aaron.phillips@usda.gov	Diagnostician; Wildlife Disease Diagnostic Laboratory
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- stacie.robinson@usda.gov	Rodents
Root, Jeff	(970) 266-6050 jeff.root@usda.gov	Project Leader: 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
Smyser, Timothy	(970) 266-6365 timothy.j.smyser@usda.gov	Genetics
Snow, Nathan	(970) 266-6041 nathan.p.snow@usda.gov	Feral swine
Stokes, Keith	(671) 686-2731 keith.stokes@usda.gov	Island invasives, brown treesnakes, Guam
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
APHIS	Animal and Plant Health Inspection Service
ASF	African swine fever
BPI	biological performance indicator
bTB	bovine tuberculosis
CTMM	continuous-time movement model
CWD	chronic wasting disease
DNA	deoxyribonucleic acid
eDNA	environmental DNA
EPA	U.S. Environmental Protection Agency
FAD	foreign animal disease
GPS	global positioning system
HPAI	highly pathogenic avian influenza
IACUC	Institutional Animal Care and Use Committee
IAV	influenza A virus
I&E	immobilization and euthanasia
NAHLN	National Animal Health Laboratory Network
NFSDMP	National Feral Swine Damage Management Program
NRMP	National Rabies Management Program
NWRC	National Wildlife Research Center
ORV	oral rabies vaccine
PAPP	para-aminopropiophenone
PSD	Pocatello Supply Depot
RHDV2	rabbit hemorrhagic disease virus 2
TWS	The Wildlife Society
UAS	unmanned aircraft system
USDA	U.S. Department of Agriculture
USFS	U.S. Forest Service
WS	Wildlife Services

Issued May 2024

U.S. Department of Agriculture
Animal and Plant Health Inspection Service
Wildlife Services
APHIS-24-016