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SEVENTEENTH WILDLIFE DAMAGE MANAGEMENT CONFERENCE

Perdido Beach Resort
Orange Beach, AL
February 26 – March 1, 2017

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Facilitated by
Wildlife Damage Management Working Group of The Wildlife Society
Alabama Cooperative Extension System
School of Forestry and Wildlife Sciences, Auburn University
USDA Wildlife Services-Alabama

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Published at
Southern Illinois University, Carbondale, IL USA

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Published at Southern Illinois University, Carbondale, IL

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Challenges and Opportunities for the Wildlife Damage Management Profession in the Face of Expanding Wildlife Populations: An Extension Perspective

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ABSTRACT: Many wildlife populations are expanding both their range and population densities given effective management practices. This wildlife expansion, combined with concomitant human expansion, has led to increased human-wildlife conflict in many parts of North America. Managing these conflicts has become more difficult given increased regulation on many management tools, leading to a need for new, effective strategies for mitigating these conflict situations, as well as a clearer understanding of how current management practices influence both target and non-target wildlife. A greater and more focused effort on education and outreach is needed to clearly inform all parties about true versus perceived risks associated with controversial management strategies given that the general populace will likely drive most future wildlife damage management regulation. As wildlife scientists, our goal should be to allow society to make management decisions that are based on sound science rather than on limited data sets, or worse yet, conjecture or social dogma. Such a strategy would allow for management programs that are both socially acceptable and effective in minimizing human-wildlife conflict.

Key Words extension, predator, regulation, research, rodent

Proceedings of the 17th Wildlife Damage Management Conference. (D. J. Morin, M. J. Cherry, Eds). 2017. Pp. 1-8.

Wildlife provide many positive attributes including physical utility, recreational, and ecological values (Conover 2002). However, wildlife often come in conflict with humans as well. This applies both to native (e.g., coyotes [*Canis latrans*], pocket gophers (Geomyidae], voles [*Microtus* spp.]) and non-native species (e.g., rats [*Rattus* spp.], house mice [*Mus musculus*], wild pigs [*Sus scrofa*]), with such conflict often resulting from expanding wildlife populations. Recent expanse of wildlife populations and concomitant human-wildlife conflict has occurred for a variety of reasons including changes in how land is managed, intended and unintended supplementation of wildlife diets, and better regulation of harvest (Timm et al. 2004, Hristienko and McDonald 2007).

Not surprisingly, managing human-wildlife conflict in the face of expanding wildlife populations is difficult and becoming more complicated. In many situations, we have the tools to remediate these conflicts, but increasing regulation and changing public opinion limits what can be done. The management of burrowing rodents provides a great example, where anticoagulant rodenticides have recently become restricted-use pesticides (Hornbaker and Baldwin 2010), an extended buffer zone has been enacted around buildings where certain burrow fumigants can be used (e.g., aluminum phosphide, Baldwin 2012), and trapping has been banned in some states (e.g. Washington). Similar restrictions have been observed with commensal rodents in California, where second-generation anticoagulants have become restricted-use products, are currently banned in some areas, and may be banned statewide in the future (proposed California Assembly Bill 1687). This has substantial impacts on human health

and safety given potential disease transmittance and structural damage caused by these rodents, not to mention the damage these species cause to the agricultural industry (Pimentel 2007).

There have also been increases in human conflicts with predators in recent years, largely due to both expanding predator and human populations (e.g., black bear [*Ursus americanus*], Hristienko and McDonald 2007; wolf [*Canis lupus*], Treves et al. 2004; coyote, Gompper 2002). During this same timeframe, we have seen increased restrictions on the use of lethal tools for managing predators including complete protection status, restrictions on hunter take, and changes in trapping laws (Manfredo et al. 1997, Wolch et al. 1997, Hristienko and McDonald 2007). This has led to a proliferation of non-lethal management tools that have often proved effective (Miller et al. 2016). However, there is some concern as to the long-term effectiveness of these non-lethal approaches when lethal removal is concurrently eliminated given the need for many of these non-lethal approaches to induce a fear response in the predator (e.g., repellents and frightening devices; Conover 2002). Indeed, there has been a substantial increase in pet and human attacks by coyotes in many residential areas where coyote removal is largely absent (Timm et al. 2004, Baker 2007, Quinn et al. 2016).

Of course increasing regulation is not the only limitation to effective management of human-wildlife conflict, as limited supplies have reduced the use of some management tools (e.g., strychnine shortage; Baldwin et al. 2017), while further technological development for other potential management options is needed to fully realize their utility (e.g., bait box for wild pig management; Campbell et al. 2013). There is also a strong need for more information on species' biology life requisites, as this knowledge can greatly influence the effectiveness of management programs (Baldwin et al. 2014).

Is research the answer?

With all of these potential challenges, there is a need to identify effective solutions. Certainly, research could address many of these issues. For example, continued research is needed to better understand the potential impacts that anticoagulant rodenticides have on non-target species. How prevalent is exposure, and does exposure relate to impact? Current data on exposure often comes from biased sources (e.g., dead or injured individuals; Ruiz-Suárez et al. 2014, Huang et al. 2016), thereby rendering interpretation difficult. Likewise, it is unclear how wildlife become exposed to anticoagulant rodenticides, obviously making it difficult, if not impossible, to identify effective strategies to mitigate these risks without implementing an outright ban on their use. We also continue to lack an understanding of how non-lethal exposure to anticoagulants impacts non-target species, and at what threshold these impacts are exhibited (Rattner et al. 2014, Webster et al. 2015). Simply stating that all exposure to such toxicants is harmful clearly overstates their impact on wildlife populations. Furthermore, we have little conformational evidence that anticoagulants have a substantive impact on non-target predators at the population level following legal applications (Silberhorn et al. 2006; but see Gabriel et al. 2012 for example of negative impact to fisher populations from extensive illegal applications of anticoagulant rodenticides).

Effective rodent management would also benefit from greater exploration into alternative management strategies. The development of new toxicants could provide effective results while minimizing non-target risk (e.g., cholecalciferol + anticoagulants and sodium nitrite; Witmer et al. 2013,

Baldwin et al. 2016, 2017). Alternatively, the refinement of automatic and self-resetting trapping devices has shown substantial utility in managing rodent pests in New Zealand and may be expanded globally (Carter et al. 2016). There is also increasing interest in the use of natural predators to manage rodent populations. Although results have not always been positive, some potential may exist for natural predation to provide relief in some situations (e.g., Kan et al. 2014, Labuschagne et al. 2016). Further exploration may parse out where, and to what extent, those benefits could be realized.

Of course rodents are not the only wildlife species for which additional information is needed. We also need additional strategies to effectively manage predator impacts in both rangeland and residential/urban areas. In particular, there is a dearth of knowledge on population status of many predatory species throughout the U.S. A better understanding of population size and distribution of predators throughout the landscape, as well as how these change over time, would allow us to better plan management actions (Mitchell et al. 2004). This information would also provide insight into whether increases or decreases in conflict events were due to changes in population status and distribution of these predators or because of some other factor.

Predators certainly have an impact on livestock operations, both through direct and indirect losses. Recent research has shown that indirect losses are more extreme (Rashford et al. 2010, Steele et al. 2013), yet there has been relatively little research into the financial burden borne by ranchers faced with this challenge. Such information is needed to provide a foundation for supplementing rancher incomes if they are expected to remain viable while coexisting with increasing predator abundance (Young et al. 2015). There also is a substantial need for research-driven cost estimates of both lethal and non-lethal management strategies to better balance these costs with expected gains in ranching incomes from their use (Miller et al. 2016).

Research into effective predator management strategies continues to be conducted, but this research needs to be implemented over a broad range of ecological conditions; not all sites are the same, and efficacy will vary depending on the local environment (Parks and Messmer 2016, Van Eeden et al. 2017). Likewise, there has been little investigation into the long-term efficacy of non-lethal management programs that are conducted in the absence of lethal removal. Such longitudinal studies are needed, as some individual predators will become more aggressive over time if unexposed to some general level of persecution (Timm et al. 2004, Blackwell et al. 2016).

A need for expanded education and outreach efforts

Although there is a lot that we do not yet know about managing human-wildlife conflicts, we do have a good knowledge base to draw from for many conflict situations. Wildlife scientists need to do a better job educating the public on the need to manage wildlife, as well as the need for many tools to mitigate potential conflicts. For example, it is well known that an integrated pest management (IPM) approach is the most effective strategy for managing rodent pests (Engeman and Witmer 2000, Baldwin et al. 2014). However, an IPM approach relies on the availability of many tools to effectively and economically manage rodent conflicts. Eliminating safe and effective tools reduces the effectiveness of IPM programs, and forces reliance on fewer and fewer options. This ultimately can lead to a reduction in effectiveness of those remaining tools (e.g., resistance development to rodenticides, Myllymäki 1995, Salmon and Lawrence

2006) and perhaps illegal use of non-registered management strategies (Hornbaker and Baldwin 2010).

Likewise, stronger education efforts are needed to allow the public to differentiate between perception and what current research supports. For example, there is currently a strong push by some groups to eliminate the use of many lethal tools for rodent management; use of natural predation, particularly raptors, is often advocated instead (e.g., Raptors are the Solution: http://www.raptorsarethesolution.org/). Although there may be some situations in which raptors might be able to help manage rodents (R. Baldwin, unpublished data), this concept has yet to be conclusively proven. In fact, many scientists have considered this approach impractical given the extreme reproductive capacity of most rodent species (Marsh 1998, Moore et al. 1998). At a minimum, use of natural predation by itself will not likely be successful in all situations for managing rodent pests, and as such, other tools will still be needed. This point must be clearly articulated to ensure continued availability of alternative management strategies. That said, a stronger effort is needed to educate the public on proper application of management strategies. In particular, individuals using lethal tools need to be better informed on how to use them safely, what species they are legal for, and when they can be effectively used. When used appropriately, lethal tools are generally believed safe to non-target species (e.g., trapping, Witmer et al. 1999; first-generation anticoagulant rodenticides, Silberhorn et al. 2006). It is when they are used improperly that non-target impacts occur (e.g., Gabriel et al. 2012).

A similar opportunity exists for better education surrounding human-predator conflicts. Although efforts to educate the general public on the dangers of feeding wildlife are prevalent in many areas of North America, it still occurs fairly regularly, either intentionally or unintentionally. Access by coyotes to anthropogenic food sources is believed to be one factor in the increase in the number of human and pet attacks in the southwestern U.S. (Timm et al. 2004, Baker 2007, Carrillo et al. 2007, Quinn et al. 2016). Many in the public do not know that such risks are real and continue to provide wildlife with access to foods. Likewise, there is a general sense among many urban and residential citizens that predation of livestock has little impact on ranchers or rancher livelihoods (Young et al. 2015). Such an impression is clearly inaccurate (e.g., Steele et al. 2013), but it highlights the need for more extensive and efficient outreach efforts to educate a greater segment of the general public on the impacts that predators can have on human populations in the absence of effective management.

We also need to focus outreach efforts on providing better information on what strategies are available and effective at mitigating human-predator conflicts. These outreach efforts need to take into account the differing levels of effectiveness for management strategies across geographical areas given that not all strategies work in every situation (Miller et al. 2016, Parks and Messmer 2016, Van Eeden et al. 2017). Effective management may include lethal removal in some situations where it is legal and warranted (e.g., Bradley et al. 2015, Van Eeden et al. 2017). That said, it is important to stress that predator management is a two-way street. Predators are a valuable part of our natural ecosystem and are here to stay. However, land managers need access to a suite of effective strategies to efficiently manage human-predator conflicts (Young et al. 2015, Blackwell et al. 2016). Hopefully understanding this duality will provide the middle ground needed to better manage predators in the future.

CONCLUSIONS

Human-wildlife conflict has always been present, but in many ways, managing these conflict situations is becoming more difficult, largely driven by personal beliefs and general perceptions by all relevant parties. The big question is, what do individuals in the wildlife damage management profession do to advance effective management in the face of this spirited discussion? Should wildlife damage management professionals simply adhere to the overriding public perception on a given issue, or do they fight the sociopolitical battle if they believe that public perception is out of line with what research indicates is the best strategy? Perhaps the best strategy is to let science speak. Rather than actively engaging in public discourse about what is right or wrong, ethical or unethical, etc., the general public can be provided with the information they need to better understand the issues at hand, thereby making more informed decisions on what management actions are appropriate. This approach would allow scientists and managers to avoid advocacy for any political stance, thereby maintaining credibility throughout the process.

One major limitation of this approach is making sure scientists and managers provide credible information to the general public in a manner that they will consume. This can be done in a variety of different ways, but in today's current environment, that often involves the use of social media. Many advocacy groups consistently provide information to their audience through social media outlets. Sometimes this information is accurate, but sometimes it is not. Wildlife damage management professionals would likely reach a greater audience by more frequently using social media opportunities, potentially countering misinformation received from other outlets. It is important to remember that regulation is often driven by the concerns of political entities, special interest groups, and the general public irrespective of whether or not those concerns are real or perceived (Conover 2002, Mallonee 2011). Hopefully, through targeted research and outreach efforts, these respective audiences will be able to make better informed decisions. This research may or may not result in findings that support the continued use of a particular management practice, but that is the point of the research. In the end, what really matters is that society makes management decisions that are based on sound science rather than on limited data sets, or worse yet, conjecture or social dogma. Such a strategy would allow for management programs that are both socially acceptable and effective in minimizing human-wildlife conflict. This seems to be the most appropriate path to take.

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Busy Being Born: Embracing Change in Wildlife Damage Management

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Proceedings of the 17th Wildlife Damage Management Conference. (D. J. Morin, M. J. Cherry, Eds). 2017. Pp. 9-12.

In 1965, Bob Dylan released a song called "It's Alright, Ma (I'm Only Bleeding)", and it contained one of the decade's most memorable lyrics – "He not busy being born is busy dying" (Dylan 1965). At the same time sobering and hopeful, the lyrics present purposeful rebirth as the salve for what otherwise would do us in. Wildlife damage management as a profession has been busy being born for decades. The work is bound to human values and communities, social and political priorities, scientific advancements, and landscape and wildlife population changes. Our profession cannot help but evolve.

The Public Trust Doctrine under the North American Model of Wildlife Conservation establishes that wildlife is owned by the public and that governments serve as trustees by managing the resource for the good of current and future generations. In 2010, The Wildlife Society (TWS) published a Technical Review of the Public Trust Doctrine and identified threats to it, including "Indifference to Wildlife" (Batcheller et al. 2010). Left unchecked, wildlife damage erodes public confidence in government and fosters indifference and devaluation of wildlife. Wildlife damage management optimizes public value of wildlife by addressing problems experienced by people - it is conservation at its best. Anchored by the Public Trust Doctrine, wildlife damage management will continue to evolve amidst scientific discovery and social change. As professionals, our ability to embrace change in the areas of collaboration, agility, and diversity will guide our success or failure in building the future of our profession.

Collaboration

Historically, wildlife damage management programs were funded and conducted with an agency and a recipient working together, and with minimal involvement of others. Gradually that changed. Collaboration among agencies and stakeholders is the foundation of wildlife damage management programs today. This is especially true for landscape level programs that cross jurisdictions and for which solutions involve a wide variety of approaches. Two such programs are those related to elimination of nutria in the Chesapeake Bay and feral swine damage management.

The Chesapeake Bay Nutria Eradication Project was initiated in 2002, and has removed nutria from more than 250,000 acres of tidal wetland. Operational work conducted primarily by USDA APHIS Wildlife Services (WS) encompasses an array of methods to remove nutria, and monitoring techniques, outreach, coordination, and communication. This Project is led by a Management Team

consisting of representatives from the U. S. Fish and Wildlife Service, WS, Maryland Department of Natural Resources, U. S. Geological Survey, and others. The effort is enhanced by support of its conservation partners. Hundreds of public and private landowners have allowed WS access and provided information essential to success.

The World Conservation Union has characterized feral swine as one of the "world's worst invasive alien species." The APHIS National Feral Swine Management Program's Goal is to minimize damage associated with feral swine. The APHIS strategy is to provide resources and expertise at a national level, while allowing flexibility to manage operational activities from a local and state perspective. Beginning in 2015, APHIS personnel have worked collaboratively with other agencies at the international, federal, state, territorial, Native American Tribal, and local levels, and with private organizations and entities. At the onset of the program, the agency established a benchmark of collaboration: APHIS will seek partners in all aspects of feral swine damage management (USDA 2015).

Agility

An agile wildlife damage management program thrives amidst change. Agile program managers accomplish success by constantly seeking new tools and by resisting "that's the way we've always done it" thinking. Agility in wildlife damage management work today is evidenced by expansion of airport wildlife hazard management programs, emergence of genetic solutions, integration of economics, and increased use of social media. Agility is also shown in the cooperative APHIS WS rabies, feral swine, and nutria programs where resources are moved with solution accomplishment and new needs. Going forward, our agility and comfort with change will determine our individual success and that of our organizations.

Airport wildlife hazard management has been developing since the 1950's. Following a number of high profile crashes and Federal Aviation Administration regulatory developments, the field expanded rapidly in the 1970's through the 1990's, when operational wildlife hazard management programs were initiated at Atlantic City International Airport, John F. Kennedy International Airport, Chicago's O'Hare International Airport., and Whiteman Air Force Base in Missouri. In 1998, WS assisted 193 airports and military airfields; by 2016 that number had increased to 853. Internationally, WS has conducted operational airport/airbase wildlife hazard work to other countries, including Iraq, Afghanistan and Kuwait.

Gene editing and other advances in biotechnology, including gene drives, gene silencing, and genotyping, could change how we understand damage situations and manage some wildlife damage conflicts. Genetic approaches are already assisting operational wildlife damage management work. The WS National Wildlife Research Center (NWRC) has developed an environmental DNA technique to detect swine presence through genetic markers in water. WS NWRC maintains a National Feral Swine Genetic Archive. Genetic technologies and this archive are helping WS better understand feral swine population dynamics and movements. This includes the genetic ancestry of feral swine populations and the origin of swine that seem to "pop up" where they are not expected. Genetics are used to identify source populations, and indicate whether the animals originated from domestic stock, transplants from other states, or natural range expansion from adjacent areas.

As transparency and accountability in public service increases, economics and new media-based communication with stakeholders have become integrated into wildlife damage management work. The WS NWRC brought on its first Research Economist in 2003; today the Economics Project consists of 5 Economists and a Human Dimensions specialist. While it remains critically important to document the basic economic impact of wildlife damage and costs of solutions, the development of more sophisticated economic models is essential to better characterize complex economic questions related to wildlife management. The Project's BioEcon model is used to integrate economic and biological information and estimate the benefits and costs associated with combinations of potential management actions. This model forecasts costs of management actions and can help managers determine the optimal mix of actions depending on project goals and budget constraints.

To communicate with stakeholders, agencies are now using social media, including YouTube, Facebook, FLIKR, and Twitter. APHIS' YouTube site contains videos and playlists related to rabies, feral swine, and airport wildlife hazard management, and more are being developed and planned for posting. Videos and GPS-data-based Story Maps can be profiled in tweets that lead Twitter users to other videos and presentations. These new media technologies reach more and different people than would print, television or radio.

Agile wildlife damage management programs, including APHIS/WS programs related to rabies, feral swine, and nutria, move effort across landscapes to where it is most needed. The WS National Rabies Management Program goal related to raccoon rabies is to first establish and maintain a barrier to the westward spread of the disease. Operational efforts will move that barrier eastward until eventual elimination of raccoon rabies from North America. Towards that goal, the program's oral rabies vaccination (ORV) baits are delivered strategically along the ORV zone and as necessary where cases emerge that threaten short and long-term management objectives.

The APHIS Feral Swine Program is not like programs of the past where funding levels and effort remained static for decades. This program responds to local conditions and accomplishments within compressed time frames. In 2015 and 2016, feral swine have been eliminated from six states: ID, MD, NJ, NY, WA, and WI. The Agency will continue to monitor in these States to ensure feral swine are not reestablished. Further, the program will start shifting funding away from these areas that have achieved success towards other locales with solvable problems. Similarly, in the Chesapeake Bay, nutria project operations move through the phases of elimination of invasive species from specific areas: delimiting surveys, population reduction, verification and surveillance. The last nutria WS removed from the Chesapeake Bay was in May 2015. Now, APHIS is rotating the monitoring of six watersheds, covering 360,000 acres, annually to confirm elimination and prevent the re-infestation of the area.

Diversity

Program and workforce diversity may evolve organically as collaboration and new approaches become the norm. Wildlife damage management programs now have many different components: economics, genetics, technological solutions for communication and field work, as well as new species/problem situations. As the need for wildlife damage management increases, opportunities for wildlife professionals with diverse expertise will grow. Our

responsibility is to get better at reaching out to a broad array of students and professionals to communicate the variety of wildlife damage management opportunities. TWS and Wildlife Damage Management Conference panels on wildlife careers will be important conversation starters to inspire interest in our profession. We must reach and hire people who share our public service and wildlife conservation values, and whose unique backgrounds, perspectives, and styles will bring diversity to strengthen our ranks.

We have an opportunity for legacy. By 2050, there will be an estimated 10 billion people on Earth, and there will be unprecedented pressure on the landscape and the agricultural community to feed people. Wildlife damage problems may become more severe and less tolerable as global demand for food increases. Across our organizations, collaboration will be the foundation of every important endeavor. Agility and diversity will allow our work to continue to remain relevant to society as change comes. By keeping busy being born and embracing change, we will become better stewards of wildlife resources and more effective mentors for the next generation of professionals.

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Is Razor-wire an Effective Deterrent for Birds Perching on Security Fences at Airports?

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ABSTRACT: Wildlife-aircraft collisions (wildlife strikes) pose a serious risk to aircraft and cost civil aviation in the United States an estimated $957 million annually. Blackbirds and doves in particular have caused some of the most devastating aircraft accidents related to wildlife strikes in the United States and Europe. Birds perching on security fences and other structures are a problem at airports and other locations where birds are not desired. Reduction of available perching sites should make airports less attractive to these species and thus reduce the risk of damaging wildlife strikes. We conducted a series of experiments to determine if 3 species of birds hazardous to aviation [i.e., mourning doves (*Zenaida macroura*), common grackles (*Quiscalus quiscula*), and brown-headed cowbirds (*Molothrus atar*)] were deterred from perching sites at the top of a 3-stranded security fence by the application of Razor–ribbon™ Helical razor-wire. We determined bird use (for perching) of 3-stranded barbed wire security fences, with and without the addition of razor-wire using 6 birds each in 2 3.6- x 8.5- x 2.4-m flight cages. Treatment perches consisted of the top portion of a 3-stranded barbed wire security fence (2.5-m in length) with 2.5-m of razor-wire attached. Control perches consisted of an identical portion of security fence without the razor-wire. During the experimental period, mourning doves were observed on razor-wire protected fences twice as often, brown-headed cowbirds were observed similar amounts of time, and common grackles were observed 4 times as often as they were on unprotected fences. We found no evidence that razor-wire provided any deterrence to birds that perch on security fences.

Key Words airports, anti-perching, bird strikes, brown-headed cowbird, common grackle, mourning dove.

Proceedings of the 17th Wildlife Damage Management Conference. (D. J. Morin, M. J. Cherry, Eds). 2017. Pp. 13-19.

Wildlife-aircraft collisions (wildlife strikes) pose a serious safety risk to aircraft and the flying public. Wildlife strikes cost civil aviation at least $957 million annually in the United States (Dolbeer et al. 2016). Over 169,850 wildlife strikes with civil aircraft were reported to the U.S. Federal Aviation Administration (FAA) during 1990–2015 (Dolbeer et al. 2016). Aircraft collisions with birds accounted for 97% of the reported strikes, whereas strikes with mammals and reptiles were 3% and <1%, respectively (Dolbeer et al. 2016). Gulls (*Larus* spp.), waterfowl such as Canada geese (*Branta canadensis*), raptors (hawks and owls), and blackbirds (Icterinae)/starlings (*Sturnus vulgaris*) are the species presently of most concern at airports (Dolbeer et al. 2000, Dolbeer and Wright 2009, DeVault et al. 2011). Mourning doves are also a significant hazard and have resulted in damaging strikes to both civil (Dolbeer et al. 2000, Dolbeer et al. 2016) and military aviation (Zakrajsek and Bissonette 2005). Sound management techniques that reduce bird numbers in and

around airports are therefore critical for safe airport operations (DeVault et al. 2013).

Large-scale killing of birds to solve conflicts is often undesirable or impractical (Dolbeer 1986, Dolbeer et al. 1997). Nonlethal frightening techniques to keep birds away from airports are available (Marsh et al. 1991, Cleary 1994) but can be cost-prohibitive or only temporarily effective (Dolbeer et al. 1995). Habitat management within airport environments, including modification of potential perching areas, is the most important long-term component of an integrated wildlife damage management approach to reduce the use of airfields by birds and mammals that pose hazards to aviation (U.S. Department of Agriculture 2005, DeVault et al. 2013).

Effective anti-perching techniques are an important part of an integrated wildlife damage management program at airports (DeVault et al. 2013). Security fences, buildings, signs, light fixtures, and other locations within airport environments provide roosting habitat for many species of birds, most notably many species that pose a hazard to safe aircraft operations. We reviewed the scientific literature found only one study that evaluated anti-perching methods for security fences. The findings of Seamans et al. (2007) suggest that anti-perching devices, such as Bird-wire™, might be useful in deterring birds from using airport security fences as a place to perch or roost.

Following the terrorist attacks that occurred in the USA on September 11, 2001 there has been increased interest, available monies, and implementation of measures to deter humans from entering airfields. Consequently, the use of razor-wire has increased significantly as an anti-personnel security technique and this trend will likely continue into the future. To our knowledge, no information exists in the published literature regarding the efficacy of the razor-wire as a device to reduce the amount of perching by birds on fences within airport environments.

The objective of this study is to determine if the installation of razor-wire onto the barbed wire components of airport security fences will deter birds from perching on the fences. Our null hypothesis is that bird use of 3-stranded barbed-wire security fencing components will not differ with or without razor-wire attached.

METHODS

Our studies were conducted in 2004 and 2005 at the U.S. Department of Agriculture's, Wildlife Services, National Wildlife Research Center, Ohio Field Station at the National Aeronautical Space Administration Plum Brook Station, Erie County, Ohio, USA (41°27' N, 82°42' W). This facility is a 2,200-ha fenced installation with large tracts of fallow fields, interspersed with woodlots, and surrounded by agricultural fields.

Bird Species

We conducted a series of experiments with 3 species of birds that are hazardous to aviation: mourning doves (*Zenaida macroura*), common grackles (*Quiscalus quiscula*), and brown-headed cowbirds (*Molothrus ater*; Dolbeer et al. 2016). The mourning dove experiment was conducted 25 – 29 October 2004 (pre-treatment period) and 1 – 5 November 2004 (experimental period). We conducted the common grackle experiment during 29 November – 17 December 2004 (pre-treatment period) and 6 – 10 December 2004 (experimental period). The brown-headed cowbird experiment was conducted 2 – 6 May 2005 (pre-treatment period) and 9 – 13 May 2005 (experimental period).

Anti-perching Experiments

For each species (independently), bird use (for perching) of 3-stranded barbed wire security fences, with and without the addition

of razor-wire, was evaluated using groups of birds in 2, 3.6- x 8.5- x 2.4-m flight cages. Groups of birds (12 birds/group) were randomly assigned to each of the 2 cages in two-choice tests to determine the effect of mounted razor-wire on bird use of perches. Once a bird group was established, the members stayed in the cage for the entire period.

Observers conducted experimental observations from an observation tower (20 m from the flight cages) with the aid of binoculars. Spot counts of the birds in the cages were conducted every 1 minute for a 1-hour period (beginning at 09:00 each day). The location of each the birds (perched on the control fence, on the ground, cage sides, food or water pan) was recorded. Similar observations were conducted for a second 1-hour period (beginning at 11:00). This series of observations was made for a 5-day period (pre-treatment period); during this time both perches (fences) in each cage were control perches (no razor-wire).

Following the pre-treatment period, razor-wire was attached to 1 of the 2 perches in each cage. Pre-treatment data was examined to determine if the birds exhibited a preference for either perch; the razor-wire was attached to the perch used most frequently. Treatment perches consisted of the top portion of a 3-stranded barbed-wire security fence (2.5-m in length) with 2.5-m of razor-wire attached. Razor–ribbon™ Helical razor-wire (Allied Tube and Conduit Inc., Hebron, Ohio) was attached using a 26-cm (14-inch) spacing between coils. Spacing between coils was set to 26-cm as this distance is slightly narrower than the average wingspan of mourning doves; our intention was to make it difficult for the birds to land and take off on the fence between the razor-wire coils. Control perches consisted of an identical portion of security fence without the razor-wire. A second series of observations (experimental period) was then conducted for a 5-day period.

Statistical Analyses

Our response data (perching rate) was non-normally distributed and we were unable to successfully transform them. Thus, we used Wilcoxon Sign Rank tests to compare the perching rate of birds on the control and razor-wire sections during the experimental period (razor-wire present) for each bird species independently (Zar 1996). In addition, we used Mann–Whitney *U* tests to compare the perching rate of birds on control, razor-wire, the ground, and on other locations between the pre-treatment and experimental treatment periods for each bird species independently (Zar 1996).

RESULTS

Attaching razor-wire did not reduce perch use of 3-stranded barbed-wire security fences by the 3 species of birds. During the experimental period, mourning doves were observed on razor-wire protected fences twice as often (W = 1.96; P = 0.05) as on unprotected fences (Table 1). Common grackles perched on razor-wire protected fences and unprotected fences with similar (W = 1.79; P = 0.07) frequency (Table 1). Brown-headed cowbirds perched on razor-wire protected fences 4 times more often (W = 3.45; P = 0.001) that on unprotected fences (Table 1).

The 3 bird species differed in the specific part of the razor-wire protected fences where they perched (Figure 1). Mourning doves perched on the razor-wire itself the vast majority of the time, common grackles perched on the barbed-wire and the razor-wire equally, and brown-headed cowbirds perched on the barbed-wire twice as often as they perched on the razor-wire itself (Figure 2).

Table 1. Percentage of observations (total of 14,400 per period for each species) that mourning doves, common grackles, and brown-headed cowbirds were perched on control fences, on razor-wire fences, on the ground, and on other places during experiments conducted in Erie County, Ohio, 25 October 2004 to 18 May 2005. Other places consisted of food and water pans and on the side of the flight cages.

	Pre-treatment Period (5 days)		Experimental Period (5 days)	
Species	Location	% of Observations	Location	% of Observations
Mourning doves	Control	21%	Control	8%
	Control (RW)*	29%	Control (RW)	18%
	Ground	47%	Ground	64%
	Other	3%	Other	1%
	Control	2%	Control	1%
Common grackles	Control (RW)*	20%	Control (RW)	1%
	Ground	49%	Ground	80%
	Other	29%	Other	18%
Brown-headed cowbirds	Control	5%	Control	4%
	Control (RW)*	21%	Control (RW)	17%
	Ground	67%	Ground	67%
	Other	7%	Other	12%

* During the pre-treatment period, the fences where the razor-wire was attached (for the post-treatment period) were controls.

Figure 1. Mourning doves (*Zenaida macroura*) perched on the Razor–ribbon™ Helical razor-wire during the experimental period.

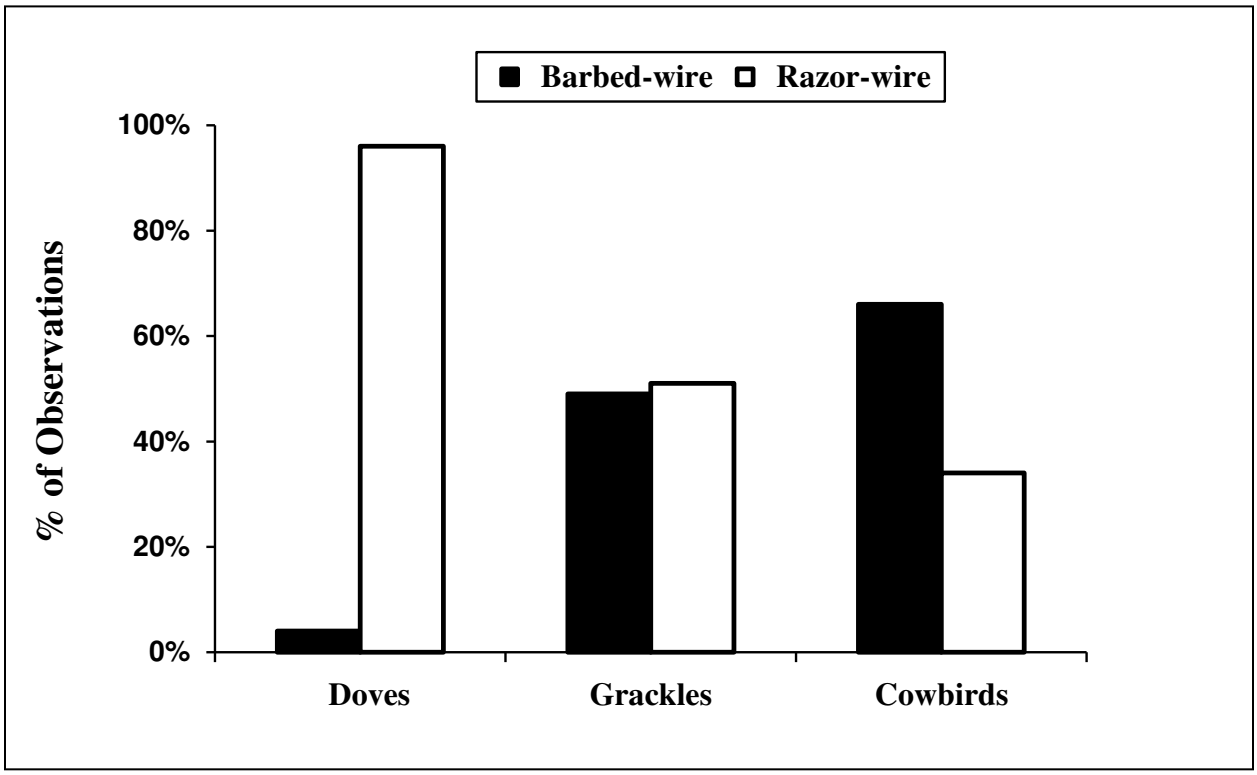

Figure 2. Percentage of observations showing where mourning doves, common grackles, and brown-headed cowbirds were perched within a 3-stranded barbed-wire fence that had razor-wire attached to the fence.

Mourning doves and common grackles spent more time on the ground (doves: $U = 4.57$, $P = 0.03$; grackles: $U = 27.26$, $P < 0.0001$) and less time on the control perches (doves: $U = 7.97$, $P = 0.005$; grackles: $U = 6.70$, $P = 0.01$), razor-wire protected perches (doves: $U = 5.19$, $P = 0.02$; grackles: $U = 29.35$, $P < 0.0001$), and other locations (doves: $U = 11.17$, $P = 0.001$; grackles: $U = 12.00$, $P = 0.0005$) during the experimental treatment period compared to the pre-treatment period. In contrast, brown-headed cowbirds spent similar amounts of time perching on the ground ($U = 0.35$, $P = 0.55$), on control perches ($U = 2.66$, $P = 0.10$), and razor-wire perches ($U = 0.29$, $P = 0.59$) during the pre-treatment and experimental treatment periods. Brown-headed cowbird use of other location perches was higher ($U = 9.02$, $P = 0.003$) during the experiment treatment period compared to the pre-treatment period.

DISCUSSION

Razor–ribbon™ Helical razor-wire was not an effective deterrent for reducing perch use of 3-stranded barbed-wire security fences by birds. Although the razor-wire is sufficiently sharp to inflict wounds to humans and thus acts as an effective anti-personnel barrier, it does not exclude birds from perching on security fences or the razor-wire itself. Mourning doves, common grackles, and brown-headed cowbirds were observed perching on all parts of the razor-wire during the experiments.

Common grackles and mourning doves spent less time perched on the fences with and without razor-wire attached and more time on the ground during the experimental period. Although it is possible that the attachment of the razor-wire might have influenced this response, other factors

are likely to have caused this change in behavior. Acclimating to the flight cages as the experiment progressed, in addition to continual harassment by avian predators [e.g., Cooper's hawks (*Accipiter cooperii*)], likely reduced the amount of time the birds perched on fences and increased the amount of time spent on the ground.

Modification of airfield habitats (e.g., removal of woody vegetation) to reduce perching and roosting opportunities to wildlife hazardous to aviation is an important part of an integrated wildlife damage management program (U.S. Department of Agriculture 2005, DeVault et al. 2013). However, birds commonly perch on a diversity of artificial structures present on airports, including buildings, signs, light structures, and security fences. Exclusion of birds from such man-made structures might be achieved through the placement of specialized perch exclusion products (Avery and Genchi 2004, Seamans et al. 2007, Seamans and Blackwell 2011). However, further research to develop and evaluate the efficacy of anti-perching tools and methods that can be practically implemented to prevent birds from perching on airport security fences and other airport structures are needed. Other types of razor-wire or different attachment methods for the razor-wire might be more effective in deterring birds from perching on security fences.

ACKNOWLEDGMENTS

U.S. Department of Agriculture, Wildlife Services, National Wildlife Research Center employees, including D. Helon, J. Dierker, and T. Seamans assisted with the bird observations and other aspects of the study. T. DeVault and T. Seamans provided excellent comments regarding the manuscript. This study was funded by Phoenix Sky Harbor International Airport and Luke Air Force Base. Allied Tube and Conduit Inc. provided the Razor–ribbon™ Helical product. The National Wildlife Research Center Institutional Animal Care and Use Committee approved procedures involving birds in this study (QA-1132).

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Great Lakes Restoration Initiative Activities in Illinois to Reduce Canada Goose Impacts on Lake Michigan

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ABSTRACT: The Great Lakes Restoration Initiative (GLRI), led by the Environmental Protection Agency, was created in 2010 to address threats to the Great Lakes region. A convenient year-round water source and abundant food source of managed turf grass has resulted in an overabundance of Canada Geese (*Branta canadensis*) in Chicago City Parks within the watershed of Lake Michigan. The anthropogenic mediated benefit to goose populations and their associated damages qualifies Canada geese in Chicago as native invaders-where a native species is human induced to behave similar to invasive species. The objective of this project is to provide a long-term strategy to protect vegetation and reduce non-point source contamination from entering the nearshore waters of Lake Michigan, and as a by-product improve human enjoyment of the parks. To accomplish this goal, the U.S. Department of Agriculture's Wildlife Services (WS) program in cooperation with the Chicago Park District (CPD) continued, for the sixth year, to manage overabundant Canada goose populations in CPD parks with funding provided by GLRI. Between 2011 and 2016, we applied food grade corn oil to all Canada goose nests found within 24 sensitive lakefront parks in Chicago and successfully reduced hatching success and subsequent fledging. The number of nests found and treated during 2012 through 2016 has consistently been less than during the initial year of egg oiling in 2011. In March 2016, we treated a total of 115 nests containing 676 eggs with corn oil to prevent hatching; compared to 159 nests and 892 eggs in 2011.

We applied a chemical application of the Anthraquinone-based foraging repellent, FlightControl® PLUS (FCP) to the grass every 3 weeks in 6 parks in an attempt to discourage geese from foraging and loafing in locations that directly drain into the nearshore water of Lake Michigan. To gauge the effectiveness of the FCP applications, we performed goose presence/behavior surveys in the 6 treated parks. The surveys helped to obtain a better understanding of how many geese were utilizing the untreated and treated areas and how many of those geese were consuming grass on the FCP treated areas. The surveys demonstrated that more geese used untreated areas compared to treated areas of the parks. A total of 5,511 geese were observed (3,221 in the untreated areas and 2,290 in the treated areas) during the survey period. While geese may be present in the treated areas, only 40% of all geese consumed grass in treated areas. Alternatively, 58% of all geese present in the untreated areas consumed grass. The surveys also showed that FCP treatments became less effective each week post spraying. The mean number of geese present and feeding in the treated areas showed a diminishing effectiveness from the FCP spraying on the treated areas across weeks. The statistical results confirmed this strong week-post-spray by treatment interaction.

The disparity in numbers of geese actually consuming grass within the treated versus untreated areas reflects that the FCP treatments were effective at deterring geese from consuming grass in FCP treated areas, but did not necessarily result in the birds dispersing away from FCP treated vegetation. Future applications of FCP are recommended where high concentrations of geese congregate on sensitive habitats or in areas of high public use along the lakefront. Continued population management through egg oiling is recommended to help prevent further environmental contamination and soil erosion in this sensitive Lake Michigan environment.

Proceedings of the 17th Wildlife Damage Management Conference. (D. J. Morin, M. J. Cherry, Eds). 2017. Pp. 20-21.

Examination of the Spatial Distribution of Trapping Success on a Wild Pig Removal Cooperative in Alabama

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ABSTRACT: As wild pig removal programs continue throughout the United States, few programs have provided detailed information regarding landscape features, property ownership, and management activities that may impact trapping success. Whereas a greater amount of research is being conducted to understand the spatial ecology of wild pigs, there still exists a paucity of information with regards to wild pig movements which likely hampers removal efforts. Likewise, no studies have examined landscape characteristics that may impact local trapping success. Therefore, we examined the spatial distribution of trapping success of wild pigs on a 1,821 ha removal cooperative of three private landowners in central Alabama during 2014-2016. The study site consisted predominantly of forest land intermixed with small agricultural fields and wetlands along Bughall Creek, a large waterway system, in Macon county. In cooperation with USDA Wildlife Services removal operations, we recorded the date, trap location, and number of wild pigs captured at 13 trap sites distributed throughout the cooperative. Most traps consisted of three 4.8-m x 1.5-m horse panels with various steel or wooden trap doors baited with whole kernel corn and checked daily. All traps were active nearly continuously from about May-October, and opportunistically from November-April, each year. We captured at total of 757 wild pigs during 2014-2016 with most of these captures (68%) occurring during the May-October trapping period. Whereas the number of wild pigs captured declined over three years (2014=359, 2015=232, 2016=166), significant numbers of wild pigs were still being removed in 2016. Trapping success (range=2-139 pigs captured/trap) varied spatially and temporally across the cooperative and among years with the constant influx of wild pigs likely due to movement along riparian corridors from source populations in adjacent properties. Trapping success was consistently greater for those traps located closer to water sources. Landscape features and sporting activities of adjacent landowners may significantly influence the movement of wild pigs onto a property and should be considered when assessing damage and subsequently developing removal programs. Future research should focus on understanding the spatial ecology of wild pigs within the context of removal operations.

Proceedings of the 17th Wildlife Damage Management Conference. (D. J. Morin, M. J. Cherry, Eds). 2017. Pp. 22.

Phase 2 Wildlife Management - Addressing Invasive and Overabundant Wildlife: The White-tailed Deer Continuum and Invasive Wild Pig Example

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ABSTRACT: Wildlife managers in many countries around the world are facing similar challenges, which include: a lack of means to address invasive species and locally overabundant native species issues particularly in the face of declining fiscal resources, reduced capacity to achieve management goals, and a need to garner public support in the wake of changing societal values and increasing human populations. Meeting these challenges requires building off the profession's successes and developing new paradigms and strategies to curtail the negative impacts invasive and overabundant species are having on our natural resources. Like our predecessors in conservation succeeded in developing our profession and initiating a movement that led to the recovery of many valued native species, now it is us who face a comparable albeit somewhat opposite mandate. Our charge is to curtail and reverse the further establishment and impacts of invasive and overabundant species. We must not fail, but with just existing methods and decision processes we cannot succeed. Using wild pigs as an example invasive species and white-tailed deer as a corollary locally overabundant native species, we begin to lay out why we believe we have entered a second herculean phase of our profession that is as crucial to the quality of our future as the initiation of conservation was a century ago.

Proceedings of the 17th Wildlife Damage Management Conference. (D. J. Morin, M. J. Cherry, Eds). 2017. Pp. 23-26.

THE TALE OF TWO REVERED AND DESPISED UNGULATES

Concurrent with European settlement of North America, white-tailed deer populations began to decline sharply from pressures of market hunting. At the same time domestic swine were introduced, it was the continent's first seeding of invasive wild pig populations which now range over an area that rivals that of deer (see Snow et al. (2017) for current and potential range of wild pigs). In the wake of rapid human expansion several species of native wildlife suffered greatly, some to the point of extinction (e.g., passenger pigeon) and others to extremely low levels (e.g., white-tailed deer, wild turkey, beaver). Theodore Roosevelt and his constituents in conservation instigated what became the field of wildlife management and reversed the trend. The initial focus of the profession was restoring those species so impacted by unregulated market consumption. The deer population line in the figure demonstrates this point (Figure 1). Which brings us to more recent times, where white-tailed deer have become overabundant in many areas,

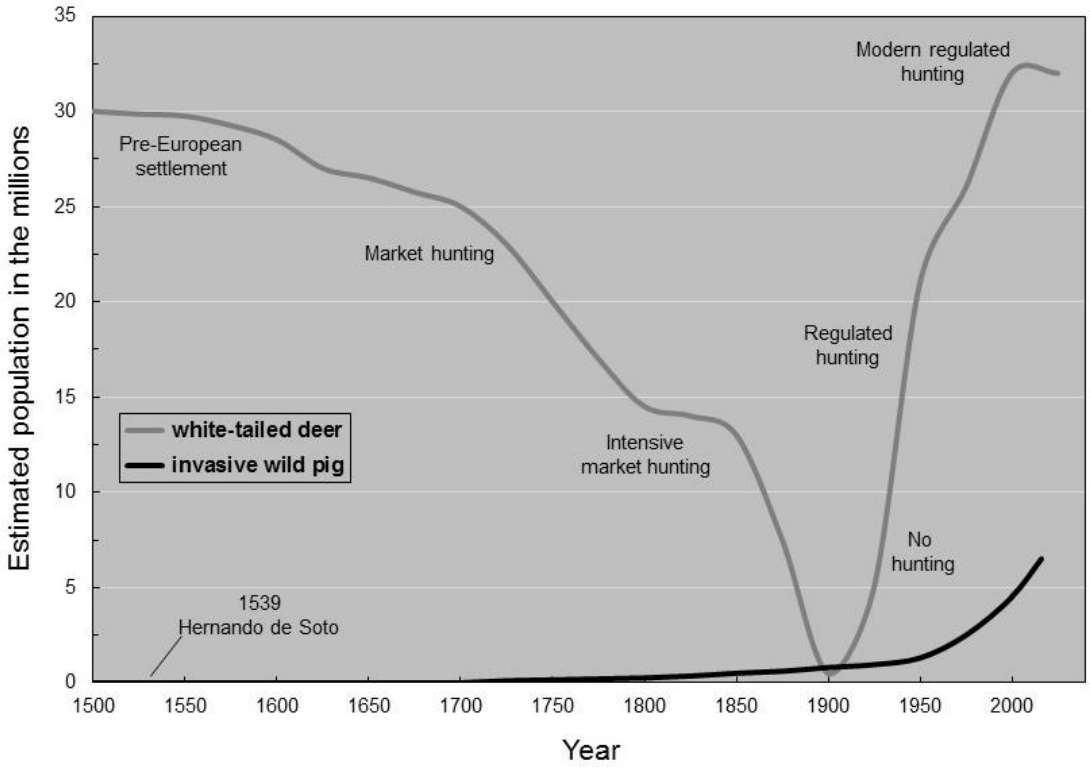

Figure 1. History of white-tailed deer and invasive pig populations in the United States

guilty of causing substantial damage in agricultural and urban settings, and in many cases unable to be managed effectively through recreational hunting as dictated by what has come to be known as the North American Model of Wildlife Conservation (NAMWC; VerCauteren et al. 2011).

Interestingly, when deer populations were at their lowest, just over 100 years ago, invasive wild pig populations had slowly been taking root and were at about that same level. Thus, from a common starting point of about 100,000 individuals, white-tailed deer populations shot to over 30 million where they are stabilizing (VerCauteren 2003) while wild pig populations have lagged but are now increasing more rapidly with current populations exceeding 6 million and predicted to reach over 20 million if not curbed (Lewis et al. in review). These species serve as examples of a common native and common invasive species for which we may need to expand upon, modify or discount aspects of the NAMWC to optimize wise-use and responsible population management (relative to deer see VerCauteren et al. 2011, relative to wild pigs see Bodenchuck and VerCauteren In Press).

Wildlife managers are adept at being flexible, it is a necessity of nudging populations in the desired direction. Our profession has created innovative adaptive management principles and modeling strategies to successfully restore and maintain populations of valued species at goal levels (e.g., Nichols et al. 1995, Berkes et al. 2000, Williams 2011). Associated with some species, like invasive wild pigs and in some cases overabundant white-tailed deer, we have stepped into a second phase of wildlife management where we must purposefully extend upon adaptive management theory to suppress populations.

For wild pigs, where feasible, this means targeting eradication.

How do we do it? By basing our adaptive management strategies off of science-based research results that build upon the foundation we have created as a profession. Just like populations of big game and waterfowl are routinely assessed through a variety of monitoring methods so that management strategies can be tweaked to direct the populations toward management goals, we can apply innovative manipulations of these same principles to achieve goals relative to wild pigs, other invasives, and overabundant natives.

In recent years the wildlife damage management branch of our profession has made great strides in going beyond the data being collected only being reports of the numbers of target animals being removed. In today's world body counts alone are not an acceptable currency. Effort must be put into collecting more data, like that associated with the amount of effort expended to harvest a given number of animals (Davis et al. 2016) or to estimate densities pre- and post-control efforts (Smith 2002). Doing so allows managers to be science-based in evaluating and optimizing their strategies. The next step in contemporary management, then, is to measure the species impacts on resources and economics. By assessing the costs of damage being incurred before and after management actions the relationship among population density, costs of management actions themselves and associated changes in damages incurred can be determined. Though it's not intuitive that diverting limited resources from strictly being used to reduce populations is wise, current research and modeling efforts are demonstrating that because of the knowledge gained from population and damage assessments better decisions can be made for optimizing our ability to best achieve management goals (K. Pepin and A. Davis Unpublished Data). And, importantly, the rationale for management actions are then much more easily justified to all publics and decision makers.

When colleagues ask us if we feel wide-scale eradication of wild pigs is possible we wholeheartedly say "Yes!" Look back at the figure and how deer populations (and those of so many other species) were decimated by lack of knowledge and management, and that was before the advent of semi-auto firearms, helicopters, night-vision and other technological advances. Of course, in today's world we will have unprecedented challenges associated with societal desires, politics, and economics – but we are the next generation of wildlife conservationists, we are up to the task.

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Evaluation of Scents Attractants for Baiting Wild Pigs

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ABSTRACT: Lethal removal by trapping is one of the most cost- and time-effective means for managing wild pigs (*Sus scrofa*). Scent attractants are frequently used to lure wild pigs to camera stations for scouting or monitoring wild pig populations or at trap sites to reduce the amount of time for pigs to locate the trap. However, the effectiveness of scents to attract and increase wild pig visitation to camera stations or traps is debatable. Therefore, our objective was to determine if wild pigs visited camera stations sooner and more frequently when scents were used in addition to whole kernel corn. We conducted our study on portions of the state-owned Lowndes County Wildlife Management Area (5,650 ha) and on privately owned property (1,820 ha) in Lowndes and Macon counties, AL, respectively, during 2014-2016. We selected portions within these study areas where active, premeditated wild pig removal (trapping, shooting) had not occurred for at least 1 year in order to minimize biases associated with trap shy pig behavior. We sectioned each study area into 1km^2 grids and assigned a camera station to each grid cell overlapping the study area. Within each grid cell, the camera station was subjectively placed in forest cover near water. We then assigned randomly treatments of corn (11.3 kg), corn and a molasses-based attractant (0.23 L), or corn and a pig urine attractant (15 ml) to each of 66 camera stations. Corn and attractants were replenished after 7 days. We then used motion-sensitive game cameras to record the time (in min) from the initial placement of bait and scent at each station until the first wild pig was captured on camera images. Cameras remained active on each station for 14 days and were set to capture 3-picture bursts with a 10-second delay among pictures and 1-minute delay between bursts. Camera stations were distributed within each study area at a density of approximately one station per 100-250 ha. We recorded the time of first detection, frequency of visits, and identifying characteristics of pigs and sounders. We used a X^2 test to determine if frequency of visits differed among treatments and an ANOVA to determine differences in time until first visit differed among treatments. Wild pigs visited 23 of 66 (35%) bait stations which did not differ among treatment sites (P=0.231). Of these 23 active camera stations, time until first visit did not differ among treatments (P=0.599). Mean time until first visit to a station was approximately 62.0 hours (about 2.6 days). Scent attractants did not have a noticeable effect on increasing wild pig visitation to baited camera stations suggesting managers

should focus on proper placement of bait stations or traps in areas frequented by wild pigs rather than relying on scents to lure pigs to desired locations.

Proceedings of the 17th Wildlife Damage Management Conference. (D. J. Morin, M. J. Cherry, Eds). 2017. Pp. 27-28.

Rapid Sounder Removal: A Russell County, Alabama Wild Pig Control Project

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ABSTRACT: Rapid Sounder Removal™ is a time sensitive strategy where emphasis is placed on efficient removal of every sounder expanding at least 1,012 ha within 30 days of operation. The mission is to quickly and efficiently remove 100% of each individual sounder, on multiple properties, in the shortest time possible. Several Integrated Wild Pig Control strategies can be implemented in unison to eliminate wild pig escapes, education, and reproduction from large tracts of land at one time. This concept should be applied by all adjacent landowners to remove entire feral pig populations from a county, water conservation district, or wildlife management area at one time. In February 2016, 2 members of the Russell County, Alabama Soil & Water Conservation Committee requested wild pig control on approximately 1,214 ha of agricultural property. A single Hog Control Operator™ was hired to remove the total wild pig population from the property. The project eliminated 310 wild pigs (294 trapping and 16 thermal shooting) in 25 events (19 trapping and 6 thermal shooting). We recorded a 96.7% capture success rate deploying four M.I.N.E.™ Trapping Systems with 15.75 hours of trap construction labor. Two hundred and one feral pigs were removed during the first 28 nights of operation. Farmers, landowners, and land managers should weigh the relative cost and benefits of Rapid Sounder Removal™ when developing a large-scale wild pig control program.

Key Words Rapid Sounder Removal™, Integrated Wild Pig Control™, Hog Control Operator™

Proceedings of the 17th Wildlife Damage Management Conference. (D. J. Morin, M. J. Cherry, Eds). 2017. Pp. 29-33.

Wild pigs, feral hogs, feral swine, wild boar, or "Russian" boar—all names to describe one of the most destructive animals in the United States (US) today (Foster and Mengak 2015). Wild pigs were first introduced to the US landscape in the 1500s by Spanish conquistadores (Barret and Birmingham 1994). When these explorers landed on the coast of Florida they left domestic pigs behind as a readily available food source upon their return. Seeing that pigs were a fantastic food source, Native Americans promoted pig populations. Early European settlers favored pigs as a livestock crop because of the lack of care needed to raise them. Settlers used free range practices for centuries. Of course, many of these domestic pigs were never reclaimed and became a part of the wild population. The issue was further compounded with the introduction of the Eurasian boar in the early 1900s in both North Carolina and California. The two populations interbred and became what are now the wild pigs of today.

The unique biological characteristics of wild pigs allowed populations to explode. However, these populations were limited to only a few areas in the US. It has only been within the last 20 to 30 years that they have expanded to the densities that exist today. While their biological characteristics played a significant role in this expansion, humans

are the primary reason there are an estimated six million nationwide. The increased desire to hunt wild pigs has led to the capture, transport, and release of these animals across the country.

The increased density and distribution of wild pigs across the nation has greatly increased the amount of damage experienced by landowners across the country. Current estimates total $2.5 billion annually in crop, pasture, turf grass, ornamentals, forestry, and livestock damages. With billions of dollars in lost commodities across the country, many landowners are striving to find ways to rid themselves of these nuisance animals. While there are several methods of control that have been employed over the years, there is no silver bullet answer to the problem. However, the strategic implementation of a combination of techniques greatly increases the likelihood of completely removing a sounder of pigs from a given property.

The goal of this publication is to outline the implementation of Integrated Wild Pig Control™ by using a case study from a Russell County, Alabama Hog Control Project. This approach to wild pig control utilizes a series of lethal control techniques applied in a specific sequence based on seasonal food availability. With this approach, emphasis is placed on the efficient removal of entire pig sounders at one time to eliminate escapes, reproduction, and education. The number of pigs eliminated is not as important as the number of pigs left behind.

STUDY AREA

The Speake's Farm was a 1,012-ha property located in Russell County, Alabama. The property consists of 2 separate tracts of land (Figure 1). The eastern tract was southeast of Fort Mitchell, Alabama and is largely comprised of agricultural row crops with interspersed hardwood islands between fields. The crop fields were planted in peanuts the previous planting season and were planted in cotton by the end of control operations. The surrounding vegetation was dominated by planted loblolly pine and clear-cuts. The Chattahoochee River flows 266 m to the south and 970 m to the east of the southernmost crop field of this tract. There was an unnamed body of water 80 m to the northeast of the northernmost crop field. The vegetative cover between the water bodies and crop fields were mixed hardwood forests, predominately oaks and hickories. There was a 191-ha forest between easterly crop fields (Hog Pin, North Barn, Middle Barn, and South Barn) and westerly crop fields (Norman Drive, Big Highway Field, Small Highway Field, and Highway Field). However, trapping was not allowed on 89 ha of the forest. An 89-ha 30-year old stand of pines was located to the east of these crop fields and was bordered by the Chattahoochee River; this area was clear-cut after control operations and was also off limits to wild hog removal. A 77-ha subdivision was located to the west of the westerly crop fields.

The western tract of the Speake's Farm was located north of Holy Trinity, Alabama and was bordered by Highway 165 at the most westerly side of the property. Lonesome Duck Lake was located 50 m south of the western crop field. The eastern most crop field was located 415 m north of Highway 54 and 215 m west of a railroad track. The area between the 2 larger fields was approximately 66 ha of pine hardwood forest. Smaller crop fields were located to the east of the eastern field and to the southwest of the forested area between the 2 larger fields. The surrounding vegetation included a mix of hardwoods and planted loblolly pines. Much like the eastern tract, the crop fields on the western track had been planted in peanuts the previous planting season. The topography of both tracts of the Speake's

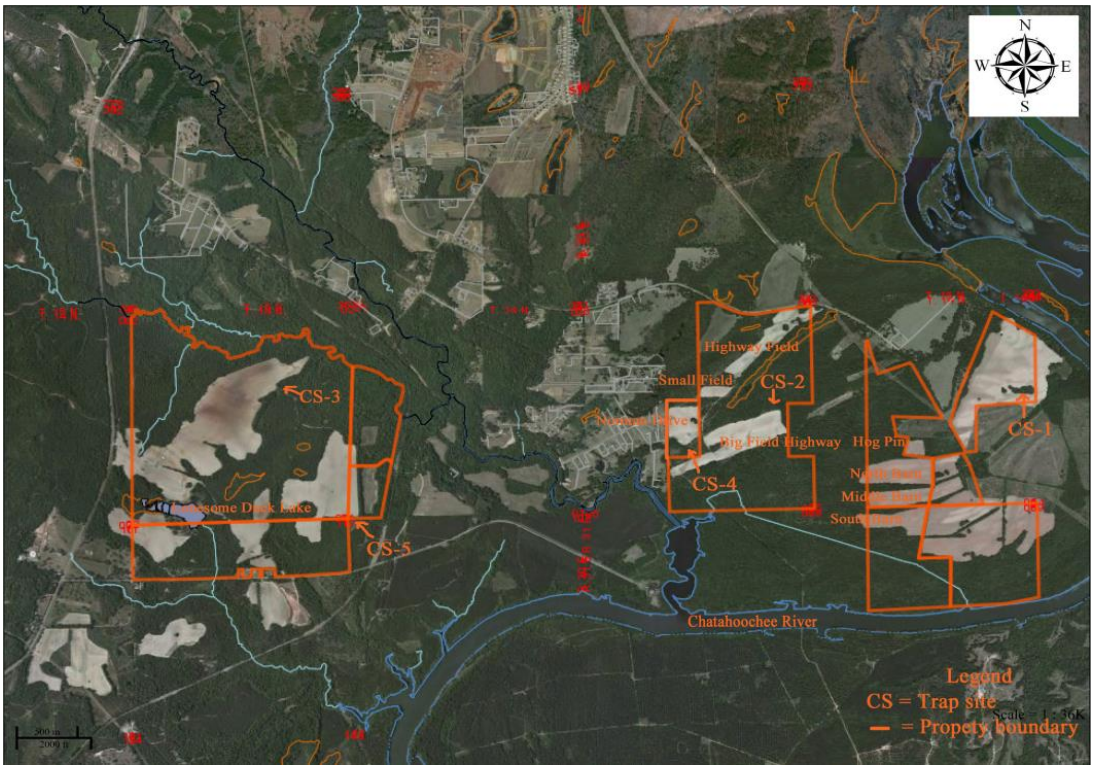

Figure 1: Speake's Farm property boundaries and trapping locations.

farm was flat in the crop fields and slightly undulating hills in the surrounding areas. The average elevation was 140 m above sea level.

METHODS

Trapping Operations

In February 2016, the Russell County, Alabama Soil & Water conservation Committee requested wild pig control on approximately 1,012 ha of agricultural property. A single Hog Control Operator™ (HCO) from JAGER PRO Hog Control Systems was hired to implement JAGER PRO's Integrated Wild Pig Control™ (IWPC) program. Trapping and shooting operations occurred in March, April, May, June, and August. The first step taken by the HCO was to scout the Russell County property. The HCO was not only looking for damaged areas, but travel corridors most heavily utilized by wild pigs. Much of the surveillance of sounders was done using high definition, infrared-triggered cameras deployed throughout the property. The images gathered were used to determine direction and timing of travel from bedding areas to food sources, the number of sounders, and the size and demographics of each sounder. These travel corridors were key trapping locations. Trapping operations occurred throughout the entire 6-month control project.

Once the HCO located the primary travel corridors, 4 digitally timed automatic feeders were erected and filled with whole corn to condition wild pigs to a new food source. The automatic feeders were equipped with a metal shroud (termed a dinner bell) to retain disbursed corn inside a 4.6 m diameter circle around the feeder legs. In addition, this device familiarizes wild pigs with a metallic sound which conveys a new food source is available.

After wild pigs became conditioned to the feeders, the HCO deployed 4 Manually Initiated Nuisance Elimination (M.I.N.E.™)

trapping systems in several different locations on the Russell County property. A fifth trapping system was deployed; however, it was unproductive and was removed early in the project. The M.I.N.E.™ trapping system uses a 10.7-m diameter corral enclosure equipped with one or two 2.4-m guillotine gates. These traps are furnished with cellular wireless receivers allowing the HCO to trigger gates closed from a remote location using their cell phone, tablet, or computer. The traps used on this project were equipped with double guillotine type gates; one on either side of the trap. This strategy was often used on travel corridors to rapidly habituate wild pigs to the new structure as it provided 2 entry and exit points.

Rapid Sounder Removal™ time limitations did not allow for long-term habituation of trap resistant individuals. Trap gates were closed within 5 nights of conditioning and any uncaptured pigs were immediately shot outside the trap enclosure with .308 caliber rifles equipped with thermal scopes. Trapped pigs were shot inside the trap using a suppressed .22 caliber rifle and removed from the trap after data was collected.

Night Shooting Operations

Most night shooting events during this project occurred during the summer months (June and August) due to the abundance of alternative food sources available outside trap enclosures or in an adjacent crop damaged field. Only singles or feeding pairs were targeted for night stalks. Any sounder located with thermal spotting scopes were strictly observed to better identify a future trap site for capture. The only exception to this standard occurred on 10 August 2016 during the final weeks of the project. Remaining time did not allow for an additional trapping scenario.

Night shooting operations involved 2 or 3 trained marksmen working in unison. Semi-automatic rifles in .308 caliber were equipped with thermal imaging optics to properly identify and eliminate feral swine in complete darkness. The spot and stalk technique involved trained shooters stalking single file into the wind. Gunners took a tripod supported shooting position within 45.7 m of foraging animals while standing side-by-side for safety purposes. A 3-2-1 countdown was used to synchronize the initial shot from each shooter ensuring multiple targets were engaged at the same time.

RESULTS

In 25 events, (19 trapping and 6 thermal shooting) a total of 310 wild pigs were removed from the Russell County property (Table 1). However, a total of 324 wild pigs were identified in scouting efforts. Therefore, the combine success rate for this project was 92.8 %, which resulted in 14 pigs remaining across a 1,012 ha landscape.

The labor investment for shooting and trapping events was 49.75 hours. The hours invested yielded 9.63 minutes per pig removed. The overall cost of the Russell County Hog Control Project was $29,500. This included 4 traps at $3,500 each ($14,000 total) plus an additional $15,500 in HCO labor costs. The average loss due to crop damage is $400 per pig; therefore, the total amount of damage prevented came to $124,000. Subtracting the total investment from the loss prevented revealed a $94,500 advantage which yielded a 320 % return on investment (ROI).

DISCUSSION

Trapping success varies with the time of year. Generally, higher trapping success is seen between December and March due to natural nutritional stress periods. During this time, the quality and quantity of food is limited, and pigs are more likely to utilize bait sites. However, baiting laws in Alabama

Table 1. Harvest efficiency data for a 6-month Integrated Wild Pig Control™ project in Russell County, Alabama.

	Juveniles	Adults	Trapping	Shooting	Number Killed	Number in Sounder	Building Traps (hrs)
Trapping Totals	176	118	19	0	294	304	15.75
Shooting Totals	2	14	0	6	16	30	0
Project Totals	178	132	19	6	310	334	15.75
Project Efficiency						92.80%	

prevents the use of baits during deer hunting season.

Although trapping operations occurred throughout the entire removal program, the HCO was unable to take full advantage of the winter nutritional stress period due to the aforementioned baiting laws. Gaining 2 additional prime trapping months in January and February could have contributed to a higher success rate using fewer man hours in labor. It is important to remember that the baiting method used in the IWPC program revolves around the use of automatic feeders. This method, in addition to conditioning pigs to a timely available food source, is key to saving fuel, time, and labor because the HCO does not have to rebait daily which increases efficiency. In addition to working around state hunting regulations, we experienced opposition from local hunting clubs and surrounding landowners who were utilizing the wild pig population for profit along with one instance of vandalism. Despite the constraints and opposition, trapping efforts utilizing the M.I.N.E™ trapping system and a trained HCO were of greater success compared to traditional efforts employed by the landowners prior to hiring Jager Pro, LLC (only 88 wild hogs were captured the previous year).

MANAGEMENT IMPLICATIONS

Trapping and shooting continues to be the most effective means of controlling wild pig populations. However, the traditional methods utilized by untrained individuals require more time and labor and do not tend to be as effective, often educating more pigs than are caught. The methods and technology utilized on the Russell County Hog Control Project significantly increased the overall effectiveness and efficiency of wild pig removal. The IWPC™ model promoted performance-based decisions with specific performance measures necessary to properly implement and evaluate each critical task. Focusing control efforts to first identify, then eliminate entire feral pig populations (one sounder at a time) will reduce long-term damage to agriculture, natural resources, and property. Implementing the most efficient methods and technologies to accomplish whole-sounder removal reduces fuel, time, labor and resource expenses while significantly increasing the landowner's ROI.

ACKNOWLEDGEMENTS

We extend thanks to the Speake's Farm for affording us the opportunity to utilize our innovative technology to remove wild pigs and preventing further damage. We also thank Lance Dement, the HCO, for his dedication to the project and achieving a 93% success rate.

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Pseudorabies Virus Shedding and Antibody Production in Invasive Wild Pigs in California

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ABSTRACT: Pseudorabies virus (PrV) is a herpesvirus endemic in invasive wild pigs in the United States. The virus has the potential to spill over into domestic herds and wildlife causing extensive morbidity and mortality. We surveyed 35 wild pigs from Kern County, California for evidence of exposure to PrV using serological analysis and for viral shedding using quantitative PCR. All 29 individuals that had sufficient sera to screen for antibody production via serological assay were positive. Two of 35 individuals were found to be shedding virus via genital mucosa. An additional 5 individuals were suspected to be shedding virus either in genital mucosa or circulating virus in their bloodstream, but these results were not definitive. The prevalence of viral shedding for PrV in Kern County, California (6%) suggests that native wildlife are susceptible to spillover of this virus which is deadly to carnivore species.

Key Words Aujeszky's Disease, feral swine, qPCR, serology, spill-over, viral reactivation

Proceedings of the 17th Wildlife Damage Management Conference. (D. J. Morin, M. J. Cherry, Eds). 2017. Pp. 34-40.

Wild pigs (*Sus scrofa*) have been in California since the 1920s when Eurasian boar were introduced as game, and domestic pigs were released and became feral (Waithman et al. 1999, Mayer and Brisbin 2008). Wild pigs are considered a game mammal by California Department of Fish and Wildlife, yet throughout much of the United States (US) wild pigs are viewed as an exotic invasive species and classified as feral livestock, nuisance wildlife, or as an invasive exotic mammal because of their destructive

potential to native flora, fauna, and personal property. In addition, wild pigs harbor many pathogens that are damaging to native wildlife, livestock, and public health. Wild pigs are known to carry multiple protozoan, bacterial and viral agents including *Toxoplasma gondii*, *Brucella* spp., *Leptospira* spp., porcine parvovirus, porcine reproductive and respiratory syndrome virus, porcine circovirus, and pseudorabies virus (Cleveland et al. 2017).

Pseudorabies virus (PrV) is an alphaherpesvirus endemic to wild pigs throughout the US (Pedersen et al. 2013). Typical serological prevalence ranges from 2 to 64% in invasive wild pigs in the US and its territories (Cleveland et al. 2017; Musante et al. 2014). The virus causes mild symptoms in adult domestic and wild pigs, but unweaned piglets have significant morbidity and mortality associated with infection (Hahn et al. 1997; Müller et al. 2001). In 2004, the US swine industry concluded a successful vaccination effort for domestic pigs that rid the industry of the disease. Wild pigs pose the threat of reintroduction of PrV back into commercial herds.

In addition to threatening the livestock industry, PrV can spillover into wildlife species where it is deadly to carnivore species (Müller et al. 2001). Mortalities due to PRV infection have been documented in raccoons (*Procyon lotor*; Thawley and Wright 1982; Platt et al. 1983), bears (Schultze et al. 1986; Zanin et al. 1997) canids (Caruso et al. 2014; Verpoest et al. 2014), and the endangered Iberian lynx (*Lynx pardinus*; Masot et al. 2017). PRV is also a significant cause of mortality in the endangered Florida panther (*Puma concolor coryi*; Glass et al. 1994; M. Cunningham pers. comm.). Transmission occurs from eating infected tissue as a result of predation, when scavenging species feed on swine carcasses, or when hunters feed raw meat to hunting dogs. In California, black bears (*Ursus americanus*) and cougars (*Puma concolor*) have been documented to depredate wild pigs and are thus at risk of contracting PrV.

Like other herpesviruses, PrV produces a lifelong infection in swine that can reactivate during periods of stress. As the virus reactivates from a latent state, it begins to circulate and shed from mucous glands in the mouth, nose, and genitalia; it can also circulate in the blood (Hernández et al. in review). Animals can thus sporadically shed and transmit the virus throughout their lifetime. While most studies of wildlife diseases estimate the number of animals that have been exposed to a pathogen and are producing antibodies to the virus (serological analysis), few studies actually estimate the number of infectious animals that are actively shedding the pathogen. Knowledge regarding the prevalence of PrV viral shedding is important in understanding the risk of transmission to native wildlife. In this study, we surveyed wild pigs from Kern County, California for evidence of exposure to and shedding of PrV.

STUDY AREA

The study was conducted on a 1,100 km^2 privately owned cattle ranch located approximately 100 km north of Los Angeles, California in the Tehachapi Mountains in Kern County, California. This mountain range ran southwest to northeast, was bordered by the Grand Central Valley and Mojave Desert, and formed a linkage between the Coast and Sierra Nevada Ranges. Due to its unique geographic location, the ranch hosted a diverse assemblage of vegetation communities including oak savannahs and woodlands, conifer forests, and riparian corridors.

METHODS

From June 2016 through January 2017, biological samples were collected from wild

pigs that were collared for an animal movement study. Pigs were trapped using a corral style trap with panels and a swing head gate. A heavily modified squeeze chute originally designed for sheep and goats was attached to the head gate with tie down straps. The door to the trap and one end of the squeeze chute were opened and pigs were herded into the squeeze chute one at a time. For adult animals only, approximately 40 ml of blood was drawn from the jugular vein, and the mouth, nose, and genital region were swabbed. Sex and ear tag number were recorded. All animals were handled by USDA APHIS WS Operations personnel. Animal handling followed established protocols and was approved by the National Wildlife Research Center Institutional Animal Care and Use Committee (IACUC protocol: QA-2521).

Serology

To assess PrV antibody production, we collected sera from whole blood. Whole blood was immediately placed into Covidien® serum separator tubes (Covidien AG, Dublin, Ireland). Samples were refrigerated at 4 C as soon as possible after collection, and centrifugation occurred within 12 hours of collection. Sera were aliquoted into 2-mL Corning® cryovials (Corning Incorporated, Lowell, Massachusetts, USA) and labeled with a unique barcode for each wild pig. Samples were frozen for up to a month prior to shipment on ice packs to the Kentucky Federal Brucellosis Laboratory. Sera were screened using the PrV-gB enzyme-linked immunosorbent assay per the manufacturer's recommendations (ELISA; IDEXX Laboratories, Westbrook, Maine, USA).

Viral shedding

We used the detection of viral genetic material to infer viral shedding of PrV in wild pigs. Although the detection of viral genetic material does not necessarily reflect pathogen viability in tissues, a previous study of PrV found that when viral DNA was detected, live virus was also recovered from the same tissues and was indicative of infectious material (Müller et al. 2001). Whole blood (0.5 mL) was stored immediately in 1 mL mammalian lysis buffer (Qiagen, Valencia, CA, USA) in the field. Nasal, oral, and genital swabs were collected and stored in 1.5 mL mammalian lysis buffer. Samples were immediately refrigerated at 4 C or kept on ice packs, transported to the University of Florida and stored at -80 C until DNA could be extracted. Due to logistical constraints, we were not able to collect every sample type from every animal.

For downstream analyses of viral DNA shed into blood and mucous, we extracted DNA from these biological samples using previously published methods (Hernández et al. in review). We used previously published primers and a probe targeting the 5' coding region of the PrV glycoprotein B (*gB*) gene (also known as *UL27*) in order to detect PrV DNA in all sample types. All reaction conditions were used as in Sayler et al. (*in press*). To control for false negatives due to low sample yield, we used a commercially available nucleic acid internal control (VetMax Xeno Internal Positive Control DNA, Applied Biosystems, Foster City, CA). Assays were also run with negative controls (molecular grade water) and extraction controls (i.e., no template controls) to detect false positives due to contamination. The cutoff value for this qPCR assay was 39 Cq (threshold cycle), which corresponded to the average Cq for the detection of 10 copies of PrV DNA which represented the lower limit of detection of the assay (Sayler et al. *in press*). PCR amplification that cycled after this threshold value was considered a negative result. PCR-positive samples were confirmed in triplicate

Table 1. Results of serology and qPCR for 7 positive and suspected positive invasive wild pigs from Kern County, California.

Pig ID	Date collected	Sex	Serology (+/-)	qPCR Positive/ Suspected Positive	qPCR Ave. Cq value[a]
1	7/13/2016	F	+	Suspected Positive	34 (1/3)
2	12/8/2016	F	+	Suspected Positive	38 (1/3)
3	12/13/2016	M	+	Suspected Positive	39 (1/3)
4	7/12/2016	F	+	Suspected Positive	34 (1/3)
5	11/8/2016	M	+	Suspected Positive	35 (1/3)
6	11/15/2016	F	+	Positive	37.6 (3/3)
7	12/21/2016	M	+	Positive	38.3 (3/3)

[a] Numbers in parentheses refer to the number times successful amplification occurred in triplicate samples.

when at least two-thirds of the replicates were PrV DNA positive.

RESULTS

Serology was conducted when enough sera was collected for testing on 29 of 35 individuals, and all samples tested positive for the presence of antibodies to PrV. We performed PrV-gB qPCR assays on 145 samples collected from 35 animals; three individuals were sampled twice. qPCR was conducted on 37 blood, 38 nasal, 38 oral, and 32 genital samples. We detected PrV DNA above the threshold of detection (Cq=39) in three of three replicate tests for two genital samples from two unique individuals. One sample came from a female wild pig collected in November 2016. The other positive sample came from an adult male who was not shedding virus in July 2016, but tested positive for shedding in December of the same year. Five additional samples (3 genital and 2 blood samples) tested positive initially, but those results were not replicated upon additional testing and were therefore considered suspected positives without confirmation (Table 1). Each positive or suspected positive came from a unique animal. No animal had a positive or suspected positive result in > 1 sample type.

DISCUSSION

All animals that were tested for antibody production were seropositive (n=29) suggesting that all animals had been exposed to PrV and were possible carriers of the virus. This is the highest prevalence of PrV exposure reported to date in the US. It is not surprising that we found two individuals (6% prevalence) which were shedding virus, and 5 additional animals (20% prevalence) which were suspected to be positive for viral shedding. All of these animals had levels of circulating virus that were near the limit of detection of the assay (Sayler et al. in press), which is the likely reason we had multiple suspected positives that could not be confirmed. The Cq values of our samples further suggest that virus was circulating in animals at a low level which is consistent with a herpesvirus that has reactivated and is recirculating in an animal.

The percentage of wild pigs shedding virus (6-20%) was similar to previously published studies of viral shedding from animals in Europe (5.5% in Spain; González-Barrio et al. 2015 and 18.7% in Italy; Verin et al. 2014) and in the US (0-60% in Florida; Hernández et al. in review). In these areas, PrV has been documented to kill endangered and threatened species such as the Iberian lynx (Masot et al. 2017) and Florida Panther (Glass et al. 1991). The route of spillover transmission to wildlife has been linked to consumption of infected prey or carcasses. Contributing factors that may promote PrV transmission via scavenging includes the disposal of unwanted parts of wild pigs carcasses in ‘gut pits’ or at harvest sites (Gioeli and Huffman 2012). PrV has been

shown to remain intact in the environment for one to two weeks (Sobsey and Meschke, 2003; USDA Animal and Plant Health Inspection Service 2008; Paluszak et al. 2012) and may facilitate additional opportunities for PrV to spill over into wildlife via environmental exposure.

MANAGEMENT IMPLICATIONS

All wild pigs in our study had been exposed to PrV and had the potential to be carriers of the virus. While the two positive animals were circulating virus in the fall, virus reactivation can occur at any time of year by any carrier animal. Suspected positive animals were found in July, November, and December; thus, native wildlife on this cattle ranch are potentially exposed to PrV throughout the year. Native wildlife on this property that are susceptible to disease from PrV include 13 species of carnivores. Carnivores that have the potential to be exposed via scavenging include raccoon, badger (*Taxidea taxus*), bobcat (*Lynx rufus*), cougar, coyotes (*Canis latrans*), gray fox (*Urocyon cinereoargenteus*), red fox (*Vulpes vulpes*), the endangered San Joaquin kit fox (*Vulpes macrotis*), and black bear. Black bear and cougar have been documented to prey on wild pigs on the property. Given the threat of PrV to native wildlife including threatened and endangered species, control of the wild pig population may be warranted and care should be taken by hunters to dispose of offal and carcasses in a manner that does not allow carnivores or companion animals to scavenge the remains.

Surveillance for viral shedding provides a more comprehensive indication of the risk of transmission of PrV from pig to pig and from pigs to wildlife. Like previous studies (Hernández et al. in review), we found evidence of viral shedding from multiple tissue types. For a more accurate estimation of viral shedding, we recommend that biosamples from multiple origins (oral, nasal, genital, and blood) be collected from each animal to provide an accurate representation of viral shedding in the population.

ACKNOWLEDGEMENTS

The authors wish to thank M. White and B. Teton of Tejon Conservancy for access to land and assistance in the field; B. Lowry, J. Seidel, M. Williams, K. Banford, and D. Orthmeyer USDA APHIS WS for assistance with trapping and handling animals; and M. Poulos, California Department of Food and Agriculture for veterinary oversight. Partial funding was provided by University of Florida Institute of Food and Agricultural Sciences.

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Applications of Sensory Ecology for Wildlife Damage Management

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ABSTRACT: Human-wildlife conflicts typically involve fundamental processes associated with the feeding behavior and/or the spatial behavior of wildlife. Thus, most human-wildlife conflicts arise from wildlife consuming products and/or wildlife occupying places valued by humans. For mammals, taste is the most important sensory cue for selecting nutrients and avoiding toxins. Most birds use both flavor (i.e. taste, odor, texture) and visual cues for their food selection process. We previously learned that an ultraviolet visual cue can enhance the repellency of an anthraquinone-based repellent for blackbirds, starlings, Canada geese and wild turkeys. Although the ultraviolet cue is not itself aversive, novel repellent formulations including ultraviolet cues have provided repellent efficacy at reduced concentrations of the repellent active ingredient. Ultraviolet repellent formulations are currently being developed for the protection of ripening agricultural crops from bird depredation. With regard to spatial behavior, exteroceptive sensory cues (e.g. visual, auditory, tactile cues) are reliably used for patch selection. We suggest that sensory cues and their paired consequences can be exploited for the development and application of effective strategies for wildlife damage management.

Proceedings of the 17th Wildlife Damage Management Conference. (D. J. Morin, M. J. Cherry, Eds). 2017. Pp. 41.

A Novel Technique for Removing Beaver Dams Using a Portable Winch System

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ABSTRACT*:* Dams and associated impoundments created by American beaver (*Castor canadensis*) are viewed as positive or negative depending on stakeholder values, their levels of acceptance, and timing. When levels of flooding at beaver dams exceed acceptance levels, immediate actions are required to reduce damage and protect human safety. In Virginia, USDA/APHIS/Wildlife Services (WS) often provides assistance to reduce flooding caused by beavers, especially where it affects transportation infrastructure. WS specialists choose from a variety of techniques to best address each unique situation. Until recently, moving damming material by hand or with binary explosives were the most common practices to provide immediate relief. However, WS specialists devised a novel technique for dam removal that uses a portable winch, rope, and a variety of terminal end pieces that are specific to different situations. The main component is a gas-powered capstan winch that weighs approximately 35 lbs and has a maximum pulling force of 2200 lbs (1000 kg) at a speed of 40'/min. They use double braided polyester rope (1/2" diameter) which they coil in bags for easy transport and deployment. To remove damming material from plugged culverts, they use a 10' piece of galvanized rigid conduit to push through the debris. The conduit is closed on both ends with threaded caps to prevent debris from entering the conduit. Once the conduit is through the dam, a modified 24" agricultural disc is slid onto the pipe and held in place by the pipe cap. The winch line is connected to the loop with a carabiner and run to the winch. Pulling power can be increased by increments of 2200 lbs. (1000 kg) up to a maximum 11,000 lbs. (5000 kg) with the use of single and double snatch blocks. The winch and blocks can be anchored to a variety of points with polyester tow straps. Once all components are connected, the material is pulled out of the culvert. This setup is also used for pulling out dams that are primarily of mud and dirt, as the disc will dig out large pieces at a time. For traditional beaver dams in streams, the terminal end is a grappling hook. We have found that a 3-prong grappling hook (approximately 30" circumference) welded from 1"rebar with reinforcing works well for most situations. In some situations, dams may be removed by simply pulling out large anchoring material (logs) with a polyester strap at the terminal piece. The entire system can easily be transported by hand, or in a 16' canoe if accessible by water. With this system, water can be released at a controlled rate, decreasing potential for downstream flooding. This portable winch system has proven to be

faster and less expensive to use than binary explosives, and has eliminated the use of binary explosives for dam removal by WS in Virginia.

Proceedings of the 17th Wildlife Damage Management Conference. (D. J. Morin, M. J. Cherry, Eds). 2017. Pp. 42-43.

Cage efficacy study of an experimental rodenticide using wild-caught house mice

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ABSTRACT: The availability and effectiveness of rodenticides in the US and elsewhere has been changing for various reasons. As a result, new rodenticide formulations and active ingredients are being investigated in the US and other countries. We conducted a cage efficacy study of a paste bait containing 4.4% alphachloralose. A commercial product of this nature is manufactured and used in parts of Europe. While the formulation we tested was effective (100%) in a no-choice trial with wild caught house mice, it was not effective in two-choice trials (≤ 35%). We surmise that palatability may be an issue as the mice consumed very little of the paste bait. It was also clear that the paste bait is more effective at cooler temperatures. Future efforts could focus on identifying more palatable formulations.

Key Words alphacloralose, house mouse, *Mus musculus*, rodent damage, rodenticide

Proceedings of the 17th Wildlife Damage Management Conference. (D. J. Morin, M. J. Cherry, Eds). 2017. Pp. 44-53.

Originally from the Middle East and Asia, house mice (*Mus musculus*) have followed humans around the world and are now found worldwide (Long 2003, Witmer and Jojola 2006). In many situations they live in a close commensal relationship with humans, but on many tropical islands and on portions of some continents, they are free-ranging and do not need the food and shelter provided incidentally by humans. House mice pose a threat to the native flora and fauna of islands (Angel et al. 2009, Burbidge and Morris 2002) and can cause significant damage to agricultural commodities and property (Long 2003, Timm 1994a). Most seabirds that nest on islands have not evolved to deal with predation and are very vulnerable to introduced rodents (Moors and Atkinson 1984). House mice are very prolific and populations have irrupted periodically to cause "plagues" in places such as Australia and Hawaii (Long 2003). There has been an effort to eradicate introduced house mice from some islands with some successes (e.g., Burbidge and Morris 2002). Successful eradication rates for house mice, however, have lagged behind rates for rats (MacKay and Russell 2007). Three APHIS pesticide registrations for rodenticide baits (two with brodifacoum and one with diphacinone) are now available to allow rodenticide baiting of conservation areas to eliminate introduced rodent populations (Witmer et al. 2007). Unfortunately, the diphacinone formulation has not proven very effective for house mouse control (Pitt et al. 2011, Witmer and Moulton 2014). Studies in New Zealand have also shown that effective anticoagulant rodenticide formulations for house mice have

proven elusive (Fisher 2005, Morriss et al. 2008).

Many commercial rodenticide baits are available on the market and many of these list house mice as a targeted species (Jacobs 1994, Timm 1994a, 1994b). Witmer and Moulton (2014) tested many commercial products, but found few (only 5 of 12 formulations tested) effective with wild-caught house mice from the mainland United States (US). While a wide array of rodenticides have been available for use in the US, the continued use of some rodenticides is uncertain because of one or more issues such as toxicity, residue persistence, reduced effectiveness, hazards to non-target animals, environmental contamination, and humaneness (e.g., Cowled et al. 2008, Eason et al. 2010a, Mason and Littin 2003). As a result of this situation, there has been an increase in research on new products that would remove or reduce some of the detrimental characteristics of currently registered rodenticides (Baldwin et al. 2016, Eason et al. 2010a, 2010b; Eason and Ogilvie 2009; Schmolz 2010, Witmer et al. 2017).

One potential new rodenticide for the US is alphachloralose. This chemical is registered for use in the US as a bird anesthesia agent (Timm 1994b). However, it has been used in some European countries as a rodenticide (Cornwell 1969). Alphachloralose is a centrally active drug with both stimulant and depressant properties on the central nervous system. In rodents, it slows metabolism, lowering body temperature to a degree that may be fatal in small mammals. The smaller the body mass to surface area the more sensitive the animal; hence, house mice are very sensitive to alphachloralose intoxication especially at temperature lower than 15°C (Cornwell 1969, Timm 1994b). Generally, ataxia occurs in mice in 5-10 minutes following ingestion of the chemical. Then feeding usually ceases within 20 minutes and mice are usually unconscious within 1 hour.

We could find very little literature on the use of alphachloralose as a rodenticide beyond the article by Cornwell (1969). If it is to be registered as a new house mouse rodenticide in the US, data sets on its cage and field efficacy must be submitted to the US Environmental Protection Agency (USEPA). Hence, we conducted a cage efficacy study with an alphachloralose (4.4%) food bait using wild-caught house mice to determine if the USEPA cage efficacy level of 90% would be achieved.

The objective of this study was to determine the efficacy of a rodenticide paste bait containing 4.4% alphachloralose. The efficacy was determined using a protocol recommended by the USEPA: EPA Laboratory Test Method 1.210: Standard Mouse Acute Placepack Dry Bait Laboratory Test Method with the bait removed from the sachet (USEPA 1991). The trial was a two-choice trial whereby the rodenticide bait was presented along with the USEPA challenge diet. The trial used wild-caught house mice. The USEPA required a cage efficacy of at least 90%.

METHODS

House mice for this study were wild-caught mice from the Fort Collins, Colorado, area. Mice were kept in individual numbered, plastic shoebox cages in a climate–controlled animal room of the Invasive Species Research Building (ISRB). They were fed a maintenance diet of rodent chow pellets and received water *ad libitum.* They were provided with bedding and a den tube. There was a 3-week quarantine period before the study began to help assure that animals were healthy, acclimated, and females were not pregnant.

The original, approved study protocol was amended to meet some requirements of the USEPA. This included:

1) following the USEPA Test Method 1.210 (paste bait removed from the sachets before being placed in the cages), 2) the room temperature was raised from 68°F (20°C) to 72°F (22.2°C), and 3) the room humidity was raised from ambient to 50% humidity. The study used individually-housed mice during the efficacy trial. There were 10 cages of male mice in the treatment group and 10 in the control group. There were also 10 cages of female mice in the treatment group and 10 in the control group. For the trials, each mouse was housed in a plastic shoebox cage with a den tube and bedding material. Mice were randomly assigned to the treatment and control groups although an effort was made to distribute mice of differing weights rather evenly so that no group is comprised of larger mice versus smaller mice. The weight, sex, cage number, and treatment of each mouse were recorded before the initiation of the trial.

On day 1 of the efficacy trial, all mice were placed in clean cages with no maintenance food. Pre-weighed foods were placed in 2 opposite corners of the cage in shallow bowls. For the treatment cages, one corner had a paste bait (sachet cover removed); the other corner bowl contained the USEPA challenge diet (USEPA 1991). The control mice were only presented with the USEPA challenge diet (as required by the USEPA). Remaining food in the bowls was replenished with weighed amounts as needed so that both food types were always available. After 2 days of bait exposure, the mice were put into clean cages with the maintenance diet for a 5-day post-exposure observation period. All remaining food in the dirty cages was removed and weighed. The total amount of foods consumed in each cage was determined by subtracting the remaining weight from that added over the course of the 2-day exposure period.

Mice were examined twice daily by the study staff and their condition and any mortalities were recorded on animal health log sheets. Because the USEPA required death as an end point for this study, no intervention and euthanasia was used in this toxicity trial. Dead mice were placed in individual, labeled zip-lock bags and refrigerated for later incineration. All surviving mice were weighed, euthanized and incinerated at the end of the study.

The percent efficacy (i.e., mortality) of treatment groups and the control group was determined by the percent of animals that died during the trials in each group. Mouse weights were compared using *t*-tests. Food consumption of rodenticide bait versus the USEPA challenge diet and by males versus females was compared with *t*-tests. We also compared food consumption at the high versus low temperatures with *t*-tests.

RESULTS

Part 1 Trial (72°F, 22.2°C)

Of the 20 treatment mice in this two-choice trial, only one (a female) died. This equates to an efficacy of 5%. We noted, however, that 5 other treatment mice (2 males and 3 females) became "comatose" but recovered (sometimes it was a whole day or two later). Some went down very quickly after eating some bait. None of the 20 control mice died.

All mice tended to lose a gram or 2 of weight over the course of the 7-day trial (2 days exposure, 5 days post-exposure observation). Most mice ate relatively little of the bait, generally 0.1-0.4g. The one treatment mouse that died ate a little more (0.6g). Because of the poor performance of the paste bait in the part 1 trial, we did not tabulate the results like we did for the Part 2 and part 3 trials.

Over the course of the part 1 trial, the room temperature averaged 71.7°F (SD = 0.10) and the humidity averaged 49.5% (SD = 0.52).

Part 2 Trial (72°F, 22.2°C)

Because only 1 of 20 mice died in the two-choice trial (part 1 trial), we conducted a no-choice trial at the same room temperature. This was to make sure that there was an adequate concentration of the alphachloralose in the paste bait to cause mortality. Five mice were used (3 males and 2 females). The mice were lightly fasted by removing all food the afternoon before the paste bait was added the next morning. All mice became comatose during the day the paste bait was added. All five mice eventually died, but this varied from 1 to 6 days later (Table 1). The average alphachloralose bait consumption was 0.6g (SD = 0.1) with a range of 0.4-0.8 g. This average consumption was comparable to the amount eaten (0.6g) by the one mouse that died in the two-choice trial (part 1 trial). All 5 mice lost some weight over the course of the no-choice trial, probably because they stopped all feeding once they quickly became comatose and later died. The mice starting weights averaged 17.7g (SD = 1.4), while the end weights averaged 13.7g (SD = 0.9).

Table 1. Results of the no-choice alphachloralose feeding trial using wild-caught house mice.

Animal ID	Sex	Trial Start Mouse Weight (g)	Mean (SD) Start Weight (g)	Final Weight (g)	Mean (SD) Final Weight (g)	Comments
14	M	18.25		13.9		comatose; died 10/26/15
34	M	16.50		14.1		comatose; died 10/22/15
42	M	18.80	17.73 (1.4)	12.2	13.7 (0.9)	comatose; moving around 10/23 am; comatose 10/23 pm; died 10/26/15
10	F	16.00		13.6		comatose; died 10/24/15
23	F	19.10		14.5		comatose; moving around 10/26; died 10/27/15

Part 3 Trial (62°F, 16.7°C)

Because of the poor efficacy in the part 1 trial, we amended the protocol a second time. This was to repeat the previous trial, but at a lower temperature (62°F, 16.6°C). All other aspects of the trial were conducted as per the part 1 trial.

While the result were better than in the part 1 trial, they still were not very good. Only 7 of the 20 treatment mice died (4 males and 3 females; Table 2). This amounts to an efficacy of about 35%. No control mice died during this trial.

The treatment mice tended to gain a little weight over the course of the 7-day trial (2 days exposure, 5 days post-exposure observation), but only <1g (Table 2). The control mice tended to lose weight, but, again <1 g. There were no significant differences (F = 1.91; p = 0.145) in the starting weights of mice in the 4 groups (treatment males, treatment females, control males, control females).

As in the part 1 trial, most of the mice that died tended to eat a little more of the bait than the mice that lived, although the difference was not significant (t = 1.75; p = 0.097). Mice that died ate an average of 0.37g (SD = 0.18) of paste bait, while mice that lived ate an average of 0.22g (SD = 0.20) of paste bait (Table 3).

The amount of paste bait consumption did not vary significantly (t = 0.65; p = 0.525) between males (mean = 0.29g; SD = 0.23) and females (mean = 0.23g; SD = 0.182). However, both males and females consumed much more challenge diet than the paste bait (Table 3). For example, males consumed significantly more

Table 2. House mouse fates and weights in the two-choice alphachloralose trial at 62°F (16.7°C).

Group	Animal ID	Sex (M/F)	Start Weight (g)	Final Weight (g)	Comments
Treatment Males	7	M	15.2	16.0	
	15	M	18.2	19.2	
	22	M	19.9	19.1	comatose 11/2; recovered 11/3 am
mean start weight 18.2g (SD = 1.7)	24	M	20.0	19.4	
	28	M	20.1	19.7	comatose 11/2; dead 11/3 am
	31	M	19.3	18.4	
mean final weight 18.4g (SD = 1.1)	35	M	17.2	18.3	comatose 11/2; dead 11/3 am
	40	M	17.6	18.7	
	44	M	16.2	18.3	comatose 11/2; dead 11/3 am
	46	M	17.8	17.1	comatose 11/2; dead 11/3 am
Treatment Females	6	F	15.9	18.1	dead 11/3 am
	8	F	12.6	12.4	
	12	F	16.2	16.1	
mean start weight 17.2g (SD = 2.1)	16	F	17.0	17.4	
	20	F	19.6	21.4	dead 11/3 am
	32	F	18.5	18.4	
mean final weight 17.7g (SD = 2.5)	38	F	16.6	18.4	
	47	F	17.2	16.0	
	49	F	19.5	18.1	
	52	F	18.8	20.4	dead 11/3 am
Control Males	4	M	22.0	19.3	
	21	M	16.6	16.6	
	26	M	18.9	18.5	
mean start weight 19.7g (SD = 2.9)	27	M	19.2	19.0	
	29	M	17.8	18.5	
	33	M	23.6	23.0	
mean final weight 19.3g (SD = 2.4)	37	M	22.8	22.3	
	43	M	16.8	17.5	
	45	M	22.9	22.1	
	50	M	16.5	16.0	
Control Females	1	F	21.9	21.1	
	3	F	18.8	19.2	
	5	F	17.4	17.3	
mean start weight 18.1g (SD = 2.7)	17	F	21.4	17.7	
	18	F	17.9	17.7	
	19	F	20.0	19.0	
mean final weight 17.2g (SD = 2.5)	25	F	18.8	17.5	
	30	F	17.4	16.5	
	36	F	13.4	12.3	
	39	F	14.3	13.9	

($t = 5.68$; $p < 0.001$) challenge diet (mean = 8.21g; SD = 4.40) than the paste bait (mean = 0.29g; SD = 0.23). Females exhibited the same pattern and both males and females consumed similar amount of paste bait and similar amounts of the challenge diet.

Over the course of the part 3 trial, the room temperature averaged 62.6°F (SD = 0.11) and the humidity averaged 50.3% (SD = 0.89).

When we compared the paste bait consumption by males at the higher temperature (part 1 trial) versus the lower temperature trial (part 3 trial), there was no significant difference ($t = 0.69$; $p = 0.502$). The same result occurred when the female bait consumption was compared between the

Table 3. House mouse fates and alphachloralose bait (AC) and challenge diet (CD) consumption by mouse in two-choice alphachloralose trial at 62°F (16.7°C). All food was added Nov 2 2015 and replaced and weighed Nov 4 2015; type of food: L=left side of cage; R=right side of cage.

Animal ID	Type of Food [Cage Size]	Container Weight (g)	Intake Container + Food Weight (g)	Intake Food Weight (g)	Additional Food Added (g) & Date	Outake Container + Food Weight (g)	Amount Eaten (g)	Fate (A/D) & Date	Comments
PL07M	CD [L]	6.1	16.1	10.0	10.2; 11/3/15	16.6	9.7	A	
PL07M	AC [R]	6.1	16.2	10.1		16.0	0.2		
PL15M	CD [R]	6.3	16.4	10.1	10.2; 11/3/15	12.1	14.5	A	
PL15M	AC [L]	6.1	16.0	9.9		15.9	0.1		
PL22M	CD [L]	6.0	16.1	10.1	10; 11/3/15	16.7	9.4	A	comatose 11/2; recovered 11/3 am
PL22M	AC [R]	6.0	15.8	9.8		15.6	0.2		
PL24M	CD [R]	6.1	16.0	9.9	10.1; 11/3/15	12.2	13.9	A	
PL24M	AC [L]	6.3	16.2	9.9		16.0	0.2		
PL28M	CD [L]	6.2	16.3	10.1		13.5	2.8	D; 11/3/15	comatose 11/2; dead 11/3 am
PL28M	AC [R]	6.1	17.1	11.0		16.8	0.3		
PL31M	CD [R]	6.1	16.2	10.1	10.2; 11/3/15	16.6	9.8	A	
PL31M	AC [L]	6.2	16.2	10.0		16.2	0.0		
PL35M	CD [L]	6.1	16.0	9.9		11.8	4.2	D; 11/3/15	comatose 11/2; dead 11/3 am
PL35M	AC [R]	6.1	16.5	10.4		16.1	0.4		
PL40M	CD [R]	6.3	16.5	10.2	10.1; 11/3/15	15.8	10.8	A	
PL40M	AC [L]	6.2	16.9	10.7		16.1	0.8		
PL44M	CD [L]	6.3	16.2	9.9		12.7	3.5	D; 11/3/15	comatose 11/2; dead 11/3 am
PL44M	AC [R]	6.1	17.0	10.9		16.8	0.2		
PL46M	CD [R]	6.1	16.1	10.0		12.6	3.5	D; 11/3/15	comatose 11/2; dead 11/3 am
PL46M	AC [L]	6.2	16.7	10.5		16.2	0.5		
PL06F	CD [L]	6.0	16.2	10.2		8.3	7.9	D; 11/3/15	dead 11/3 am
PL06F	AC [R]	6.0	16.8	10.8		16.2	0.6		
PL08F	CD [R]	6.2	16.2	10.0	10; 11/3/15	18.3	7.9	A	
PL08F	AC [L]	6.3	16.7	10.4		16.4	0.3		
PL12F	CD [L]	6.0	16.1	10.1	10.1; 11/3/15	15.6	10.6	A	

PL12F	AC [R]	6.0	15.8	9.8		15.7	0.1		
PL16F	CD [R]	6.1	16.0	9.9	10; 11/3/15	13.9	12.1	A	
PL16F	AC [L]	6.2	17.0	10.8		16.9	0.1		
PL20F	CD [L]	6.1	16.1	10.0		8.5	7.6	D; 11/3/15	dead 11/3 am
PL20F	AC [R]	6.2	15.9	9.7		15.8	0.1		
PL32F	CD [R]	6.0	16.0	10.0	10; 11/3/15	14.1	11.9	A	
PL32F	AC [L]	6.3	16.1	9.8		16.0	0.1		
PL38F	CD [L]	6.2	16.6	10.4	10; 11/3/15	15.1	11.5	A	
PL38F	AC [R]	6.0	16.5	10.5		16.4	0.1		
PL47F	CD [R]	6.2	16.2	10.0	10; 11/3/15	15.3	10.9	A	
PL47F	AC [L]	6.1	17.0	10.9		16.8	0.2		
PL49F	CD [L]	6.1	15.9	9.8	10.1; 11/3/15	16.2	9.8	A	
PL49F	AC [R]	6.2	16.2	10.0		16.0	0.2		
PL52F	CD [R]	6.1	16.3	10.2		8.5	7.8	D; 11/3/15	dead 11/3 am
PL52F	AC [L]	6.0	15.9	9.9		15.4	0.5		

two temperatures ($t = 0.98$; $p = 0.341$). Hence, males and females ate similar amounts of the paste bait, and those amounts were similar regardless of room temperature. A very different pattern occurred when the challenge diet consumption is compared between males at the two different temperatures. Males consumed significantly more challenge diet ($t = 2.93$; $p = 0.009$) in the higher temperature trial (mean = 14.4g; SD = 5.09) than during the lower temperature trial (mean = 8.19; SD = 4.43). The same pattern was observed for females at the two different temperature trials ($t = 8.76$; $p < 0.001$).

DISCUSSION

The cage efficacy of an alphachloralose paste bait provided by the Lodi, Inc., company of France was poor in both the high (72°F, 22.2°C) and low (62°F, 16.7°C) temperature trials. As expected, temperature does appear to make a difference in efficacy of this rodenticide; efficacy increased from 5% at the higher temperature to 35% at the lower temperature. We discussed this in various conference calls and there was some interest expressed in having a temperature effects study done. Based on the results of our cage efficacy trials at two different temperatures, it would seem that a temperature effects study could prove valuable. On the other hand, because the paste bait is only meant for use inside buildings, it would be most valuable to have a formulation that was effective at room temperature or perhaps at a somewhat lower temperature, but not substantially lower. In our no-choice trial, we had very good efficacy (100%), suggesting that the active ingredient was present in the paste bait and in adequate concentration to cause mortality, even when a relatively small amount (0.4-0.8g) of the bait was consumed. We did not do a chemical analysis of the paste bait, but relied on the certificate of analysis provided by the Lodi, Inc., company.

Odor and taste cues are important in the attractiveness of a rodenticide bait (Jackson et al. 2016, Witmer et al. 2014). The fact that very little of the paste bait was consumed by the mice suggests that improvement could be made in the formulation to increase the palatability. We thought that we were testing the commercial bait manufactured and sold in Europe in our trials. However, we later learned that a flavoring ingredient (hazelnut) used in the commercial product had been left out of the paste bait provided to us. We were told that this was at the request of the USEPA because hazelnut is not on their list of inert ingredients. It is possible that this explains the poor cage efficacy results in our trials and why so little of the paste bait was eaten. Perhaps one of the other tree nuts that are listed on the USEPA inert ingredients list could be used as a flavor and odor enhancer: almonds, peanuts, or walnuts.

ACKNOWLEDGEMENTS

This study was conducted under the NWRC IACUC-approved study protocol QA-2464. We thank the Lodi Group, Inc., company for providing funding and the rodenticide paste bait for these trials. We also thank the landowners that allowed us to live-trap house mice from their properties for this study. The mention of a commercial product or company does not represent an endorsement by the U.S. government.

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A Cage Efficacy Study of Sodium Nitrite Formulations for Rodent Control

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ABSTRACT: Rodents cause extensive damage to human and natural resources around the world. Rodenticides are heavily relied upon to reduce rodent populations and damage. However, some rodenticides are becoming less effective while others are becoming more restricted in their use. Additionally, there are growing concerns about the non-target effects of rodenticides and the humaneness of some rodenticides. In this study, we tested some formulations containing sodium nitrite, a salt that can be toxic in high enough concentrations. One of our previous studies indicated an LD_{50} of about 246 mg/kg for various rodent species. It was also determined that rodents could eat enough sodium nitrite-laced food to consume a lethal dose if the concentration of sodium nitrite was high enough. However, in the current study, none of the formulations tested had hardly any efficacy at all ($\leq$ 20%) with wild-caught house mice and Norway rats in two-choice trials. While it appears that sodium nitrite may be an effective toxicant for some targeted species, such as feral swine, it appears that it will not be effective for problem rodents unless concentration and palatability issues can be resolved.

Key Words house mouse, *Mus musculus*, Norway rat, rodent damage, *Rattus norvegicus*, rodenticide, sodium nitrite

Proceedings of the 17th Wildlife Damage Management Conference. (D. J. Morin, M. J. Cherry, Eds). 2017. Pp. 54-63.

Rodents cause significant damage to a variety of resources required by a growing human population (Witmer and Singleton 2010). Damage can be especially severe when rodent population densities are high (Witmer and Proulx 2010). When introduced to islands, rats and mice can cause substantial damage to flora and fauna (e.g., Angel et al. 2009). A variety of methods are used to reduce damage by rodents, generally framed within an Integrated Pest Management (IPM) strategy (Witmer 2007). One of the most important categories of available and effective tools is rodenticides (Witmer and Eisemann 2007).

Many commercial rodenticide baits are available on the market and many of these list house mice and commensal rats as targeted species (Jacobs 1994, Timm 1994a, 1994b, 1994c). Witmer and Moulton (2014) tested many commercial products, but found few (only 5 of 12 formulations tested) effective with house mice from the mainland US. While a wide array of rodenticides have been available for use in the United States (US), the continued use of some rodenticides is uncertain because of one or more issues such as toxicity, residue persistence, reduced effectiveness, hazards to non-target animals, environmental contamination, and humaneness (e.g., Cowled et al. 2008, Eason

et al. 2010a, Mason and Littin 2003). As a result of this situation, there has been an increase in research on new formulations and/or active ingredients that would remove or reduce some of the detrimental characteristics of many currently registered rodenticides (Eason et al. 2010a, 2010b; Eason and Ogilvie 2009; Schmolz 2010).

One potential new rodenticide is sodium nitrite. This chemical has wide uses in the food and pharmaceutical industries, but is known to be toxic at high enough doses. The LD50 for rats is in the range of 130-180 mg/kg (Cowled et al. 2008). It is being investigated as a feral pig (*Sus scrofa*) toxicant in Australia (Cowled et al. 2008, Lapidge et al. 2009), in New Zealand (Charles Eason, pers. comm.), and in the US (Snow et al. 2016). Some of the desirable attributes of sodium nitrite as a toxicant are that it is fast-acting, is considered humane, leaves no residues, has an antidote, and is rapidly degraded in the environment (Cowled et al. 2008, Lapidge et al. 2009). Cowled et al. (2008) reported that the symptoms in dosed pigs in the order of their occurrence were lethargy, dyspnoea (shortness-of-breath), reduced consciousness, and terminal seizures followed quickly by death. Some feral pigs vomited. The average time to death was 107 min (n = 10) when delivered by oral gavage (although 85 min if a delayed accidental death through handling a low-dosed animal is removed) or 140 min (n = 6) when a food bait is used and digestion is required. The mode of action of nitrite is the oxidization of the iron in oxyhemoglobin in red blood cells from the ferrous state to the ferric state to form methemoglobin (MetHb). MetHb is incapable of carrying oxygen and respiratory distress and cyanosis results with death occurring if the MetHb levels are high enough (Cowled et al. 2008, Smith and Beutler 1966). If the animal does not receive a lethal dose MetHb will undergo chemical reduction, through the action of MetHb reductase, back to oxyhemoglobin, the rate of which differs between species (Smith and Beutler 1966, Agar and Harley 1972). Certain reducing agents such as methylene blue can accelerate that process and, hence, can be given as an antidote to nitrite poisoning (Lapidge et al. 2009).

We could find no literature on the use of sodium nitrite as a rodenticide. Hence, our preliminary studies (QA-1752; Witmer 2013) were to assess the potential of sodium nitrite as a rodenticide. The main objective of QA-1752 was to determine the LD50 of sodium nitrite in a variety of native and invasive rodent species, using oral gavage into the stomach. This was accomplished and while there was some variation across species and genders, the LD50 averaged about 246 mg/kg. The time-to-death was 41-55 minutes for 5 species, but somewhat longer (97 minutes) for Norway rats (*Rattus norvegicus*). The clinical symptoms observed in mice were lethargy, then loss of motor control followed by labored breathing with some gasping, and finally, spasms, coma and death. A secondary objective was a "proof-of-concept" small trial using the remaining animals to see if rodents could eat enough sodium nitrite-containing food bait in a single feeding to consume a lethal dose. A very simple food bait containing peanut butter, rolled oats, and encapsulated sodium nitrite (ESN) was presented to the rodents in a no-choice feeding trial. Additionally, all food was removed from the cages the afternoon before the ESN bait was to be added the next day so that the rodents were lightly fasted. Only 4-8 rodents of each species were available, so this was not really an efficacy trial and we varied the concentration of ESN as the various rodent trials based on the results of the previous oral gavage trial. We started with Richardson's ground squirrels (*Spermophilus richardsonii*) and a 10% ESN bait; 3 of 5 animals died (60% efficacy). We next used house mice

(*Mus musculus*) and upped the concentration to 15% ESN; only 1 of 4 died (25% efficacy). For the remaining four species of rodents (*Microtus montanus*, *Rattus norvegicus*, *R. rattus*, *Cynomys ludovicianus*), we upped the concentration to 20% ESN; with 2 species we had 0% efficacy and with the other 2 species we had 50% efficacy. Hence, based on those preliminary results, we are mainly using a 20% ESN in the food baits tested in this study. We also concluded that additional research should be conducted to identify a highly palatable food bait and an appropriate sodium nitrite concentration that results in high mortality levels in rodents.

In this follow-up study, we conducted a preliminary evaluation of several potential food baits containing sodium nitrite as an oral rodenticide, using wild-caught house mice and Norway rats. The objective of this study was to identify effective new formulations of rodenticide food baits containing encapsulated sodium nitrite (ESN) for the control of house mice and rats. We hypothesized that some of the test food baits would exhibit a high efficacy (> 80% mortality) when presented to house mice and rats.

House Mouse Methods

House mice for this study were wild-caught mice from the Fort Collins, Colorado, area. Mice were kept in individual numbered shoebox cages in an animal room of the Invasive Species Research Building (ISRB). The weight, sex, and cage number of each mouse was recorded when they were brought into captivity. They were fed a maintenance diet of commercial rodent chow pellets (Lab Diet 5001) and received water ad libitum. They were provided with bedding and a den tube. There was a two-week quarantine period before the study began. There were 6 treatment groups with 5 or 10 animals (mixed genders) randomly assigned to each group. There was also a control group of 10 mice. The 6 treatment groups are listed and described below.

1. A peanut paste block (20% ESN)
2. A peanut paste sachet (20% ESN)
3. Cracked wheat coated with ESN in oil (20% ESN)
4. Cracked wheat coated with ESN glued on (20% ESN)
5. Cooked rice with ESN absorbed (13% sodium nitrite; not encapsulated)
6. Peanut butter mixed with rolled oats (20% ESN)
7. Control (rats on maintenance diet and no ESN)

These were two-day feeding trials whereby the food is added in the afternoon and removed two afternoons later. Foods were replenished as needed. Foods were weighed at the start and at the end of the trials. When test foods were removed, they were replaced with the maintenance diet for a 2-3 day post-exposure observation period. The first trial was a no-choice trial with 5 mice per group in which the mice were lightly fasted before the treatment baits were added. All maintenance food was removed in the late afternoon. The next morning, the treatment baits were added.

The second trial was a two-choice trial with 10 mice per group. The mice always had access to the maintenance diet. We fed the mice a non-toxic food bait for two days to allow them to acclimate to a new food type. The non-toxic food bait for the peanut paste block and for the peanut butter and rolled baits was a mix of peanut butter and rolled oats, but did not contain ESN. The food bait for the rice bait was cooked rice that did not contain sodium nitrite. After 2 days, the non-toxic food bait was replaced with the ESN food baits for the next 2 days. When test foods were removed, they were replaced with the maintenance diet for a 2-3 day post-exposure observation period.

Mice on trial were examined twice daily by the study staff and their condition and any mortalities were recorded. Dead mice were weighed before disposal by incineration. All surviving mice were weighed and then euthanized and incinerated at the end of the study.

House Mouse Results

The results of the no-choice trial (trial 1) are presented in Table 1. Some mice (1-4 mice in each group of 5 mice) died in each treatment group. Consequently, efficacy in the treatment groups ranged from 20% to 80%. The two groups with the 80% efficacy were the treated rice group and the peanut butter-oats-ESN (PB-Oats) group. The mice in the peanut paste group and the PB-Oats group died relatively quickly (0.5-2 hrs), whereas, the mice that died in the other treatment groups took much longer to die (24-80 hrs.). We suspect that mice in the first two groups died as a result of ESN consumption (i.e., oxygen deprivation), whereas, the mice in the latter three groups died from not eating enough food/bait. All treatment mice lost weight over the course of the study with a range of -0.3 to -5.7g. In contrast, all control mice survived and gained some weight with a range of +0.7 to +2.6g. The mice in the rice treatment group lost the most weight with a range of -2.8 to -5.7g.

The results of one of the treatment groups in the two-choice trial are presented in Table 2. We only present the results of the PB-Oats group because that is the only treatment group in which some mice died. All mice in the other two treatment groups and the control group survived. Four of 10 mice in the PB-Oats group died for an efficacy of 40%. All these mice died relatively quickly (~0.75 hrs) suggesting that oxygen deprivation by consumption of the ESN was the cause of death. The mice that died all consumed ESN bait with a range of 0.04-0.11g of food bait consumed. This is similar to the amounts consumed in the no-choice trial by the mice that died: 0.08-0.19g consumed. Hence, it appears that very little of the ESN bait needs to be consumed to be lethal. Any mice that did not die during the study were euthanized with carbon dioxide and incinerated at NWRC.

Norway Rat Methods

Norway rats for this study were live-trapped in the Fort Collins, Colorado, area. Rats were kept in individual numbered rat-sized, plastic shoebox cages in an animal room of the Invasive Species Research Building (ISRB) at the National Wildlife Research Center (NWRC) in Fort Collins, Colorado. They were fed a maintenance diet of rodent chow pellets, carrot or apple chunks, and received water ad libitum. They were provided with bedding and a den tube, and material to chew on (e.g., chew stick or wood chunks). There was a two-week quarantine period before the study was started. There were two tiers to this study. The tier 1 trial was a two-choice trial with rats receiving both the treatment bait and their normal maintenance diet. The four treatment baits used were produced by Connovation, New Zealand, and shipped to NWRC for the trials. Each of these four baits contained 20% encapsulated sodium nitrite (ESN). One bait was a peanut paste block and one bait was a peanut paste sachet. One bait had the ESN glued to grain and the fourth bait had the grain coated with oil containing the ESN. There were no other additives (such as flavors or sweeteners) added to the baits. There were 5 rats randomly assigned to each treatment group with a mixture of males and females in each group. There also was a control group of 5 rats. The weight, sex, cage number, and treatment of each rat were recorded before the initiation of the trial. A weighed and recorded amount of bait (37-40g) was added to each cage. The treatment baits were added to the cages on day one of

Table 1. Results of the no-choice bait with 20% ESN baits and 13% sodium nitrite rice, using wild-caught house mice.

Treatment	Mouse ID	Sex	Bait Weight (IN) g	Bait Weight (OUT) g	Amount Eaten (g)	Fate (A/D)	Time Until Death (hours)	Mouse Weight Change (g)
Peanut Paste Block ESN	PI04	F	19.49	19.40	0.09	D	1.5	-0.3
	PI20	M	19.55	19.47	0.08	D	2	-0.3
	PI34	F	19.54	12.87	6.67	A		-2.8
	PI54	M	19.95	15.20	4.75	A		-2.3
	PI64	M	18.76	18.71	0.05	D	1.5	-0.4
Peanut Paste Sachet ESN	PI84	F	13.30	13.24	0.06	D	28	-2.0
	PI19	M	13.36	13.15	0.21	D	24.5	-1.1
	PI43	M	12.44	3.58	8.86	A		-2.6
	PI50	M	13.33	13.17	0.16	D	24.5	-1.0
	PI59	F	12.78	10.00	2.78	A		-1.7
Glued Grain ESN	PI11	F	30.78	28.98	1.80	D	31.25	-2.0
	PI17	M	30.49	27.30	3.19	A		-2.4
	PI33	M	30.53	26.74	3.79	A		-2.8
	PI49	M	30.59	26.82	3.77	A		-2.4
	PI63	F	30.83	27.64	3.19	D	73	-1.3
Rice SN	PI08	F	26.30	25.97	0.33	D	80	-5.7
	PI16	F	30.21	29.54	0.67	A		-2.8
	PI42	F	25.07	25.21	-0.14	D	49	-4.1
	PI52	M	27.28	27.34	-0.06	D	24	-3.1
	PI61	M	30.87	32.16	-1.29	D	48	-4.9
Coated Grain ESN	PI07	F	30.42	28.51	1.91	D	72	-4.8
	PI21	F	31.50	27.71	3.79	A		-1.4
	PI40	M	31.34	28.62	2.72	A		-0.7
	PI55	F	30.73	28.52	2.21	A		-3.5
	PI65	M	30.03	28.90	1.13	A		-3.2
Peanut Butter Oats ESN	PI01	F	19.68	19.55	0.13	D	0.5	-0.3
	PI30	M	18.62	18.54	0.08	D	0.5	-0.5
	PI37	M	20.83	13.73	7.10	A		-0.8
	PI51	F	22.50	22.37	0.13	D	0.5	-0.9
	PI67	M	20.22	20.03	0.19	D	6.5	-0.6
Control	PI05	F	N/A	N/A	N/A	A		+1.4
	PI31	F	N/A	N/A	N/A	A		+1.6
	PI80	M	N/A	N/A	N/A	A		+2.6
	PI48	F	N/A	N/A	N/A	A		+2.1
	PI72	M	N/A	N/A	N/A	A		+0.7

Table 2. Results of the two-choice trial with the peanut butter-rolled oats bait with 20% ESN, using wild-caught house mice.

Treatment	Mouse ID	Sex	Bait Weight (IN) g	Bait Weight (OUT) g	Amount Eaten (g)	Fate (A/D)	Time Until Death (hours)
Peanut Butter Oats ESN	PI03	F	19.70	19.66	0.04	D	0.75
	PI12	M	18.03			A	N/A
	PI22	M	20.08	20.00	0.08	D	0.75
	PI48	F	19.28			A	N/A
	PI68	F	21.43			A	N/A
	PI73	F	20.03	19.96	0.07	D	0.75
	PI77	F	20.94			A	N/A
	PI82	F	23.82			A	N/A
	PI89	M	20.95			A	N/A
	PI95	M	21.79	21.68	0.11	D	0.75

the trial and the rats were observed twice daily for the next 2 days. At the end of the second day of bait exposure, the rats were put into clean cages, back on the maintenance diet, and observed for 5 more days.

Because no rats died in the tier 1 two-choice trial, the tier 2 trial was conducted. This trial was a no-choice trial with 5 rats assigned to each treatment as previously described. For 2 of the treatment groups, the afternoon before the start of the trial, the rats were put in clean cages with no food; hence, they were slightly food deprived when the baits were added the next morning. One group of rats received the peanut paste ESN block, but it was first dipped in corn syrup (a sweetener). A second group of rats received the grain-coated ESN and a small amount of corn syrup was mixed with it before the bowl was placed in the rat cage. Each of these rats received 22-31g of the bait. The rats were observed twice daily for the next 2 days. A third treatment group received cooked rice that had been allowed to absorb sodium nitrite. The sodium nitrite concentration in the rice was determined to be 13.3%. The rats in this third treatment group were given "placebo" cooked rice (containing no sodium nitrite) 2 days before the treated cooked rice was added so they could become familiar with the new food type. One day after the placebo cooked rice was added, the maintenance diet was removed from the cages of the third treatment rats to further encourage them to eat the placebo cooked rice. One day later, the sodium nitrite treated rice was added to each cage of the group 3 rats. Each rat received 50-51g of the treated rice. A fourth group of 5 rats served as the control group and continued to receive the maintenance diet. All rats were observed twice daily for the next 2 days after the treatment baits were added. At the end of the second day of bait exposure, the rats were put into clean cages with the maintenance diet and observed for 5 more days. Any rats that did not die during the study were euthanized with carbon dioxide and incinerated at NWRC.

Norway Rat Results

In the tier 1 trial (the two-choice trial) none of the treatment rats died (Table 3). Consequently, we did not determine the amount of food bait consumed. Because that trial was not successful, the tier 2 trial was conducted which was a no-choice trial (Table 4). None of the rats in the two 20% ESN treatment groups died even with the addition of some sweetener (corn syrup). Only one rat in the third treatment group died. That group had received the rice with sodium nitrite (13.3%) absorbed. Hence, the efficacy of all baits used in the 2 trials was very low (< 20%). The amount of food bait consumed in the tier 2 trial varied from 1.0g to 14.3g.

DISCUSSION

Overall, the results of this study with these sodium nitrite baits with wild-caught house mice were not very good. However, they were somewhat better than the results of the sodium nitrite baits with wild-caught Norway rats. Hence, while our original study (QA-1752; Witmer 2013) suggested that sodium nitrite had some potential as a new active ingredient for rodenticides, the latter two studies with mice and rats did not support that finding. We suspect that palatability may still be an issue even when encapsulated sodium nitrite (ESN) is used. Additionally, a higher concentration of ESN may be needed, but that may exacerbate the palatability issue. Additional research might be able to resolve these issues, but as it stands, it does not look promising for sodium nitrite to be a new active ingredient for rodenticides. Efforts to produce an effective toxic bait for invasive, feral swine using sodium nitrite have been more successful (e.g., Snow et al. 2016), perhaps in part because feral swine will eat more in a single feeding and, hence, are more likely to consume a lethal dose.

It appears that research to identify new, effective rodenticides will need to continue. Fortunately, researchers in several

Table 3. Results of 20% ESN baits with wild-caught Norway rats in a two-choice trial. Because no rats died, we did not determine the amount of bait consumption.

Treatment	Rat ID	Sex	Bait Weight (IN) g	Bait Weight (OUT) g	Fate (A/D)
Grain w/ Glue	PA01	M	40.02	N/A	A
	PA07	M	39.97	N/A	A
	PA21	F	40.12	N/A	A
	PA23	M	40.02	N/A	A
	PA73	F	40.03	N/A	A
Peanut Sachet	PA02	M	37.57	N/A	A
	PA10	M	37.18	N/A	A
	PA25	M	38.33	N/A	A
	PA27	F	39.16	N/A	A
	PA56	F	37.53	N/A	A
Grain w/ Oil	PA14	M	39.88	N/A	A
	PA28	F	40.18	N/A	A
	PA29	M	40.19	N/A	A
	PA34	M	40.09	N/A	A
	PA59	F	40.08	N/A	A
Peanut Block	PA04	M	37.18	N/A	A
	PA18	M	36.86	N/A	A
	PA31	M	36.66	N/A	A
	PA40	F	37.90	N/A	A
	PA61	F	37.44	N/A	A
Control	PA05	M	0	N/A	A
	PA19	M	0	N/A	A
	PA32	M	0	N/A	A
	PA41	F	0	N/A	A
	PA65	F	0	N/A	A

Table 4. Results of 20% ESN baits and a rice bait with 13.3% sodium nitrite with wild-caught Norway rats in a no-choice trial.

Treatment	Rat ID	Sex	Bait Weight (IN) g	Bait Weight (OUT) g	Amount Eaten (g)	Fate (A/D)
SN Rice (13.3%)(no-choice)	PA05	M	50.2	36.2	14.0	A
	PA41	F	50.0	52.1	-2.1	D*
	PA46	M	50.0	42.9	7.1	A
	PA55	M	50.5	36.2	14.3	A
	PA88	F	50.2	40.3	9.9	A
Sweetened 20% ESN Peanut Block (no-choice)	PA35	M	22.4	15.3	7.1	A
	PA39	M	23.5	22.5	1.0	A
	PA52	M	23.3	15.2	8.1	A
	PA91	F	23.5	17.0	6.5	A
	PA118	F	23.0	20.7	2.3	A
Sweetened 20% ESN - Coated Grain (no-choice)	PA38	M	28.7	23.9	4.8	A
	PA53	M	29.2	24.8	4.4	A
	PA68	M	31.4	24.0	7.4	A
	PA76	F	25.2	19.1	6.1	A
	PA112	F	29.3	22.7	6.6	A
Control	PA42	M	N/A	N/A	N/A	A
	PA54	M	N/A	N/A	N/A	A
	PA82	M	N/A	N/A	N/A	A
	PA86	F	N/A	N/A	N/A	A
	PA115	F	N/A	N/A	N/A	A

* placebo rice in treated rice

countries are pursuing this needed work with some promising results (e.g., Baldwin et al. 2016, Eason et al. 2010a, 2010b, Eason and Ogilvie 2009, Schmolz 2010, Witmer and Moulton 2014, Witmer et al. 2017).

ACKNOWLEDGEMENTS

This study was conducted under the NWRC IACUC-approved study protocols QA-2300 and QA-2467. Funding for this study was provided by the Invasive Animal Cooperative Research Centre (IACRC) of Australia. Baits were provided by Connovation of New Zealand and the NWRC formulation chemist Scott Stelting. We thank the landowners that allowed us to live trap mice and rats from their properties for use in this study. The mention of a commercial product or company does not represent an endorsement by the U.S. government.

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A Field Evaluation of the Efficacy of Milorganite® as a Repellent for Non-Venomous Rat Snakes (*Elaphe obsolete*)

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ABSTRACT: The objective of this study was to evaluate the efficacy of Milorganite® as a repellent for rat snakes. Milorganite® is the bio solids by-product left from the activated sludge process from the Milwaukee Metropolitan Sewer District. During 3, 7-day release periods, 5-6 mature rat snakes were placed within a 0.1ha plastic fence enclosure intended to impede escape. The enclosure contained natural and artificial hides and water. Snakes were fitted with an externally attached radio transmitter with location of each snake determined 3 times per day by radio telemetry and visual confirmation. During the first 2, 7-day period, with no Milorganite® treatment, snakes were contained within the enclosure for a similar ($p>0.05$) duration of 9.1h±1.8 and 9.4h±1.8 respectively, before escaping. Prior to release of snakes in period 3, a total of 907.2g of Milorganite® was applied by hand in a 20cm width strip along the interior perimeter of the enclosure fence. During period 3, 6 snakes were maintained within the enclosure longer ($p< 0.005$) compared to periods 1 and 2, with an average containment time of 23.5h/day±0.5. Total snake-hours that animals were maintained in the enclosure was higher ($p<0.005$) during the Milorganite® treatment (164.0h±1.4) compared to non-treated period 1 (64.0h±1.8) or period 2 (66.0h±9.0). All snakes remained within the enclosure throughout the 7-day treatment period. One snake died on day 6, post-treatment from unknown causes. Results of this study suggest Milorganite® was effective as a repellent for the rat snake under these experimental conditions.

Key Words Milorganite, radio telemetry, rat snakes, repellent, snake enclosure.

Proceedings of the 17th Wildlife Damage Management Conference. (D. J. Morin, M. J. Cherry, Eds). 2017. Pp. 64-69.

While the desire to repel snakes from an area is not a new concept, identification of compounds determined effective has been limited. Flattery (1949) tested materials ranging from DDT, rotenone, arsenic, chlordane, nicotine sulfate and various gasses. Extensive testing of home remedies including; moth balls, sulfur, cedar oil, lime, coal tar, creosote, liquid smoke, King snake musk and artificial skunk scent has been documented (San Julian and Woodward 1985). While several of these compounds were lethal, none were reported to be effective as a repellent in either of these studies. Numerous fumigants, pesticides, toxins and natural aromatic oils from woody plants have been tested on brown treesnakes (*Boiga irregularis*), with results ranging from no effect, to classification as an irritant or being lethal (Kraus et al. 2015, Clark and

Shivik 2002, Savarie and Bruggers 1999). Varying results of repellent properties have also been reported for commercial products such as, Liquid Fence and Shoo Snake (Sukumaran et al. 2012). One of the first commercially marketed repellents, Snake-A-Way (7% naphthalene and 28% sulfur) has been found to have limited effectiveness on numerous species of venomous and non-venomous snakes (Moran et al. 2008, Ferraro 1995, Marsh 1993). In a previous study, Milorganite®, the biosolids by-product left from the activated sludge process from the Milwaukee Metropolitan Sewer District, demonstrated significant potential as a repellent for non-venomous snakes (Gallagher et al. 2012).

Numerous compounds tested as deterrents were based on influencing the olfactory senses of snakes. Chemical sensitivity of the olfactory system in snakes is reported to be the most important sense in prey detection, orientation and sexual behavior (Muntean et al. 2009). The tongue itself may increase odor-sampling area and directly transfer contacted chemical to a highly developed vomeronasal system for analysis (Muntean et al. 2009, Parker et al. 2009). Based on gene analysis of olfactory receptors, it was predicted that snakes rely heavily on the olfactory receptor system as a method of odor detection (Byerly et al. 2010). Ferraro (1995) suggested examining repellents or olfactory based compounds based on confinement studies that removed the snake from the natural environment and allow only two choices, failed to give reliable accurate results. While numerous methodologies have evolved to examine repellent properties and snake behavior, most studies rely on relatively small evaluation chambers that exclude the natural environment (e.g., Kraus et al. 2015, Sukumaran et al. 2012, Gallagher et al. 2012, Clark 2007, Clark and Shivik, 2002, Renapurkar et al. 1991). Therefore, the objective of this study was to evaluate the potential of Milorganite® as a repellent for rat snakes (*Elaphe obsolete*) under simulated field conditions, in an outdoor enclosure encompassing a more natural environment.

STUDY AREA

This study was conducted on the 1,215 ha Berry College Wildlife Refuge (BCWR) within the 11,340 ha Berry College campus in northwestern Georgia, USA. The BCWR was within the Ridge and Valley physiographic province with elevations ranging from 172 m to 518 m (Hodler and Schretter 1986). The BCWR was characterized by campus-related buildings and facilities for the 2,100 student body, is interspersed with expansive lawns, hay fields, pastures, woodlots, and larger forested tracts. The site used for this study was characterized as an unimproved pasture at the Berry College Sheep Center. The area was not being used for grazing of domestic sheep during the study conducted, June 23, 2016 – July 28, 2016. The forage consisted predominantly of fescue (*Schedonorus phoenix*), orchard grass (*Dactylis glomerata*), and interspersed with Bermuda grass (*Cynodon spp.).* Forested areas within 200m include various species of pines (*Pinus* spp.), oaks (*Quercus* spp.) and hickories (*Carya* spp.).

METHODS

Construction of a snake enclosure began with a 25cm trench dug in a 30mx30m square (0.1ha) in an unimproved pasture that had timber selectively cut at least two years previously. Wood posts (8.9cm x 8.9cm x 2.0m) were secured on corners and at 15m intervals between each corner at an average height of 128.5cm±0.5 with an inward slope of 17.1^{o} ±0.5. Steel T-posts (2.0m) were erected to a similar height and angle at 4m intervals between wood posts and fitted with plastic insulated caps. Three strands of 17-

gage wire were secured to the top, middle and 10cm above the ground of each post. Plastic sheeting (3.04m x 30.4m x 4mm) was draped over the suspended wires with the bottom 25cm secured within the trench with dirt. All overlapping seams of plastic were secured with polypropylene tape. A single strand of the 17-gage electric wire was attached to the top inside edge of the plastic fence using duct tape. An additional strand of electric polyfence tape was also attached by duct tape to the top of the inside of the plastic fence, and to the plastic 20cm above the ground. A loop (4m) of electric polyfence tape was placed in each of the four corners of the enclosure and attached to both the top electric wire and polytape and the lower section of polyfence tape, energized by a solar powered charger with an output >5000v. In addition to natural hides, 16 artificial hides constructed of 2cm x 61cm x61m plywood were placed in the enclosure with 4 artificial brush hides, and 8 plastic containers to provide water.

Mature wild rat snakes (n=11; 138.1cm± 5.8) were hand captured, placed in 40L secure aquariums and provided water and food. Radio transmitters (Ag392, Biotrack LTD., Wareham, Dorset, UK) were attached externally approximately 25cm cranially to the cloaca, using cyanoacrylate glue and camouflaged duct tape. Each snake was provided a mouse as a food source prior to release and between each release period. During each of three release periods, 5-6 snakes were released into the enclosure typically within 48-hours of capture. The location of each snake was determined using the externally attached radio transmitters and tuned receiver (R-1000, Communications Specialist Inc., Orange, CA), 3x/day for each 7-day period. Snakes that escaped and recaptured were utilized in subsequent releases.

Prior to the second release of snakes, day/night infrared cameras (SN502-4CH; Defender Inc., Cheektowaga, NY) were positioned 10m from each corner of the enclosure, to provide continuous recordings on DVR's. Immediately before the release of snakes in period 3, a total of 907.2g of Milorganite® (226.8g/side) was applied by hand in a 20cm width strip along the interior perimeter of the enclosure fence. Analysis of the duration snakes were maintained within the enclosure was conducted using one-way ANOVA analysis procedures of IBM SPSS 24.0 (SPSS 24.0 2016). This experiment was conducted with the approval of the Berry College Institutional Animal Care and Use Committee and under the Georgia Department of Natural Resources Scientific Collecting Permit.

RESULTS

During the first 2, 7-day release periods, with no Milorganite® treatment, snakes were contained within the enclosure for a similar ($p>.05$) duration of 9.1h±1.8 and 9.4h±1.8 respectively, before escaping. Prior to release of snakes in period 3, a total of 907.2g of Milorganite® was applied by hand in a 20cm width strip along the interior perimeter of the enclosure fence. During period 3, all snakes remained within the enclosure throughout the 7-day treatment period. It should be noted that one snake died within the enclosure on day 6 of the 7-day period. There were no indications of a specific cause of death following a necropsy. Thus, containment was longer ($p< 0.005$) compared to periods 1 and 2, with an average time of 23.5h/day±0.5. Total snake-hours that animals were maintained in the enclosure was higher ($p<0.005$) following Milorganite® treatment (164.0h±1.4) compared to non-treated period 1 (64.0h±1.8) or period 2 (66.0h±9.0). Results of this study suggest Milorganite® continues to provide evidence as a potential repellent for snakes.

DISCUSSION

Anecdotal evidence of the effectiveness of Milorganite®, the biosolids by-product left from the activated sludge process from the Milwaukee Metropolitan Sewer District, as a repellent for numerous species is reported. It has been documented to reduce damage from white-tailed deer to ornamental plants, horticultural and food crops (Gallagher et al. 2007, Stevens et al. 2005). The compound likely elicits its effect through the olfactory system. As indicated by Clark and Shivik (2002), identification of repellents that are effective with minimal toxicological risks to humans and the environment would be ideal. Toxicology reports provided by the manufacturer suggest limited risk to humans, animals or the environment (Milorganite.com).

In a previous study, Milorganite® demonstrated significant potential as a repellent for non-venomous snakes in an indoor testing environment (Gallagher et al. 2012). However, numerous challenges occur when conducting studies that involved confinement and limited choices. Ferraro (1995) indicated that most repellent studies involved removal of snakes from their environment and placing them in an unnatural restricted containment structure. The animals are typically subjected to a treatment or control option that forces the snake to choose an action with only two options failed to give reliable or accurate results.

In the current study, it was attempted to provide a larger, more natural environment complete with natural and artificial hides and sources of water. Construction of a fence intended to contain the animals within the .1ha enclosure was deemed necessary in order to have sufficient numbers of animals to test the treatment.

Maintaining snakes within the fence constructed alone was not successful. Prior to application of Milorganite in period 3, snakes were contained within the enclosure for only 9.1h±1.8 and 9.4h±1.8 post-release, during the first two periods, respectively. While incorporating the use of electrified wire and electric polytape followed recommendations by Perry and coworkers (1998), video evidence indicated snakes used the electrified polytape in the corners to escape the enclosure. This weakness is likely due to insufficient grounding of the snake to receive a shock and not the concept of incorporating electricity as a part of an effective snake fence.

Detection of the externally mounted transmitters was typically <50m. While this range was sufficient to assist in locating snakes within the enclosure, it often was not effective when attempting to locate snakes that escaped the fenced area. During the first two releases of snakes (n=10), animals breeching the fence were frequently recovered. However, four individuals escaping the enclosure and not located using radio telemetry, ranged from 1-21d post-transmitter attachment, (12.3d± 4.7). At the end of the third period, the fence was removed allowing the five remaining snakes with transmitters attached to disperse. Despite a series of extensive search efforts, no snakes could be located or recovered within 12h of the fence removal.

While recovery of externally mounted transmitters occurs with ecdysis, snakes (n=4) shedding their skin and the transmitter prior to the end of the study was also problematic. In this study, transmitters that were recovered as a result of shedding occurred within 6-17d post-attachment (11.7d ±2.4). This effect could be avoided by keeping snakes in a captive environment until ecdysis is complete and then attaching transmitters.

It is recognized that while the enclosure fence was not successful in preventing snakes from leaving the experimental site, its presence likely influenced behavior. Regardless, the fact that

all snakes were maintained in the enclosure after treating the interior perimeter of the fence suggests Milorganite® was a significant contributing factor in eliminating escape, thus providing additional evidence as a potential repellent for the rat snake.

ACKNOWLEDGMENTS

Funding for this research project was provided by a grant from the 2016 Berry College's Laura Maddox Smith Summer Research Institute for the Environmental Sciences. Additional funding was provided by the Dana Corporation Endowed Chair at Berry College. The authors also wish to thank Mr. Anthony King for his invaluable assistance in collecting snakes and providing significant technical support.

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Management of Wintering Short-eared Owls at Airports in the Lower Great Lakes Region

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ABSTRACT: USDA Wildlife Services airport wildlife biologists have been tasked with reducing the hazards that raptors (including owls) pose to safe aircraft operations at airports and military airfields throughout the USA. A review of available wildlife strike information suggests short-eared owls (*Asio flammeus*) are frequently struck by aircraft during the winter months at numerous airports within the Lower Great Lakes Region of the United States. Further, this species is listed as 'endangered' by state fish and wildlife agencies in many states, although not at the federal level. Consequently, there is particular interest in developing non-lethal management tools for reducing the hazards posed by this species. In an effort to gain a better understanding of the efficacy of managing the hazards to aviation posed by short-eared owls, we developed methods to live-capture, mark with USGS aluminum leg bands, and translocate short-eared owls from airport environments (i.e., airfield areas) as part of the overall programs to reduce wildlife hazards to safe aircraft operations at airports. During 2012−2015, a total of 32 short-eared owls was live-captured, banded, and translocated to release sites approximately 64 to 80 km (40 to 50 miles) away from the airports. Only 1 short-eared owl (3%) was resighted and this bird was found on a different airport from where it had been translocated from. Future research in needed to evaluate the efficacy of translocating wintering short-eared owls from airport environments.

Key Words *Asio flammeus*, airport risk, bird strikes, raptors, short-eared owls, translocation.

Proceedings of the 17th Wildlife Damage Management Conference. (D. J. Morin, M. J. Cherry, Eds). 2017. Pp. 70-76.

Wildlife-aircraft collisions (wildlife strikes) pose a serious safety risk to aircraft. Wildlife strikes cost civil aviation at least $957 million annually in the United States (Dolbeer et al. 2016). Aircraft collisions with birds accounted for 97% of the reported strikes, whereas strikes with mammals and reptiles were 3% and <1%, respectively (Dolbeer et al. 2016). Sound management techniques that reduce the presence and abundance of wildlife hazardous to aviation in and around

airports are therefore critical for safe airport operations (DeVault et al. 2013).

Raptors (i.e., hawks and owls) are one of the most frequently struck bird guilds within North America. Integrated wildlife damage management programs combine a variety of non-lethal and lethal management tools to reduce the presence of raptors on airports. Given high public interest, logistical and financial constraints, and other factors, managing raptors at airports presents unique challenges. Non-lethal tools are favored by the public, so airports with a raptor translocation program often receive strong public support.

Short-eared owls have one of the larges geographic ranges of owls in the world (Wiggins et al. 2006). This species favors grassland habitats for nesting, roosting, and foraging (Clark 1975); thus, the large expanses of such habitats at an airport can be attractive to these birds. Short-eared owls are long-distance migrants (they breed in Arctic areas and typically move south during winter months) in North America and use airports in temperate climates only during their wintering period.

Effective, publicly accepted methods to reduce the hazards posed by short-eared owls to aviation safety are needed. Here, we examine historical and current patterns of short-eared owl strikes at airports within the Lower Great Lakes Region and discuss a non-lethal management program to reduce the airfield presence of wintering short-eared owls and the frequency of owl-aircraft collisions at these airports.

SHORT-EARED OWL–AIRCRAFT STRIKES

Methods

We used data from the FAA National Wildlife Strike Database for a 27.5-year period (1990 − April 2016) for civilian and joint-use airports. We queried this database and selected only those strike records that were reported to have occurred within 7 states (i.e., Illinois, Indiana, Kentucky, Michigan, Ohio, Pennsylvania, and Wisconsin) and the species struck was identified as a short-eared owl. Many owl strike reports were incomplete. Either specific fields of information were missing, unknown, or we were unable to effectively obtain the information from report narratives. Thus, sample sizes varied for individual variables and among specific analyses.

We determined the month and time of day each short-eared owl strike event occurred based on the reported local time of the event. We examined each strike event and categorized the time of day as 'dawn', 'day', 'dusk', or 'night'. We used *G*-test for goodness-of-fit analyses (Zar 1996) to determine if the frequency of short-eared owl strikes varied by month or time of day.

Phase of flight was defined as the phase of flight the aircraft was in at the time the owl strike occurred (FAA 2004). Aircraft on 'final approach' were in early stages of the landing process (≤ 30.5 m [100 feet] AGL, typically on or over an airfield. 'Landing' aircraft were in the final stages of landing and had one of more wheels on the ground. Aircraft in the 'take-off' phase were rolling along the runway (with one or more wheels in contact with it) or were in the process of ascending upward (≤30.5 m AGL). Aircraft in the 'climbout' phase were in the latter stages of taking off (>30.5 m AGL), typically on or over the airfield. We used *G*-test for goodness-of-fit analyses (Zar 1996) to determine if the frequency of short-eared owl strikes varied among aircraft phases of flight.

Results

During 1990 – April 2016, we found a total of 182 short-eared owl strikes that were reported to have occurred in 7 states within the Lower Great Lakes Region (Table 1). Short-eared owl-aircraft collisions had a damaging strike rate of 12.5%. Reported

damage costs ranged from $45 to $100,000 per strike.

Table 1. Conservation status of short-eared owls in states within the Lower Great Lakes Region of the United States. This information was obtained from the websites for each of the appropriate state wildlife agencies.

State	Conservation Status
Illinois	Endangered
Indiana	Endangered
Kentucky	Endangered
Michigan	Endangered
Ohio	Species of Concern
Pennsylvania	Endangered
Wisconsin	Species of Concern

Short-eared owls strikes varied (G = 201.4, df = 11, p < 0.0001) among the months of the year. A clear seasonal pattern was present in short-eared owl-aircraft collisions, with 82% of these incidents occuring during months of November through March (Figure 1). This finding is not unexpected, as we believe that short-eared owl use of these airports occurs primarily during the owls' wintering periods. Short-eared owls strikes were not (G = 53.6, df = 3, p < 0.0001) equally distributed among times of the day; three-quarters of the short-eared owl-aircraft collisions occurred during night-time hours (Figure 2). Likely, short-eared owls are active hunting during night-time hours (Wiggins et al. 2006) and thus the risk of owl-aircraft collisions is highest during the night.

Short-eared owl strike reports that included aircraft phase of flight information (n = 49) showed that owl strikes occurred during the final approach (22.4%), landing roll (36.7%), take-off run (28.6%), and climbout (12.3%) phases of flight. The frequency of owl strikes was similar (G = 6.7, df = 3, p = 0.08) among aircraft phases of flight. Considering the location of the aircraft during these phases of flight relative to the airfield itself, almost all short-eared owl strikes likely occurred within the airport environment itself. Consequently, management actions to reduce the presence / airfield use of short-eared owls should be focused on the airfield.

Discussion

This information is critical for understanding the current situation at an airport and essential for the development of effective and species-specific management plans (Cleary and Dolbeer 2005). Evaluations of the historical and current strike rates of short-eared owls, in addition to recommendations provided during Wildlife Hazard Assessements at these airports, demonstrate that this species presents a risk to safe aircraft operations and consequently management actions are needed to reduce this risk.

Habitat selection and use by short-eared owls is directly related to prey populations (Clark 1975, Wiggins et al. 2006) and therefore management actions to reduce the abundance of small mammals and other prey resources might be effective in reducing the presence of short-eared owls on airports and consequently reduce the risk of owl-aircraft strikes.

NON-LETHAL HAZING OF SHORT-EARED OWLS

We queried Wildlife Services' Management Information System database for management events associated with the non-lethal hazing of short-eared owls that occurred during a 13-year period (i.e., 2004−2016) at airports in 7 states within the Lower Great Lakes Region. Non-lethal hazing was conducted using pyrotechnics and/or motor vehicles. On average, 59 hazing activities associated with short-eared owls were conducted at these airports each year (range 0 to 478). During 2013, 449 of the 478 (94%) hazing events occurred in

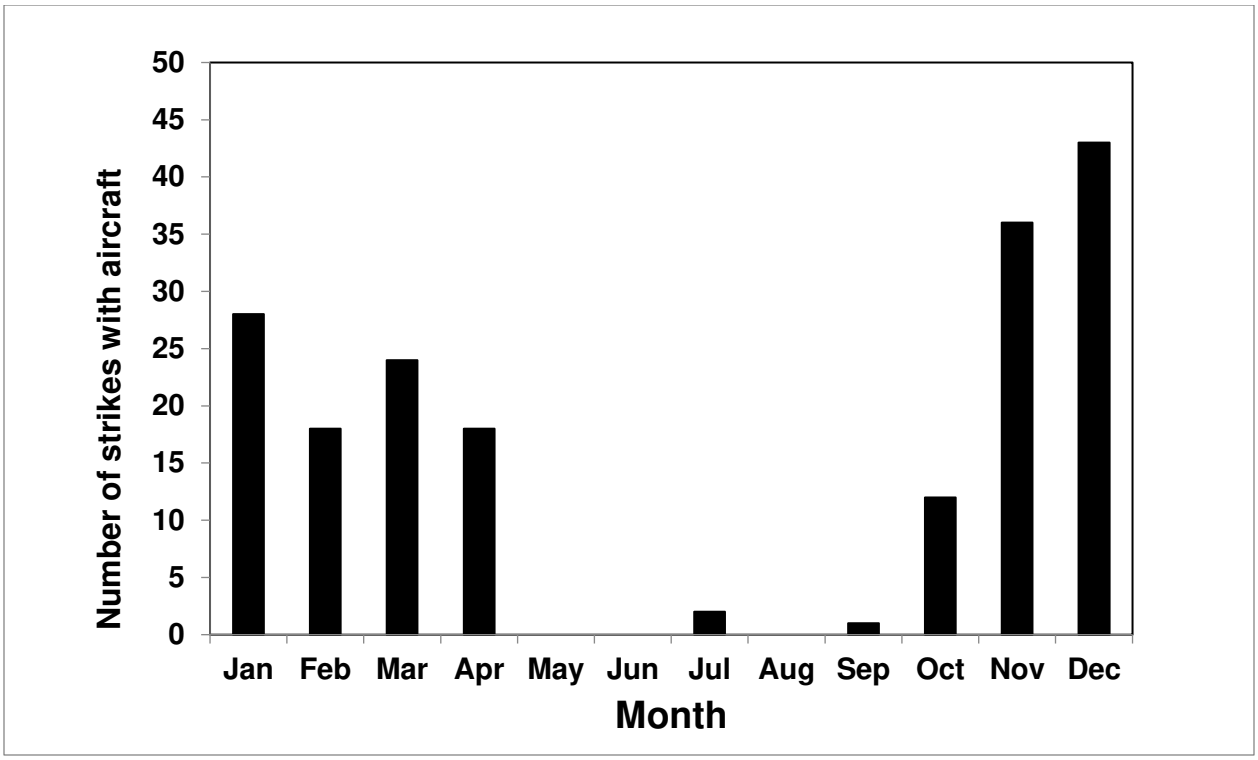

Figure 1. Monthly total number of short-eared owl-aircraft collisions (n = 182) with U.S. civil aircraft during 1990 – April 2016 in 7 states in the Lower Great Lakes Region.

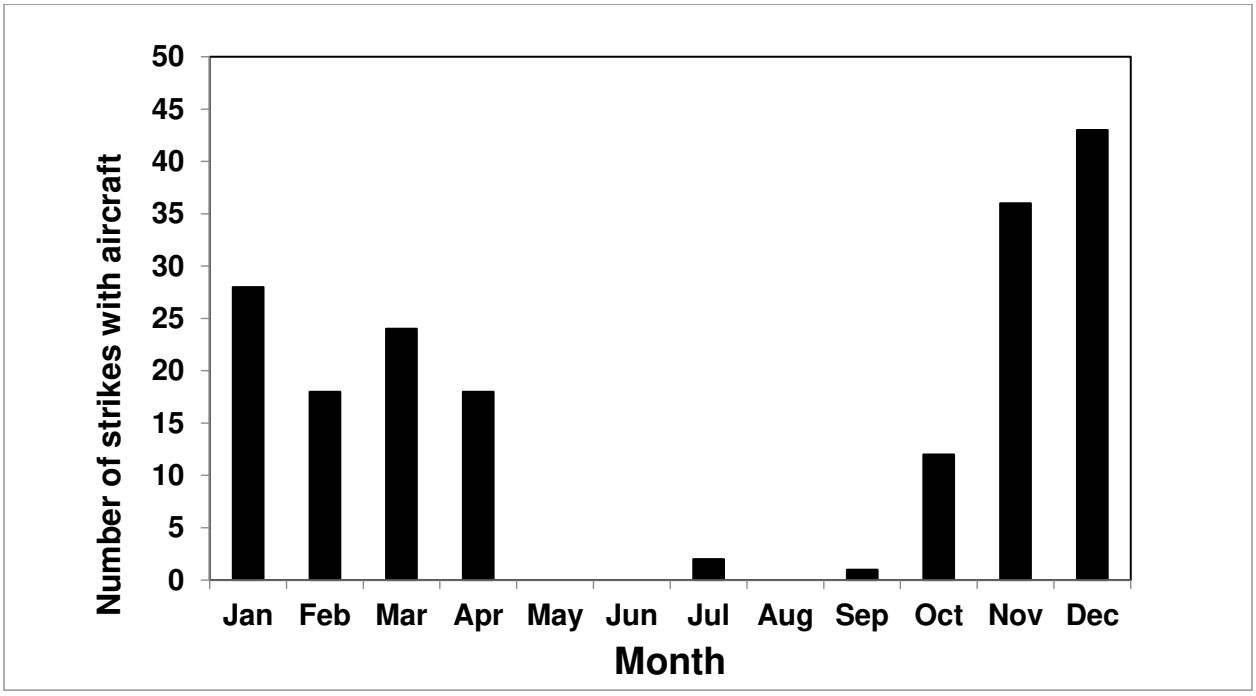

Figure 2. Distribution of the time of day for short-eared owl-aircraft collisions (n = 44) with U.S. civil aircraft during 1990 – April 2016 in 7 states in the Lower Great Lakes Region.

Indiana. This heightened level of non-lethal management coincided with a time period when more than 30 short-eared owls spent several months at one particular airport. Although non-lethal hazing is not very effective at deterring wildlife use of an airfield in the long-term, it represents an important component of an integrated wildlife damage management program, especially when state-listed threatened and endangered species are involved.

SHORT-EARED OWL TRANSLOCATION

Live-capture and translocation of problematic individuals is a common practice used in the management of human-wildlife conflict situations (Fisher and Lindenmayer 2000, Sullivan et al. 2015). Translocation of raptors from airport environments is a non-lethal method with the goal of reducing raptor abundance within airport environments (Guerrant et al. 2013, Schafer and Washburn 2016). At 5 airports in the Lower Great Lakes Region, we conducted live-capture (Bub 1991, Bloom et al. 2007) and translocation activities involving short-eared owls (to reduce the airfield presence and frequency of bird strikes involving this species) as part of the integrated wildlife damage management programs at these airports. Owl translocations were conducted under the authority of all necessary permits and National Environmental Policy Act considerations. To better understand whether or not translocated short-eared owls return to airport environments, birds that were translocated were marked with a USGS federal bird band. During 2012−2015, 32 short-eared owls were live-captured, banded, and translocated to release sites approximately 64 to 80 km (40 to 50 miles) away from the airports. Several live-capture methods were used to catch these owls; however, pole traps with padded foot-hold traps was the most effective (Table 2). All of these translocation events occurred from November to March. During 2013–2016, only 1 short-eared owl (3%) was resighted and this bird was found on a different airport from where it had been translocated from. These findings suggest that live-capture and translocation of wintering short-eared owls from airports may be an important non-lethal component of an integrated wildlife damage mitigation program, but further research is necessary to determine the fate of translocated individuals.

Table 2. Methods used to live-capture 32 short-eared owls from 5 airports within the Lower Great Lakes Region of the United States during 2012−2015.

Live-Capture Method	Number of Owls Captured
Pole Trap with padded foot-hold	25
Net gun or air cannon	3
Carpet noose (in roosting location)	3
Swedish goshawk trap	1

SUMMARY

Wintering short-eared owls pose a long-term risk to aviation safety at airports within the Lower Great Lakes Region of the United States. Consistent reporting of short-eared owl strikes, monitoring of the airfield for the presence/abundance of short-eared owls and other hazardous wildlife, and the use of primarily non-lethal methods are essential components of an integrated wildlife mitigation program conducted by airport biologists. Live-capture, banding, and translocation of short-eared owls (and other raptors) should be continued into the future to allow for the evaluation of this non-lethal program and to help increase our understanding of this method to reduce the presence of wintering short-eared owls within airport environments. Additional management actions to reduce the

availability of roosting habitat and food resources (e.g., small mammals) for wintering short-eared owls within airport environments should be investigated and evaluated.

ACKNOWLEDGMENTS

We thank the U.S. Department of Agriculture and 5 civil airports in the Lower Great Lakes Region for providing valuable logistical support, advice, and funding. T. DeVault provided excellent comments regarding the manuscript. Any use of trade, product, or firm names is for descriptive purposes only and does not imply endorsement by the U.S. government.

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Evaluating Blackbird Behavioral Response Toward Unmanned Aircraft Systems (UASs): Exploiting Antipredator Behavior to Enhance Avoidance

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ABSTRACT: Animals respond to nonlethal forms of human disturbance using behavior strategies adapted to detect, avoid, and evade natural predators. This phenomenon suggests antipredator behavior can be exploited to optimize efficacy of wildlife management tools such as visual deterrents. According to models of antipredator theory, wildlife managers could encourage animals to abandon a resource patch in zones of human-wildlife conflict by enhancing perceived predation risk associated with disturbance stimuli. One human-wildlife conflict of interest is the economic loss and human safety hazards caused by birds. For example, blackbirds (*Icteridae)* pose a significant risk to the commercial aviation industry through bird strikes and to agriculture through crop predation. Several nonlethal frightening devices have been used in an attempt to reduce negative impacts of large blackbird flocks with varying effectiveness, thus the need for new or optimized tools remains. A promising tool in the field of wildlife damage management is the unmanned aircraft system (UAS), which provides a dynamic object able to overcome mobility limitations faced by other nonlethal deterrents. We intend to evaluate antipredator response of blackbirds toward two UAS platforms. We will compare a multirotor quadcopter UAS with a radio-controlled (RC) predator model. Current UASs show promise as precision agriculture tools and are easier to fly, but may not elicit an antipredator response due to lack of similarity with natural predators. We hypothesize that blackbirds will assess platforms with different intensities of perceived predation risk, and as a result, initiate flight at farther distances from the platform perceived as more threatening. Our objectives are to 1) compare the response of captive red-winged blackbirds (*Agelaius phoeniceus)* to a multirotor quadcopter UAS and a RC predator model approaching at direct and overhead trajectories; and 2) approach wild flocks of red-winged blackbirds to gauge response of free-ranging birds toward both UAS platforms. The results of this study will help develop UASs as potential hazing tools to disperse and deter birds from areas of human-wildlife conflict (i.e., airports, agricultural areas, and municipalities).

Key Words unmanned aircraft system (UAS), antipredator behavior, alert distance, flight-initiation distance.

Proceedings of the 17th Wildlife Damage Management Conference. (D. J. Morin, M. J. Cherry, Eds). 2017. Pp. 77-79.

Animals respond to human disturbance using behavior strategies adapted to detect, avoid, and evade natural predators (Frid and Dill 2002; Lima et al. 2015). Recently, unmanned aircraft systems (UAS) have been suggested as a nonlethal method to deter birds from areas of human-wildlife conflict (Ampatzidis 2015). Several studies have evaluated the response of wildlife toward UAS, but few have operated UAS in a manner to intentionally provoke an escape response (Vas et al. 2015; McEvoy et al. 2016). UAS can elicit antipredator behavior in birds, suggesting potential utility as a nonlethal hazing tool (Blackwell et al. 2012; Doppler et al. 2015). The antipredator behavior of animals may be exploited to optimize the efficacy of physical frightening devices such as UAS (Blumstein and Fernández-Juricic 2010). If effective, UAS could potentially be incorporated into an integrated pest management plan to reduce economic loss and safety hazards caused by birds. This study aims to evaluate blackbird antipredator response toward UAS. We will compare the response of captive red-winged blackbirds (*Agelaius phoeniceus)* to a multirotor quadcopter UAS and a radio controlled (RC) fixed-wing predator model approaching at direct and overhead trajectories. We will also evaluate the response of free-ranging blackbirds toward both UAS platforms. Our specific objectives are to identify features and flight dynamics that enhance UASs as hazing tools to disperse and deter flocks of birds from areas of concern (e.g., airport environments and commercial crop fields).

PROPOSED METHODS

Semi-natural Experiment

During trials, captive blackbirds will be temporarily placed in an enclosure (3.7 x 4.0 x 3.1 m). A single blackbird will be randomly selected to be the target individual and placed on the side of the enclosure exposed to UAS flights. Two additional birds will be placed in the opposite side of the enclosure to facilitate flock behavior, but be visually obstructed from UAS approach. To simulate foraging conditions in agricultural fields (e.g. commercial sunflower), blackbirds will be provided food in a feeding tray at 2 m height. The birds will then be approached by either the RC predator model or quadcopter style UAS at a starting distance of 300 m. We will record avian alert distance and flight initiation distance during each trial using four cameras facing the birds. Alert response will be defined as a transition from relaxed foraging behavior (e.g. pecking, preening, loafing, eating, or general scanning) to a vigilant behavior directed toward the approaching aircraft (e.g. head up and neck extended, increased scanning, or crouching; Fernández-Juricic et al. 2001; Blackwell et al. 2009; Blackwell et al. 2012). Flight initiation distance will be defined as the distance from UAS approach that a bird departs from the feeding perch.

Field Experiment

We will conduct the field study in the Prairie-Pothole Region of North Dakota, an area with a historically large red-winged blackbird population (Peer et al. 2003). Thirty commercial sunflower fields (40-160 ha) across North Dakota will be targeted for UAS flights. Upon locating a sunflower field containing a foraging flock, we will record approximate flock size and distance between wetland edge and flock edge. We will approach the blackbird flock directly at a controlled flight speed and altitude using one of the UAS platforms. An approximated flight-initiation distance from approaching UAS platforms and total flight time of the blackbird flock will be recorded.

SUMMARY

By measuring behavioral response of red-winged blackbirds, this study will evaluate the efficacy of both a quadcopter style UAS and RC predator model as potential hazing tools. If the quadcopter provokes a delayed escape response in blackbirds when compared to a simulated raptor, modifications to enhance antipredator behavior toward this UAS platform may be necessary for an effective hazing campaign. Future directions may involve evaluating the effects of speed, size, flight dynamics, and color of UAS on avian escape response (Vas et al. 2015).

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Anatomy of a Snake Fence Intended to Prevent Escape of Non-Venomous Rat Snakes (*Elaphe obsolete*) From an Enclosure

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ABSTRACT: We constructed a fence enclosure with the objective of preventing escape of rat snakes (*Elaphe obsolete*) as part of a repellent study. A 25cm trench was dug in a 30m × 30m square (0.1ha) in an unimproved pasture. Wood posts (8.9cm × 8.9cm × 2.0m) were secured on corners and at 15m intervals between each corner at an average height of 128.5cm ± 0.5 height with an inward slope of 17.1° ± 0.5. Steel T-posts (2.0m) were erected to a similar height and angle at 4m intervals between wood posts and fitted with plastic insulated caps. Three strands of 17-gauge wire were secured to the top, middle and 10cm above the ground of each post. Plastic sheeting (3.04m × 30.4m × 4mm) was draped over the suspended wires with the bottom 25cm secured within the trench with dirt. All overlapping seams of plastic were secured with polypropylene tape. A single strand of 17-gauge electric fence wire and a strand of electric polyfence tape were attached by duct tape to the top of the inside of the plastic fence. An additional strand of electric polyfence was attached by duct tape to the plastic 20cm above the ground. A loop of the electric polytape was also attached in each corner and connected to the wire and polytape on the top and lower strand of polytape. The electric fence strand and all polytape was energized by a solar powered charger with an output > 5000v. During two releases of 5 mature rat snakes (n = 10; 136.7cm ± 6.4), containment within the enclosure was similar ($p > 0.05$), and limited to 9.1h ± 1.8 and 9.4h ± 1.8 respectively. Video analysis indicated snakes were climbing the electric charged polyfence tape and escaping over the fence without evidence of receiving an electric shock. This fence design was not sufficient to maintain mature rat snakes.

Key Words snake enclosure, rat snake

Proceedings of the 17th Wildlife Damage Management Conference. (D. J. Morin, M. J. Cherry, Eds). 2017. Pp. 80-84.

The effects of fencing for snakes has been evaluated for decades. In some cases, concern of mortality of snakes as a result of entanglement in fencing, predominantly intended for erosion control, has been reported (Kapfer and Paleski 2011, Walley et al. 2005). However, most efforts related to fencing have been for exclusion purposes.

The development of fencing designs and materials tested are numerous. Materials suggested for fencing purposes have included: textured cloth/erosion fencing

(Baxter-Gilbert et al. 2015, OMNR 2013, Walley et al. 2005), weather shade (Perry et al. 1998), wire mesh (Anderson et al. 1998), netting (Perry et al. 1998), vinyl (Vice and Pitzler 2000, Perry et al. 1998), masonry (Perry et al. 1998), concrete (Perry et al. 2001, Vice and Pitzler 2000), flyash applied to a foundation wall (Rodda et al. 2007), and various combinations of electrified fencing often in association with materials previously presented (Campbell 1999, Perry et al. 1998, Hayashi et al. 1983).

Several designs of snake exclusion fences include details of construction but little evidence of effectiveness (OMNR 2014, Byford 1994, Brock and Howard 1962). Perry and coworkers (1998) reported that success in development of an exclusion fence requires consideration of fence height, an overhang or lip at the top of the fence, as well as a smooth surface. The addition of electrified wire or poly tape has also been found to be a useful component of an effective fence, particularly if mortality of the animals is not a concern (Campbell 1999, Perry et al. 1998, Hayashi et al. 1983). It has also been suggested that burying the fence below ground level is important to prevent snakes from escaping at or below ground level (Baxter-Gilbert et al. 2015, OMNR 2013, Byford 1994, Brock and Howard 1962).

The recommended height of snake exclusion fences ranged from <1m (Baxter-Gilbert et al. 2015) to 2m (OMNR 2013). However, effectiveness of some of these fence heights is not reported (OMNR 2013, Byford 1994, Brock and Howard 1962) or found to be ineffective (Baxter-Gilbert et al. 2015). For the Brown tree snake (*Boiga irregularis*), an arboreal species, fences ranging from 1.1m to 1.4m in height, with an overhang of .2m has been reported to be effective using various fence materials (Rodda et al. 2007, Perry et al. 2001, Campbell 1999).

Cost of implementation of the fence as well as longevity and maintenance are important considerations. While concrete or masonry structures are reported to be effective, they would likely be cost prohibitive under a number of scenarios. Therefore, the objective of this study was to construct an inexpensive, short-term fence designed to keep snakes within an enclosure as a component of a repellent study

STUDY AREA

This study was conducted on the 1,215 ha Berry College Wildlife Refuge (BCWR) within the 11,340 ha Berry College campus in northwestern Georgia, with the approval of the Berry College Institutional Animal Care and Use Committee and under the Georgia Department of Natural Resources Scientific Collecting Permit. The site used for this study was characterized as an unimproved pasture at the Berry College Sheep Center. The forage consisted predominantly of fescue (*Schedonorus phoenix*), orchard grass (*Dactylis glomerata*), and interspersed with Bermuda grass (*Cynodon spp.).* Forested areas within 200m include various species of pines (*Pinus* spp.), oaks (*Quercus* spp.) and hickories (*Carya* spp.).

METHODS

A 25cm trench was dug using a commercial trenching machine, in a 30m × 30m square (.1ha) of the unimproved pasture. Round wood posts (8.9cm × 8.9cm × 2.0m) were secured on corners and at 15m intervals between each corner resulting in a vertical height of 128.5cm ± 0.5 and an inward slope averaging 17.1^{o} ± 0.5. Steel T-posts (HDX, Model# 901176HD, Home Depot, Atlanta, GA), 2.0m in height, were erected to a similar height and angle at 4m intervals between wood posts and fitted with plastic insulated caps (Model #: ITCPB-ZC, ZarebaSystems, Lititz, PA). Three strands of 17-gauge wire (Model# 317752A, FarmGard, Glencoe,

MN) were secured to the top, middle and 10cm above the ground of each post to provide a support lattice for the plastic sheeting. Plastic sheeting (Model # CFHD0410C, HDX, Home Depot, Atlanta, GA) with dimensions of 3.04m x 30.4m x 4mm, was draped over the suspended wires with the bottom 25cm buried within the trench with dirt. All overlapping seams of plastic were secured with polypropylene tape. A single strand of the 17-gauge electric wire (Model# 317752A, FarmGard, Glencoe, MN) was also attached to the top inside edge of the plastic fence using duct tape. An additional strand of electric polyfence tape (Model # 631666, Farm Supply, Barnesville, GA) was also attached by duct tape to the top of the inside of the plastic fence, and to the plastic 20cm above the ground. A loop (3m) of electric polyfence tape was placed in each of the four corners of the enclosure and attached to both the top electric wire and polytape and the lower section of polyfence tape. This configuration was done to energize the electric polyfence tape located near the ground and to reduce the chance of corners of the enclosure from being used to facilitate escape by the snakes. The electric wire and electric polytape was energized by a solar powered charger with an output >5000v and .07J (ZarebaSystems, Lititz, PA). Artificial and natural brush hides, as well as numerous containers with water were provided. Two white oaks (*Quercus alba*) and Loblolly pine *(Pinus taeda*) were also located within the experimental site.

Mature wild rat snakes (n=10; 136.7cm± 6.4) were hand captured for each of two release periods, and placed in 40L aquariums and provided water and food. Radio transmitters (Ag392, Biotrack LTD., Wareham,Dorset, UK) were attached externally approximately 25cm cranially to the cloaca, using cyanoacrylate glue and camouflaged duct tape. During each of the two release periods, snakes (n=5) were released into the enclosure with the location of each animal determined by using a radio receiver (R-1000, Communications Specialist Inc., Orange, CA), tuned to the attached radio transmitters, 3 times per day for each 7-day period. Digital day/night infrared cameras (SN502-4CH; Defender Inc., Cheektowaga, NY) were positioned 10m from each corner of the enclosure, and recorded on DVR's prior to the second release of snakes.

Evaluation of the duration snakes were maintained within the enclosure was conducted using one-way ANOVA analysis procedures of IBM SPSS 24.0 (SPSS 24.0 2016).

RESULTS AND DISCUSSION

Significant effort in snake fencing has been related to the Brown tree snake as an invasive species with tremendous impact on fauna where introduced. It is typically less than 3m length, and tends to be thinner, nocturnal, and more arboreal than many snakes (Rodda and Savidge 2007). Perry and coworkers (1998) outlined primary considerations in constructing a snake fence including: height, a smooth surface, an overhang to decrease the ability to climb vertically and the addition of electrified wire. It was also suggested that interior corners of a fence should be greater than 90° to prevent use of these edges to breach the fence. The height of fences reported effective for the Brown tree snake ranged from 1.1m – 1.4m (Rodda et al. 2007, Campbell 1999), with a .2m overhang, composed typically of solid smooth materials with various configurations of including electrified fencing (Rodda et al. 2007, Perry et al. 2001, Campbell 1999).

In the current study, the objective was to construct a temporary fence to create an enclosure as part of a repellent study. Concepts presented by Perry and coworkers (1998) were incorporated in the fence design. The average fence height was 128.5cm ± 0.5,

with an inward slope of 17.1° ± 0.5 to serve as an overhang. Plastic sheeting was used as a smooth surface and was also buried in the ground at least 25cm. Electrified wire, and electrified polytape was utilized on the inside top of the fence, 20cm from the bottom of the fence and within the corners to discourage escape.

During the first of two releases of mature rat snakes, (n = 10; 136.7cm ± 6.4), containment within the enclosure was limited to 9.1h ± 1.8. With no visible evidence of how snakes escaped, digital recordings were obtained from cameras with day/night capabilities placed within the enclosure. Following the second release of snakes (n = 5), the duration (9.4h ± 1.8) of containment within the enclosure was similar ($p > 0.05$) to the first release. Analysis of the digital recordings provided clear evidence that snakes were utilizing the loops of electric polytape in the corners to escape. While it was verified daily that all polytape, the electric wire on top of the fence and the loops of polytape in the corner were electrified, the video recordings provided no visible evidence of a snake receiving a shock. It is likely that snakes were not being sufficiently grounded to receive an electrical shock intended to discourage climbing due to the exceptional drought conditions occurring during the experiment. Based on these results, this fence design was not sufficient to maintain mature rat snakes.

It should be noted that when a repellent being tested for this study was applied in a 20 cm strip along the interior of the plastic fence, a third release of snakes (n = 6) were maintained within the enclosure for the entire 7-day experimental period. Regardless, the pairing of a ground wire in close proximity to energized wires would likely increase the chance of a snake receiving an intended shock when using electric fence materials including potentially the corners.

ACKNOWLEDGMENTS

Funding for this research project was provided by a grant from the 2016 Berry College's Laura Maddox Smith Summer Research Institute for the Environmental Sciences. Additional funding was provided by the Dana Corporation Endowed Chair at Berry College. The authors also wish to thank Mr. Anthony King for his invaluable assistance in collecting snakes and providing significant technical support.

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A Field Evaluation of Two External Attachment Locations of Radio Transmitters on Non-Venomous Rat Snakes (*Elaphe obsolete*)

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ABSTRACT: The objective of this study was to determine the effectiveness of external attachment of radio transmitters at one of two locations on mature rat snakes (*Elaphe obsolete*). Transmitters were attached to mature snakes (n = 10; 136.7cm ± 6.4) on either the ventral surface (n = 5) or dorsal-lateral surface of the rib cage (n = 5), approximately 25cm cranially to the cloaca. Transmitters (18mm × 8mm × 2mm) were attached by one drop of acrylamide gel glue to the adhering side of camouflage duct tape (20cm × 30mm), a single drop of glue on the exposed side of the transmitter, and secured by wrapping the tape to the snake's body with the transmitter in the appropriate location. A second piece of duct tape (20cm × 40mm) overlapped and secured the first piece of tape with the transmitter. Snakes were placed in a 0.1ha plastic fence enclosure, (128.5cm ± 0.5 height, and 17.1° ± 0.5 inward slope) in an unimproved pasture with numerous hides, water and food. Snakes (n = 4) shed their skin and the transmitter, within 6-17d post-attachment (11.7d ± 2.4). Snakes (n = 4) escaping the enclosure and not located, ranged from 1-21d post-attachment, (12.3d ± 4.7). There was no difference ($p > 0.05$) in functional days snakes were located by radio telemetry due to attachment site or sex. Transmitter reception distance was typically < 50m and often problematic. Results of this study suggest that the location of external attachment of transmitters had no influence on duration of effectiveness. However, shedding and limited telemetry range under these conditions should be considered to determine if the methodology is appropriate for the desired objectives.

Key Words attachment site, external transmitter, rat snakes

Proceedings of the 17th Wildlife Damage Management Conference. (D. J. Morin, M. J. Cherry, Eds). 2017. Pp. 85-89.

The utility of radio telemetry techniques for the study of reptiles is well documented (Kingsbury and Robinson 2016). In addition to traditional uses for habitat determination, home range analysis, and foraging strategies, radio transmitter technology has been shown to be successful in the "Judas" technique to aid in the removal of Burmese pythons in the Everglades National Park (Smith et al. 2016).

Despite improvement in surgical implantation of transmitters (Anderson and Talcott 2006, Weatherhead and Anderka 1984, Reinert and Cundall 1982), problems such as post-surgical infection and inflammation (Lentini et al. 2011, Weatherhead and Blouin-Demers 2004), changes in movement (Breininger et al. 2012, Lentini et al. 2011, Weatherhead and Blouin-Demers 2004) and occasional high mortality rates (Do et al. 2014) have been reported.

External attachment of transmitters using various types of tape to the end of the tail of numerous species tended to impede movement and often resulted in snagging and/or removal of the instrument (Wylie et al. 2011, Gent and Spellerberg 1993, Rathbun et al. 1993). In more recent studies transmitters were attached approximately 70% of the body length from the head, in a dorsal-lateral location, using various types of tape (Sacerdote-Velat et al. 2014, Wylie et al. 2011, Tozetti and Martins 2007), cyanoacelyate glue (Jellen and Kowalski 2007, Cobb et al. 2005) or a combination of tape and glue (Madrid-Sotelo and Garcia-Aguayo 2008). Wylie and coworkers (2011) also examined attachment of transmitters to the ventral surface of snakes suggesting that the transmitter would not interfere with the cross section of the snake due to the location of ribs, thus minimizing interference movement in the environment.

The objective of the study was to examine the effect of dorsal-lateral and ventral radio transmitter attachment locations on rat snakes (*Elaphe obsolete*) utilized in a field based repellent study.

STUDY SITE

This study was conducted on the 1,215 ha Berry College Wildlife Refuge (BCWR) within the 11,340 ha Berry College campus in northwestern Georgia, with approval of the Berry College Institutional Animal Care and Use Committee and under the Georgia Department of Natural Resources Scientific Collecting Permit.

The BCWR was characterized by campus-related buildings and facilities for the 2,100 student body, is interspersed with expansive lawns, hay fields, pastures, woodlots, and larger forested tracts. The site used for this study was characterized as an unimproved pasture at the Berry College Sheep Center. The forage consisted predominantly of fescue (*Schedonorus phoenix*), orchard grass (*Dactylis glomerata*), and interspersed with Bermuda grass (*Cynodon spp.).* Forested areas within 200m include various species of pines (*Pinus* spp.), oaks (*Quercus* spp.) and hickories (*Carya* spp.).

METHODS

Mature wild rat snakes were captured and placed in 40L secure aquariums and provided with bedding, cover, water and food within a climate controlled laboratory. Radio transmitters (Ag392, Biotrack LTD., Dorset, UK) were attached externally using a modification of the procedure by Wylie and coworkers (2011). In addition to total length, the distance from the cloaca to the tip of the tail was obtained and an ink mark was applied that distance cranial to the cloaca to identify the site of transmitter attachment. A single drop of cyanoacrylate glue (234790, Loctite., Westlake, OH) was placed 5cm from the end of a 20mm × 20cm piece of camouflage duct tape (1409574, ShurTech Brands, Avon, OH) on the adhering side. The body of the transmitter was secured to the drop of glue, perpendicular to the tape. A drop of cyanoacrylate glue was then applied directly to the transmitter. The tape and transmitter were secured to the snake by wrapping at the marked location, with the transmitter either in the ventral or dorsal-lateral location and antenna directed toward the tail. A second piece of camouflage duct tape (40mmx20cm)

was applied over the first piece of tape with the transmitter.

Snakes were released in two groups (n = 5) into a 0.1ha, plastic fence enclosure, 128.5cm ± 0.5 height, and 17.1° ± 0.5 inward slope, in a field with natural and artificial hides, water and food. The location of each snake with a transmitter attached was determined using a radio receiver (R-1000, Communications Specialist Inc., Orange, CA), 3 times per day until the transmitter was either dislodged by shedding or no radio signal could be located. To examine activity at the fence, day/night infrared cameras (SN502-4CH; Defender Inc., Cheektowaga, NY) were positioned 10m from each corner of the enclosure, and recorded on DVR's.

Evaluation of the duration snakes were maintained within the enclosure was conducted using one-way ANOVA analysis procedures of IBM SPSS 24.0 (SPSS 24.0 2016).

RESULTS AND DISCUSSION

Results of this study suggests that external attachment of radio transmitters in the ventral or dorsal-lateral location was successful in the rat snake, a semi-arboreal, predominantly terrestrial species. There were no differences ($p > 0.05$) in functional days snakes were located by radio telemetry due to transmitter attachment site, or sex. No observable differences in behavior or movement, including ability to climb, were noted as a result of radio attachment.

Among the snakes released (n = 10), four individuals shed their skin and the transmitter 6-17d post-attachment (11.7d ±2.4) in this study. If possible, maintaining animals until ecdysis is complete before attaching transmitters can significantly increase the duration of attachment as demonstrated by Cobb and coworkers (2005).

Transmitter reception distance was typically < 50m and problematic. During the two releases of snakes (n = 10) into the 0.1ha enclosure, snakes breaching the fence were frequently recovered. However, among those released during the first two periods, some individuals (n = 4) escaped the enclosure from 1-21d post-attachment (12.3d ± 4.7). Jellen and Kowalski (2007) indicted vegetation entanglements of snakes due to antenna length was problematic. The authors further present the challenge facing investigators that while increasing the length of transmitter antenna increases reception distance, the longer antenna increases the chance of entanglement and snagging. In the current study, using transmitters with a relatively short 22cm antenna, likely influenced the distance of reception but there was no evidence of entanglement or snagging on vegetation.

As a part of a repellent study, a third group of snakes (n = 6) were released and remained in the enclosure for 7-days. There was one case of snake mortality within the enclosure on day 6 of this group. However, there was no indication, visual or by necropsy, to suggest the radio transmitter attachment or antenna was a contributory factor. Upon removal of the enclosure fencing, snake dispersal was rapid. In less than 12 hours, no snakes could be located by radio telemetry despite extensive searching efforts. This would suggest that the range of the radio transmitter reception was a limiting factor and not failure of the transmitters.

The results of this study suggest that attachment of radio transmitters to a dorsal-lateral or ventral location does not impair movement of mature rat snakes, nor influence radio transmission. Investigators interested in utilizing the technique should evaluate the duration of attachment required to meet the objectives since ecdysis results in the removal of the transmitter. Care should also be exercised in determining the minimal length of antenna necessary to provide sufficient transmitter reception, yet not

impede movement or increase the chances of entanglement within an environment.

ACKNOWLEDGMENTS

Funding for this research project was provided by a grant from the 2016 Berry College's Laura Maddox Smith Summer Research Institute for the Environmental Sciences. Additional funding was provided by the Dana Corporation Endowed Chair at Berry College. The authors also wish to thank Mr. Anthony King for his invaluable assistance in collecting snakes and providing significant technical support.

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Foraging behavior of red-winged blackbirds (*Agelaius phoeniceus*) on sunflower (*Helianthus annuus*) with varying coverage of anthraquinone-based repellent

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ABSTRACT: Animals attempt to maximize foraging efforts by making strategic foraging decisions. Foraging efforts can be influenced by chemically defended food. Food resources that are chemically defended force foragers to balance the nutritional gain with the toxic costs of foraging on a defended food resource. Chemical defense, in this case sunflower treated with chemical repellent, may be capable of deterring birds from foraging on treated crops. Blackbirds (*Icteridae*) cause significant damage to sunflower (*Helianthus annuus*) with damage estimates of $3.5 million annually in the Prairie Pothole Region of North Dakota, the largest sunflower producing state. Chemical repellents may be a cost-effective method for reducing bird damage if application strategies can be optimized for sunflowers. Anthraquinone-based repellents have been shown to reduce feeding on sunflower achenes by more than 80% in lab studies, but results in the field are inconclusive due to application issues where floral components of sunflower result in low repellent contact with achenes. Ground rigs equipped with drop-nozzles have shown promise in depositing repellent directly on the sunflower face but coverage is variable. We propose to evaluate the feeding behavior of red-winged blackbirds (*Agelaius phoeniceus*) and the efficacy of an anthraquinone-based avian repellent when applied directly to the sunflower face in a lab-based experiment. Our main objectives are to 1) evaluate the coverage needed on the face of the sunflower to establish repellency, 2) evaluate achene removal rates over time to understand time to aversion at varying repellent coverages, and 3) evaluate the feeding behavior and activity budgets of red-winged blackbirds on treated and untreated sunflower. The results of this study will inform repellent coverage needed at the scale of the sunflower plant to deter feeding or alter time budgets of foraging red-winged blackbirds to ultimately reduce sunflower damage.

Key Words foraging, *Agelaius phoeniceus*, repellent, sunflower, blackbird

Proceedings of the 17th Wildlife Damage Management Conference. (D. J. Morin, M. J. Cherry, Eds). 2017. Pp. 90-94.

Foraging theory predicts that animals maximize foraging efforts and these efforts can be influenced by a chemically defended food resource where foragers must balance the nutritional gain with the toxic costs (Emlen 1966; MacArthur & Pianka 1966; Skelhorn & Rowe 2007). Chemical defense, in this case sunflower treated with chemical repellent, may be capable of deterring birds from foraging treated crops. Blackbirds (*Icteridae*) cause significant damage to sunflower (*Helianthus annuus*) in the Prairie Pothole Region of North Dakota with damage estimates of over $3.5 million annually (Peer et al. 2003; Klosterman et al. 2013; Hulke & Kleingartner 2014). Various management strategies have been considered to reduce blackbird damage to crops although current strategies suffer from a combination of limited extent of effectiveness in space and time, cost-benefit ratios, or the habituation of birds toward the tool (Gilsdorf et al. 2002; Linz et al. 2011; Klug 2017). Chemical repellents may be a cost-effective method for reducing bird damage if application strategies can be optimized for sunflowers. Anthraquinone-based repellents have been shown to reduce feeding on sunflower achenes by more than 80% in lab studies, but results in the field are inconclusive due to application issues where floral components of sunflower result in low repellent contact with achenes. In semi-natural field tests, blackbird consumption was successfully reduced when the repellent was applied directly to the sunflower face using a CO_2 backpack sprayer (Werner et al. 2011; 2014). Repellent application using ground rigs equipped with drop-nozzles have shown promise in depositing repellent directly on the sunflower face, but Klug (2017) found coverage to be variable (range 0-71%). Complete coverage of each sunflower head in a field is improbable, but partial coverage may be sufficient to reduce bird damage by altering foraging behavior. The purpose of our study is to assess the efficacy of an AQ-based repellent to reduce blackbird damage when applied to the face of ripening sunflower and evaluate how partial coverage of an avian repellent affects blackbird foraging behavior at the scale of a single sunflower head. We will test the chemical repellent applied to sunflower heads in a lab setting to determine 1) the repellent coverage on a sunflower face that results in > 80% repellency; 2) the amount of seeds consumed and time to aversion for each treatment by evaluating seed removal rates; and 3) changes in foraging behavior and time budgets between untreated sunflower heads and sunflower heads treated with different repellent coverage.

METHODS

Repellent Efficacy

We will test birds naïve to AQ in individual cages to evaluate repellency at repellent coverages ranging from 25%-100%. We will test 48 male red-winged blackbirds using no-choice tests to evaluate repellency for each treatment without alternative food. We will test 48 additional male red-winged blackbirds using two-choice tests to evaluate repellency for each treatment with alternative food available (untreated sunflower head). Tests include 1 day of acclimation, 2 days of pretest, and 1 day of treatment (2 days of treatment for two-choice tests). We will record both daily damage and consumption by weighing sunflowers before and after each day. Birds will be ranked according to pretest daily consumption and assigned to treatments such that each treatment group is similarly populated with birds exhibiting high to low daily consumption. Residue analyses will be conducted on both achenes and disk flowers to assess repellent concentrations for each treatment.

Foraging Behavior

We will evaluate foraging behavior on treated sunflower heads by video recording the aforementioned no-choice and two-choice tests. We will record bird activity for 8 hours between 08:00 and 16:00 as this is when red-winged blackbirds are most active (Hintz & Dyer 1970). We will measure achene and disk flower removal by using a 5-cm^2 template grid to measure removal at set intervals (every 5 minutes for the first hour, every hour for the remaining 7 hours). Treated and untreated removal rates will be compared and used to estimate how long it takes an individual bird to consume the necessary amount of repellent to reach aversion for each treatment. Additionally, we will record foraging activities while birds are exposed to untreated (control) and treated sunflowers to evaluate changes in foraging activity budgets. Activities will be will be recorded during the first 60 minutes and the last 15 minutes of each subsequent 7 hours of feeding. Intervals will include time not on the sunflower as well as time of specific behaviors when on treated or untreated sunflowers (Table 1). We will record pecking events during sampling intervals and compare pecking frequencies when birds are exposed to untreated and treated sunflowers as pecking rates are an accepted index for feeding rates (Smith 1977). For each activity, we will record position on the sunflower using a 360° protractor transparency to identify the part of the sunflower heavily used by blackbirds. We will construct frequency distributions and compare between treated and untreated sunflowers.

SUMMARY

The results of this project will be informative for both foraging theory and sunflower damage management. Foraging theory enables the prediction of how animals forage. This study will further our understanding of foraging decisions at the scale of a single sunflower head and how the presence of a

Table 1. Foraging behaviors to be used in evaluating time budgets during feeding trials of red-winged blackbirds (*Agelaius phoeniceus*) on unadulterated sunflower (*Helianthus annuus*) and sunflower treated with various coverages of anthraquinone-based avian repellent. Previous studies recognize that granivorous birds, such as red-winged blackbirds, are capable of compatible food handling, where food can be processed while scanning their surroundings. Therefore, we will record the behavior as scanning in the absence of an achene being processed and as seed handling with the presence of achene processing. We will record birds as 'NOSF' if not on the sunflower in the 'no-choice' test and not on either sunflower in the two-choice test. During the two-choice test the sunflower treatment will be identified with the prefix 'T' for treated and 'N' for not treated to identify where the behavior is taking place.

Code	State (duration)	Description
ALBE	Alert Behavior	Sudden increased scanning, crouching, neck extension, or feather compression
BRTE	Bract Tearing	Pecking, tearing, or manipulating bracts; bird not focused on seeds
HAND	Handling	Processing seed; includes seed entering beak until hull ejected or seed processing complete
PREE	Preening	Cleaning feathers, stretching legs or wings, wiping beak, or head shaking
SRCH	Searching	Selecting seed, from the time a bird begins looking at seeds until a seed is obtained or search ended
SCAN	Scanning	Scanning surroundings without seed in beak
NOSF	Not on Sunflower	Bird is off the sunflower and/or not within camera view

toxin, in this case an added repellent, can influence those decisions. Additionally, this study will evaluate how toxin presence affects foraging decisions both with and without an alternative food resource. Furthermore, foraging behavior studies also neglect to relate changes in GUD to displayed behaviors of foragers. Our study will quantify foraging behavior changes before and after the presence of a repellent in a captive setting to evaluate key behavior changes that influence GUD in the presence of varying toxin densities. In terms of avian damage to sunflowers, chemical repellents can be a cost-effective management tool provided application difficulties can be overcome and alternative food is available for foraging birds (Klug 2017). Results from this study would inform the potential efficacy of an AQ-based repellent for use on foliar sunflower as well as inform repellent application strategy needed to maintain repellency considering the growth form and protective disk flowers of sunflower. Our study will also inform repellent effectiveness both with and without an alternative food source. Additionally, understanding how a repellent changes the time budget of individuals can be useful in implementing more effective integrated pest management strategies (e.g., decoy crops and physical hazing) that exploit these time budget changes. Future studies should investigate repellent coverage at the scale of an entire field, focusing on the required percentage of treated sunflower heads within a field to influence birds to abandon foraging at a field. Eventually, research should evaluate how the distribution of repellent coverage over the landscape influences repellency of each field.

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Wild Pig Hunting Outfitters in the Southeast

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ABSTRACT: Wild pigs (*Sus scrofa)* are an invasive nonnative species brought to the United States in the 1500s by Spanish explorers. Because wild pigs are habitat generalists and in combination with high fecundity rates, translocation by humans, dispersal from shooting preserves, and movement through populations, wild pigs can be found in 42 of the 50 states. They are considered the most abundant free-ranging exotic ungulate in the United States. Because wild pigs are expanding throughout the United States each year, there are more opportunities for landowners/outfitters to sell wild pig hunts on their property. The southeast holds the largest continuous distribution of wild pigs is the US. Because of this distribution in the southeast, our objective was to quantify the number of outfitters offering wild pig hunts in the southeastern states and to contact outfitters to learn how effective their operations are in controlling wild pig populations. To determine the number of guided and non-guided wild pig hunting outfitters in 12 Southeastern states (Georgia, Florida, Alabama, Tennessee, South Carolina, Kentucky, North Carolina, Virginia, West Virginia, Arkansas, Louisiana, and Mississippi) and 2 northern states (Ohio and Pennsylvania), we conducted internet searches to locate contact information for advertised outfitters. Data collection included county and state in which they operate, hunters served, hunter success, outfitters fees, pig sightings and other information. Data on the number of wild pig hunting outfitters in the southeast will give us a better understanding as to how many outfitters offer wild pig hunting opportunities and information on their operation and possible impacts (biological and economic).

Proceedings of the 17th Wildlife Damage Management Conference. (D. J. Morin, M. J. Cherry, Eds). 2017. Pp. 95-96.

METHODS

We generated the list from the internet and advertisements in hunting magazines. Once the list and contact information was created, we randomly contacted 20% of the outfitters per state. If we could not reach the outfitter, we would leave a voice message and move to the next outfitter on the list. We asked specific questions such as: pigs harvested, acres hunted, total clients per year, success rate, fence enclosure (height of fence), county of operation, if land is personal/private/leased, and if the operation is full-time, or a side-endeavor.

RESULTS

We found contact information for 147 outfitters. Twenty-four outfitters (16%) were no longer in business. We contacted n=123 outfitters, 30 (24.4%) were willing to take the phone survey. Four of the 123 (3.2%) did not want to participate in the survey, and 89 (72.3%) did not answer our call nor did they call back in response to our voice message. Georgia (6,035) and Florida (5,345) harvested the greatest number of pigs. The average number of pigs harvested per outfitter (Florida, Georgia, Tennessee, Pennsylvania, South Carolina, and Alabama) was 390. We were only able to use averages of states with outfitters that 1) had more than three outfitters per state, and 2) three or more outfitters completed the survey. Tennessee averaged the highest number of clients per

year (525) and Alabama averaged the lowest (88).

Of the 30-wild pig hunting outfitters we contacted, 13 of the 30 (43.3%) were operating a high fence operation in addition to free-range hunts. The height of the fences ranged from 4 feet to 9 feet 10 inches. Georgia and Alabama were the two states we contacted that did not have a high fence operation. This does not mean there are no high-fence operation in the state, it means of the 20% of the outfitters we contacted in GA and AL, none were operating under high fence conditions. Only two states reported high-fence only operations (Tennessee, Pennsylvania). High fence only operators charged a higher price per hunt (Tennessee, average price = $760; Pennsylvania, average price = $725). The average cost of high fence hunts across all states was $561 and free-range hunts averaged $358 per hunt.

The average amount of land hunted varied greatly between states. The largest average acreage per outfitter was Florida (19,095 ac), followed by Georgia (14,813 ac), South Carolina (7,500 ac), Alabama (3,250 ac), Tennessee (1,419 ac), and Pennsylvania (115 ac). There are currently 5 states (Kentucky, North Carolina, Virginia, West Virginia, and Ohio) that we cannot collect data due to the limited number of outfitters, and the low probability (72.3%) of contacting the outfitter.

DISCUSSION

Overall, the cooperation of outfitters was better than expected. Because most outfitters did not answer the phone, we question this business model. Based on limited data collected to this point, it seems likely that outfitters have little impact on wild pig population control. Their websites display successful pictures but the attention to customer service is lacking. We were unable to locate any outfitters in Virginia and located one outfitter in Kentucky. We plan to re-contact outfitters that did not respond to our initial wave of contact in order to increase our sample size.

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